PORT AUTHORITY NY NJ

AIR LAND RAIL SEA

Green Infrastructure Design Manual

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Abbreviations & Acronyms

BMP	Best Management Practice	**NJ DEP**	New Jersey Department of Environmental Protection
CADD	Computer-Aided Design & Drafting	**NYC**	New York City
CDG	PANYNJ Civil Design Guidelines	**NYS DEC**	New York State Department of Environmental Conservation
CFS	Cubic feet per second	**O&M**	Operations and maintenance
CRG	PANYNJ Climate Resilience Design Guidelines	**PA**	Port Authority of New York and New Jersey
EADD	Engineering and Architectural Design Division	**PANYNJ**	Port Authority of New York and New Jersey
FAA	Federal Aviation Administration	**RE**	PANYNJ Resident Engineer
GI	Green Infrastructure	**RSD**	Port Authority Engineering Department Resilience & Sustainable Design group
GIDM	Green Infrastructure Design Manual	**SBG**	PANYNJ Sustainable Building Guidelines
GIS	Geographic Information System	**SDG**	PANYNJ Sustainable Design Guidelines
HDS	Hydrodynamic Separator	**SF**	Square feet
Hr.	Hour	**SIG**	PANYNJ Sustainable Infrastructure Guidelines
HVAC	Heating, ventilation, and air conditioning	**SPDES**	State Pollutant Discharge Elimination System
In.	Inch	**SRI**	Solar Reflectance Index
ISI	Institute for Sustainable Infrastructure	**SW**	Stormwater
LE/A	Lead Engineer / Architect	**SWPPP**	Stormwater Pollution Prevention Plan
LEED	Leadership in Energy and Environmental Design	**TSS**	Total Suspended Solids
LL	Local Law	**USDA**	United States Department of Agriculture
MRM	Modified Rational Method	**USGBC**	United States Green Building Council
NAVD 88	North American Vertical Datum of 1988	**V**	Volume
NCRS TR-55	Natural Resource Conservation Service - Technical Release 55	**WQv**	Water Quality Volume

GREEN INFRASTRUCTURE DESIGN MANUAL QUICK GUIDE

Click on yellow circles to jump to relevant manual section

STAGE I/II

3.1 Define GI as a PROJECT GOAL if:

☐ Project includes stormwater management scope

AND

☐ Is subject to stormwater regulations, **OR**
☐ Does not reduce net impervious area, **OR**
☐ Is located within 100 feet of wetlands, **OR**
☐ Is located within 100 feet of open waters, **OR**
☐ Is subject to PANYNJ Sustainable Design Guidelines

Stormwater Regulations may include:

- New York or New Jersey State Regulations
- Municipal regulations, local laws, building codes
- SPDES/NJPDES permits
- Federal Requirements

Planning for GI Before Design

During planning phase, discuss stormwater scope and opportunities for:

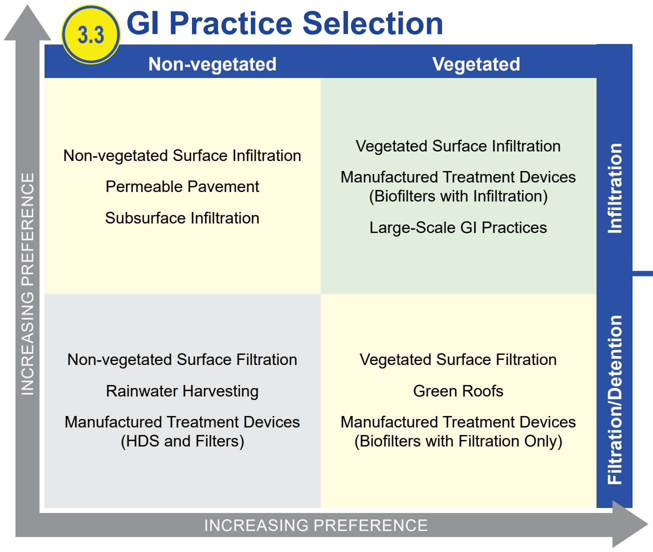
- Reducing impervious surfaces
- NON-STRUCTURAL green infrastructure practices
- Rainwater harvesting
- Large-Scale GI Practices

GI Schematic Design Tools include:

- GIS Screening Tool – provides basic topographic, geotechnical, and flood risk data
- GI Calculator – estimates design storm volume and peak flow and GI footprint sizes

3.2.1 Desktop Site Assessment → 3.2.2 Site Investigation → 3.2.3 Tributary Analysis → 3.2.4 Geotechnical Investigations → 3.2.5 Survey → 3.2.6 Structural Investigations

3.3 GI Practice Selection



	Non-vegetated	Vegetated
Infiltration	Non-vegetated Surface Infiltration Permeable Pavement Subsurface Infiltration	Vegetated Surface Infiltration Manufactured Treatment Devices (Biofilters with Infiltration) Large-Scale GI Practices
Filtration/Detention	Non-vegetated Surface Filtration Rainwater Harvesting Manufactured Treatment Devices (HDS and Filters)	Vegetated Surface Filtration Green Roofs Manufactured Treatment Devices (Biofilters with Filtration Only)

Large-Scale GI Practices include:

- Detention/Retention Basins
- Constructed Wetlands
- Living Shorelines

3.4 PANYNJ Engineering Guidelines include:

- Civil Design Guidelines
- Sustainable Building Guidelines
- Sustainable Infrastructure Guidelines
- Climate Resilience Design Guidelines
- Aviation Landscape and Sustainable Design Criteria

STAGE III

4.1 Select the Project Design Storm → 4.1.1 Calculate Design Storm Volume → 4.2 Calculate Required GI Size → 4.3 Calculate Peak Flow → 4.4 Calculate Pollutant Removal (as required) → 4.5 Select Vegetation → 4.6 Complete Design Drawings

1.0 Introduction

To support the agency's long-standing commitment to embracing best-in-class standards for sustainable and resilient design and construction, the Port Authority Engineering Department is pleased to introduce its first Green Infrastructure Design Manual (GIDM). "Green infrastructure" refers to a broad array of stormwater management strategies that use natural (or nature-based) systems to manage runoff. Green infrastructure may be employed on its own or, more likely, in conjunction with traditional "grey" systems to cost-effectively meet and exceed standards for runoff quantity and quality. Green infrastructure also potentially offers numerous co-benefits for the Port Authority and our host communities, including the reduction of urban heat-island effects, beautification and, where appropriate, the enhancement of natural habitats.

Why Green Infrastructure?

Traditional urban stormwater management techniques include hardened curb and channel, drains and catch basins, and subsurface drainage pipes. These "grey" infrastructure strategies can alter the pre-development hydrology by increasing the volume, velocity, and temperature of stormwater runoff while decreasing the ability to filter and remove pollutants.

When appropriately employed, green infrastructure practices can help alleviate these challenges by capturing and conveying treated runoff into the surrounding subsurface or to downstream drainage systems at a controlled rate. Green infrastructure can help meet stormwater management regulatory requirements while also contributing environmental, social, and economic co-benefits. Considered holistically, green infrastructure is often comparable or preferable to traditional grey stormwater infrastructure from a lifecycle cost perspective.

Green infrastructure may refer to a wide array of nature-based stormwater management practices. This Manual defines and focuses on the following green infrastructure types:

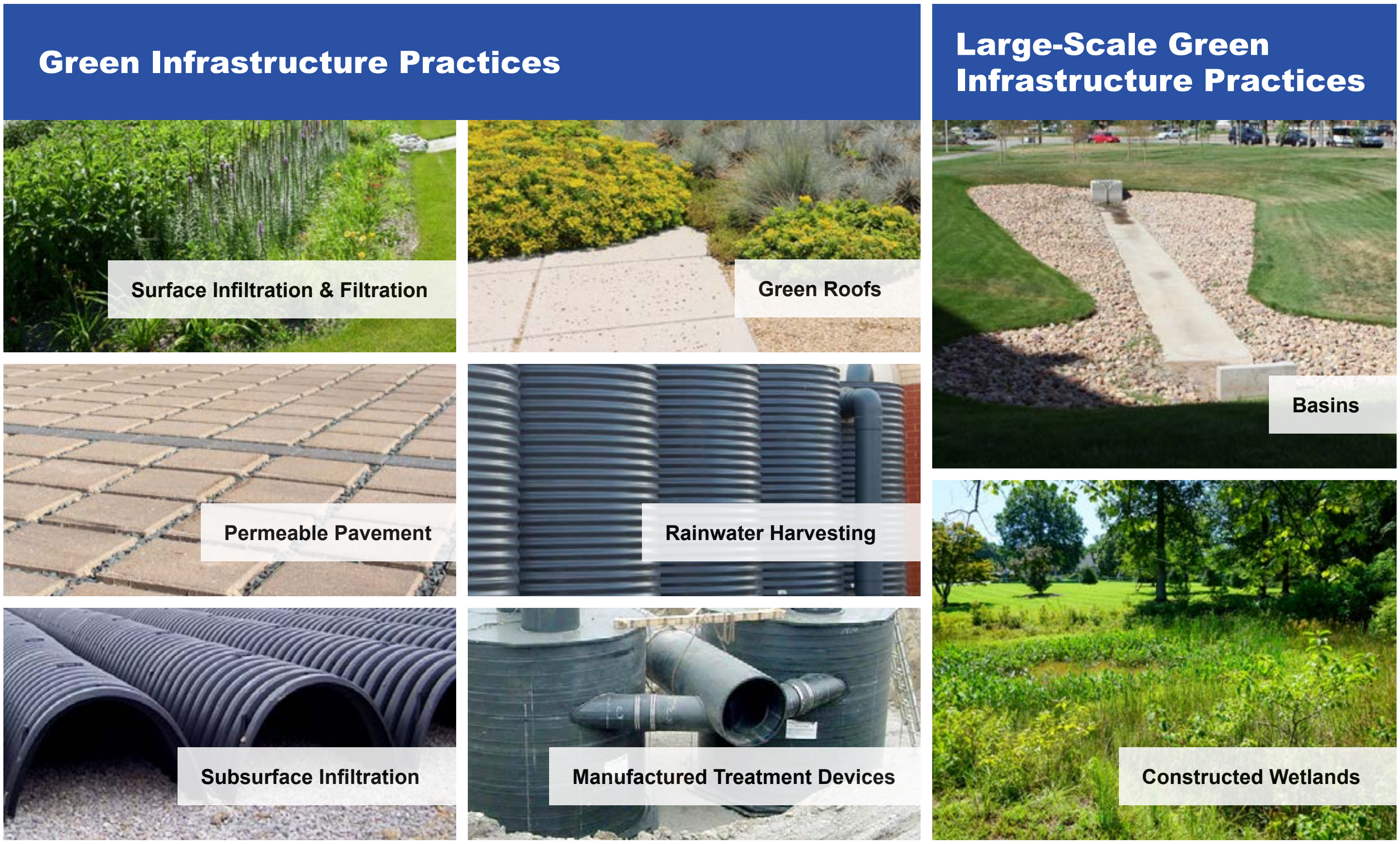


Figure 1.1 – Types of Green Infrastructure

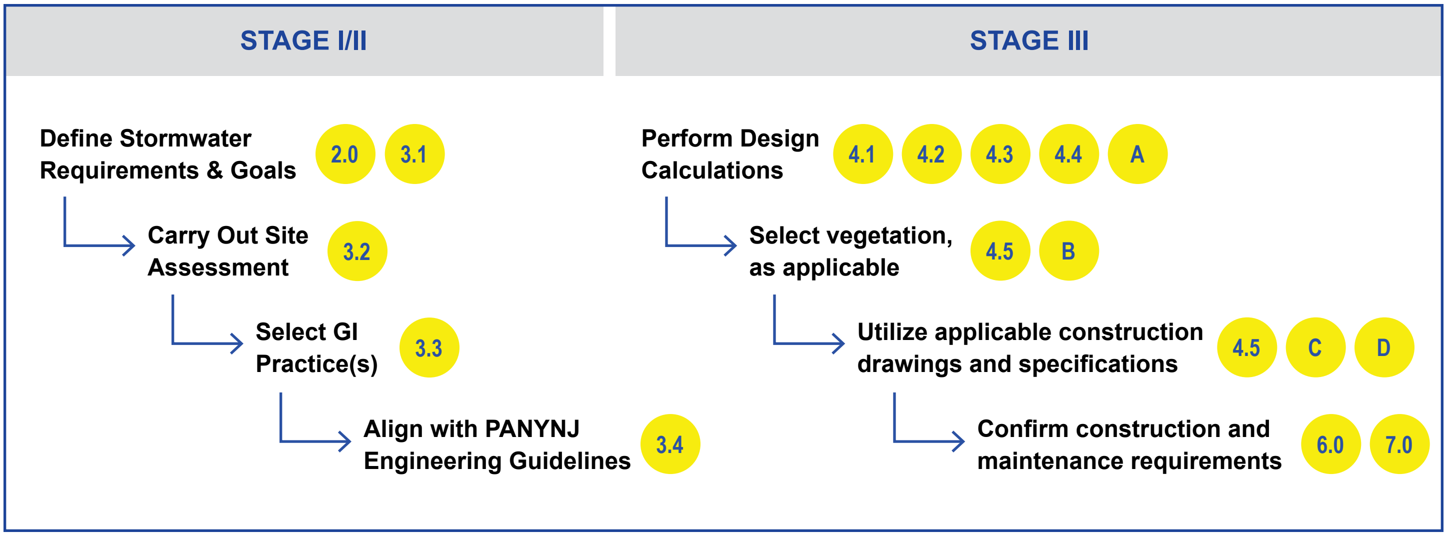


Figure 1.2 – GIDM Manual Overview

Why a Port Authority Green Infrastructure Design Manual?

Over the past several decades, public agencies and regulatory entities have published a range of detailed guidance resources for implementing green infrastructure practices in New York and New Jersey. This Manual is not intended to replicate these manuals, nor does it constitute an exhaustive study of regulatory frameworks or design techniques. Rather, it leverages existing resources to provide design guidance and key considerations for implementing green infrastructure practices at the Port Authority's unique and highly active air, land, rail, and sea facilities.

How Should I Use this Manual?

The GIDM is an optional resource for Port Authority design teams—both internal and external—and facility staff seeking effective, cost-conscious, and aesthetically-pleasing solutions to common stormwater challenges at the agency's unique facilities. The Manual references industry best practices and regulatory guidance to outline a unified process for siting, selecting, and designing the most applicable green infrastructure solution(s) for a given project. The Manual is augmented by a suite of resources to support implementation at all stages of the design process.

The Manual and associated tools and templates are intended to supplement—not replace—the Authority's existing Engineering Guidelines; in the instance that conflicts or inconsistencies arise, the Guidelines always govern. Users of this Manual are ultimately responsible for producing designs that comply with the most recent and applicable codes, ordinances, statutes, rules, regulations, and laws.

How is the Manual Organized?

The Green Infrastructure Design Manual is organized based on the Engineering and Architectural Design Division (EADD) design Stages.

- **Section 2.0** summarizes the regulatory framework for GI.
- **Section 3.0** defines the processes for Stage I (and/or Stage II) site assessment, GI selection, and compliance with PANYNJ design guidelines.
- **Section 4.0** covers the Stage III detailed design steps.
- **Section 5.0** consists of GI "fact sheets" which give more detailed design guidance for each practice type. Finally,
- **Sections 6.0** and **7.0** give an overview of GI construction and maintenance best practices.

Where Can I Find Additional Resources?

In addition to this manual and its appendices, the following companion resources are included on the PANYNJ Resilience and Sustainable Design (RSD) SharePoint site:

- **PANYNJ GI Screening Tool:** GIS-based system which assists designers in screening project locations for GI inclusion
- **PANYNJ GI Calculator:** Excel-based tool that uses general assumptions to help designers estimate the design storm volume, peak flow, and resulting GI footprint areas for a single tributary during Stage I/II

To access these tools, please refer to the links in **Appendix F.** Note that PANYNJ staff should automatically have SharePoint access. External consultants should request access from RSD at SustainableDesignManager@panynj.gov.

2.0 Stormwater Rules, Regulations & Permitting

PANYNJ projects fall under the jurisdiction of several regulatory bodies which may require or promote using green infrastructure to meet stormwater management requirements. Associated regulations include state and municipal rules, local laws, building codes, and site connection rules. PA policy complies with the regulations applicable to the project location, at a minimum.

Figure 2.1 references the primary regulations which may govern the implementation of GI, including associated guidance documents, primary triggers for GI, and how it may influence the design. **Note that this table is not exhaustive and that municipalities may have their own stormwater regulations which supersede or supplement the state guidance. Appendix E** includes an expanded list of these and other regulations which may affect stormwater design.

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Disclaimer

The goal of the GIDM is not to reproduce or replace regulatory guidance. All regulatory information is included for reference only and does not fully represent state or local guidance. Designers are responsible for identifying and fully complying with the most current and applicable regulations for their projects.

Location	Regulation	Guidance Document	General Overview	Minimum Applicability	Influence on GI Design
New Jersey	Stormwater Management Rule N.J.A.C 7:8	NJ DEP Best Management Practices Manual GI Rule effective 3/2/2021	Provides guidance, examples, and methods for implementing stormwater best management practices	Land disturbance > 1 acre	Requires GI to meet stormwater quantity, quality, and groundwater standards
New York State	Clean Water Act/ State Pollutant Discharge Elimination System (SPDES)	NYS DEC Stormwater Management Design Manual	Provides design standards intended to protect the water of New York from adverse impacts of urban stormwater runoff	Land disturbance > 1 acre	Sets stormwater quantity and quality requirements
New York City	NYC Local Law 94 of 2019	N/A	Amends the NYC Building Code to require green roofs and/or solar panels on all new or replacement roof decks and assemblies	New or refurbished roof deck > 100 square feet	Requires green roofs and/or solar panels on new roof decks

Figure 2.1 – Regulation Summary Table

State Pollutant Discharge Elimination System (SPDES) Permit

Most PANYNJ facilities are subject to their own SPDES Permits (referred to as NJPDES permits in New Jersey) relating to their drainage discharges. These permits include limits on certain contaminant discharges and/or site-specific water quality requirements for the subject facility. Designers are responsible for compliance with the terms of these permits and are encouraged to incorporate GI to meet these requirements to the greatest extent feasible.

3.0 Stage I: Green Infrastructure Selection Process

The selection of green infrastructure for stormwater management consists of six general factors which are discussed in more detail throughout this chapter:

1. Stormwater quality requirements and goals (reduction of total suspended solids, nutrients, trace metals, chlorides, hydrocarbons, and pathogens).
2. Stormwater quantity requirements and goals (reduction of stormwater volume, peak flow, and velocity).
3. Consideration of site characteristics and constraints (topography, geotechnical, utilities, vegetation, space limitations).
4. Evaluation of facility operations (parking spaces, site access, maintenance, operations such as vehicle movements and snow removal).
5. Consideration of environmental, social, and economic co-benefits.
6. Cost (lifecycle cost analysis including construction, operations, and maintenance).

The following sections summarize the procedure for integrating these factors into the GI design process.

(Flickrcc: Center for Neighborhood Technology)

3.1 Define Stormwater Requirements and Goals

Upon project initiation the designer, Lead Engineer / Architect (LE/A), associated design disciplines, and facility staff should define the stormwater management scope and whether green infrastructure helps meet regulatory requirements or PANYNJ project goals.

Designers first define, identify, and document all stormwater management rules, regulations, and permits that apply to their project. Refer to **Section 2.0** for a discussion of applicable regulations. The designer should carefully review any local statutes as these may contain more stringent or different requirements than state requirements.

All projects are also subject to agency engineering guidelines. This includes PANYNJ's Civil Design Guidelines, Sustainable Design Guidelines, and Climate Resilience Design Guidelines. See **Section 3.4** for a summary of applicable agency engineering guidelines.

Designers then determine if GI is a project goal as per the checklist in **Figure 3.1**. The following sections assist the designer in answering these questions. Designers should attempt to meet project goals to the greatest extent practicable.

GI is a PANYNJ GOAL if project scope includes stormwater management AND:

☐ Does not reduce net impervious area, or
☐ Is located within 100 feet of wetlands, or
☐ Is located within 100 feet of open waters, or
☐ Includes operational water use, or
☐ Is subject to PANYNJ Sustainable Design Guidelines

Figure 3.1 – Criteria for GI as a Project Goal

Operational Water Use

Operational water use may include irrigation, water cooling systems, toilet flushing, washing & cleaning, decorative fountains, and any other activity which expends potable water.

Once stormwater requirements and goals are determined, teams may discuss opportunities and constraints that define the parameters for GI design, such as:

- Methods for reducing stormwater runoff quantity and improving stormwater runoff quality.
- Strategies to minimize impervious surfaces in the project area.
- Site limitations such as poor geotechnical conditions, steep slopes, subsurface utilities, available space, mature trees, etc.
- Operational water uses which could utilize harvested rainwater.
- Opportunities to integrate GI with existing drainage infrastructure.
- Alternate approaches to stormwater management such as stormwater disconnection.
- Opportunities for GI to contribute to the project's climate resilience strategy.
- Coordination of design with the facility's operations and maintenance group.
- Opportunities to align with pollution prevention and good housekeeping requirements.
- Project's impact on public safety, pedestrian/vehicular movements, site security, and aesthetics.

The results of these planning and early design exercises should be included in the drainage sections of the Stage I report.

Planning for GI Before Design

During project planning, designers may identify opportunities to shape and refine the layout and programming of the project itself to reflect existing drainage patterns. These planning-level, holistic strategies are considered "non-structural" and can help reduce the impacts of stormwater runoff. Non-structural strategies include minimizing impervious area, maintaining natural drainage features, and protecting existing vegetation.

Since non-structural practices consider stormwater as a hydrologic process at the site level, they are often more effective than singular constructed or "structural" stormwater systems such as basins, swales, or filters. Non-structural practices may also require less maintenance than structural strategies.

Non-structural strategies should be the first and primary focus of drainage design. By making minor revisions to the site layout, designers may reduce the costs involved in siting and designing structural stormwater practices. If non-structural practices are successful in reducing the net impervious area, they may preclude the need for additional structural practices. See **Section 3.3** for more details on non-structural best management practices.

3.2 Site Assessment

The site assessment process informs the Stage I design and assists in siting and selecting the most appropriate green infrastructure practice(s). Designers may perform these steps discretely or integrate them into parallel processes as part of a greater project scope.

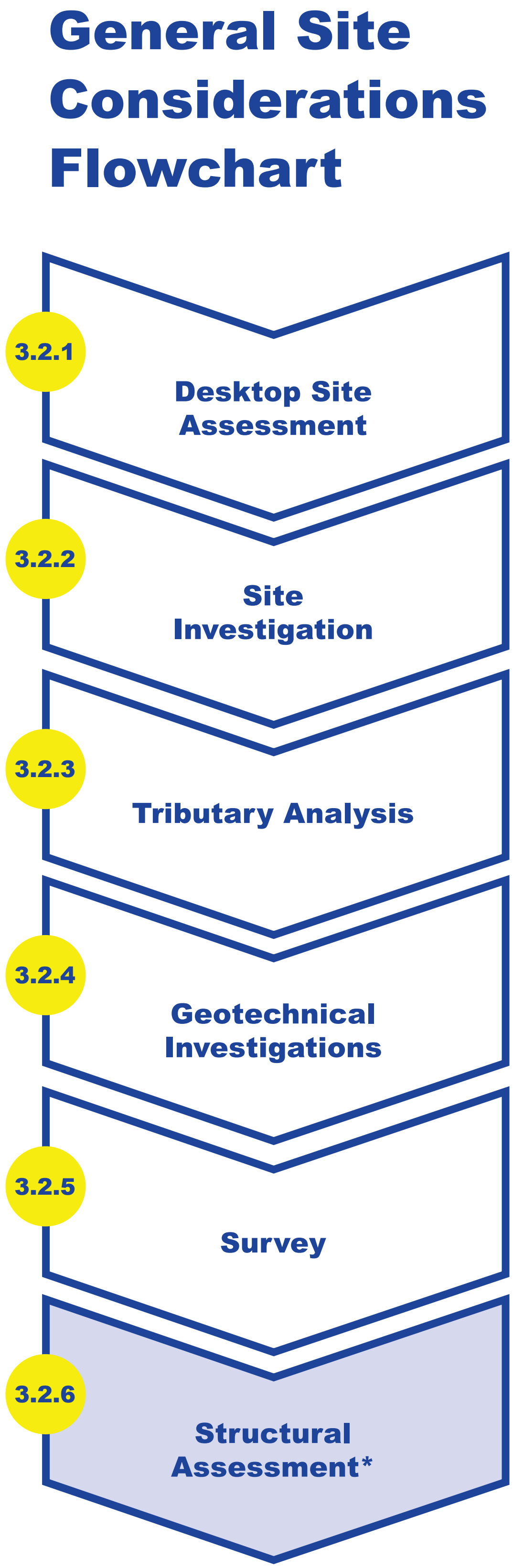
Site assessment begins with a desktop study and field investigations to determine the suitable locations and conditions for GI.

Designers then delineate the tributaries of the proposed site conditions and estimate size and location of initial GI practices.

Further activities such as topographic survey and geotechnical investigations confirm the feasibility of GI and help select which types are most applicable. Specifically, this information helps decide if a GI practice can utilize infiltration or not.

Designers and responsible disciplines should summarize the results of this assessment in their respective sections of the Stage I report.

The following sections detail each step in this process.



→ ***For rooftop retrofits only**

Figure 3.2 – Site Assessment Steps

3.2.1 Desktop Site Assessment

Upon Stage I/II kickoff, designers collect site information such as drainage patterns, topography, geotechnical conditions, and usage. Designers can use this information to screen for ideal GI locations and identify conditions which would preclude the implementation of stormwater infrastructure.

Designers should compile as much of the following information as possible:

- Site plan and project boundaries, including maps or GIS layers of wetlands, waterways, floodplains, and other ecologically critical areas such as buffer zones or forests.
- Facility programming information that may affect GI design and access during construction and maintenance.
- Topographical information and contour lines (in CADD or GIS format, if available) to identify high points, low points, and flow paths.
- As-built and/or alignment plans of existing stormwater infrastructure (including sewer system connections, outlets, outfalls or other points of discharge) and other utilities which may affect construction of GI.
- Historic geotechnical information, including permeability rate, soil boring logs, depth to groundwater table, and depth to bedrock.
- Previous environmental reports, Stormwater Pollution Prevention Plans (SWPPP), and contamination records covering the project area and vicinity.
- Existing circulation patterns for vehicles and pedestrians.

3.2.2 Site Investigation

Designers may perform a preliminary site visit to confirm the information gathered in the desktop site assessment and to fill in any information gaps. The site investigation should:

- Confirm topographic information and location of existing drainage structures and utilities. Confirm location and elevation of existing site outfalls.
- Note location of existing trees, canopies, and other vegetation.
- Note any surface conditions such as high and low points which may affect surface runoff flow paths.
- Confirm existence, type, condition, and locations of surface utilities, manholes, and other infrastructure.
- Identify site features which may influence runoff flow paths or tributary boundaries.
- Identify conditions which may limit access to GI for construction or maintenance.
- Identify vehicular and pedestrian traffic patterns and accessibility requirements.
- Confirm or refine understanding of drainage problems or recurring ponding/flooding.
- Identify visible signs of environmental contamination/hot spots

Green Infrastructure Screening Tool

For expedited desktop assessments, designers can use the **PANYNJ Green Infrastructure Screening Tool** (see **Appendix F**). This GIS-based tool compiles shapefiles covering several of the site assessment factors to give a quick indication of GI suitability. Layers include topographic information, geotechnical data, flood zones, and location of wetlands and open waters. These shapefiles and datasets are limited by the quantity and quality of the information they contain. Therefore, this tool does not replace a full site assessment, but can offer a quick indication of site suitability.

Tributary Delineation

A tributary is the surface area which contributes runoff to a terminal point such as a drain, low point, or green infrastructure practice. **A Tributary Drainage Analysis** delineates each distinct tributary within the proposed project area to identify the most effective location(s) for GI. See example in **Figure 3.3.**

Note that proposed conditions may vary significantly from those existing. Designers should propose topography to optimize the stormwater hydrology.

Site Specific Factors

Each facility will have unique, inherent factors which will influence GI design. For example, projects located near aviation facilities may be subject to Federal Aviation Administration (FAA) guidelines requiring wildlife deterrents, especially when selecting vegetation (see PANYNJ Aviation Landscaping and Sustainable Design Criteria for more information). Facilities may have site programming or geotechnical conditions which limit the use of certain GI types.

Designers should consider the body of institutional knowledge held by PANYNJ for each of their facilities. This includes:

- Existing GI practices at project facilities
- History of GI successes and failures at each facility
- Known locations of recurring surface flooding or subsurface drainage issues such as basement flooding
- Present and future access routes and site programming
- Location of stockpiles for plowed snow and/or salts and deicing materials
- Available equipment and maintenance staff to maintain GI practices
- Previous boring logs and permeability tests adjacent to proposed GI practices
- Preferred landscaping and vegetation for successful establishment and ease of maintenance

Refer to *Investigation of Green Infrastructure Stormwater Management Solutions at the Holland and Lincoln Tunnels* for examples of how to investigate and document site-specific factors.

For site-specific map layers to help with GI siting, refer to the **PANYNJ Green Infrastructure Screening Tool**.

(flickrcc: Montgomery County Planning)

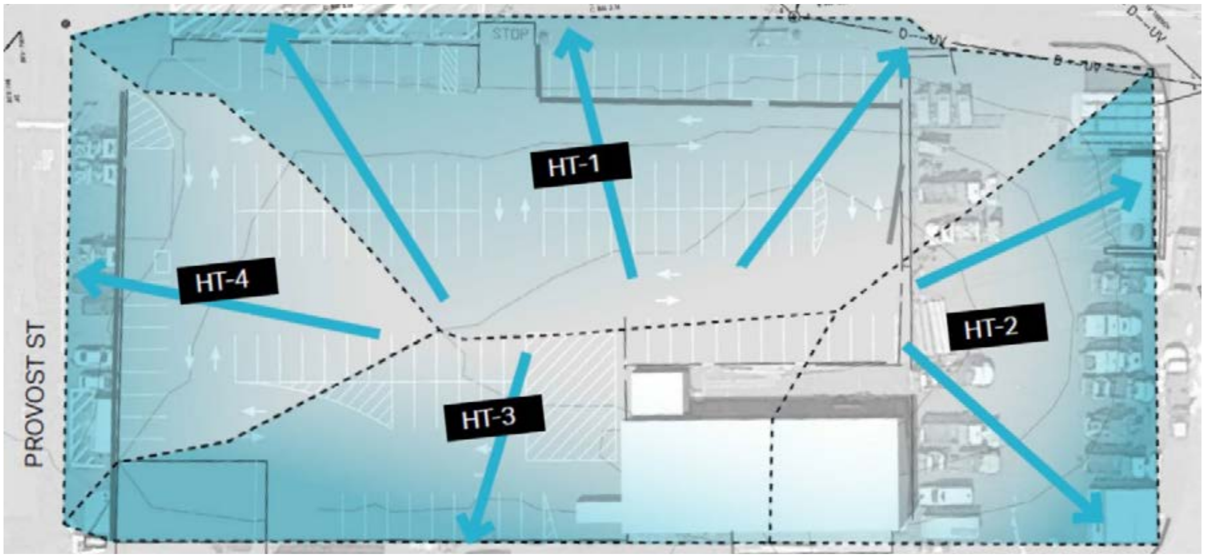


Figure 3.3 – Example Tributary Drainage Plan. The arrows show the surface runoff flow direction and the dotted lines delineate the tributaries, labeled HT-1, HT-2, etc.

3.2.3 Tributary Drainage Analysis & Preliminary Siting

Designers use the collected site information, together with preliminary design plans, to delineate the runoff flow paths and tributary areas for the proposed conditions. This exercise uses existing topographic maps, proposed grading and civil plans, and existing drainage infrastructure locations to map the surface areas which drain to each low point, stormwater collection device, project boundary, or other terminal flow location. Note that surface drainage structures and roof downspouts may significantly influence tributary boundaries. Designers should note the surface material of each tributary and calculate the total impervious and pervious surface area within each.

Once the tributaries are defined and labeled for the proposed conditions, the design team confirms the overall stormwater management strategy and selects preliminary locations for GI practices. The **PANYNJ Green Infrastructure Calculator** can estimate the GI footprint size using basic tributary information (refer to **Appendix F**). As a rule, designers should locate GI to maximize runoff capture from impervious surfaces, typically immediately upstream of drains or catch basins.

Tributary delineation and GI footprint sizing are the first steps of an iterative GI design process. The tributary boundaries, GI types, sizes, and locations will evolve with the project. Designers may reconfirm these parameters as the proposed design changes and new site information is presented. **Section 3.3** gives more details on the iterative GI selection process.

3.2.4 Geotechnical Investigation

GI practices that rely on infiltration require soils with certain permeability rates and a minimum separation between the seasonal high groundwater table and bedrock. Geotechnical investigations are necessary to confirm these conditions are met. These investigations are typically managed by PA Geotechnical and carried out by PA Materials as per the procedure summarized in Figure 3.4.

PANYNJ Geotechnical Procedure

1	Designer defines location(s) of permeability test(s) and conveys to PA Geotechnical
2	PA Materials carries out falling head permeability test(s) at depths of 5’ and 10’
3	Boring log includes depth to bedrock, depth to seasonal groundwater table, and depth(s) of impermeable soil strata, if encountered
4	PA Materials will also perform soil classification upon request
5	Design discipline determines viability of green infrastructure based on geotechnical results

In general, infiltration practices require a minimum of 0.5 in/hr permeability rate and must be 3’ clear vertically of bedrock, groundwater, or impermeable soil strata.

Figure 3.4 – Geotechnical Procedure Overview

Utility Survey

As-built utility information and utility surveys should include as much of the following information as possible:

- Utility name, dimensions/diameter, material, installation date
- Number of ducts/pipes/conduits (if multiple)
- Cover depth, depth to invert
- Invert of inlet and outlet pipes (for manholes and drainage structures)
- Rim/lid level (for underground vaults with surface access)

Refer to PANYNJ Central Survey guidance for further direction on obtaining this information.

Each proposed infiltration practice should have at least one permeability test within its footprint. For larger GI practices, permeability tests should be performed in 50’ intervals across the entire practice footprint. Footprint sizes should be conservative so future design iterations do not necessitate additional permeability tests. Geotechnical investigations must also meet any applicable regulatory guidance.

3.2.5

Survey

Topographical surveys confirm the spatial and hydrologic properties of the overall project site and form the foundation of the design drawings. When making the request to PANYNJ Central Survey for areas containing proposed GI practices, the designer or LE/A should specify the inclusion of the below information:

- Limits of proposed GI practice footprints (typically using 25’ x 25’ grid increments).
- Contours at 0.5-foot intervals, high and low points.
- Surface elevations and/or invert levels of drainage infrastructure at hydrologic and hydraulic connection points.
- Trees/vegetation (including trunk size, canopy extents).
- Locations of drainage structures and utilities (either surveyed or CADD files from PANYNJ Utility Management System). See Utility Survey text box.
- Surface features (curbs, retaining walls, utility poles, etc.).
- Existing buildings/structures, property lines.
- Accessibility features such as building entrances, curb cuts, driveway aprons, pedestrian ramps, etc.

GI practices that infiltrate runoff require setbacks from certain structures and infrastructure. The survey should confirm the following horizontal setbacks are met:

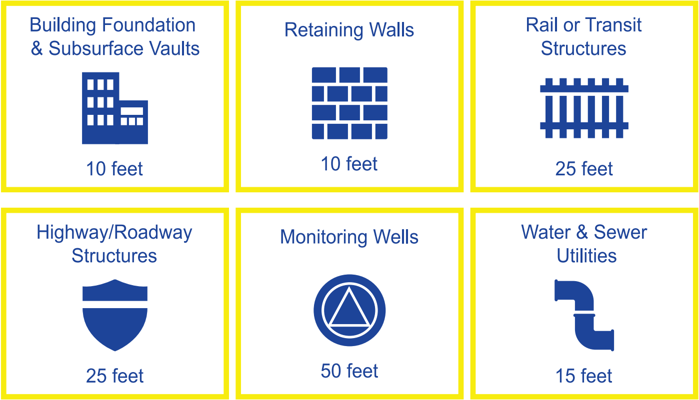


Figure 3.5 – Horizontal Setbacks

Designers should confirm the required horizontal and/or vertical setbacks for other utilities with the utility owner or authority. In some cases, utility owners may allow ducts to run though GI practices if properly sleeved and/or protected. This is especially true for smaller utilities and laterals. In other cases, smaller utility lines may be relocated through coordination with the utility owner.

Note that extremely high infiltration rates may affect groundwater recharge rates and may signify the presence of subsurface voids or leaking chambers or basements. Designers are responsible for confirming adequate groundwater recharge as required by regulations and confirming suitable subsurface conditions.

3.2.6

Structural Assessment (rooftop practices only)

If a project has to potential to include a green roof or stormwater harvesting system on an existing rooftop, designers should complete a structural assessment to confirm the structure is capable of supporting the proposed system in fully inundated conditions. Designers should also confirm the structural integrity of any pipe networks used for green infrastructure conveyance which are affixed to structures.

For rooftop practices on new buildings, designers should coordinate with the structural engineer to ensure they have incorporated these loadings into their design.

3.3 Green Infrastructure Practice Selection

The siting, selection, and design of green infrastructure practices is an iterative process which evolves with the proposed design. With the collection of new site information and updates to the design strategy, designers should revisit the tributary map and proposed GI strategies, sizes, and locations to verify they meet design requirements and goals.

The following sections guide designers in selecting the practices which are most suitable to meet the site constraints and the project goals. It starts by considering the practices with the most benefits and co-benefits and moves through the list to identify feasible design options.

3.3.1 Non-Structural Best Management Practices

The first priority of the stormwater design process is to implement strategies to reduce impervious surfaces during site planning. This and other non-structural best management practices can reduce the required size of GI practices and increase their longevity by reducing the runoff load. If employed strategically, the use of non-structural practices may preclude the need for additional structural GI practices.

Non-structural GI strategies include the following:

- Replacing impervious surfaces with pervious surfaces.
- “Disconnecting” impervious surfaces by allowing impervious runoff to sheet flow over pervious areas.
- Protecting vegetation and site features which provide water quality benefits.
- Protecting areas susceptible to erosion.
- Slowing runoff velocity by adding native vegetation, planting trees, reducing slopes, and using vegetated channels and swales instead of piping and grey infrastructure.
- Minimizing site disturbance, soil compaction, clearing, and grading.
- Minimizing turfgrass lawn and using low-maintenance native landscaping instead.
- Maintaining natural drainage features and characteristics.

The volume and peak flow reduction benefits of these strategies will become apparent when completing the design storm calculations in **Section 4.0.**

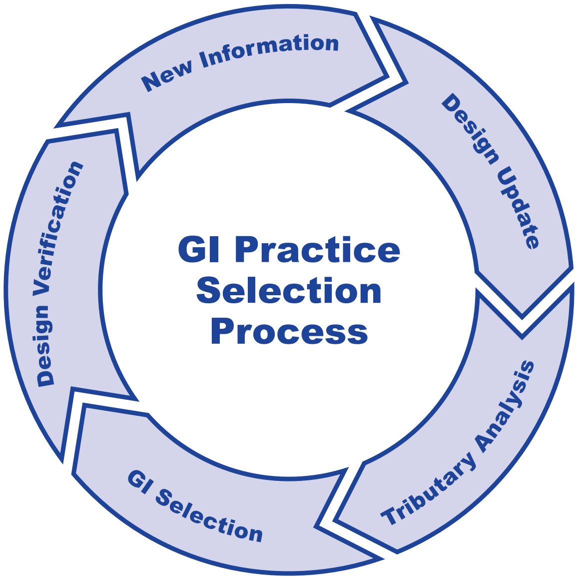
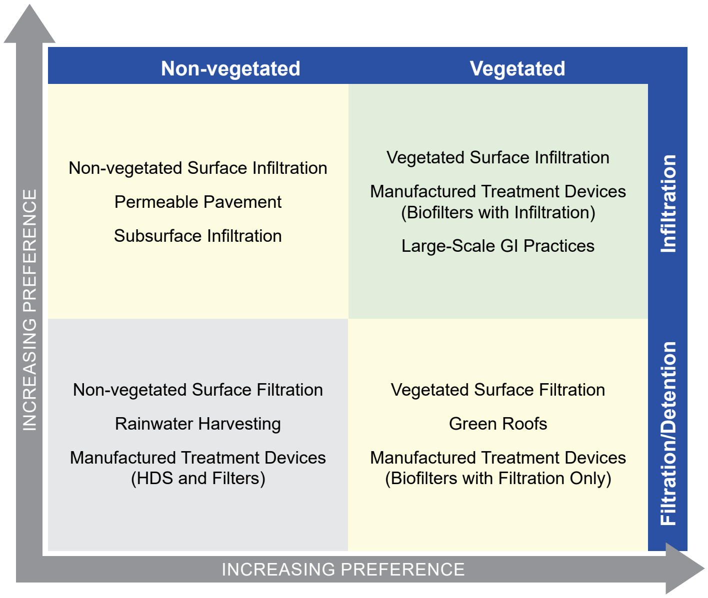


Figure 3.6 – Iterative GI Practice Selection Process

3.3.2 Structural Green Infrastructure Practices

Once non-structural options have been implemented, designers can select structural green infrastructure practices which meet the remaining stormwater management requirements, offer the most co-benefits, and align with PANYNJ resilience and sustainable design initiatives.

Designers should place highest preference on GI types that utilize infiltration and/or vegetation, as these offer the most benefits and co-benefits. Lower priority goes to GI types that only offer stormwater filtration or detention and are non-vegetated. Additionally, surface practices are more preferable than subsurface practices, rooftop practices, and manufactured treatment devices (MTDs). These priorities are demonstrated in **Figure 3.7.**



Non-vegetated	Vegetated	
Non-vegetated Surface Infiltration Permeable Pavement Subsurface Infiltration	Vegetated Surface Infiltration Manufactured Treatment Devices (Biofilters with Infiltration) Large-Scale GI Practices	Infiltration
Non-vegetated Surface Filtration Rainwater Harvesting Manufactured Treatment Devices (HDS and Filters)	Vegetated Surface Filtration Green Roofs Manufactured Treatment Devices (Biofilters with Filtration Only)	Filtration/Detention

Figure 3.7 – Structural GI Practice Preference

The following sections compare these factors and explain why certain practices types are preferred over others.

3.3.2a Filtration vs. Filtration/ Detention Practices

Designers should give top priority to **infiltration practices** which fully convey runoff into the surrounding soils. This permanently diverts water from existing drainage systems and recharges the groundwater table. Infiltration practices are most effective for preventing surface flooding and lessen the impact of runoff on downstream infrastructure. These practices also include more co-benefits and meet higher achievement levels for LEED and Envision credits (refer to **Section 3.4**). However, infiltration practices require adequate soil permeability and separation between bedrock and the seasonal high groundwater table

Filtration practices and **detention practices** capture, filter, detain, and slowly release runoff into the adjacent stormwater system. These practices can be shallow and do not depend on surrounding soil for permeability. However, they generally need to be part of a larger GI strategy since they offer fewer stormwater benefits on their own.

3.3.2b Vegetated vs. Non-Vegetated Practices

Vegetated practices are preferable to **non-vegetated practices** because trees and plants offer myriad environmental co-benefits (refer to **Section 3.3.3**). **Appendix B** includes a plant palette to assist designers in selecting the vegetation most appropriate for the site. It includes a list of vegetation and factors such as size, sun and water requirements, tolerances, and suitability for aviation facilities.

Some project locations, such as aviation facilities, may limit or restrict the use of certain vegetation. Designers should identify these limitations and select vegetation accordingly.

3.3.2c Surface vs. Subsurface vs. Rooftop Practices

Surface Practices are most preferable due their accessibility for construction and maintenance However, in cases where site limitations prevent surface GI, **subsurface practices** using pipes, chambers, and drainage media may be the best way to implement stormwater management. These practices can have an open or closed bottom depending on geotechnical conditions and can be configured to fit in most locations. If the project site includes a new or modified building, designers may consider **rooftop practices** to meet regulatory requirements or supplement stormwater management.

3.3.2d Constructed vs. Manufactured Practices

Designers should prioritize **constructed practices** consisting of common building materials such as stone, soil, and vegetation that are assembled on site. These practices are generally cheaper to source and install and offer greater flexibility for constraints such as irregular surface areas or subsurface utilities.

Manufactured treatment devices (MTDs) include hydrodynamic separators (HDS), filter inserts, and modular bioretention and biofiltration. HDS and filter inserts offer water quality benefits but are not considered “green” practices due to their lack of vegetation and infiltration. Biofilters are similar to surface practices in function and benefit but are generally more expensive to install. MTDs consist of large, modular concrete chambers so may incur significant delivery and transportation costs. These chambers require large excavations and are less flexible due to their predefined dimension.

3.3.2e Rainwater Harvesting

Designers may consider **rainwater harvesting** practices if the project includes operational water uses which could be supplemented or fully accommodated by collected runoff. Cisterns may be located underground, aboveground, or on rooftops depending on the site constraints. These practices can permanently remove captured runoff from the downstream drainage system or release it slowly to reduce peak flows.

3.3.2f Green Infrastructure Selection Questions

The green infrastructure selection questions in **Figures 3.8a** and **3.8b** use the preferences detailed in previous sections to outline a basis for identifying feasible GI types. Answering each of the four questions will help establish a menu of potential GI practices for consideration.

Once designers establish a list of potential GI practices, they can asses site limitations and use the information in the GI Fact Sheets in **Section 5.0** to select the most feasible and appropriate practices.

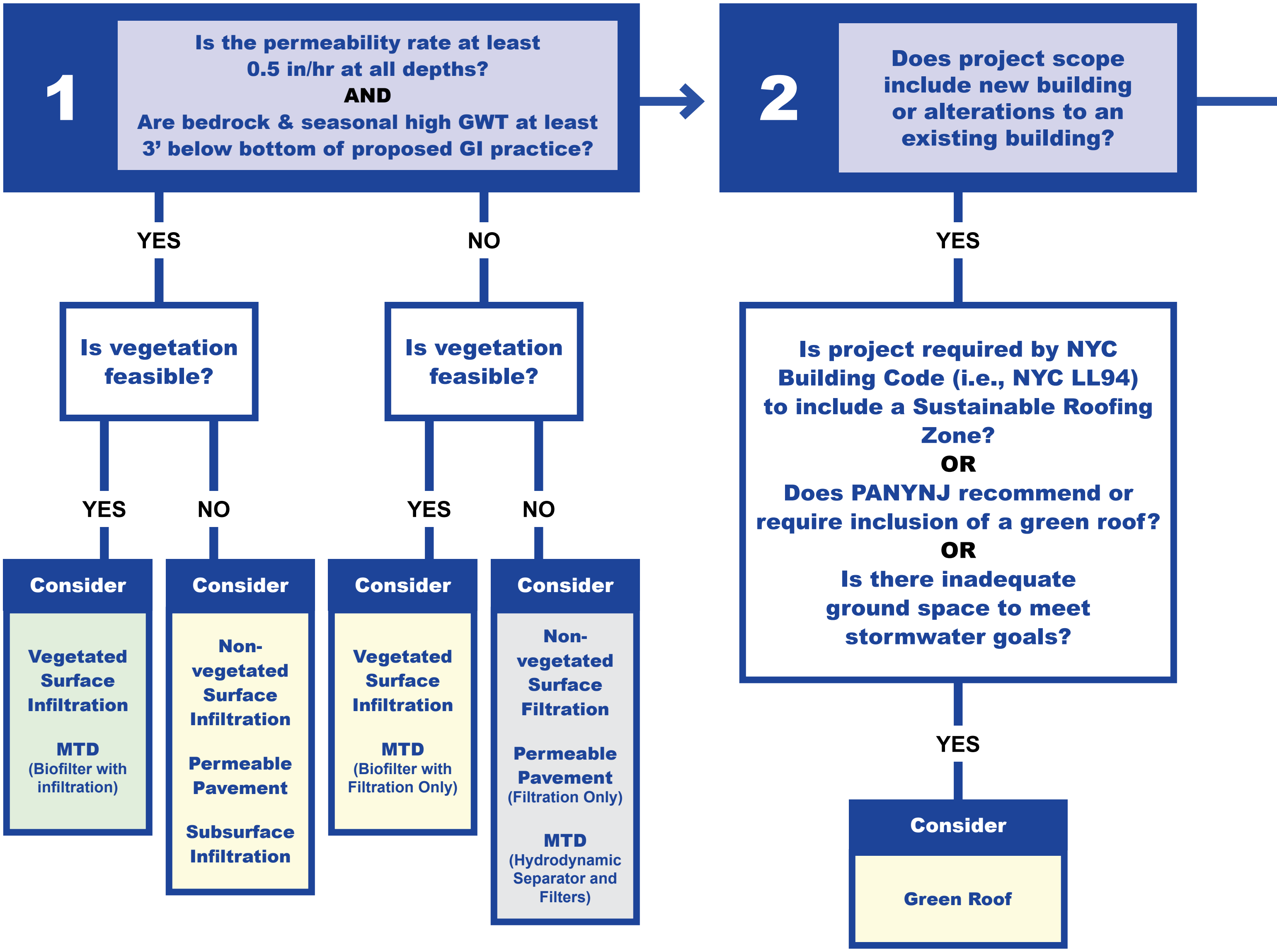


Figure 3.8a – GI Selection Questions

	Stormwater Management Benefits			
Green Infrastructure Type	**Water Quality**	**Water Volume**	**Peak Flow Reduction**	**Groundwater Recharge**
Vegetated Infiltration	●	●	●	●
Non-Vegetated Infiltration	●	●	●	●
Vegetated Filtration*	●	○	●	○
Non-Vegetated Filtration	●	○	●	○
Rainwater Harvesting	◐	●	●	○
Retention/Detention Basins	◐	◐	●	◐
Constructed Wetlands	●	◐	●	◐

Figure 3.9 – GI Benefits and Co-Benefits

*includes green roof

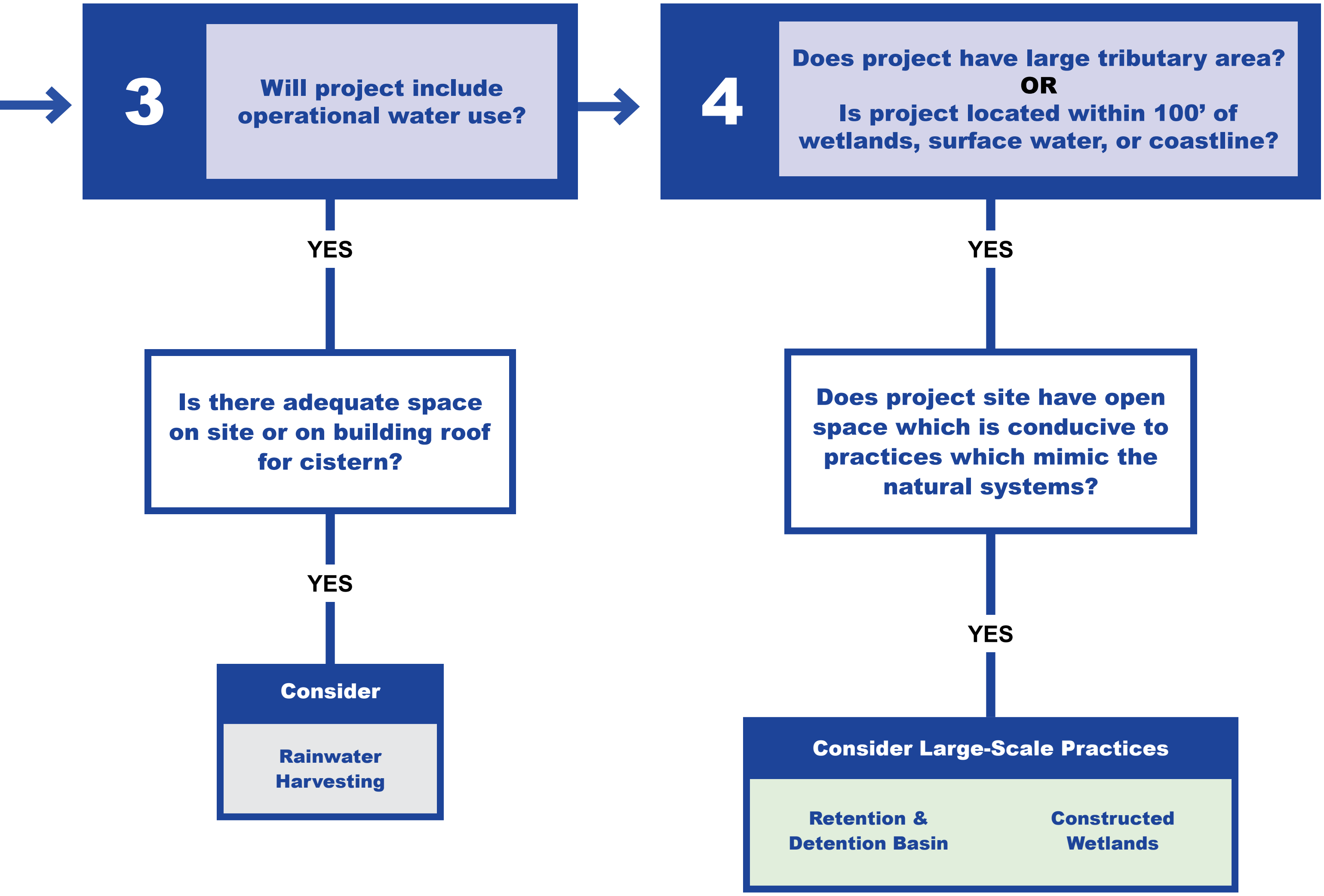


Figure 3.8b – GI Selection Questions

Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infrastructure Durability	Decreased Site Maintenance
◐	◐	●	●	●	○	○
◐	○	○	◐	◐	◐	◐
◐	◐	●	●	●	○	○
○	○	○	◐	◐	◐	◐
●	○	○	○	○	○	○
◐	◐	◐	●	◐	◐	●
◐	●	●	●	●	●	●

● Usually ◐ Sometimes ○ Rarely

3.3.3 Stormwater Benefits and Co-Benefits

Each type of GI practice offers its own stormwater management benefits and environmental, social, and economic co-benefits. Stormwater management benefits represent the primary criteria necessary to meet stormwater quantity and quality metrics and reduce peak flow. Co-benefits range from water use reduction to air quality improvements to increased infrastructure durability. Figure 3.9 gives an overview of the various benefits afforded by each GI type. A summary table of these benefits and co-benefits is located in **Appendix F.**

These benefits and co-benefits can inform a GI life-cycle cost assessment or cost-benefit analysis for comparing potential GI practices with other GI strategies or with traditional grey infrastructure.

Terminology: Peak Flow Reduction

The peak flow rate of a storm is directly proportional to the hazards it poses to downstream infrastructure and receiving water bodies. High volumes and velocity of flows transport heavy loads of sediment and pollutants, inundate drainage systems, increase surface flooding, increase frequency of combined sewer overflows, and cause scour and erosion. GI practices reduce peak flow by a) gradually releasing collected runoff, and/or b) slowing the velocity of surface runoff and delaying or flattening the peak flow response.

(flickrcc: Padraic)

3.3.4 Site Constraints & Design Solutions

Projects often present limitations and site constraints which require innovative design strategies to overcome. Figure 3.10 includes examples of common siting constraints, together with possible design solutions.

Constraint	Possible Design Solutions
High Bedrock/ Groundwater Table	Shallower practices with a larger surface area
	Detention/filtration practices which don't depend on infiltration
	Above-grade or rooftop practices
Space Constraints	Permeable pavement
	Subsurface retention or detention
	Combined green and grey infrastructure*
Inadequate Hydraulic Grade	Piped filtration and conveyance systems
	Active management and pumping solutions (not covered in this manual)
Inadequate Pollutant Removal	GI treatment train (practices in series)*

*See case studies on facing page

Figure 3.10 – Site Constraints and Design Solutions Table

Focus on Design Solutions: Combined Approaches

A single green infrastructure practice is not always the most feasible or effective stormwater management solution for a site. Designers may need to consider approaches which combine different types of GI or pair GI with more traditional stormwater infrastructure strategies.

Green Infrastructure in Series

Individual GI practices provide a range of stormwater management and water quality benefits. Often, a single practice may not be adequate to meet site pollutant removal requirements. When practices are used in conjunction or in series, the system can provide greater benefits than any single practice.

A common "treatment train" configuration is a vegetated surface collection device, such as a planter box, which drains filtered runoff to an underground retention or detention facility. This provides an accessible inlet structure with a small footprint and a large underground storage area which is unseen from the surface.

Planter boxes in Portland, Oregon (photo from American Forests website)

Green & Grey Infrastructure Integration

"Green" infrastructure refers to natural stormwater management systems while "grey" infrastructure refers to the hardened network of curbs, channels, and pipes which comprise traditional urban drainage systems. Designers should prioritize GI, but evaluate the strengths and weaknesses of each approach to make an informed decision. Combining natural and engineered stormwater management techniques may provide a wider array of benefits and more flexibility than either green or grey infrastructure would offer separately.

An example of this strategy is using traditional grey collection systems, such as roadway curbs and channels, to direct runoff to green practices such as bioretention or subsurface detention. Designers may also configure an inverse system where GI filters or detains stormwater before releasing it at a controlled rate to the downstream drainage network.

Right-of-way bioswales in NYC use the street slope, curb, and channel to intercept stormwater runoff before entering catch basins (photo from NYC DEP Green Infrastructure website)

3.4 Aligning with PANYNJ Engineering Guidelines

All green infrastructure practices must adhere to applicable PANYNJ Engineering Guidelines. Due to the stormwater drainage and, in some cases, vegetation characteristics of green infrastructure, the Civil Design Guidelines and Aviation Landscape and Sustainable Design Criteria are most commonly applicable. These manuals are summarized below.

Due to the many potential sustainability, resilience, and community stewardship benefits of green infrastructure, these practices may also support the Authority's Sustainable Design Guidelines and Climate Resilience Design Guidelines. Figure 3.11 offers a high-level credit applicability matrix relative to the Leadership in Energy and Environmental Design (LEED) BD+C system, which is incorporated by reference into the Sustainable Building Guidelines. Figure 3.12 provides a similar matrix relative to the Envision Sustainability Rating System, which is incorporated by reference into the Sustainable Infrastructure Guidelines.

Refer to the respective Guidelines for more detailed information (links provided in **Appendix F**).

3.4.1 PANYNJ Sustainable Building Guidelines & LEED Credits

The PANYNJ Sustainable Building Guidelines leverage US Green Building Council (USGBC) LEED credits. The below matrix shows which GI practices may support achievement of various LEED v4 credits. This list is not exhaustive and designers are responsible for assessing all applicable LEED credits.

	Vegetated Infiltration	Non-Vegetated Infiltration	Vegetated Filtration	Non-Vegetated Filtration	Rainwater Harvesting	Retention/ Detention Basins	Constructed Wetlands
Location & Transportation							
LT: Sensitive Land Protection	○	○	○	○	○	◐	●
LT: High Priority Site	○	○	○	○	○	◐	●
Sustainable Sites							
SS: Site Development - Protect/Restore Habitat	◐	○	◐	○	○	◐	●
SS: Open Space	●	○	●	○	○	●	●
SS: Rainwater Management	●	●	●	●	●	●	●
SS: Heat Island Reduction	●	◐	●	◐	○	●	●
Water & Environment							
WE: Outdoor Water Use Reduction (Prereq.)	◐	○	◐	○	●	◐	◐
WE: Outdoor Water Use Reduction	◐	○	◐	○	●	◐	◐

Figure 3.11 – LEED Credit Table

● Usually ◐ Sometimes ○ Rarely

3.4.2 PANYNJ Sustainable Infrastructure Guidelines & Envision Credits

The PANYNJ Sustainable Infrastructure Guidelines leverage Institute for Sustainable Infrastructure (ISI) Envision credits. The below matrix shows which GI practices may support achievement of various Envision v3 credits. This list is not exhaustive and designers are responsible for assessing all applicable Envision credits, especially those dealing with water resources and environmental conservation.

The Climate Resilience credits (especially CR 2.2, CR 2.3, and CR 2.4) may also be applicable if the project uses GI to mitigate climate hazards as per the following section.

	Vegetated Infiltration	Non-Vegetated Infiltration	Vegetated Filtration	Non-Vegetated Filtration	Rainwater Harvesting	Retention/ Detention Basins	Constructed Wetlands
Quality of Life							
QL 3.4: Enhance Public Space and Amenities	◐	◐	◐	◐	○	◐	●
Leadership							
LC 2.3: Plan for Long-Term Monitoring & Maintenance	◐	◐	◐	◐	◐	◐	◐
Resource Allocation							
RA 3.2: Reduce Operational Water Consumption	◐	○	◐	○	●	◐	◐
Natural World							
NW 1.1: Preserve Sites of High Ecological Value	○	○	○	○	○	◐	●
NW 1.2: Provide Wetland & Surface Water Buffers	○	○	○	○	○	○	●
NW 2.2: Manage Stormwater	●	●	●	●	●	●	●
NW 2.3: Reduce Pesticide and Fertilizer Impact	◐	○	◐	◐	○	◐	●
NW 3.1: Enhance Functional Habits	◐	○	◐	○	○	◐	●
NW 3.2: Enhance Wetland & Surface Water Function	○	○	○	○	○	◐	●
NW 3.4: Control Invasive Species	◐	○	◐	○	○	◐	●

Figure 3.12 – Envision Credit Table

● Usually ◐ Sometimes ○ Rarely

3.4.3 PANYNJ Climate Resilience Design Guidelines

Projects which are subject to PANYNJ Climate Resilience Design Guidelines (CRG) must include design strategies to mitigate climate stressors. Primarily, designs must consider sea level rise and coastal inundation. However other stressors such as increasing heat and increasing precipitation are also important resilience factors. GI may contribute to hazard mitigation strategies for each of these stressors as per the below examples.

- **Sea Level Rise / Coastal Inundation:** GI can include berms or elevated areas to protect assets from floodwaters. Mitigation strategies should meet the Sea Level Rise Design Flood Elevation (SLR DFE) as detailed in the CRG.
- **Increasing Heat:** GI can increase the solar reflectance index (SRI) of roofs, sidewalks, parking lots, plazas, and other hardscaped areas. Using trees for shading and other vegetation for ground cover can reduce ambient temperature of a site or provide thermal insulation, resulting in a reduction of HVAC costs and increased longevity of covered assets such as roof membrane. These strategies can work in combination to reduce the urban heat island effect.
- **Increasing Precipitation:** GI can be designed to manage projected future precipitation events or cloudburst events with extreme rainfall intensity. This helps protect downstream assets from surface flooding and reduces the stress and strain on the drainage network, increasing longevity.

GI practices themselves are also subject to climate change stressors. Increasing precipitation and heat may overwhelm systems and put vegetation at risk. Designers should consider these stressors during GI development when selecting the design storm and plant palette.

Refer to the CRG and/or solicit RSD guidance for appropriate climate projections.

3.4.4 PANYNJ Civil Design Guidelines

This document, administered by PANYNJ Civil Discipline, covers design standards for roadways, container terminals and transfer yards, airfields, track work, pavements, stormwater, water supply, sanitary sewer, and gas utility. GI designs must adhere to these guidelines.

3.4.5 PANYNJ Aviation Landscape and Sustainable Design Criteria

PANYNJ Landscape Architecture group administers these guidelines to detail landscaping strategies at aviation facilities and provide guidance on sustainable practices. This manual covers design parameters and recommendations, design criteria for bird deterrents, plant palettes, irrigation, hardscape and maintenance, and strategies for reducing construction impacts.

GI projects in the vicinity of aviation facilities must adhere to these guidelines.

(flickrcc: NYS Stormwater)

4.0 Stage III: Detailed Design

During Stage III, designers take the proposed green infrastructure practices from Stage I and advance them through detailed design, confirming the practices meet regulatory requirements, conform to PANYNJ Guidelines, and align with PANYNJ goals and initiatives.

This process includes calculating runoff volumes and flows from the design storm, sizing the GI practice and its components, confirming pollutant removal rates, selecting vegetation, developing design drawings, and compiling specifications.

The following sections give an overview of these steps. More specific design guidance for each GI type is included in the fact sheets in **Section 5.0.**

Certain agencies, including NJ DEP, also require specific groundwater recharge rates. These calculations are not covered in this manual but are the responsibility of designers to address as required.

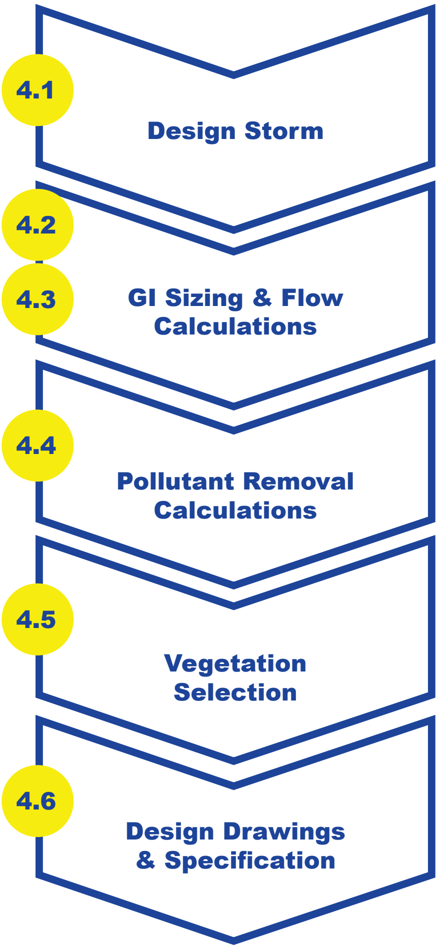


Figure 4.1 – Detailed Design Process

4.1 Stormwater Management Design Storm

For both water quality and water quantity metrics, the design storm determines the volume and/or flow that green infrastructure practices should be designed to manage. The design storm may be defined differently depending on the applicable guidelines.

Figure 4.2 provides an overview of applicable design storms for PANYNJ projects.

Design Storm Terminology

Common terms used to define storm events are listed below with their definitions:

- **Percentile:** the storm of a certain percentile has a rainfall depth greater than or equal to the corresponding percentage of storms for the time period analyzed. For example, a 90th percentile storm has a rainfall depth greater than or equal to 90% of all documented storms for a given location and duration.
- **Probability and Return Period:** the probability of a certain storm magnitude being met or exceeded in a single year can be given in terms of percent probability or in a statistically-expected frequency (usually in years). For example, a storm event with 20% probability of occurring in a given year can also be referred to as a “5-year storm” since it would statistically occur at least once over this time period on average.
- **Intensity:** rainfall intensity is measured in depth over time, usually inches per hour. Storms can be defined by their intensity, such as a 1.25 inch/2-hour event. Rainfall intensity is typically used to calculate the storm’s peak flow.

Disclaimer

This table is for reference only and does not replace or supersede the actual guidance documents. It also does not include municipal regulations which may be more stringent than state regulations. Certain agencies, including NJ DEP, also require specific groundwater recharge rates, which are not covered in this manual. Designers are responsible for complying with all applicable rules, regulations, and design calculations.

	Guidelines	General Applicability	Water Quality Design Storm	Water Quantity Design Storm
State	**NYS DEC Stormwater Management Design Manual**	Land disturbance > 1 acre	Must manage Water Quality Volume (WQv)=runoff volume from 90th percentile storm depth	
	NJ DEP Best Management Practices Manual (updated 3/2/2021)	Land disturbance > 1 acre	Must manage Stormwater Quality Design Storm = volume from 1.25 inch / 2-hour storm	Design must not exceed preconstruction flow for 2-, 10-, 100-year 24-hour storm events*
PANYNJ	**Civil Design Guidelines (Stormwater Drainage)**	All PANYNJ projects with stormwater drainage scope	Defers to NYS DEC and NJ DEP requirements above	Must manage 10-year storm volume
	Sustainable Building Guidelines (LEED v4 SS Credit: Rainwater Management)	Building projects > 1,000 gross square feet	Must manage 95th or 98th Percentile 24-hour storm event	
	Sustainable Infrastructure Guidelines (Envision v3 Credit NW 2.2: Manage Stormwater)	Infrastructure projects of significant scope (consult RSD)	Must manage 100% of the below storm volumes for various achievement levels (150% if detention only): **Enhanced:** 85th percentile/2-year event **Superior:** 90th percentile/10-year event **Conserving:** 95th percentile/50-year event **Restorative:** 95th percentile/100-year event	Design must not exceed preconstruction flow for 2-, 5-, and 10-year 24-hour storm events
	Climate Resilience Design Guidelines	Building or Infrastructure projects which are within, or in proximity to, current or future floodplains	Consult RSD for guidance in designing to future rainfall events and climate projections	N/A

* NJ DEP Best Management Practices Manual allows for additional compliance pathways

Figure 4.2 – Design Storms Overview

Because of the variations in applicability and magnitude of these design storms, designers should compare each and select the design storm for the project which achieves the below criteria:

1. Meets all regulatory requirements.
2. Meets PANYNJ Civil design requirements.
3. Maximizes LEED and/or Envision achievement levels to meet PANYNJ Sustainable Design Guidelines criteria.
4. Aligns with PANYNJ climate resilience goals.

State stormwater design guidance, and therefore PA Civil design guidance, is generally at or below the minimal threshold for third-party sustainability achievement. To achieve LEED and/or Envision credits and meet future stormwater challenges associated with climate change, designers may need to design for storms beyond these regulatory guidelines.

4.1.1 Calculating Water Quantity: Design Storm Volume & Peak Flow

Using the project's design storm from the previous step, designers can calculate the most critical outputs for managing water quantity: **Design Storm Volume** and **Design Storm Peak Flow.** These values are typically established using one of three methods: the USDA Natural Resources Conservation Service (NRCS) methodology (including TR-55), the Rational Method, or the Modified Rational Method (MRM). Software modeling packages must be preapproved by the LE/A. In cases where more complex analysis is needed, designers may also develop a runoff hydrograph which plots the design storm flow over time. See **Appendix A** for resources to employ these methods.

4.2 Green Infrastructure Sizing Calculations

Green infrastructure practices should have adequate capacity to store the entire design storm volume without overflowing. Storage capacity is defined as the sum of all void spaces within the practice. Designers should select the GI footprint area, depth, storage components (e.g., chambers, tanks, pipes, cisterns), and/or drainage media (e.g., stone, soil) to provide adequate design capacity.

To calculate capacity, designers first determine the volume (V) and porosity (φ) of all components. Multiplying the porosity by the volume will equal the total void space (i.e., capacity) of that media. A general equation for sizing is below:

$$\textbf{GI Capacity} = V_{ponding} + V_{storage} + \sum(\varphi_{media} * V_{media})$$

The PANYNJ Green Infrastructure Calculator includes a streamlined interface for calculating GI capacity based on general assumptions.

Site constraints such as limited space or high seasonal groundwater or bedrock may prevent designers from being able to achieve full design capacity. Individual jurisdictions may offer waivers in certain cases when regulations cannot be met. For PANYNJ projects, designers should consider both non-structural strategies for reducing runoff volumes and structural strategies for maximizing the capacity of the GI practice.

Porosity is the fraction of voids in a material or defined space. Since tanks and chambers are completely hollow, they have a porosity of 1.0. Other common porosities are below. Note that these values will vary between products and jurisdictions.

- Ponding area = 1.0
- Storage components = 1.0
- Open-graded stone reservoir = 0.4
- Engineered soil = 0.2

(flickrcc: Aaron Volkening)

4.3 Green Infrastructure Peak Flow Rate

Regardless of whether a green infrastructure practice has adequate capacity to store the design storm, the practice should be designed to safely convey its peak flow. A GI practice should be able to:

1. Safely convey the peak flow from the design storm through the GI practice.
2. Control outflow to adjacent drainage systems to meet site connection requirements (if applicable). Refer to PANYNJ Civil Design Guidelines for more information on stormwater conveyance design.
3. Draw down any standing water in 48 hours or less. If the practice is designed to have open-water pools, water should draw down to the permanent pool elevation within 48 hours.
4. Safely bypass or overflow excess runoff when design storm is exceeded.

The overall flow rate of a GI practice is defined by its most limiting component (i.e., the one which provides the lowest passing flow rate). This may be an inlet structure, drainage media such as soil, outlet structure, surrounding soil, or other design component. For manufactured treatment devices, the flow rate capacities are included in the specifications.

Often, filtration and detention practices need to include slow-release orifices to control the flow into the downstream drainage system. This helps to attenuate peak flows and lessens the burden on the drainage system. Designers should ensure the GI practice has adequate capacity to accommodate the reduced outflow rate. If project site discharges stormwater to municipal drainage systems, they must meet applicable site connection rules.

Once the flow rate capacity is confirmed, designers should calculate the drawdown time to make sure it is less than 48 hours in order to prevent mosquito propagation.

Because GI practices typically don't manage flow rates above that of the design storm, designers must provide safe overflow and/or bypass pathways for excess runoff.

4.4 Pollutant Removal Calculations

Both New York and New Jersey state regulations require major development projects to meet pollution removal rates for total suspended solids (TSS) and the nutrients nitrogen and phosphorus. These rates are based on the ability to manage the stormwater quality design storm as defined for each regulatory entity:

- **NYS DEC:** Stormwater practices must manage 100% of Water Quality Volume (WQv), which is based on the 90th percentile storm depth.
- **NJ DEP:** Stormwater practices must manage 100% of volume from the Stormwater Quality Design Storm, which is a 1.25 inch / 2-hour storm event.

The removal requirements for each pollutant are summarized in Figure 4.3:

	General Applicability	Total Suspended Solids (%)	Total Nitrogen (%)	Total Phosphorus (%)
Regulatory Guidance				
NYS DEC Stormwater Management Design Manual	Project disturbance > 1 acre	80	Maximum extent practicable	40
NJ DEP BMP Manual / SW Rule N.J.A.C 7:8 (updated 3/2/2021)	Project disturbance > 1 acre	80 (Roadways ony)	Maximum extent practicable	Maximum extent practicable
PANYNJ Criteria				
GIDM Recommendations	Project scope includes stormwater management	Maximum extent practicable	Maximum extent practicable	Maximum extent practicable

Figure 4.3 – Pollutant Removal Overview

The guidance manuals for both states include methods for calculating the water quality design storms and provide resources for designing green infrastructure to meet the pollutant removal criteria. If GI practices follow the design recommendations of the manuals, the regulatory entities presume the criteria is achieved.

Additionally, individual PANYNJ facilities may be subject to SPDES or NJPDES permits which define water quality requirements.

The GIDM does not mandate specific pollution removal rates per GI practice. However, designers should follow best practices and configure GI to remove TSS, nitrogen, and phosphorus to the maximum extent practicable. Designers should refer to the respective state and municipal guidance for applicability requirements and guidance. The state manuals include pollutant removal rates for various practices and strategies for implementing treatment trains (i.e., GI practices designed in series) to maximize removal efficacy.

!

Disclaimer

This table is for reference only and does not replace or supersede the actual guidance documents. It also does not include municipal regulations which may be more stringent than state regulations. Designers are responsible for complying with all applicable rules, regulations, and design calculations.

Pretreatment Devices

Pretreatment devices capture trash, sediment, and other pollutants from stormwater runoff before it enters the GI practice, thus preventing clogging and minimizing maintenance. Pretreatment components can include a variety of structures such as: sumped inlets, sediment/grit chambers, separators, media filters, inlet inserts, or other sediment and floatables removal devices. The devices should be easy to access for cleanout and maintenance. Pretreatment is typically necessary in practices with a tributary greater than one acre.

4.5 Vegetation Selection

If a green infrastructure practice includes vegetation, designers should employ or consult a landscape architect for selecting appropriate trees, shrubs, grasses, and other plants.

GI practices consist of different inundation zones which plants should be designed to tolerate. Plants should also be capable of handling the expected sediment and pollutant load from the upstream tributary.

Designers may also consider factors such as water, sunlight, and maintenance needs. If the practice is located in or near an aviation facility, it must conform to the PANYNJ Aviation Landscape and Sustainable Design Criteria.

Appendix B includes a list of common plants which PANYNJ recommends for use in GI practices. It summarizes the selection criteria for each plant and includes photographs of the mature species.

Vegetated GI Practice – Blue False Indigo, Purple Coneflower

4.6 Design Drawings and Specifications

Designers must follow all applicable PANYNJ guidelines pertaining to development of Stage III design drawings. The drawings should include the following details of each green infrastructure practice, at a minimum:

- Full-page tributary delineation with hydrologic and hydraulic design calculation tables detailing:
  - Design storm volume
  - Peak flow
  - Capacity of GI practices to manage design storm volume
  - Outflow rate (if filtration or detention practice)
- Plan view of entire GI practice.
- Typical cross-section of GI practice.
- Cross-section along primary runoff flow path, with critical elevations labeled.
- Details of pretreatment devices, inlets, outlets, underdrains & conveyance piping, overflow structures, or other specialized drainage features.
- Landscaping plan for vegetated practices.

Example GI designs are included in **Appendix C**. These drawings may be used as reference templates and are available in CAD format on request (email sustainabledesignmanager@panynj.gov).

Designers should also include construction specifications specific to the GI practices and their components. Since PANYNJ may not have standard or custom specifications available for all GI components, designers may be responsible for developing their own.

Appendix D includes example construction specification language for the following components:

- Engineered Soil.
- Open-graded Stone Reservoir.
- Perforated Underdrain with Outlet Control.
- Precast Porous Concrete Panels.
- Permeable Asphalt.
- Pervious Concrete.

5.0 Green Infrastructure Practice Types

This section provides more details on the green infrastructure types discussed in this manual. Each section consists of fact sheets with descriptions of practices and information such as: common variations, facility applicability, minimum design criteria, design components, co-benefits, and maintenance considerations. The overview of the GI fact sheet sections is shown in Figure 5.1.

	GI Practices	
5.1	**Surface Infiltration & Filtration**	Vegetated Surface Infiltration Non-vegetated Surface Infiltration Vegetated Surface Filtration Non-vegetated Surface Filtration
5.2	**Permeable Pavement**	Permeable Pavers Precast Porous Concrete Panels Permeable Asphalt Pervious Concrete
5.3	**Subsurface Infiltration**	Subsurface Chambers Gravel Bed Systems Dry Wells
5.4	**Green Roofs**	Extensive Systems Intensive Systems
5.5	**Rainwater Harvesting**	Below-grade Cisterns Above-grade Cisterns
5.6	**Manufactured Treatment Devices**	Hydrodynamic Separators Media Filter Devices Biofilters
5.7	**Large-Scale GI Practices**	
	Basins	Detention Basin Retention Basin
	Constructed Wetlands	Tidal Wetlands Non-Tidal Wetlands

Figure 5.1 – GI Fact Sheet Index

(flickrcc: Aaron Volkening)

(flickrcc: Center for Neighborhood Technology)

(Contech)

(flickrcc: Dan Keck, The Ohio State University)

(flickrcc: Michael Coghlan)

5.1 SURFACE INFILTRATION & FILTRATION

(flickrcc: Aaron Volkening)

FACILITY APPLICABILITY

Airside Aviation 🟡	Terminals 🟢	Rail Corridors 🟢	Buildings 🟡	Campus & Plazas 🟢	Roads & Parking Lots 🟢

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Surface infiltration and filtration practices function by collecting surface runoff and conveying it through various layers of permeable media, such as engineered soil, open-graded stone, or sand. The captured runoff then either infiltrates into the underlying soil (infiltration) or releases into the adjacent stormwater system (filtration). These practices may or may not include vegetation.

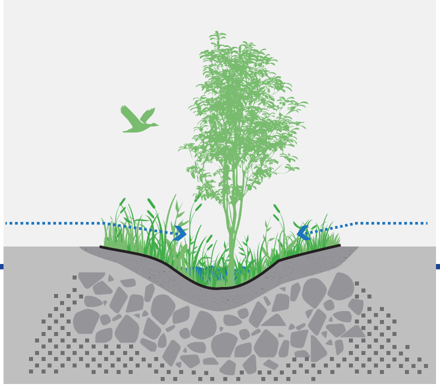
Infiltration practices provide two fundamental stormwater management functions: decrease of runoff quantity and improvement of the stormwater quality. Depending on the configuration, these practices filter stormwater pollutants, contribute to groundwater recharge, decrease runoff peak flow rates, and decrease the overall volume of stormwater runoff discharging to the drainage system or receiving water body.

Filtration-only practices offer similar water quality and peak flow reduction benefits to infiltration, but typically do not contribute to groundwater recharge and provide limited overall volume reduction. Designers may need to pair them with other GI practices to meet stormwater quantity goals.

Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	**Water Quality**	**Water Volume**	**Peak Flow Reduction**	**GW Recharge**	**Water Use Reduction**	**Wildlife Preservation**	**Air Quality**	**Heat Island Reduction**	**Aesthetic Improvement**	**Increased Infra. Durability**	**Decreased Site Maintenance**
Bioretention	●	●	●	●	◐	◐	●	●	●	○	○
Infiltration Basin	●	●	●	●	◐	◐	●	●	●	○	○
Infiltration Trench	●	●	●	●	◐	○	○	◐	◐	◐	◐
Biofiltration	●	○	●	○	◐	◐	●	●	●	○	○
Stormwater Planters	●	○	●	○	◐	◐	●	●	●	○	○
Sand Filtration	●	○	●	○	○	○	○	◐	◐	◐	◐

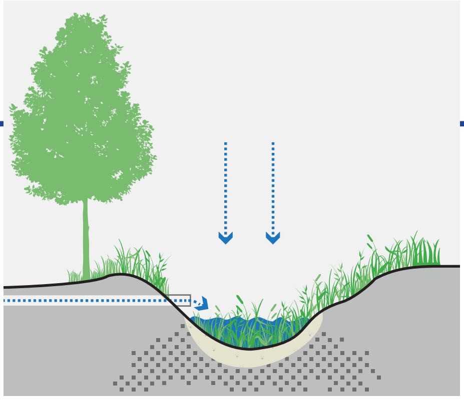
● Usually ◐ Sometimes ○ Rarely

Variations: Vegetated Surface Infiltration

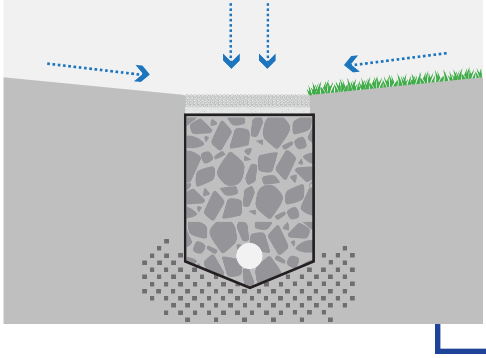


Bioretention: shallow, vegetated areas with sloped sides designed to capture and infiltrate stormwater into the ground. The side slopes and bed are typically planted with native species that are resilient to periods of inundation and drought (wet and dry conditions). The vegetation is underlain by engineered soil and usually includes a stone storage reservoir below. Bioretention practices are typically 2 to 5 feet deep. Subtypes include rain gardens and vegetated swales.

Infiltration Basin: a deep, vegetated retention area designed to capture and infiltrate stormwater from a large area. It is similar in makeup and function to other bioretention practices, but is generally larger, contains mostly densely planted grasses, and is underlain by sand filtration layers. Infiltration basins can range from 2 to 12 feet in overall depth.



Variations: Non-vegetated Surface Infiltration



Infiltration Trench: a shallow non-vegetated trench, typically up to 2 to 4 feet deep. The trench is filled with a coarse stone aggregate which allows for the collection and storage of runoff as it infiltrates into the surrounding soil.

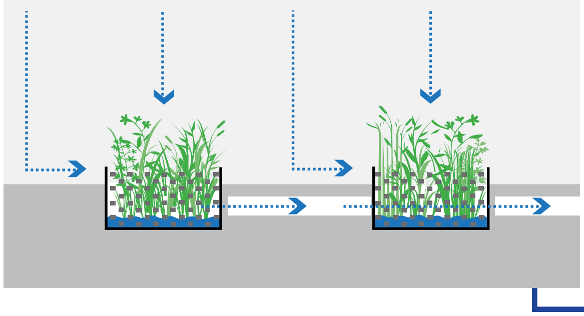
Bioretention

(flickrcc: Aaron Volkening)

Infiltration Trench

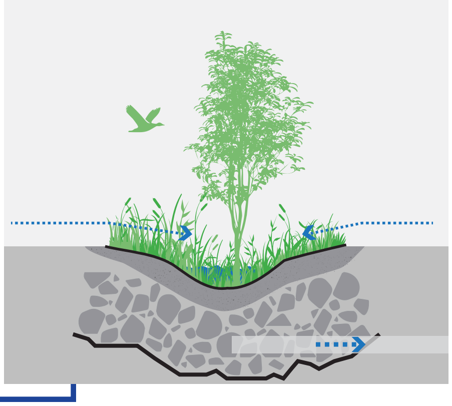
(flickrcc: Center for Watershed Protection, Inc.)

Variations: Vegetated Filtration

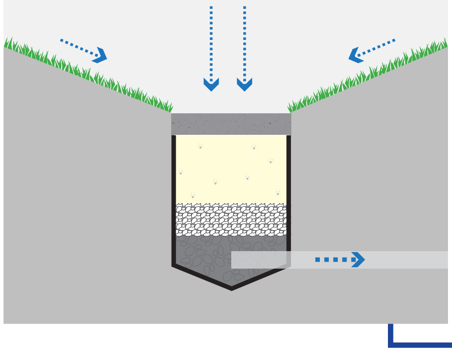


Stormwater Planters: self-contained, vegetated areas which filter and convey stormwater to the downstream drainage network or waterway via a system of underdrains. Flow-through planters are most effective at treating small storm events because of their comparatively small individual treatment capacity. They typically treat runoff directly from drainage downspouts or other piped conveyance systems.

Biofiltration: similar in composition to bioretention but uses underdrains to convey filtered stormwater back to the drainage system rather than rely on infiltration. These practices are best suited for areas with high bedrock or groundwater table or where surrounding soil permeability is below the minimum threshold. Shallow biofiltration practices may also be located above some underground vaults and utilities.



Variations: Non-Vegetated Filtration



Sand Filter: a non-vegetated stormwater filtration system which captures and filters runoff through layer of clean, medium-aggregate sand. Sand filters typically return the treated runoff to the stormwater system but may allow it to partially infiltrate into the surrounding soil depending on soil properties. Sand filters are up to 5 feet deep. Note that designers may propose sand filters with vegetation and/or infiltration to improve the benefits.

Biofiltration Planter

(flickrcc: Radcliffe Decanay)

Sand Filter

(flickrcc: Center for Watershed Protection, Inc.)

Applications

The selection of surface infiltration and filtration practices types primarily depends on drainage area size, permeability rate of soil, depth to groundwater table and/or bedrock, utility locations, and vegetation restrictions.

Designers should give priority to vegetated infiltration practices since they offer the greatest stormwater benefits. Consider filtration practices only where geotechnical limitations preclude infiltration or where additional water quality benefits are needed.

At aviation facilities, surface media may need to be secured using netting or meshes to prevent any foreign object debris/damage issues.

The below matrix shows the applicability criteria for each practice.

GI Practice	Tributary Area (acre)	Min. Soil Permeability Rate (in/hr)	Min. Separation from GWT and Bedrock (ft)	Includes Vegetation
Bioretention	< 1	0.5	3	Yes
Infiltration Basin	< 5	0.5	3	Yes
Infiltration Trench	< 5	0.5	3	No
Biofiltration	< 1	N/A	1	Yes
Stormwater Planters	< 0.25	N/A	1	Yes
Sand Filtration	< 5	N/A	1	No


Bioretention

(flickrcc: Center for Neighborhood Technology)


Infiltration Trench

(flickrcc: Montgomery County Planning)

Design Criteria

- **Water Quantity (Infiltration):** infiltration practices should have the capacity to store 100% of the design storm volume, at a minimum; may be higher if pursuing LEED or Envision credits.
- **Water Quantity (Filtration):** filtration practices should be capable of filtering 100% of the peak flow rate of the design storm (150% if pursuing Envision credit NW 2.2: Manage Stormwater).
- **Water Quality:** drainage media should be configured to remove 80% of total suspended solids (TSS) and maximum amount practicable of phosphorus and nitrogen.
- Maximum slope of practice and tributary area is 15%.
- Maximum ratio of tributary area to GI footprint area is 10:1.
- Maximum side slope ratio for earthen embankments is 3:1.
- Surface ponding should drain within 48 hours.
- If low infiltration or high groundwater, entire practice may be surrounded in an impervious liner.

Design Components

Surface infiltration and filtration practices generally consist of the components in the table below. The following sections give an overview of each.

GI Practice	Ponding Area	Engineered Soil	Sand Layer	Stone Reservoir	Vegetation	Forebay*	Underdrain
Bioretention	●	●	○	●	●	◐	◐
Infiltration Basin	●	◐	●	◐	◐	◐	◐
Infiltration Trench	●	○	○	●	○	◐	◐
Biofiltration	●	●	○	●	●	◐	●
Stormwater Planters	●	●	○	○	●	◐	●
Sand Filtration	●	○	●	○	○	◐	●

● Usually ◐ Sometimes ○ Rarely

**Forebay to be included based on sediment load from contributing drainage area*

Note that some manufacturers offer prefabricated biofiltration devices which include all the above components in a single package. These products are discussed in more depth in **Section 5.6: Manufactured Treatment Devices**.

Ponding Area

Designers should base ponding depth on storage capacity requirements, adjacent land use, and maximum allowable drawdown time of 48 hours (to prevent mosquito proliferation). When used, ponding area should have a minimum depth of 3 inches, but the actual ponding depth may vary across the site. There should be at least three inches vertically between the top of ponding area and the adjacent grade. Ponding depth should not exceed 12 inches.

Designers should specify overflow devices to control maximum surface ponding depth.

Engineered Soil

Engineered soil is a specialized growing medium which allows for healthy plant growth while also maximizing its permeability rate. Engineered soil should be deep enough to accommodate root establishment and provide any required pollutant removal. Vegetated practices with trees should have a minimum soil depth of 2.0-2.5 feet, depending on size and species. Vegetated practices without trees should have a minimum soil depth of 1.5 feet. Engineered soil layers generally require geotextile fabrics for containment and to maintain separation with adjacent media.

Stone Reservoir

The void spaces in the stone reservoir are the primary means of stormwater storage capacity in some practices. The volume of the stone reservoir depends on the design storm volume and the void ratio between the stones. Designers may maximize storage volume by extending the reservoir beyond the practice's surface footprint. However, practices should not exceed the maximum ratio of tributary area to footprint area detailed in the Design Criteria. Stone reservoirs generally require geotextile fabrics along the sides and top only for containment and to maintain separation with adjacent media.


Bioretention

(flickrcc: NYCDEP)


Bioretention

(flickrcc: Center for Neighborhood Technology)

Sand Filter Layer

The sand filter layer is effective in removing common pollutants from stormwater. Designers should select the depth of sand layer based on the water quality requirements for the site. Sand filter layers generally require geotextile fabrics for containment and to maintain separation with adjacent media.

Vegetation

Appropriate vegetation is essential to the functionality of any vegetated practice. The designer should select plants based on their ability to withstand wet and dry conditions, maintenance requirements, site constraints, and available sunlight. At aviation facilities, plants must not attract wildlife. The vegetative cover may also help provide an aesthetic benefit and prevent erosion, particularly on sloped areas. Refer to **Appendix B** for guidance on plant selection and suitability.

Forebay & Inlet Structures

Depending on the upstream tributary, designers may elect to include inlet design elements which dissipate runoff velocity and/or offer pretreatment for runoff with high levels of debris and sediment. Strategies may include inlet baffles, sumps, riprap, buffer vegetation, or manufactured pretreatment devices. Designers should size these elements properly to accommodate the calculated flows.

Underdrains

Underdrains convey stormwater from the green infrastructure practices to nearby stormwater systems or waterways. They are the primary means of conveyance for filtration practices but can also be used by infiltration practices to supplement stormwater management in cases of low permeability. The following guidelines apply:

- Underdrains should be perforated within the footprint of green infrastructure practices and have a minimum 6" internal diameter.
- All underdrains should include vertical cleanout ports which are accessible from the surface.
- Underdrains should be designed to safely convey the design storm without surcharging the GI practice.
- If connecting to stormwater systems, a low flow orifice should control underdrain discharge as per regulatory site connection requirements or as specified by PANYNJ.

Bioretention

(flickrcc: Center for Neighborhood Technology)

Bioretention

(flickrcc: Eric Fischer)

Infiltration Basin

(flickrcc: MassDOT)

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Document that engineered soil, sand, and stone conform to the design specifications. Resident Engineer may require batch testing to confirm that individual loads confirm to design specifications.

Refer to **Section 6.0** for general GI construction considerations.

Maintenance Considerations

Common regular maintenance tasks and general frequencies are listed below. Note that these may vary significantly between practices and locations. Each green infrastructure practice should be accompanied by a robust maintenance plan, which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	General Frequency
Trash/debris removal	Monthly
Sediment removal	Monthly
Weeding	Monthly
Underdrain flushout	Quarterly
Structural pruning	Annually
Replanting (as necessary)	Annually
Structural inspection	Annually

Other considerations for maintenance include:

- Watering may need to be completed as needed during drought conditions or on a more frequent schedule during the initial plant establishment period.
- Designer should consider access routes for maintenance.
- Surface infiltration and filtration practices may not be used for stockpiling plowed snow and ice, compost, or any other material

Resources

NJ DEP Stormwater BMP Manual (March 2021)

- Chapter 9.7: Small-scale Bioretention Systems
- Chapter 9.8: Small-scale Infiltration Basins
- Chapter 9.9: Small-scale Sand Filters

NYS DEC Stormwater Management Design Manual (January 2015)

- Chapter 5.3.3: Vegetated Swale
- Chapter 5.3.7: Rain Gardens
- Chapter 5.3.9: Stormwater Planters
- Chapter 6.3: Stormwater Infiltration
- Chapter 6.4: Stormwater Filtering Systems

Links to State manuals included in **Appendix F.**

Bioretention

(flickrcc: Chris Hamby)

Bioretention

(flickrcc: Mississippi Watershed Management Organization)

5.2 PERMEABLE PAVEMENT


(flickrcc: Center for Neighborhood Technology)

FACILITY APPLICABILITY

Airside Aviation	Terminals	Rail Corridors	Buildings	Campus & Plazas	Roads & Parking Lots
🟡	🟢	🟢	🟢	🟢	🟢

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Permeable pavement (also referred to as porous pavement or pervious pavement) is a specialized type of surface infiltration practice which provides the structural support of pavement while allowing stormwater runoff to pass through into storage and filtration layers. Porous surface materials include specific types of asphalt, concrete, and paver bricks and commonly apply to roadways, sidewalks, parking lots, plazas, or other paved areas.

Permeable pavement may provide two fundamental functions in stormwater management: decrease of runoff quantity and improvement of stormwater quality. Most permeable pavement practices infiltrate captured stormwater into the ground. In areas with shallow groundwater or bedrock, permeable pavement can exclusively provide filtration and convey treated runoff to the drainage system at a controlled rate via a system of underdrains.


Permeable Block Pavers

(flickrcc: Sam Beebe)


Precast Porous Concrete Panels

(stormcrete.com)


Permeable Asphalt

(flickrcc: Aaron Volkening)


Pervious Concrete

(flickrcc: Aaron Volkening)

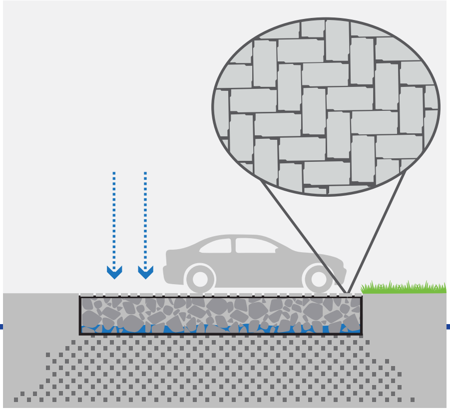
Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	Water Quality	Water Volume	Peak Flow Reduction	GW Recharge	Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infra. Durability	Decreased Site Maintenance
Porous Pavement (Infiltration)	●	●	●	●	○	○	○	◐	◐	◐	○
Porous Pavement (Filtration only)	●	○	●	○	○	○	○	◐	◐	◐	○

● Usually ◐ Sometimes ○ Rarely

Variations

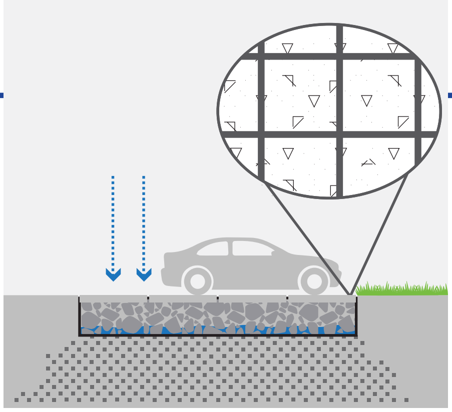
Permeable pavement includes the below surface cover options. Any of these variations may overlay similar filtration layers, subsurface storage reservoir, and/or an underdrain conveyance system. See the “Design Components” section for more information on the advantages and considerations of each.

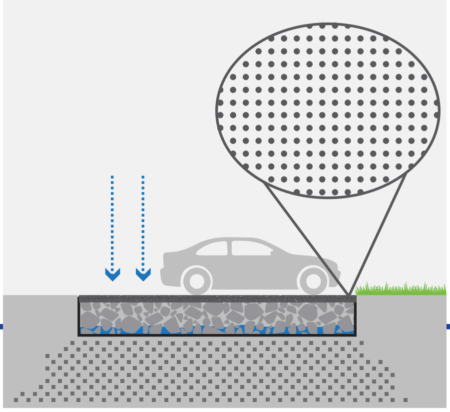
Variations: Surface Material



Permeable Pavers: precast masonry paving bricks which allow runoff to enter via porous gaps between the individual blocks. The gaps between bricks may or may not contain fine aggregate or sand.

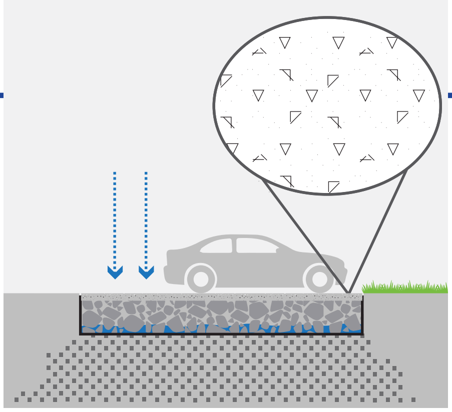
Precast Porous Concrete Panels: rectangular panels manufactured in a controlled environment which allow stormwater to pass through the concrete media itself. Panels are typically 4 to 5 feet wide and can be produced at various lengths.





Permeable Asphalt: poured-in-place asphalt with an open-graded aggregate mix design which allows stormwater to pass through it. Onsite placement requires additional quality control.

Pervious Concrete: poured-in-place concrete with an open-graded aggregate mix design which allows stormwater to pass through it. Onsite placement requires additional quality control.



Any of the above configurations may include underdrains for filtration-only practices.

Applications

Permeable pavement is best suited for low-traffic hardscaped areas such as parking lots, sidewalks, plazas, minor roadways, alleys, driveways, and maintenance accesses. Opportunities exist to install permeable pavement in many PANYNJ facilities. However, designers should consider factors such as sediment loading, leaf and seed drop from overhanging vegetation, foreign object debris (FOD) at airside locations, and heavy vehicle loads.

Designers should give priority to permeable pavement configurations which rely on storage and infiltration to manage stormwater. However, these practices are limited to locations which can achieve a minimum of 3 feet separation between the bottom of the practice and the groundwater table, bedrock, or impermeable soil layer. If these separations cannot be met, the designer may consider shallower underdrain systems to accommodate conveyance of filtered runoff to adjacent drainage networks or waterways.

GI Practice	Min. Soil Permeability Rate (in/hr)	Min. Separation from GWT and Bedrock (ft)	Includes Vegetation
Porous Pavement (Infiltration)	0.5	3	Yes
Porous Pavement (Filtration)	N/A	1	No

The porous surface materials are generally interchangeable, but some applications are more suitable in different situations. See the "**Design Components**" section for more information.

Permeable Block Pavers

(flickrcc: Jarrett M)

Design Criteria

- **Water Quantity (Infiltration):** permeable pavement that utilizes infiltration should have the capacity to store 100% of the design storm volume, at a minimum; may be higher if pursuing LEED or Envision credits.
- **Water Quantity (Filtration):** Permeable pavement that only filters runoff should be capable of filtering 100% of the peak flow rate of the design storm (150% if pursuing Envision credit NW 2.2: Manage Stormwater).
- **Water Quality:** stone layers should be configured to remove 80% of total suspended solids (TSS) and maximum amount practicable of phosphorus and nitrogen.
- Minimum surface course infiltration rate should be 20 inches per hour.
- Maximum slope of practice and tributary area is 5%; practices with steep slopes may require check dams to regulate the storage within the stone reservoir.
- Maximum ratio of tributary area to surface area is 3:1; may be higher upon PANYNJ approval.
- Reservoir should fully drain in 48 hours.
- Surface material should meet load bearing requirement determined by site usage.
- If low infiltration or high groundwater, entire practice may be surrounded in an impervious liner.

Design Components

Regardless of surface materials, permeable pavements typically overlay a choker/filtration course and a stone reservoir, separated by geotextile fabric. If infiltration is limited, designers may implement an underdrain system to accommodate outflow to adjacent drainage systems or waterbodies.

Surface Material

Designers should select the surface material most suitable for the project characteristics. The below table summarizes the advantages and considerations for the various surface materials.

Surface Material	Advantages	Considerations
Permeable Pavers	• Aesthetically pleasing • Quality controlled • Easy to repair if damaged • Provides "green jobs" for laborers	• Costly to purchase and install • Differential settlement possible • Challenging to maintain clogged joints
Precast Porous Concrete Panels	• Quality controlled • Easy to install • Easy to repair if damaged • Easy to lift for installation/access	• Harder to fit in irregular footprints
Permeable Asphalt	• Minimal seams, monolithic • Cheaper than precast products	• Quality control is a major issue • Difficult to repair if damaged • May experience aggregate raveling
Pervious Concrete	• Minimal seams, monolithic • Cheaper than precast products	• Quality control is a major issue • Difficult to repair if damaged • May experience spalling over time

The designer should also consider surface materials with the highest surface reflectance index (SRI) values in order to reduce the heat island effect.

Choker/Filtration Course

A choker course underlays the surface pavement to provide stability and to assist in runoff filtration. The choker course typically consists of clean, washed AASHTO No. 57 broken stone and is 4"-6" thick. The choker course overlays a geotextile fabric that prevents fine materials from migrating into the stone storage reservoir below.

Stone Reservoir

The gaps in the stone reservoir are the primary means of stormwater storage. Designers should specify a single stone size with 40%-50% void ratios. The stone reservoir should have enough void space to store the entire design storm volume. Designers may maximize storage depth by extending the reservoir beyond the practice's surface footprint. Stone reservoirs generally require geotextile fabrics on the tops and sides only for containment and to maintain separation with adjacent media. A minimum 3 feet of separation should exist between the bottom of the stone reservoir and bedrock or the seasonal high groundwater table for infiltrating systems.

Underdrains

Underdrains convey stormwater from the green infrastructure practices to nearby stormwater systems or waterways. They are the primary means of conveyance for filtration practices but can also be used by infiltration practices to supplement stormwater management in cases of low permeability. The following guidelines apply:

- Underdrains should be perforated within the footprint of green infrastructure practices and have a minimum 6" internal diameter.
- All underdrains should include vertical cleanout ports which are accessible from the surface.
- Underdrains should be designed to safely convey the design storm without surcharging the GI practice.
- If connecting to stormwater systems, a low flow orifice should control underdrain discharge as per regulatory site connection requirements or as specified by PANYNJ.


Pervious Concrete

(flickrcc: Center for Watershed Protection, Inc.)


Permeable Block Pavers

(flickrcc: Center for Neighborhood Technology)

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Document that in situ mixes have been adequately tested and conform to the design mix.
- Install and cure in situ pavements in suitable environmental and climactic conditions.
- Level and plane the choker course to form an even and consistent surface for installing the surface material. An inadequate choker course may lead to surface cracking and differential settlement.
- Document that stone aggregate conforms to the design specifications. Resident Engineer may require batch testing to confirm that individual loads conform to design specifications.

Refer to **Section 6.0** for general GI construction considerations.

Maintenance Considerations

Common regular maintenance tasks and general frequencies are listed below. Note that these may vary significantly between practices and locations. Each green infrastructure practice should be accompanied by a robust maintenance plan which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	General Frequency
Remove topical sediment and debris from paving area	Monthly
Ensure area is clean of sediments	Monthly
Remove sediment from surface material using regenerative air sweeper.	Seasonally
Inspect surface for deterioration, cracking, or spalling	Annually
Test the infiltration rate of surface material to confirm performance	Annually (Spring)

Other Maintenance Considerations

Permeable pavement is vulnerable to clogging and therefore requires consistent maintenance and specialized equipment. The upstream tributary and surface material type will ultimately dictate the maintenance requirements for the practice. Permeable pavement may clog more easily in the following situations:

- Downstream of tributaries with high volumes of sediment loads.
- In areas with high vehicular traffic that may cause subsurface compaction.
- In cold climate areas that use salt, sand, and other snow removal techniques.

Maintenance staff may use pressurized air or water to perform regenerative cleaning for clogged surfaces.

During winter months, pervious pavements may be damaged by snowplows or loader buckets set too low to the ground or not equipped with a rubber blade guard. Sand, grit, cinders, or other fine sediments should not be used on the surface for snow or ice control. De-icing chemicals containing magnesium chloride, calcium magnesium acetate, or potassium acetate should never be used on pervious concrete. Designer should confirm the suitability of deicing strategies for the surface material.

Resources

NJ DEP Stormwater BMP Manual (March 2021)
- Chapter 9.6: Pervious Paving Systems

NYS DEC Stormwater Management Design Manual (January 2015)
- Chapter 5.3.11: Porous Pavement
- Chapter 6.3: Stormwater infiltration
- Chapter 6.4: Stormwater Filtering Systems

Links to State manuals included in **Appendix F.**

Permeable Asphalt

(flickrcc: Aaron Volkening)

Permeable Block Pavers

(flickrcc: Center for Neighborhood Technology)

5.3 SUBSURFACE INFILTRATION

(flickrcc: Timothy Jarrett)

FACILITY APPLICABILITY

Airside Aviation 🟢	Terminals 🟢	Rail Corridors 🟢	Buildings 🟡	Campus & Plazas 🟢	Roads & Parking Lots 🟢

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Subsurface infiltration practices function by collecting surface runoff via drains, catch basins, or inlets and conveying it to underground stone storage media and/or open-bottom tanks, vaults, and or chambers. The captured runoff then infiltrates into the underlying soil via infiltration. In some cases, infiltration practices may include underdrains to supplement stormwater conveyance or reduce drawdown times.

These practices exist entirely underground, so they have no visible surface footprint. Designers should choose subsurface practices as a secondary choice when vegetated or porous surface practices such as permeable pavement or other surface practices cannot be implemented.

Subsurface infiltration practices decrease stormwater runoff quantity and peak flows while providing improved stormwater quality and groundwater recharge. Subsurface infiltration practices include dry wells, gravel bed systems, chambers, and perforated pipes.

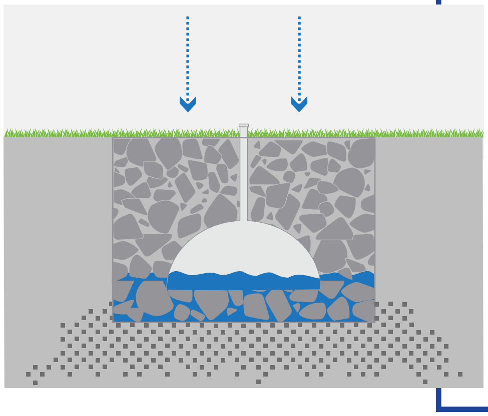
> **Subsurface detention** captures stormwater in a gravel reservoir, vault, or tank and releases it to the drainage network via an underdrain. On their own, these practices offer few water quality or water quantity benefits other than peak flow reduction and are not considered "green infrastructure". However, these practices may be used in combination with pretreatment, filtration, or other GI practices to meet stormwater management goals.

Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	Water Quality	Water Volume	Peak Flow Reduction	GW Recharge	Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infra. Durability	Decreased Site Maintenance
Subsurface Chamber	●	●	●	●	○	○	○	○	○	●	●
Gravel Bed System	●	●	●	●	○	○	○	○	○	◐	◐
Dry Wells	●	●	●	●	○	○	○	○	○	●	●

● Usually ◐ Sometimes ○ Rarely

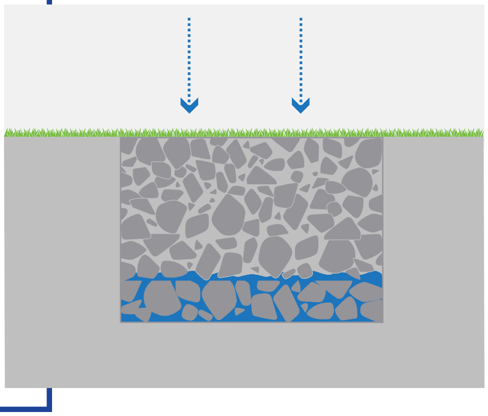
5.3 Subsurface Infiltration

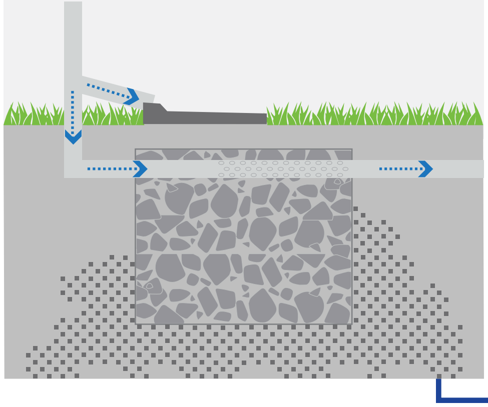
Variations: Infiltration Practices



Subsurface Chambers: single or parallel rows of open-bottom plastic pipes (or half pipes), perforated pipes, vaults, or other hollow chambers surrounded by stone aggregate. Stormwater is stored in the chambers and in the void spaces in the surrounding stone aggregate.

Gravel Bed Systems: a clean-washed, uniformly graded stone storage reservoir. Of all infiltration practices, gravel beds have the lowest void ratio and therefore require the largest footprint area to detain a given stormwater volume. However, due to the larger footprint, gravel beds may provide greater potential for infiltration performance.





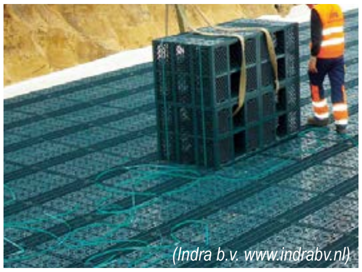
Dry Wells: a subsurface pipe, chamber, or vault which captures stormwater from disconnected roof drains and releases it through infiltration to underlying soils. There may be crushed stone surrounding and below the structural chamber. Dry wells should collect stormwater from clean roofs and have a maximum drainage area of 1 acre.

Subsurface Chambers

(Contech)

(StormTech)

(Philadelphia Water Department)



(Indra b.v. www.indrabv.nl)

Applications

The selection of subsurface infiltration practices primarily depends on: available space on site, drainage area, permeability rate of soil, depth to groundwater table and/or bedrock, and vegetation restrictions. While these practices have almost no visible surface footprint, there should be locations for inspection ports for maintenance.

Designers should choose to use subsurface practices when surface infiltration practices are not feasible. Subsurface chambers and gravel bed systems can be scaled to any size. Chamber systems provide greater storage volume per footprint area. However, they are usually more expensive than gravel bed systems. Dry wells are typically much smaller and capture water exclusively from downspout disconnects.

Note that when dry wells and gravel bed systems are clogged with sediment, they may require full replacement. Chamber-based systems typically include access ports to remove sedimentation.

GI Practice	Tributary Area (acre)	Min. Soil Permeability Rate (in/hr)	Min. Separation from GWT and Bedrock (ft)	Includes Vegetation
Subsurface Chamber	No max	0.5	3	No
Gravel Bed System	No max	0.5	3	No
Dry Well	< 1	0.5	3	No

Subsurface Chambers

(Contech)

Dry Well

(flickrcc: Timothy Jarrett)

Design Criteria

- **Water Quantity:** subsurface Infiltration practices should have the capacity to store 100% of the design storm volume, at a minimum; may be higher if pursuing LEED or Envision credits.
- **Water Quality:** Drainage media and pretreatment devices should be configured to remove 80% of total suspended solids (TSS) and maximum amount practicable of phosphorus and nitrogen.
- Maximum average slope of practice and tributary area is 15%.
- Maximum ratio of tributary area to surface area is 10:1.
- Subsurface systems should drain down in less than 72 hours.
- Subsurface systems should meet load bearing requirement determined by site usage.
- If practice with a closed tank or vault is in an area with high seasonal groundwater table or is subject to flood risk, designer should consider buoyancy.

Design Components

Subsurface infiltration practices generally consist of the components in the table below. The following sections give an overview of each.

GI Practice	Pretreatment	Inlet Control	Storage Reservoir	Outlet Control	Underdrain	Maintenance and Inspection Ports
Subsurface Chamber	●	●	●	◐	◐	●
Gravel Bed System	●	●	●	◐	◐	◐
Dry Well	●	●	●	◐	◐	●

● Usually ◐ Sometimes ○ Rarely

Pretreatment

Designers should base the pretreatment design on the peak design flows and expected pollutant loads from the tributary. When used, pretreatment can capture trash, sediment, and other pollutants from stormwater runoff before it enters the subsurface system in order to prevent clogging and minimize maintenance. Pretreatment components can include a variety of structures such as: sumped inlets, sediment/grit chambers, separators, media filters, inlet inserts, or other sediment and floatables removal devices.

Inlet Control

Designers should consider the peak design flow when choosing an inlet control structure. The inlet will convey and control stormwater to the storage area component. Inlet control components can include curb openings, energy dissipaters, inlets, and flow splitters.

Storage Reservoir

The void spaces in the gravel and storage chambers are the primary means of storing runoff until it infiltrates into the surrounding soil or discharges to an adjacent drainage network. The storage reservoir may consist of a stone-filled bed or trench with pipes, arched plastic chambers, concrete vaults, crates, plastic grids, or other manufactured structures. The storage reservoir should have enough void space to hold the entire design storm volume, at a minimum.

Underdrain

Underdrains convey stormwater from the green infrastructure practices to nearby stormwater systems or waterways. They are common for detention practices but can also be used by infiltration practices to supplement stormwater management in cases of low permeability. The following guidelines apply:

- Underdrains should be perforated within the footprint of green infrastructure practices and have a minimum 6” internal diameter.
- All underdrains should include vertical cleanout ports which are accessible from the surface.
- Underdrains should be designed to safely convey the design storm without surcharging the GI practice.
- If connecting to stormwater systems, a low flow orifice should control underdrain discharge as per regulatory site connection requirements or as specified by PANYNJ.

Outlet Control

Outlets discharge stormwater from the system to accomplish one or more goals:

- Help meet drain time requirements.
- Control the rate of discharge.
- Bypass or overflow excess runoff from large storm events.

Outlet controls often act in tandem with underdrains and may include elevated outlet pipes, slow-release orifices, weirs, level spreaders, or low-flow devices.

Inspection and Maintenance Access

In order to maximize long-term performance, inspection and maintenance access is critical. Access points can be used to either flush out or vacuum sediment from subsurface pipes, vaults, reservoirs, and underdrains. These components typically include cleanouts, inspection ports, access panels, and manholes.

Subsurface Chambers

(Cultech)

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Document that components such as stone and manufactured vaults and chambers conform to the design specifications.

Refer to **Section 6.0** for general GI construction considerations.

Maintenance Considerations

Common regular maintenance tasks and general frequencies are listed below. Note that these may vary significantly between practices and locations. Each green infrastructure practice should be accompanied by a robust maintenance plan which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	General Frequency
Trash/debris removal	Monthly
Sediment removal (Inlets & Outlets)	Monthly
Sediment Flushing / Vacuuming*	As-Needed
Hydraulic cleaning of pipes and underdrains	Annually
Structural Inspection	Annually

**not possible for gravel storage systems*

Resources

NJ DEP Stormwater BMP Manual (March 2021)

- Chapter 9.2: Dry Wells

NYS DEC Stormwater Management Design Manual (January 2015)

- Chapter 5.3.5: Disconnection of Rooftop Runoff
- Chapter 6.3: Stormwater Infiltration
- Chapter 6.4: Stormwater Filtering Systems

Links to State manuals included in **Appendix F.**

Subsurface Chambers

(StormTech)

Subsurface Chambers

(Cultech)

Subsurface Chambers

(Contech)

5.4 GREEN ROOFS

(flickrcc: Dan Keck, The Ohio State University)

FACILITY APPLICABILITY

Airside Aviation	Terminals	Rail Corridors	Buildings	Campus & Plazas	Roads & Parking Lots
🟡	🟢	🔴	🟢	🟢	🔴

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Green roofs capture runoff and direct rainfall using layers of vegetation, soil, and drainage media installed on top of a conventional flat or gradually sloped roof. These systems detain stormwater and slowly release it to the rooftop drainage, while also allowing for evapotranspiration processes. As a result, green roofs reduce the amount of runoff entering downstream systems, attenuate peak flows, and provide water quality benefits. Green roof systems also provide insulation which can lead to HVAC cost savings and can be installed in conjunction with solar photovoltaic panels.

Green roof designs are characterized as extensive or intensive, depending on overall depth. Extensive green roofs have a thin soil layer and are lighter, less expensive, and generally require less maintenance. Intensive green roofs are often characterized by a deeper soil layer with greater weight, higher capital cost, increased plant diversity, and greater maintenance requirements.

Designers should consider green roofs when a project includes a new building or alternations to an existing building, especially if no surface or subsurface space is available for siting GI.

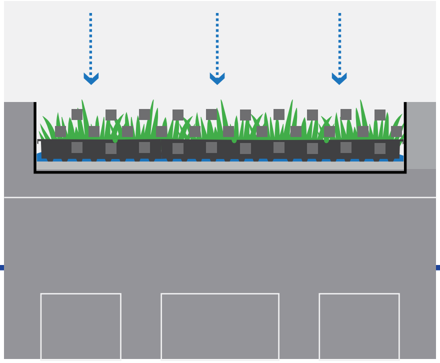
Blue Roofs

Designers may use blue roofs as non-vegetated, peak reduction alternatives to green roofs. These systems consist of runoff collection trays, baffles, and/or flow-controlled roof drains that detain runoff and either release it into the drainage system or allow it to evaporate in place. As such, blue roofs aren't considered "green" practices. However, these systems are allowed by many building codes and may be used independent of, or in series with, other green infrastructure practices to meet stormwater quantity requirements.

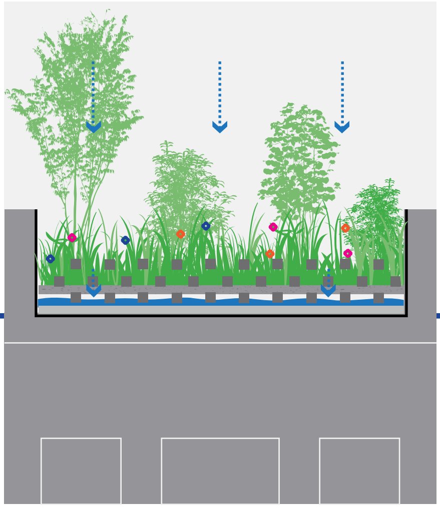
Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	Water Quality	Water Volume	Peak Flow Reduction	GW Recharge	Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infra. Durability	Decreased Site Maintenance
Extensive Systems	●	○	●	○	○	◐	●	●	●	●	◐
Intensive Systems	●	◐	●	○	○	●	●	●	●	●	○

● Usually ◐ Sometimes ○ Rarely

Variations: Green Roofs



Extensive Systems: characterized by low weight, lower capital cost, and less plant diversity compared to intensive systems. The soil media ranges between three and six inches in depth and increases the roof load by 16 to 50 pounds per square foot when fully saturated. Plant species are low and hardy and typically include alpine, arid, or native species. The preferred type of extensive green roof is the sedum tray system, which is easy to install and requires little maintenance.



Intensive Systems: have a deeper soil layer and therefore greater weight. The growing medium ranges in depth from six to 24 inches, with a saturated roof loading of between 50 and 200 pounds per square foot. Designers can use a diverse range of plants, shrubs, grasses and groundcover – as well as certain tree species – due to the thicker soil.

Extensive System

(flickrcc: oshokim)

Extensive System

(flickrcc: UNM Research Data Services)

Intensive System

(flickrcc: Padraic)

Applications

Green roofs may be required to satisfy the sustainable roofing zone requirements of New York City Local Law 94 of 2019. Where green roofs are used to meet LL94 requirements, generally extensive modular tray systems are preferable, and may be used in conjunction with solar photovoltaic systems, if desired.

If a project is also subject to regulatory stormwater quantity or quality requirements, green roofs should be designed to contribute to these goals. Since extensive green roofs rarely have the capacity to manage the full design storm volume, designers may need to consider intensive systems with greater storage or installing extensive systems in combination with surface or subsurface GI practices (in series).

In addition, designers should consider green roofs as a project goal for any project which involves new or extensively refurbished roof decks.

Designers will need to consider structural loading and bearing capacity, roof drain locations, the underlying roofing system, and construction and maintenance access.

GI Practice	**Saturated Weight (lbs/sf)**	**Includes Vegetation**	**Plant Diversity**
Extensive Systems	16-50	Yes	Low
Intensive Systems	50-200	Yes	High

Intensive System

(flickrcc: Arlington County)

Design Criteria

- **Water Quantity:** green roofs should have the capacity to store 100% of the design storm volume. However, due to several factors, these systems may not be capable of storing the entire design storm volume. Therefore, the designer may need to place green roofs in series with surface or subsurface GI practices to meet stormwater quantity requirements or goals.
- **Water Quality:** green roofs should be capable of filtering or detaining 100% of the peak flow of the design storm (150% if pursuing Envision credit **NW 2.2: Manage Stormwater**).
- Drainage media should provide optimal storage and runoff conveyance pathways, while also considering roof loading limitations.
- The structural loading calculations must include the fully saturated green roof.
- Vegetation should be able to tolerate adverse conditions, including variations in water depth and inundation, high wind speed, and temperature fluctuations.
- Design should consider roof access and the safety of workers carrying out construction and maintenance.
- Design should coordinate green roof layout with the layout of roof drains and scupper drains.
- Roof slopes over 5% may need additional stabilization. The maximum roof slope is 17% unless otherwise approved by PANYNJ. Flatter slopes offer greater detention benefits.
- Certain vegetation may require irrigation systems.

Design Components

Both extensive and intensive green roof practices generally consist of the same components. The primary difference is in the soil media and the vegetation used for each type.

The following sections give an overview of each typical component.

Note that for extensive sedum tray systems, the trays may include the drainage system, soil media, and vegetation in a single modular product.

Roof Structure

The load bearing capacity of the roof structure is critical for the support of soil, plants, and any people who will be accessing the green roof for either maintenance or public access. Structural engineers must ensure the proposed or existing roof and support systems can accommodate the green roof. Building codes may require setbacks from the edges of roofs and other roof-mounted structures.

Waterproofing

In a green roof system, the first layer above the roof surface is a waterproofing membrane. This layer ensures water does not damage the rooftop or leak into the building. The two most common waterproofing techniques are monolithic and thermoplastic sheet membranes. An additional protective layer is generally placed on top of either of these membranes followed by a physical or chemical root barrier. Once the waterproofing system has been installed it should be fully tested prior to construction of the remaining system.

Drainage System

The drainage system includes a porous media topped by a filter mat to prevent fine soil particles from clogging the void space. The drainage layer can be made up of gravels, recycled materials, or proprietary mats or products which are capable of water storage and conveyance. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater management requirements. Once the porous media is saturated, excess runoff should be conveyed to the roof drainage system.

Soil

The soil layer above the drainage system is a highly permeable growing media for the proposed vegetation. Soils used in extensive green roofs are generally lighter than standard soil mixes, and generally consist of sand, gravel, crushed brick, peat, or organic matter combined with soil. Intensive systems generally use more conventional soil. The chemical characteristics of the soil (e.g., pH, nutrients, etc.) should be carefully selected in consideration with the planting plan. The porosity and infiltration rate of the soil layer should be adequate to detain and convey the design flows. Erosion control and/or stabilization measures may be required for sloped roofs over 5%.

Planting Types

Plant selection for green roofs is governed by the rooftop microclimate, stormwater design objectives, and maintenance considerations. A qualified botanist, horticulturist, or landscape architect should select vegetation which is suitable for conditions such as high wind, drought and inundation cycles, and cold winter temperatures.

For extensive systems, plant material should be confined to hardier or indigenous varieties of grass and sedum. Root size and depth should also be considered to ensure that the plants stabilize the shallow depth of soil media. Plant choices can be much more diverse for intensive systems.

Vegetation may take 12 months or more to fully establish and the green roof performance may increase as vegetation matures. Some sedum tray systems arrive with vegetation pre-established to reduce maintenance effort during the first year of establishment.

Extensive System

(flickrcc: Arlington County)

Intensive System

(flickrcc: Dan Keck, The Ohio State University)

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Submit Construction Plan that considers access to and from the rooftop and means of delivering materials and removing waste.
- Install components in the following order to ensure functionality and increased lifespan: waterproof membrane, drainage layer, filter/separation fabric over entire drainage layer, green roof growing medium, and vegetation. Vegetation may be pre-established or allowed to establish over 12 months or more.
- Upon installation, fully test waterproof membrane prior to construction of the remaining system.
- Install green roofs during optimal construction time between the spring and fall months.
- Use a wind scour blanket or other erosion prevention strategies as necessary during vegetation establishment period.
- Install all components such that they do not compromise the waterproof membrane material.
- Coordinate manufacturer warranty for rooftop and green roof so that they either fall under the same warranty or have complementary terms and durations.

Refer to **Section 6.0** for general GI construction considerations.


Intensive System

(flickrcc: Dan Keck, The Ohio State University)


Extensive System

(flickrcc: UMBC Sustainability)

Maintenance Considerations

Common regular maintenance tasks and general frequencies are listed below. Note that these may vary significantly between practices and locations. Each green infrastructure practice should be accompanied by a robust maintenance plan which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	General Frequency
General inspection	Quarterly or after large rainfall events
Watering and weeding	Quarterly*
Establishing/restoring vegetation*	Seasonally*
Trimming and pruning	Seasonally*
Erosion, scour, and unwanted growth inspection	Annually
Structural inspection	Annually

**frequency depends on type of vegetation selected*

Other considerations for maintenance include:

- Watering, fertilizing, and weeding is typically the greatest in the first two years as plants become established.
- Maintenance largely depends on the type of green roof system installed and the type of vegetation selected.
- Maintenance requirements in intensive systems are generally more costly and continuous, compared to extensive systems.
- Access and safety should be considered during green roof design and maintenance.

Resources

NJ DEP Stormwater BMP Manual (March 2021)

- Chapter 9.4 Green Roofs
- Chapter 11.1: Blue Roofs

NYS DEC Stormwater Management Design Manual (January 2015)

- Chapter 5.3.8: Green Roofs

Links to State manuals included in **Appendix F.**

5.5 RAINWATER HARVESTING


(flickrcc: Michael Coghlan)

FACILITY APPLICABILITY

Airside Aviation 🟢	Terminals 🟢	Rail Corridors 🔴	Buildings 🟢	Campus & Plazas 🟢	Roads & Parking Lots 🟡

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Rainwater harvesting is the collection and storage of stormwater runoff for operational use, reducing the demand on potable water. Rainwater can be captured in storage facilities such as cisterns, tanks, or rain barrels which can be located underground or aboveground. Storage facilities can hold volumes ranging from a few thousand gallons to hundreds of thousands of gallons, depending on the operational need.

Facilities may use harvested rainwater for operational uses such as: landscaping, toilet and urinal flushing, and vehicle washing. Stored rainwater can also be used for washing external surfaces such as pavement, sidewalks, and buildings. The design capacity of cisterns, tanks, and rain barrels depends on the contributing drainage area, available space, and projected water use rate. The designer should ensure the water quality of the collected runoff is adequate for its intended operational use.

Stormwater vs Rainwater

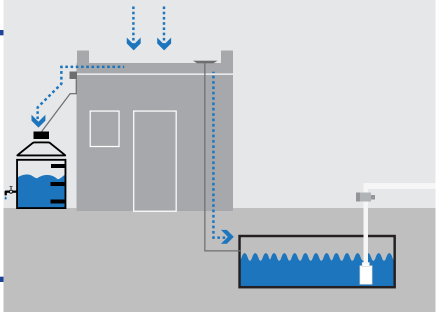
The term “stormwater” refers to all precipitation that falls during a rainfall event. Most of this water drains across ground surfaces such as parking lots, roadways, and lawns. “Rainwater” is a subcategory of stormwater and refers only to precipitation that drains from low-pollution, low-sediment impervious surfaces such as roofs. The quality of rainwater is generally much better than stormwater because ground surfaces are likely to contain contaminants such as soil, organic matter, and pavement oil residues. Both terms are used interchangeably in this document but note that only rainwater may be harvested for onsite reuse.

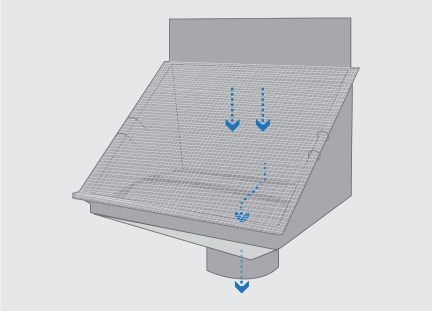
Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	Water Quality	Water Volume	Peak Flow Reduction	GW Recharge	Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infra. Durability	Decreased Site Maintenance
Cistern (surface/ subsurface)	◐	●	●	○	●	○	○	○	○	●	●

● Usually ◐ Sometimes ○ Rarely

Variations: Rainwater Harvesting

Sizing, Type, Location of Storage: All rainwater harvesting practices consist primarily of a large storage container and drainage conveyance systems. The main variations come from the size and type of the storage device and whether they are located underground, aboveground, or on rooftops or other elevated structures.





Filtration and Treatment Processes: Designers may include a range of pretreatment, filtration, and treatment processes to suit the end use of the harvested rainwater. Physical and chemical treatments are outlined in the Design Components section based on required treatment level. Designers should consider intended uses and coordinate accordingly to ensure that the resulting water quality meets chemical and public health parameters for such uses.

Tributary Area and Rainwater Quality

Rainwater harvesting cisterns should primarily collect runoff from low-pollution, low-sediment surfaces such as roof decks. The following tributary and water quality considerations apply:

- Rooftop tributaries should not include vegetated systems.
- Unless the water is exclusively used for landscape irrigation, stormwater collected from vehicular parking or pedestrian surfaces are prohibited.
- Overflow, condensate, and bleed-off pipes from roof-mounted appliances should not discharge onto rainwater collection surfaces.
- Lead-, chromium- or zinc-based paints are not permitted on rainwater collection surfaces.
- If cistern is below ground and has a tributary prone to high sediment or pollution loads, designer should specify an appropriate pretreatment device.
- Water quality must be adequate for intended operational uses. Local building and plumbing codes will have specific code sections on rainwater harvesting related to interior and exterior piping and water treatment.

Rainwater Harvesting

(flickrcc: Michael Coghlan)

Rainwater Harvesting

(flickrcc: Jan Smith)

Applications

Rainwater harvesting devices are highly flexible and can be installed to collect rainfall from most site conditions. They can also accommodate a large range of design storm volumes. The primary limitations are the availability of clean surfaces to collect rainwater from and available space on site to house the cistern. Additionally, if used in subsurface applications, tanks must be clear of utilities, bedrock, and other subsurface obstructions.

Designers should identify operational water uses early in the project which may be replaced or supplemented by harvested rainwater. The facility should also be involved in these discussions and help develop the operational water usage plan to assist in the sizing of the tank.


Rainwater Harvesting

(flickrcc: Center for Watershed Protection, Inc.)

Design Criteria

- **Water Quantity**: cisterns should have the capacity to store 100% of the design storm volume.
- **Water Quality**: cisterns will rely on pretreatment and other filtration and treatment strategies to achieve the required water quality. See **Appendix F** for detailed information on rainwater treatment configurations for various reuse cases.
- Operational water use should be enough to empty cistern within 72 hours in order to prepare for the next storm. Calculation should be based on lowest 3-day operational use average expected throughout the year.
- If the water reuse rate isn't sufficient to empty the cistern within 72 hours, a secondary tank may be needed to hold water for reuse while the primary cistern is cleared. This may require manual or real-time monitoring and controls.
- Designer should document the design calculations and assumptions in a water balance report to support tank sizing.
- If practice is within an area with high seasonal groundwater table or is subject to flood risk, designer should consider the effects of buoyancy.
- If used in a surface or roof application, the soil or roof deck must have adequate bearing capacity to support the filled tank.
- Refer to local building and plumbing codes for specific sections on rainwater harvesting as it relates to interior and exterior piping and water treatment.
- If the stored water is open to the air, it should include a mosquito screen to protect inlets and vents from insects and vermin.
- If cisterns are located above ground, they may require heat tracing to prevent freezing in winter months.
- Roof gutters, leaders and rainwater collection piping must slope continuously toward collection inlets with a slope of higher than 1/8 inch per foot along their total length.

Design Components

Rainwater harvesting practices generally consist of the components detailed in the following sections.

Pretreatment/Inlet Filter

Typically used in subsurface or at-grade systems, pretreatment captures trash, sediment, and other pollutants from stormwater runoff before it enters the subsurface system to prevent clogging and minimize maintenance. Pretreatment structures should be placed downstream of all inlets and just upstream of the subsurface system. The pretreatment structure's outlet should be directly connected to the subsurface system via a distribution or header pipe. Designers should base the pretreatment design on the peak design storm flow and expected pollution and sediment load. Pretreatment components can include a variety of structures including: sumped inlets, sediment/grit chambers, separators, media filters, inlet inserts, or other sediment and floatables removal devices. The devices should be easy to access for cleanout and maintenance.

Downspouts and leaders should be connected to a roof washer and equipped with a debris excluder to prevent contamination.

Storage

The minimum size of the tank should be the design storm volume. Operational water use should be enough to empty the cistern within 72-hours to prepare for the next storm. If the water reuse rate isn't sufficient, a secondary tank may be needed to hold water for reuse while the primary cistern is cleared. This may require manual or real-time monitoring and controls.

The designer should detail the storage sizing in a water balance report, which quantifies the expected runoff flowing into the system and the rate of water leaving the system for operational water use.

If used in a surface or roof application, the soil or roof deck must have adequate bearing capacity to support the filled tank. Designers may consider slabs or pads to distribute the weight of the cistern.

Storage tanks for rainwater ideally should be elevated; having the storage tank on the top floor of the building can eliminate/reduce pumping requirements. If the building height is enough to require multiple water pressure zones, multiple tanks can be located at varying levels with one tank cascading down to another.

If used in subsurface applications, tanks should be clear of utilities, bedrock, and other subsurface obstructions. If constructing in a high groundwater table, designers should consider buoyancy factors.

Filtration and Treatment

Filtration and treatment requirements depend on the end water use and potential for human contact. Treatment strategies will depend on the required water quality versus the actual influent pollution concentrations. When necessary, primary rainwater sanitation options are chlorine treatment and ultraviolet light treatment. Chlorine treatment is recommended for general industrial applications where large amounts of water are stored for later use. Ultraviolet light treatment is recommended for industrial applications that are sensitive to corrosion from chlorine exposure and where smaller amounts of stored water are required for a shorter time period.

See **Appendix F** for tables categorizing rainwater reuse cases and detailing rainwater treatment methods, configurations, and purposes.

Overflow/Outlet Control

Designers should include overflow configurations to bypass the system when full. At a minimum, the overflow system should have the capacity to convey the peak design flow to an adjacent drainage system. However, the designer should consider the consequences of surcharge and propose an overflow system capable of safely conveying runoff for high-intensity storm events.

For stormwater reuse outlets, surface-level or elevated cisterns typically include spigots. In cases where higher water pressure is required or water should be transferred to a secondary tank, the designer may need to include a pump system adequate to meet the operational use demand. The pump system should include a sensor and alarm to detect flows and report any failures.

Cistern outlets may require a rate-controlled orifice to provide a constant release of water. Techniques for this include constant-head orifices. Designers should consider the water use rate and outflow rate when designing cistern outlets.

Inspection and Maintenance Access

Access ports allow maintenance workers to inspect the interior of the cisterns and clean out any debris or sediment. Manufacturers may integrate these access points in their products; however, the designer may need to add these during design in some cases.

Additionally, inlet and outlet conveyance pipes may require access ports depending on the run length and presence of bends.

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Commission any alarms, pumps, or real-time controls used in the system.
- Commission and test all water reuse components for adequate pressure, conveyance, and accessibility.

Refer to **Section 6.0** for general GI construction considerations.

Maintenance Considerations

Common regular maintenance tasks and general frequencies are listed below. Note that these may vary significantly between practices and locations. Each green infrastructure practice should be accompanied by a robust maintenance plan which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	General Frequency
Pretreatment cleaning	Monthly
Tributary/gutter inspection	Monthly
Storage tank inspection	Quarterly or after > 1" rainfall events
Structural inspection	Annually
Pump, control, and alarm inspection	Annually

Water quality testing for potable rainwater harvesting applications should be performed during system commissioning and annually thereafter. The following guidelines apply.

- Rainwater for potable applications should be tested for Escherichia coli, total coliform, heterotrophic bacteria, and cryptosporidium.
- Collected rainwater tested for water quality should be the result of no less than two rainfall events.

Rainwater Harvesting

(flickrcc: Michael Coghlan)

Other considerations for maintenance include:

- Storage tank may require cleaning following inspections if there is debris, sediments, or algal buildup.
- Designers should also consider freeze and thaw in the design and operations & maintenance plan. The practices may need to be drained and decommissioned during winter months or heat traced to prevent freezing.

Resources

ASPE Plumbing Engineering Design Handbook (2008)

International Code Council B805

NJ DEP Stormwater BMP Manual (March 2021)

- Chapter 9.1: Cisterns

NJ DEP Cistern Water Reuse Calculator:

- www.nj.gov/dep/stormwater/bmp_manual/cistern_spreadsheet.xlsx

NYS DEC Stormwater Management Design Manual (January 2015)

- Chapter 5.3.10: Rain Barrels and Cisterns

Links to State manuals included in **Appendix F.**

Rainwater Harvesting

(flickrcc: Charles & Hudson)

5.6 MANUFACTURED TREATMENT DEVICES


(flickrcc: Aaron Volkening)

FACILITY APPLICABILITY

Airside Aviation 🟢	Terminals 🟢	Rail Corridors 🟢	Buildings 🟢	Campus & Plazas 🟢	Roads & Parking Lots 🟢

🟢 Usually 🟡 Sometimes 🔴 Rarely

Description

Manufactured Treatment Devices (MTDs) are proprietary products that treat stormwater runoff generated by urban development. MTDs are often specifically designed to meet regulatory pollutant removal rates and other water quality mandates.

MTDs are typically modular, subsurface vaults, tanks, or sumps which include various components for capturing, filtering, and/or separating pollutants in stormwater runoff.

There are three main types of MTDs which manage solids, debris, oil, and floatables in various ways:

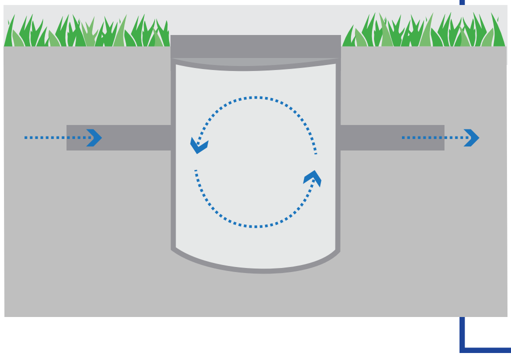
- Hydrodynamic separators (HDS)
- Filtration devices/media filters
- Biofilters

Due to their limited co-benefits, HDS and media filters typically cannot meet both water quality and water quantity metrics on their own. Designers may need to install them in series with storage practices such as bioretention or subsurface detention to meet design storm capacity requirements.

Benefits Matrix	Stormwater Management Benefits				Environmental Co-Benefits		Health & Social Co-Benefits			Economic Co-Benefits	
GI Practice	Water Quality	Water Volume	Peak Flow Reduction	GW Recharge	Water Use Reduction	Wildlife Preservation	Air Quality	Heat Island Reduction	Aesthetic Improvement	Increased Infra. Durability	Decreased Site Maintenance
Hydrodynamic Separators (HDS)	●	○	○	○	◐	◐	○	○	○	●	●
Media Filters	●	○	○	○	◐	◐	○	○	○	●	●
Biofilters	●	○	●	◐	◐	◐	●	●	●	○	○

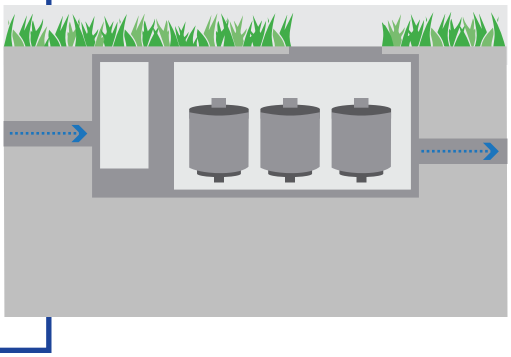
● Usually ◐ Sometimes ○ Rarely

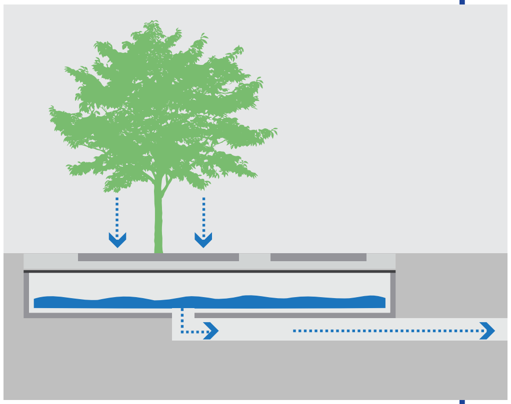
Variations



Hydrodynamic Separators (HDS): HDS devices (also called swirl separators, swirl concentrators, or oil/grit separators) control the flow path and velocity of runoff to capture oil and floating debris and promote settlement and separation of particulates. HDSs convey water through pretreatment and subsurface treatment tanks or vaults. Pretreatment allows settling of larger solids and floatables and the main treatment tank uses a spiraling flow to separate finer particles.

Media Filter Devices: Filtration devices and media filters directly remove solids, debris, pollutants, nutrients, hydrocarbons, and floatables from stormwater. These systems typically take the form of cartridges or insert filters which can be installed in catch basins or be part of a larger treatment chamber. During storm events, stormwater runoff pools in the treatment chamber and passes through cartridges from the outside surface. Cartridge filters treat the stormwater and discharge flow through a false floor and into the outlet chamber.





Biofilters: Biofilters are modular bioretention devices which use natural filtration mechanisms to remove total suspended solids (TSS), heavy metals, nutrients, gross solids, floatables, debris, and petroleum hydrocarbons.

Biofilters can have several different configurations including surface planters with an open bottom, a tree box with a grated inlet, or an underground vault and subsurface inlet pipe. Biofilters convey stormwater through soil and/or stone media into an underdrain pipe or into the underlying soils.

Due to their modular nature, these devices can often treat stormwater in a smaller footprint than traditional bioretention. However, they are typically more expensive to construct than bioswales or infiltration trenches.

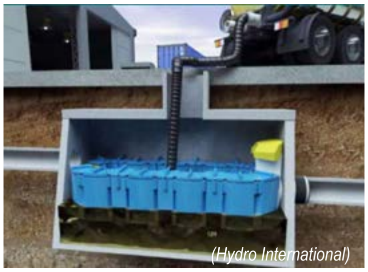
Biofilter

(NCDEQ Stormwater Design Manual)

Biofilter

(Advanced Drainage Systems)

Media Filter



(Hydro International)

Biofilter

(Oldcastle Infrastructure)

Applications

Due to their limited co-benefits, standalone MTDs should be the last resort for designers when other green infrastructure options aren't feasible due to site constraints or vegetation restrictions. However, designers may propose MTDs as a pretreatment in tandem with a large traditional green infrastructure practices.

Most MTDs are installed subsurface and therefore need adequate clearance from utilities, bedrock, and the groundwater table. Often, MTDs have little or no surface footprint, so they can be installed when surface space is at a premium.

Designers should confirm that MTDs can handle the peak flow of the design storm. Several manufacturers produce HDS, media filters, and biofilters that accommodate a range of maximum drainage area and flow rates.

GI Practice	Maximum Treatment Flow Rate (cfs)	Total Suspended Solids (TSS) Removal Rate	Includes Vegetation
Hydrodynamic Separators (HDS)	20.0	50%	No
Media filters	3.5	80%	No
Biofilters	1.0	90%	Yes

Biofilter

(Contech)

Hydrodynamic Separator

(AquaShield)

Design Criteria

- **Water Quantity:** MTDs should have the capacity to manage 100% of the peak flow of the design storm, at a minimum; may be higher if pursuing LEED or Envision credits. If unable to achieve the required volume, designers should consider installing MTDs in series with other GI practices.
- **Water Quality:** Designers should select MTDs to meet water quality mandates and/or goals. If no requirements are given, MTDs should manage 80% of total suspended solids (TSS) and the maximum amount practicable of phosphorus and nitrogen, at a minimum. The manufacturer should specify pollutant removal rates for their products.
- If practice is in an area with high seasonal groundwater table or is subject to flood risk, designer should consider buoyancy.
- Designer is responsible for meeting all manufacturer recommendations, requirements, and design guidance.
- Designers must confirm adequate soil bearing capacity, particularly in urban fill where softer soils are common.
- For biofilters, refer to **Appendix B** for plant selection and suitability.

Design Components

MTDs generally consist of the components in the table below. The following sections give an overview of each.

GI Practice	Ponding Area	Inlet Control	Treatment Area	Outlet Control	Inspection and Maintenance Access	Vegetation
Hydrodynamic Separators (HDS)	●	●	●	●	●	○
Media filters	●	●	●	●	●	○
Biofilters	◑	●	●	●	●	●

● Usually ◑ Sometimes ○ Rarely

Pretreatment

When used, pretreatment can capture trash, sediment, and other pollutants from stormwater runoff before it enters the subsurface system in order to prevent clogging and minimize maintenance. Designers should base the pretreatment design on the peak design storm flow and expected pollution and sediment load. Pretreatment components can include a variety of structures including: sumped inlets, sediment/grit chambers, separators, media filters, inlet inserts, or other sediment and floatables removal devices. The devices should be easy to access for cleanout and maintenance.

Inlet Control

Designers should consider the peak design flow when choosing an inlet control structure. The inlet will convey and control stormwater to the storage area component. Inlet control components can include: curb openings, energy dissipaters, inlets, and flow splitters.

Primary Treatment Area

The treatment area will vary for all types of MTDs. In general, these areas remove the smaller particles and pollutants that are not removed in pretreatment areas

- HDSs: consist of tanks with weirs that cause water to rotate creating a vortex motion; particles and large solids settle to the bottom of the treatment area.
- Media filters: flush water through cartridges to treat runoff.
- Biofilters: use soil and stone media to filter out larger particles.

Outlet Control

Outlets discharge stormwater from the system to accomplish one or more goals:

- Help meet drain time requirements.
- Control the rate of discharge.
- Bypass or overflow excess runoff from large storm events.

Outlet controls may include elevated outlet pipes, slow-release orifices, weirs, level spreaders, or low-flow devices.

Inspection and Maintenance Access

In order to maximize long-term performance, inspection and maintenance access is critical. Access points can be used to either flush out or vacuum sediment from subsurface pipes, vaults, reservoirs, and underdrains. These components typically include cleanouts, inspection ports, access panels, and manholes.

Biofilter

(oldcastleinfrastructure.com)

Biofilter

(NCDEQ Stormwater Design Manual)

Construction Considerations

The Resident Engineer should confirm that Contractors perform the following tasks:

- Carry out delivery, staging, installation, connections, and commissioning as per the manufacturers' recommendations. Some manufacturers may require specialized training and/or oversight of these activities by trained professionals.
- Accommodate delivery of large prefabricated devices, including the use of flatbed trucks, cranes, or other machinery.
- Document that products conform to the design specifications.

Refer to **Section 6.0** for general GI construction considerations.

Maintenance Considerations

Common regular maintenance tasks and general frequencies depend on manufacturers' recommendations. The table below lists common regular maintenance tasks for each MTD. Each practice should be accompanied by a robust maintenance plan which can adapt to the reported performance of each practice. Refer to **Section 7.0** for common maintenance plan components.

Regular Maintenance Tasks	HDS	Media Filters	Biofilters
General Inspection	●	●	●
Structural Inspection	●	●	●
Media Replacement	○	●	●
Sediment/Debris Removal	●	●	●
Cleaning Inlets and Conveyance Pipes	●	●	●
Pruning/Weeding	○	○	●
Replanting (as necessary)	○	○	●

● Necessary ○ Not Necessary

Other considerations for maintenance include:

- Some devices may require use of a vacuum truck to remove sediment.
- Maintenance may need to be performed more frequently if sediment depth exceeds the manufacturers' thresholds.

Resources

NJ DEP Stormwater BMP Manual (March 2021)

- Chapter 9.5: Manufactured Treatment Devices (GI)
- Chapter 11.3 Manufactured Treatment Devices (Non-GI)

NJ DEP Stormwater Manufactured Treatment Devices Guidance Webpage

- www.nj.gov/dep/stormwater/treatment.html

List of NJ DEP Certified MTDs

- njcat.org/verification-process/technology-verification-database.html

NYS DEC Stormwater Management Design Manual (January 2015)

- Chapter 9.4: Alternative Stormwater Management Practices Proprietary Practices

Links to State manuals included in **Appendix F.**

Biofilters

(Contech)

Media Filters

(flickrcc: Center for Watershed Protection, Inc.)

5.7 Large-Scale Green Infrastructure Practices

PANYNJ pursues large-scale green infrastructure practices on a case-by-case basis to meet specific site conditions and project goals. These practices are highly specialized and designers should employ experienced engineers to configure the GI to meet site characteristics. Designers should also consider federal aviation guidelines for wildlife deterrents if the facility is near an airport. Design teams should discuss the feasibility of these practices early in Stage I. Due to the multidisciplinary design coordination required, designers may consider including dedicated sections in the Stage I/II reports for these practices.

The following sections include an overview of each large-scale practice and design resources.


(flickrcc: Daniel •. O'Neil)

Retention basin


(flickrcc: Jeffrey Beall)

Detention basin

5.7.1 Retention/Detention Basins

Retention or detention basins (also called “wet” or “dry” basins respectively) may be suitable for large, open sites with high volumes of stormwater runoff. These facilities collect and manage stormwater runoff and release it at a controlled rate which prevents flooding, erosion, and other detrimental effects from harming downstream assets and infrastructure.

Designers considering including retention or detention basins should reference the PANYNJ Civil Design Guidelines (CDG) and the applicable chapters in the respective state guidance manuals:

- NJ DEP Stormwater BMP Manual (March 2021)
  - Chapter 10.5: Wet Ponds
  - Chapter 11.2: Extended Detention Basins
- NYS DEC Stormwater Management Design Manual (January 2015)
  - Chapter 6.1: Stormwater Ponds

5.7.2 Constructed Wetlands

Natural wetlands provide myriad environmental benefits such as sediment reduction, pollution control, stormwater flow attenuation, and wildlife habitation. For projects in or near wetlands, designers may consider implementing constructed wetlands as an alternate, more natural means of stormwater management.

Constructed wetlands are typically built by grading and installing water control devices to establish desired hydraulic flow patterns. The site can either infiltrate water into the surrounding groundwater table or be isolated using an impermeable liner if infiltration is not desired or feasible.


(flickrcc: SuSan A Secretariat)

Constructed Wetland

Constructed wetlands are often less expensive to build than traditional large-scale stormwater treatment options, have low operating and maintenance expenses, and can handle fluctuating water levels. Additionally, they are aesthetically pleasing and can reduce or eliminate odors associated with wastewater[1].

Constructed wetlands may mimic the natural functions of adjacent tidal wetlands (e.g., salt marshes, brackish marshes, intertidal flats) and non-tidal wetlands (e.g., emergent wetlands, scrub-shrub wetlands, forested wetlands).


(flickrcc: NC Wetlands)

Constructed Wetland

For additional guidance and information regarding wetlands classification and design, refer to federal and/or respective state guidance:

- US Environmental Protection – Constructed Wetlands Information Site
- NJ DEP Stormwater BMP Manual (March 2021)
    - Chapter 10.4: Standard Constructed Wetlands
    - Chapter 11.5: Subsurface Gravel Wetlands
- NYS DEC Stormwater Management Design Manual (January 2015)
    - Chapter 6.12: Stormwater Wetlands

5.7.3 Non-Stormwater Green Infrastructure: Living Shorelines

Traditionally, coastal projects use “hard” shoreline stabilization measures such as bulkheads, seawalls, and revetments. While these strategies achieve their structural goal, they may have detrimental effects on adjacent shorelines and critical habitats[2].

Living shorelines achieve coastal stabilization and erosion prevention while also incorporating features which mimic the natural environment and wildlife habitats. These strategies include those summarized in Figure 5.2.

---

[1] US Environmental Protection Agency Constructed Treatment Wetlands (August 2004)

[2] Stevens Institute of Technology; Living Shorelines Engineering Guidelines; February 2016

Marsh Sill

Reduces the wave energy at the marsh edge to allow sediment to accrete behind the structure.

Jointed Planted Revetment

Ecologically-enhanced version of a traditional stone revetment. Stone provides the structural backbone while vegetation enhances the ecological value and provides increased stability to the soil substrate.

Breakwaters

Structures typically constructed parallel to the shoreline that are designed to reduce the amount of wave energy experienced by the area directly behind them. This allows the establishment of a beach or vegetated (typically marsh) shoreline in its lee.

Living Reefs

Variation on the marsh sill strategy, where the added oyster or mussel reef provides wave dissipation.

Reef Balls

Concrete elements designed to attenuate wave energy and serve as the backbone of a natural reef.

Figure 5.2 – Living Shoreline Strategy Summary

Note that this GI strategy is the only one in the GIDM not to focus primarily on stormwater management and therefore has entirely separate design criteria. Designers should work closely with the project team to identify coastal stability, conservation goals, and other considerations for the project.

Reference Stevens Institute of Technology's *Living Shorelines Engineering Guidelines* or other guidance manuals to identify design considerations such as:

- Erosion.
- Sea level rise.
- Hydrodynamic parameters (e.g., wind, waves, wakes, current).
- Terrestrial parameters (e.g., ground slopes, widths, offshore depths, soil bearing capacity).
- Ecological parameters (e.g., water quality, soil type, native wildlife, sunlight exposure).
- Permits and regulatory requirements.
- Constructability.

6.0 Green Infrastructure Construction Oversight

Green infrastructure practices have many construction activities and drainage components in common with standard grey infrastructure. However, each GI installation also carries its own set of procedures and considerations that construction contractors should follow. The Resident Engineer (RE) should ensure that contractors follow industry best practices when excavating, backfilling, grading, and planting for GI practices. Common construction oversight considerations include:

- Contractor's construction plan should consider access to and from the site and means of delivering materials and removing waste.
- Contractor should document that drainage media and structural components conform to the design specifications. PANYNJ may require small batch testing to confirm specific loads of drainage media meet specifications.
- In all phases of construction, contractor should take precautions not to compact the soil substrate, stone reservoir, or engineered soil within the practice. This may lead to reduced permeability rates and reduced storage capacity.
- Contractor should survey inlets, outlets, and other elevation-critical drainage components to ensure the correct levels and hydraulic flow.
- Contractor should allow for RE inspection and approval of buried components such as tanks and stone reservoirs prior to backfill.
- Contractor should stabilize the upstream tributary prior to exposing the GI practices to runoff flows to prevent excess sedimentation due to adjacent construction.
- Contractor should perform post-construction testing (for example, hydrant testing) on the as-built practice to confirm stormwater management performance. If testing shows a longer drain time than designed, the Contractor should take corrective action. PANYNJ should preapprove Contractor's testing plan.

Prior to construction, the RE may develop a construction oversight checklist for field crews to verify that the contractor is properly installing GI practices.

See **Appendix G** for an example GI construction inspection checklist. REs may modify this template to suit specific GI installations.

7.0 Green Infrastructure Maintenance Overview

Maintenance is a critical factor for the long-term success of green infrastructure practices. Designers should consider maintenance access and level-of-effort during the design process. These factors may influence GI type, location, plant palette, and the configuration of other components.

Like all drainage infrastructure, GI accumulates sediment and debris carried by stormwater runoff and should be cleaned regularly. Hardscape, piping, and structural components are also subject to wear and damage and should be inspected annually, at a minimum. Vegetated practices require standard maintenance such as pruning, weeding, and watering in times of drought. They may also require more care during the vegetation establishment period.

Another important aspect of GI maintenance is the control of invasive species, especially in coastal zones and other ecologically sensitive areas. Designers should identify any concerns with invasive species early in the design in order to inform plant selection and maintenance tasks.

Maintenance Staffing & Training

Maintenance plans should nominate qualified staff for specialty tasks such as weeding and pruning. Staff may need specialized job titles such as horticulturists, arborists, and gardeners. A robust maintenance program also identifies and conducts staff training and shares lessons learned across facilities.

For standardized training, the Water Environment Federation (WEF) administers the National Green Infrastructure Certification Program (NGICP). This program provides the base-level skill set needed for entry-level workers to properly construct, inspect, and maintain GI using industry best practices.

7.1 Maintenance Plans

All stormwater infrastructure implementation should include a robust maintenance plan detailing regular maintenance activities, responsible staff, and guidance for reporting and completing corrective maintenance. A basic maintenance plan may include the below sections:

- **Introduction:** includes a list of all GI practices covered under the plan and the responsible parties for carrying out the preventative and corrective maintenance. Section should include any written agreements covering maintenance activities.
- **Preventative Maintenance:** includes a list of preventative maintenance tasks and frequencies. These tasks include inlet and outlet inspections, cleaning, flushing; mosquito control; removal of sediment, trash, and debris in practice; mowing, pruning, and restoration of vegetation. Includes approved disposal and recycling sites and procedures for sediment, trash, debris, and other material removed from the measure during maintenance operations. Section should also include any specific instructions for specialized or nonstandard maintenance tasks.
- **Corrective Maintenance:** details the procedure for identifying and carrying out as-needed corrective maintenance tasks such as drainage media restoration, flushing of tanks and underdrains, replacement of plants, repair or replacement of damaged or deteriorated components, and pest control. Plan should include any specific instructions for specialized or nonstandard maintenance tasks.
- **Maintenance Schedule:** calendar view outlining the maintenance schedule over a calendar year including appropriate frequencies of site visits and regular inspections.
- **Annual Cost Estimate:** includes labor, equipment, materials, and disposal costs.
- **Maintenance Logs:** templates for documenting above mentioned preventative and corrective maintenance tasks.
- **List of Equipment, Tools, Labor, and Supplies:** everything necessary to perform the various preventative and corrective maintenance tasks specified in the plan, including sources of specialized, proprietary, and nonstandard equipment, tools, labor, and supplies.
- **Health and Safety Overview:** covers risks and hazards for the operation and maintenance of the site. This should supplement, not replace, an approved health and safety plan.
- **As-built Plans:** includes relevant design details and copies of pertinent construction documents such as laboratory test results, permits, and completion certificates. Also includes originals or copies of manufacturers' warranties on pertinent measure components.

Maintenance needs vary between different sites and practices and may require adjustments over time. For example, the changing climate may affect maintenance frequencies and vegetated practices may need less maintenance as they establish. Facilities should review maintenance logs regularly to adjust projections for maintenance tasks, frequencies, and resource needs.

Facilities may opt to develop one-page maintenance cards for individual GI practices. These cards present the pertinent information from the maintenance plan in an easily-accessible reference.

See **Appendix H** for an example maintenance log and maintenance card. Operations and maintenance staff may modify these templates to suite specific GI installations.

Appendix A: Hydrology Calculation Resources

A.1 Design Storm Volume Calculations (New Jersey)

There are two methods for calculating the stormwater quality design storm volume: NRCS TR-55 methodology and the Modified Rational Method. The below sections provide resources for calculating each in New Jersey.

1. NRCS Methodology**:** most widely used method for computing stormwater runoff rates, volumes, and hydrographs.

The formula for the stormwater volume is:

Design Volume (V) = Runoff Depth (Q) x Tributary Area (A)

A is the total area of the tributary as measured from the plans and the formula for Q is:

$$Q = \begin{cases} 0 & \text{for } P \leq I_a \\ \frac{(P-I_a)^2}{P-I_a+S} & \text{for } P > I_a \end{cases}$$

Where:

P = rainfall (in) = 1.25 in for NJ DEP Design Storm

Ia = initial abstraction (in) = 0.2 in

S = potential maximum soil moisture retention (in) = 100/CN-10

CN = NRCS Curve Number for tributary (see table below)

Note: Since NRCS methodology is a nonlinear equation, runoff from tributaries with different curve numbers should not use a composite CN value. Instead, designers should separate the tributary into its component CN parts, calculate the volume for each, then sum them together for the composite tributary volume.

!

Disclaimer

Effective March 2, 2021, New Jersey DEP updated Chapter 5 of the BMP Manual titled “Stormwater Management Quantity and Quality Standards and Computations.” Designers should become familiar with the amendments to this chapter and how they affect the design of GI.

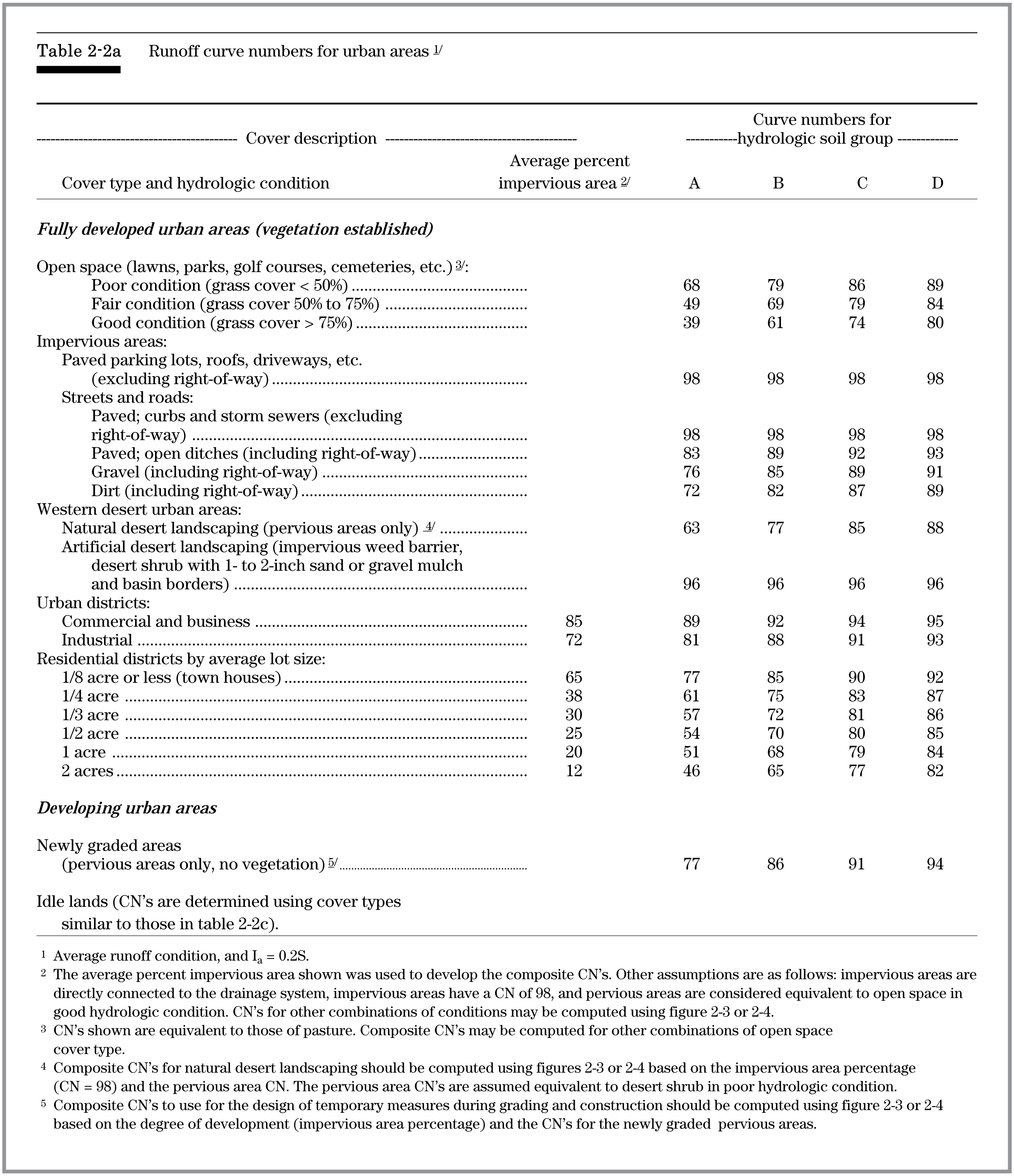


Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

---

[1] Average runoff condition, and $I_a = 0.2S$.

[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Figure A.1 - Runoff Curve Numbers (CN) from NRCS USDA Urban Hydrology for Small Watersheds - TR-55

2. **Modified Rational Method:** alternate method for calculating peak flow and design volumes for only for tributaries under 20 acres.

The formula for the stormwater volume is:

Design Volume (V) = Runoff Peak Flow (Q) x Design Storm Duration (D)

The NJ DEP design storm duration is 2 hours (or 7,200 seconds) and the equation for Q is:

$$Q = CIA$$

Where:

C = Runoff Coefficient (see table below)

I = Rainfall Intensity (in/hr) = 0.625 in/hr for NJ DEP design storm

A = Tributary Area (acres) as measured from the plan

Surface Type	Runoff Coefficient
Roofs and asphalt and concrete pavements	0.98
Grass or vegetated areas having slopes up to 2%	0.10
Grass or vegetated areas having slopes greater than 2%	0.15

Figure A.2 - Runoff Coefficient from *PANYNJ Civil Design Guidelines*

Note: Since Modified Rational Method is a linear equation, runoff from tributaries with different runoff coefficients may use a weighted, composite CN value to represent the entire tributary,

A.2 Design Storm Volume Calculations (New York)

In New York, GI practices must be capable of managing the Water Quality Volume (WQv), which is defined by the below formula:

$$WQ_v = (P * R_v * A) / 12$$

Where:

P = 90% Rainfall event (in) as per below figure

Rv = 0.05 + 0009 * I

I = % impervious cover in tributary

A = tributary area (acres)

90th Percentile Rainfall in New York State (NYSDEC, 2013)

As per NYS DEC *New York State Stormwater Management Design Guidelines*, all facilities in New York City should use a 90th percentile rainfall of 1.5” and SWF should use a depth of 1.4”.

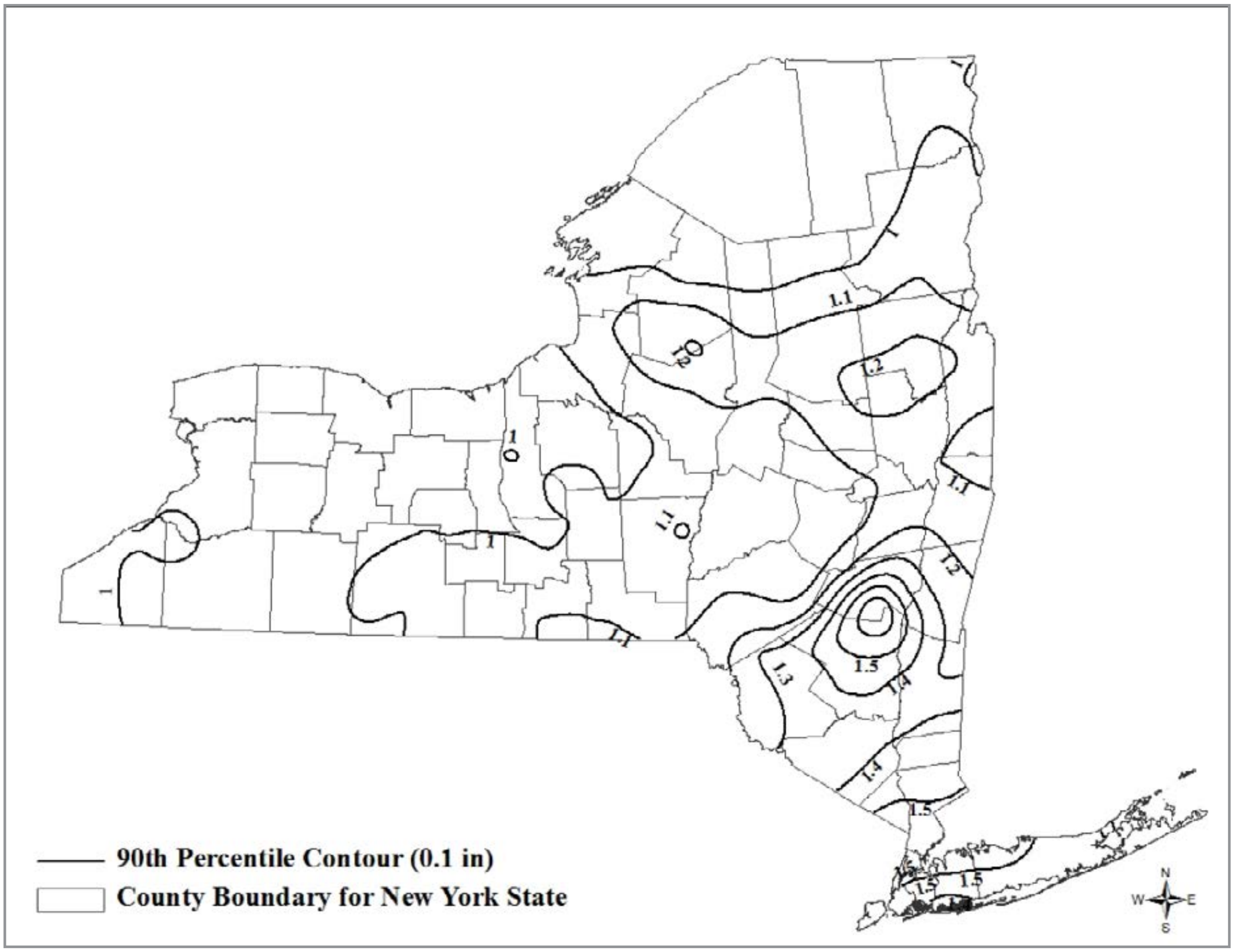


Figure A.3 – 90th Percentile Rainfall in New York State (from New York State Stormwater Management Design Manual)

A.3 Peak Flow

GI designs must be capable of managing the peak flow. To find the peak flow in any location, us the Rational Method as per Appendix A.1.2.

Q = CIA

Where:

Q = Peak flow (CFS)

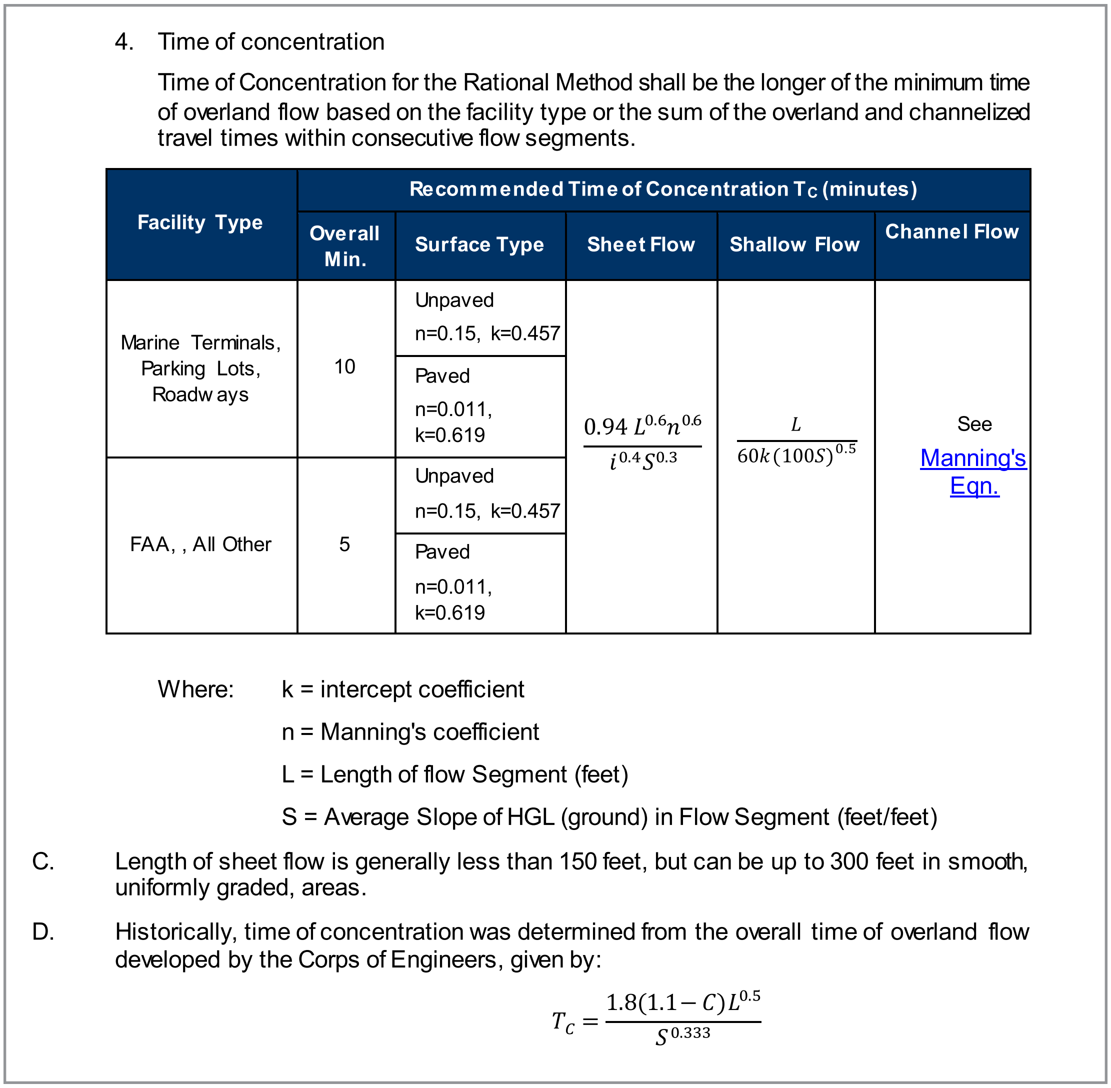
C = Runoff Coefficient (see table below)

I = Rainfall Intensity (in/hr)

A = Tributary Area (acres) as measured from the plans

However, to find the intensity designers must calculate the time of concentration (ToC) and use PANYNJ Civil Design Guidelines Intensity, Duration, and Return Period Tables for the project location.

1. To find ToC, follow the below steps:



4. Time of concentration

Time of Concentration for the Rational Method shall be the longer of the minimum time of overland flow based on the facility type or the sum of the overland and channelized travel times within consecutive flow segments.

Facility Type	Recommended Time of Concentration T_C (minutes)				
	Overall Min.	Surface Type	Sheet Flow	Shallow Flow	Channel Flow
Marine Terminals, Parking Lots, Roadways	10	Unpaved n=0.15, k=0.457	$\frac{0.94\,L^{0.6}n^{0.6}}{i^{0.4}S^{0.3}}$	$\frac{L}{60k(100S)^{0.5}}$	See Manning's Eqn.
		Paved n=0.011, k=0.619			
FAA, , All Other	5	Unpaved n=0.15, k=0.457			
		Paved n=0.011, k=0.619			

Where: k = intercept coefficient

n = Manning's coefficient

L = Length of flow Segment (feet)

S = Average Slope of HGL (ground) in Flow Segment (feet/feet)

C. Length of sheet flow is generally less than 150 feet, but can be up to 300 feet in smooth, uniformly graded, areas.

D. Historically, time of concentration was determined from the overall time of overland flow developed by the Corps of Engineers, given by:

$$T_C = \frac{1.8(1.1-C)L^{0.5}}{S^{0.333}}$$

Figure A.4 – Time of Concentration Calculation Process (from PANYNJ *Civil Design Guidelines*)

2. Use nearest ToC and relevant return period to find the Intensity (I) value for project site:

NY Facilities (Except SWF) Precipitation Intensity Duration and Return Period

Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.99	3.86	3.17	2.66	2.35	2.14	1.60	1.32
5-Yr	5.86	4.52	3.74	3.15	2.80	2.57	1.94	1.63
10-Yr	6.68	5.14	4.25	3.61	3.22	2.97	2.27	1.92
25-Yr	7.98	6.08	5.04	4.32	3.89	3.60	2.78	2.37
50-Yr	9.12	6.93	5.76	4.95	4.46	4.14	3.23	2.78
100-Yr	10.49	7.91	6.62	5.70	5.14	4.77	3.77	3.28

SWF Precipitation Intensity Duration and Return Period

Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.64	3.59	2.94	2.47	2.18	1.99	1.48	1.23
5-Yr	5.46	4.22	3.49	2.94	2.61	2.39	1.81	1.52
10-Yr	6.25	4.80	3.97	3.37	3.01	2.77	2.12	1.79
25-Yr	7.49	5.71	4.73	4.06	3.65	3.38	2.61	2.22
50-Yr	8.58	6.52	5.42	4.66	4.20	3.89	3.05	2.62
100-Yr	9.92	7.49	6.26	5.39	4.86	4.52	3.57	3.10

NJ Facilities Precipitation Intensity Duration and Return Period

Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.84	3.83	3.18	2.76	2.42	2.17	1.66	1.35
5-Yr	5.74	4.55	3.80	3.34	2.96	2.66	2.06	1.70
10-Yr	6.42	5.08	4.24	3.77	3.35	3.02	2.35	1.95
25-Yr	7.28	5.71	4.78	4.33	3.86	3.49	2.76	2.30
50-Yr	7.88	6.18	5.18	4.71	4.21	3.83	3.04	2.57
100-Yr	8.53	6.64	5.56	5.11	4.58	4.17	3.35	2.84

Figure A.5 – Intensity, Duration, and Frequency tables for PANYNJ facilities (from PANYNJ Civil Design Guidelines)

A.4 Percentile Storm Depth & Volume

GI design and/or compliance with LEED and Envision may require calculations of various percentile storm events. The below steps outline how to derive these figures from historical rainfall data.

1. Download (CSV or Excel) at least 30 years of the most recent 24-hour NOAA rainfall data from the weather station nearest to the project location.
2. In Excel, remove the rows for any days with 0.1 in of rainfall or less and any days with recorded snowfall.
3. Sort data from highest precipitation depth to lowest.
4. Use Excel's PERCENTILE() function on the dataset to generate the desired percentile depths.

   Example: for 85th Percentile Depth, the formula would be *=PERCENTILE([data set], 0.85*)
5. Use the percentile depth for P in either in the NRCS formula or the NYS DEC WQv formula to find the volume for the percentile storm.

For additional guidance, refer to US Environmental Protection Agency's *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*.

Appendix B: Plant Palette

Introduction

The plant palette comprises trees, shrubs, grasses, and perennials which are capable of experiencing extended periods of drought and inundation typical to green infrastructure.

PANYNJ specified these species based on their proven performance in stormwater management applications, regional suitability and availability, and minimal maintenance needs.

Plant Suitability Criteria

This plant palette is organized to assist the designer in selecting the most appropriate plant to meet the site conditions. Each plant is grouped by type and characterized by the following metrics:

Zone is the inundation zone within the GI practice. Zone A is within the ponding area and subject to regular flooding. Zone B is slightly upland and experiences occasional saturation. See figures on right.

Leaves denotes if a plant is Deciduous or Coniferous.

Native denotes if a plant is a native species.

Aviation denotes if a plant is suitable for use in and around aviation facilities. Suitable plants do not attract wildlife.

Conditions specifies if a plant can thrive in adverse environmental situations such as higher concentrations of salt and/or pollution or periods of drought.

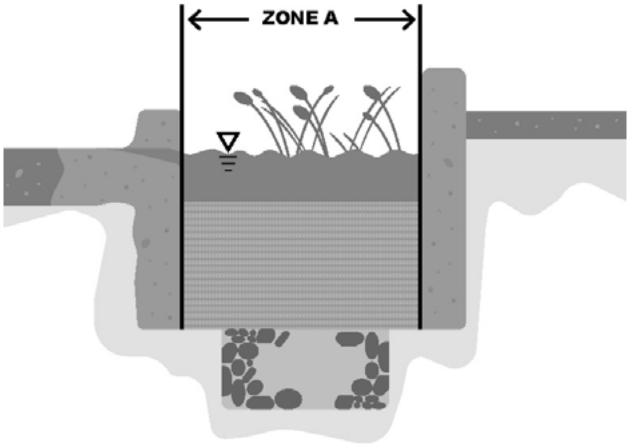
Water specifies if a plant's water requirement is relatively high, medium, or low. Based on Water Use Classification of Landscape Species (WUCOLS) guidance.

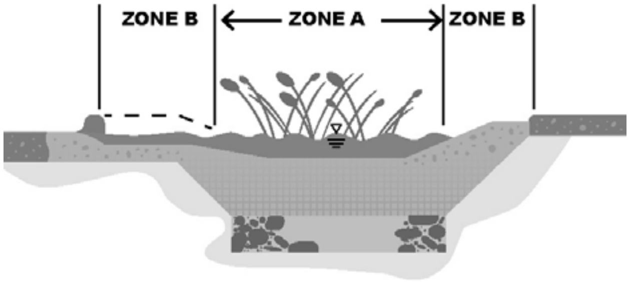
Sun denotes a plant's relative sunlight requirements.

Mature Size gives details of the height and spread of the mature plant.

Tolerances lists other adverse conditions in which the plants can thrive.

Notes general information for the siting, planting, and suitability of the plant.





Examples of Zones A & B in surface green infrastructure practices

Designers may submit plants to PANYNJ for approval which are not included in this matrix. At a minimum, the submission must include documentation sufficient to determine the above metrics for the proposed plant.

The palette also includes a **Photo Matrix** with examples of the mature state of each plant.

	Scientific Name	**Common Name**	**ZONE**		**INFO**			**CONDITIONS**			**WATER[2]**			**SUN**			**Mature Size[3]**	**Tolerances**	**Notes**
			Zone A	**Zone B**	**D or C[1]**	**Native**	**Aviation**	**Salt**	**Drought**	**Pollution**	**Low**	**Medium**	**High**	**Full**	**Partial**	**Shade**			
	Trees																		
1	***Amelanchier canadensis***	Serviceberry		●	D	●					●	●		●	●		Height: 25'-30' Spread: 15'-20'	Clay soil, some deer	No insect or pest problems. Effective along stream banks and ponds.
2	***Betula nigra***	River Birch	●	●	D							●	●	●	●		Height: 40'-70' Spread: 40'-60'	Deer, drought, clay, wet soil, air pollution	Shade tree, raingarden, floodplains, swamps, along streams.
3	***Carpinus betulus 'Fastigiata'***	European Hornbeam		●	D		●			●		●		●	●		Height: 30'-40' Spread: 20'-30'	Air pollution	Upright, narrow fastigiate form
4	***Chionanthus virginicus***	Fringe Tree	●	●	D	●	●			●		●		●	●		Height: 12'-20' Spread: 12' - 20'	Air pollution, urban, dry conditions, clay soil, black walnut	Showy flowers, rain garden, near streams and ponds
5	***Cornus kousa***	Kousa Dogwood		●	D	●						●		●	●		Height: 15'-30' Spread: 15'-30'	Deer, cold hardiness	Showy bracts and bark, speciment plant or small groupings
6	***Cornus x Ruth Ellen***	Stellar White Dogwood		●	D		●					●		●	●		Height: 12' - 18' Spread: 18' - 24'	Deer	Does not produce fruit
7	***Gingko biloba 'Autumn Gold'***	Maidenhair Tree		●	D				●	●		●		●			Height: 40'-50' Spread: 25'-20'	Deer, clay soil, air pollution	All male cultivar, beautiful foliage, great street tree
8	***Gleditsia triacanthos Inermis***	Honeylocust	●	●	D	●	●	●	●	●	●	●	●		●		Height: 50' Spread: 50'	Urban pollution and urban environments, and both dry and moist conditions	Good street tree and shade tree
9	***Koelreuteria paniculata***	Golden Rain Tree		●	D		●		●	●		●		●			Height: 30' - 40' Spread: 30' - 35'	Drought, clay soil, air pollution	Excellent flowering street tree
10	***Magnolia stellata 'Varieties'***	Star Magnolia		●	D		●					●		●			Height: 15' - 20' Spread: 10' - 15'	Dry sites and drought, alkaline and acid, salt	Fragrant blossoms, attractive bark
11	***Malus 'Coralburst'***	Coralburst Crabapple (Fruitless)		●	D		●		●			●		●			Height: 8' - 10' Spread: 12' - 15'	Disease resistant	Flowering tree, no fruits
12	***Parrotia persica***	Persian Parrotia		●	D					●		●		●	●		Height: 20' - 40' Spread: 20' - 30'	Clay soil, air pollution	Good for street tree
13	***Pinus flexilis***	Limber Pine		●	C						●	●		●			Height: 20'-30' Spread: 10'-15'	Deer, dry sites, drought, alkaline soil	Large shade tree, specimen, windbreak
14	***Platanus x acerifolia 'Exclamation'***	London Plane Tree	●	●	D					●				●	●	●	Height: 75'-100' Spread: 60'-75'	Deer, clay soil, air pollution, urban, some shade	Good for a large space
15	***Quercus phellos***	Willow Oak	●	●	D		●			●		●	●	●	●	●	Height: 50'-60' Spread: 50'-60'	Drought, clay soil, air pollution	Form is narrow-upright, columnar, fastigiate

[1] C = Coniferous; D= Deciduous

[2] Based on Water Use Classification of Landscape Species (WUCOLS) guidance

[3] Includes height, width, root ball size, and canopy/dripline radius as applicable

			ZONE		INFO			CONDITIONS			WATER[2]			SUN					
	Scientific Name	**Common Name**	**Zone A**	**Zone B**	**D or C[1]**	**Native**	**Aviation**	**Salt**	**Drought**	**Pollution**	**Low**	**Medium**	**High**	**Full**	**Partial**	**Shade**	**Mature Size[3]**	**Tolerances**	**Notes**
16	***Quercus robur 'Fastigiata'***	English Oak		•	D				•	•		•		•			Height: 20' - 25' Spread: 15' - 20'	Deer, clay soil, urban, some shade	Great street tree with flowers
17	***Syringa reticulata 'Ivory Silk'***	Ivory Silk Lilac		•	D		•			•		•		•	•		Height: 50'-75' Spread: 15'-20	Deer, erosion, clay soil, air pollution	Tolerates soil conditions from somewhat dry soils to wet soils in standing water
18	***Taxodium distichum***	Bald Cypress	•	•	C					•		•	•	•			Height: 50'-70' Spread: 35'-50'	Soils, paving, urban areas	Shade tree, street tree
19	***Tilia cordata***	Littleleaf Linden		•	D				•	•		•		•	•		Height: 60'-80' Spread: 40'-50'	Urban areas	Great street tree
20	***Zelkova serrata 'Green Vase'***	Green Vase Zelkova		•	D		•			•		•		•			Height: 60'-80' Spread: 40'-50'	Urban areas	Great street tree
	Shrubs																		
21	***Abelia grandiflora 'Edward Goucher'***	Glossy Abelia		•	D	•	•	•	•	•		•		•	•		Height: 3'-5' Spread: 3'-5'	Erosion	Good for massing on slopes or banks for erosion control, has clusters of white and pink bell-shaped fragrant flowers
22	***Baccharis halimifolia***	Groundsel Tree		•	D	•		•	•	•	•	•	•	•			Height: 5'-10' Spread: 5'-7'	Range of soil types, drought, salt	Good for edge planting, poisonous to human
23	***Baptisia australis***	Blue False Indigo		•	D	•	•	•	•	•	•			•	•		Height: 6'-12' Spread: 4'-8'	Flooding, draught, salt spary, erosion, dry soil, clay soil	Good for border plantings, naturalized settings
24	***Caryopteris x Clandonensis Inoveris***	Bluebeard		•	D			•			•	•		•			Height: 1.5'-2.5' Spread: 1.5'-2.5'	Drought	Hedge, natural, effective in groups and massing
25	***Clethera alnifolia***	Sweet Pepperbush	•	•	D	•	•	•	•	•		•	•	•	•	•	Height: 3'-8' Spread: 4'-6'	Heavy shade, erosion, clay soil, wet soil	Rain garden, natural garden
26	***Comptonia peregrina***	Sweetfern		•	D	•		•	•			•		•	•		Height: 2'-5' Spread 4'-8'	Drought	Rain garden
27	***Diervilla lonicera***	Bush Honeysuckle		•	D	•	•		•		•	•		•	•		Height: 2'-3' Spread: 2'-4'	Deer, clay soil	Hedge, natural
28	***Diervilla sessilifolia***	Southern Bush Honeysuckle		•	D							•		•	•		Height: 3'-5' Spread: 3'-5'	Erosion	Ground cover, natural
29	***Fothergilla gardenii***	Dwarf Fothergilla		•	D		•					•		•	•		Height: 1'-3' Spread: 2'-4'	Some shade	Showy aromatic flowers
30	***Hamamelis virginiana***	Witch Hazel		•	D	•	•			•		•			•	•	Height: 10'-15' Spread: 15'-20'	Deer, erosion, clay soil	Small tree or tall shrub, unique floral display.

[1] C = Coniferous; D= Deciduous

[2] Based on Water Use Classification of Landscape Species (WUCOLS) guidance

[3] Includes height, width, root ball size, and canopy/dripline radius as applicable

			ZONE		INFO			CONDITIONS			WATER[2]			SUN					
	Scientific Name	**Common Name**	**Zone A**	**Zone B**	**D or C[1]**	**Native**	**Aviation**	**Salt**	**Drought**	**Pollution**	**Low**	**Medium**	**High**	**Full**	**Partial**	**Shade**	**Mature Size[3]**	**Tolerances**	**Notes**
31	***Hydrangea arborescens***	Smooth Hydrangea		●	D							●			●		Height: 3'-5' Spread: 3'-5'	Erosion, clay soil, dry soil, set soil, shallow rocky soil	Rain garden, intolerant of drought
32	***Hypericum kalmianum/ prolificum***	Shrubby St. Johnswort	●	●	D				●			●		●	●		Height: 2'-3' Spread: 2'-3'	High pH soils	Best suited for the edges of bioswales, where soil is less saturated.
33	***Itea virginica***	Sweetspire		●	D		●					●	●	●	●	●	Height: 3'-4' Spread: 4'-6'	Heavy shade, erosion, clay soil, wet soil	Rain garden, fragrant
34	***Juniperus chinensis 'Sargentii'***	Blue Sargent Juniper		●	C		●	●	●	●		●		●			Height: 1'-2' Spread: 8'-10'	Deer, drought, erosion, dry soil, shallow rocky soil, air pollution	Groundcover
35	***Juniperus conferta 'Blue Pacific***	Shore Juniper		●	C			●	●	●		●		●			Height: 0.5'-2' Spread: 4'-6'	Deer, drought, erosion, air pollution	Groundcover
36	***Juniperus horiz. plumosa compacta 'Youngstown'***	Creeping Juniper		●	C			●	●	●		●		●			Height: 0.5'-1' Spread: 4'-6'	Deer, drought, erosion, dry soil, shallow rocky soil, air pollution	Groundcover
37	***Spiraea nipponica 'Snowmound'***	Snowmound Spirea		●	D		●		●			●		●	●		Height: 2'-4' Spread: 2'-4'	Deer, erosion, clay soils	Hedge
38	***Syringa meyeri 'Palibin'***	Meyer Lilac		●	D				●	●	●	●		●	●		Height: 4'-5' Spread: 5'-7'	Deer, drought, erosion, dry soil	Hedge, tolerates light shade, urban tolerance
39	***Taxus x media 'Tauntonii'***	Taunton Yew		●	C				●		●				●	●	Height: 3'-4' Spread: 3'-5'	Drought, heavy shade	Hedge
	Grasses Lawn																		
40	***Festuca arundinacea***	Tall Fescue	●	●			●	●	●			●		●			Maintain height: 3	Lawn grass	Swale
	Grasses Ornamental																		
41	***Calamagrostis canadensis***	Blue Joint Grass	●	●					●	●		●	●	●	●		Height: 2'-5' Spread: 1-'3'	Drought, erosion, wet soil, air pollution	Adaptable, wetland
42	***Hakonechloa macra 'All Gold'***	Gold Japanese Forest Grass	●	●				●		●		●			●	●	Height: 1'-1.5' Spread: 1'-1.5'	Deer, black walnut, air pollution	Naturalize
43	***Panicum virgatum 'Heavy Metal'***	Switch grass	●	●					●	●	●	●	●	●	●		Height: 4'-5' Spread: 1'-2'	Drought, erosion, dry soil, set soil, air pollution	Rain Garden
44	***Pennisetum alopecuroides 'Hameln'***	Fountain grass	●	●					●	●		●	●	●	●		Height: 1'-3' Spread: 1-'2'	Drought, erosion, wet soil, air pollution	Ground cover, rain garden
	Grasses Wetland																		
45	***Spartina cynosuroides***	Big cordgrass	●						●	●		●	●	●	●		Height: 1'-3' Spread: 1-'3'	Drought, erosion, wet soil, air pollution	For brackish or salt marshes and flats

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[1] C = Coniferous; D= Deciduous

[2] Based on Water Use Classification of Landscape Species (WUCOLS) guidance

[3] Includes height, width, root ball size, and canopy/dripline radius as applicable

	Scientific Name	Common Name	ZONE		INFO			CONDITIONS			WATER[2]			SUN			Mature Size[3]	Tolerances	Notes
			Zone A	Zone B	D or C[1]	Native	Aviation	Salt	Drought	Pollution	Low	Medium	High	Full	Partial	Shade			
	Perennials																		
46	***Acorus calamus***	Sweet Flag	●	●			●			●		●	●		●	●	Height: 2'-2.5' Spread: 1.5'-2'	Heavy shade, erosion, wet soil	Water plant, naturalize, rain garden
47	***Anemone canadensis***	Canadian Anemone, Windflower	●	●			●					●	●	●	●		Height: 1'-2' Spread: 2'-2.5'	Deer, clay soil	Naturalize, rain garden
48	***Asclepias incarnata***	Swamp Milkweed	●	●		●		●	●	●		●	●	●			Height: 4-5' Spread: 2'-3'	Deer, clay soil, wet soil	Good for rain garden
49	***Asclepias syriaca***	Common Milkweed	●	●		●			●	●	●	●		●			Height: 2'-3' Spread: 1'-2'	Deer, drought, erosion, dry soil, shallow-rocky soil	Rough, weedy perennial
50	***Coreopsis verticillata***	Threadleaf Coreopsis		●			●	●		●	●	●		●			Height: 2.5'-3' Spread: 1.5'-2'	Deer, drought, dry soil, shallow rocky soil	Excellent for continuous flowering
51	***Echinacea purpurea***	Purple Coneflower	●	●			●	●	●	●	●	●		●	●		Height: 2'-5' Spread: 1.5'-2'	Deer, dry soil, shallow rocky soil, air pollution	Rain garden
52	***Eutrochium purpureum***	Joe Pye Weed	●	●							●	●	●	●	●		Height: 5'-7' Spread: 2'-4'	Deer, clay soil, wet soil	Water plant, naturalize, rain garden
53	***Hemerocallis varieties***	Daylillies		●	D		●	●		●		●		●	●		Height: 2'-2.5' Spread: 2'-2.5'	Deer, dry soil, shallow rocky soil, air pollution	Showy flowers, good border plant, naturalized garden
54	***Hibiscus moscheutos***	Swamp Rose Mallow	●	●								●	●			●	Height: 3'-7' Spread: 2'-4'	Wet soil	Rain garden
55	***Iris versicolor***	Blue Flag	●	●			●					●	●	●	●		Height: 2'-2.5' Spread: 2'-2.5'	Deer, wet soil	Water plant, naturalize, rain garden
56	***Liriope muscari ' Big Blue'***	Big Blue Lily Turf		●			●	●	●	●		●		●	●		Height: 1'-2' Spread: 1'-2'	Rabbit, deer, drought, erosion, air pollution	Good for border planting, erosion control, ground cover, mass planting
57	***Nepeta faassenii 'Walker's Low'***	Walker's Low Catmint		●			●	●		●		●	●	●	●		Height: 1'-2' Spread: 1'-3'	Deer, dry soil, shallow rocky soil, air pollution, urban	Border, erosion control, ground cover, urban
58	***Osmunda cinnamomea***	Cinnamon Fern		●			●					●	●		●	●	Height: 2'-3' Spread: 2'-3'	Heavy shade, black walnut	Border, wet areas, rain garden
59	***Rosa palustris***	Swamp Rose	●	●					●		●	●	●	●			Height: 3'-6' Spread: 3'6'	Tolerant of neutral pH	Very tolerant of flooding and drought, good for rain garden
60	***Solidago sempervirens***	Seaside Goldenrod	●	●				●	●		●	●		●			Height: 2'-3' Spread: 2'-3'	Deer, drought, clay soil	Naturalize
61	***Symphyotrichum novae-angliae***	New England Aster	●	●						●		●		●			Height: 3'-6' Spread: 2'-3'	Clay soils	Suggested use for rain gardens
62	***Vernonia noveboracensis***	New York Ironweed	●	●			●	●		●		●	●	●	●		Height: 4'-6' Spread: 3'-4'	Deer, clay soil, wet soil	Naturalize, rain garden

---

[1] C = Coniferous; D= Deciduous

[2] Based on Water Use Classification of Landscape Species (WUCOLS) guidance

[3] Includes height, width, root ball size, and canopy/dripline radius as applicable

Appendix B: Plant Palette Photo Matrix

Trees

Amelanchier canadensis
Serviceberry

Betula nigra
River Birch

Carpinus betulus ‘Fastigiata’
European Hornbeam

Chionathus virginicus
Fringe Tree

Trees

Cornus kousa
Kousa Dogwood

Cornus x rutgerensis
Ruth Ellen Foliage

Ginkgo biloba
Maidenhair Tree

Gleditsia triacanthos
Honeylocust Spring

Trees

Koelreutria paniculata
Golden Rain Tree

Magnolia stellata
Star Magnolia

Malus coralburst
Coralburst Crabapple

Parrotia persica
Persian Parrotia

Appendix B: Plant Palette Photo Matrix

Trees


13

Pinus flexilis
Limber Pine


14

Platanus x acerifolia
London Plane Tree


15

Quercus phellos
Willow Oak


16

Quercus robur fastigiata
English Oak

Trees


17

Syringa reticulata
Ivory Silk Lilac


18

Taxodium distichum
Bald Cypress


19

Tilia cordata
Littleleaf Linden


20

Zelkova serrata
Japanese Zelkova

Shrubs


21

Abelia grandiflora ‘Edward goucher’
Glossy Abelia


22

Baccharis halimifolia
Groundsel Tree


23

Baptisia australis
Blue False Indigo


24

Caryopteris x clandonensis inoveris
Bluebeard

Appendix B: Plant Palette Photo Matrix

Shrubs


25

Clethera alnifolia
Sweet Pepperbush


26

Comptonia peregrina
Sweetfern


27

Diervilla ionicera
Bush Honeysuckle


28

Diervilla sessilifolia
Southern Bush Honeysuckle

Shrubs


29

Fothergilla gardenii
Dwarf Fothergilla


30

Hamamelis virginiana
Witch Hazel


31

Hydrangea arborescens
Smooth Hydrangea


32

Hypericum kalmianum
Shrubby St. Johnswort

Shrubs


33

Itea virginica
Sweetspire


34

Juniperus chinensis 'Sargentii'
Blue Sargent Juniper


35

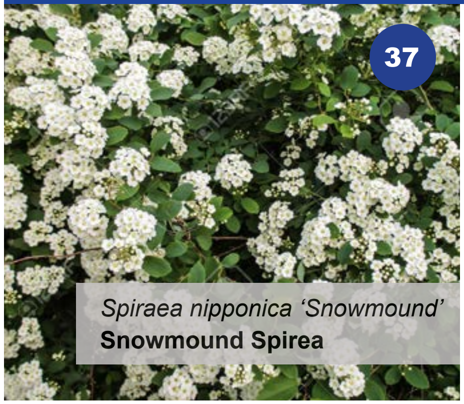
Juniper conferta
Shore Juniper


36

Juniperus horiz. plumosa compacta
'Youngstown' **Creeping Juniper**

Appendix B: Plant Palette Photo Matrix

Shrubs


37

Spiraea nipponica ‘Snowmound’
Snowmound Spirea


38

Syringa meyeri ‘Palibin’
Meyer Lilac


39

Taxus x media ‘Tauntonii’
Taunton Yew

Grasses Lawn


40

Festuca arundinacea
Tall Fescue

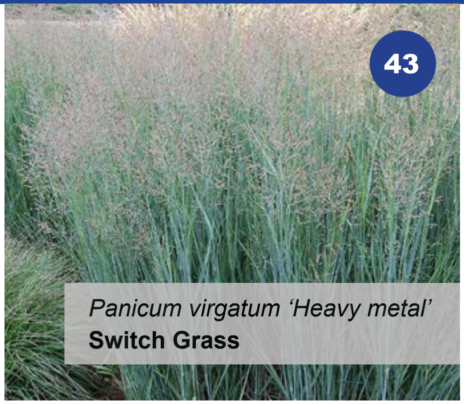
Grasses Ornamental


41

Calamagrostis canadensis
Blue Joint Grass


42

Hakonechloa macra ‘All gold’
Gold Japanese Forest Grass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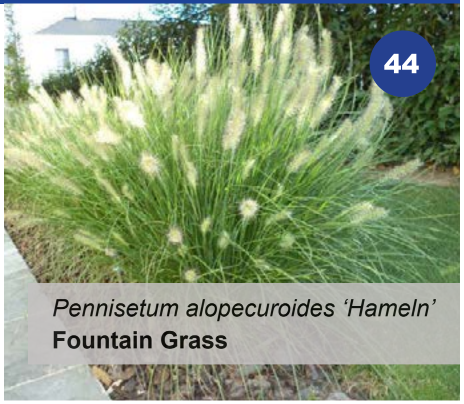
Panicum virgatum ‘Heavy metal’
Switch Grass


44

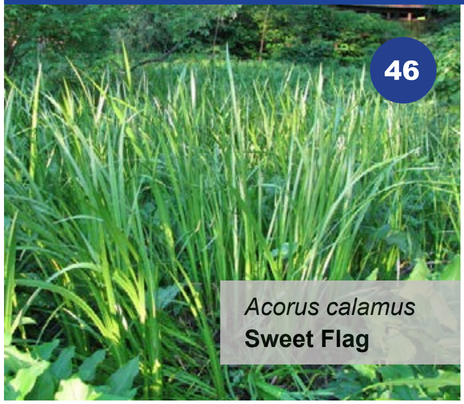
Pennisetum alopecuroides ‘Hameln’
Fountain Grass

Grasses


45

Spartina cynosuroides
Big Cordgrass

Perennials


46

Acorus calamus
Sweet Flag


47

Anemone canadensis
Canadian Anemone, Windflower


48

Asclepias incarnata
Swamp Milkweed

Appendix B: Plant Palette Photo Matrix

Perennials


49

Asclepias syriaca
Common Milkweed


50

Coreopsis verticillata
Threadleaf Coreopsis

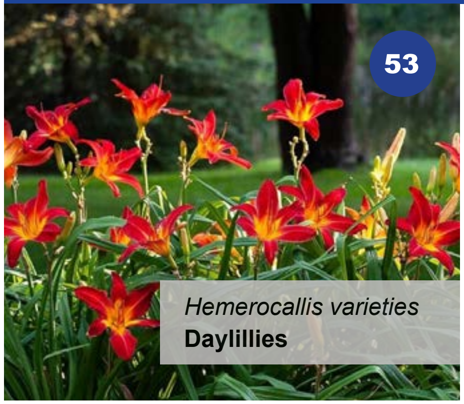

51

Echinacea purpurea
Purple Coneflower


52

Eutrochium purpureum
Joe Pye Weed

Perennials


53

Hemerocallis varieties
Daylillies


54

Hibiscus moscheutos
Swamp Rose Mallow


55

Iris versicolor
Blue Flag


56

Liriope muscari
Big Blue Lily Turf

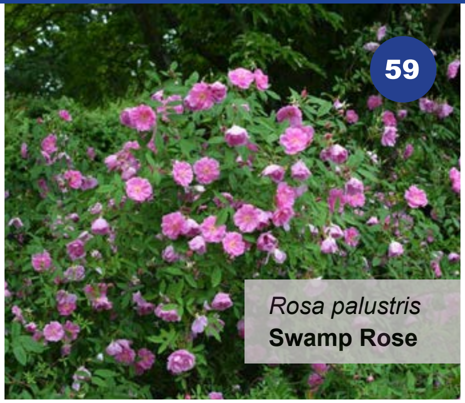
Perennials


57

Nepeta faassenii
Walker's Low Catmint


58

Osmunda cinnamomea
Cinnamon Fern


59

Rosa palustris
Swamp Rose


60

Solidago sempervirens
Seaside Goldenrod

Appendix B: Plant Palette Photo Matrix

Perennials


61

Symphyotrichum novae-angliae
New England Aster


62

Vernonia noveboracensis
New York Ironweed

Appendix C: Example Green Infrastructure Designs

Disclaimer

Note that the resources provided in this appendix are for example purposes only. Designers are responsible for ensuring their design drawings and specifications meet all PANYNJ and regulatory requirements

THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY

EXAMPLE GREEN INFRASTRUCTURE DESIGNS

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09	PERMEABLE PAVEMENT OVERFLOW STRUCTURE DETAILS
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GENERAL NOTES

1. THESE DRAWINGS ARE FOR EXAMPLE ONLY AND ARE NOT TO BE DIRECTLY USED FOR STAGE III DESIGN DRAWINGS. DESIGNERS ARE RESPONSIBLE FOR CONFORMING THESE DRAWINGS TO MEET REGULATORY REQUIREMENTS AND STORMWATER MANAGEMENT GOALS.
2. REFER TO PANYNJ "GREEN INFRASTRUCTURE DESIGN MANUAL" (GIDM) FOR DESIGN GUIDANCE.
3. FOR REGULATORY REQUIREMENTS, REFER TO THE APPLICABLE STATE AND/OR MUNICIPAL GUIDANCE MANUAL(S) FOR THE PROJECT SITE, INCLUDING BUT NOT LIMITED TO: NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION "STORMWATER BEST MANAGEMENT PRACTICES MANUAL" AND/OR NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION "STORMWATER MANAGEMENT DESIGN MANUAL".
4. DESIGNER SHOULD COORDINATE WITH PA ENGINEERING/ARCHITECTURE DIVISION PRIOR TO LOCATION AND DESIGN OF GREEN INFRASTRUCTURE COMPONENTS.
5. GREEN INFRASTRUCTURE COMPONENTS ARE DEPENDENT ON SOIL CONDITIONS, SOIL INFILTRATION RATES, DESIGN PEAK FLOW RATES, STORAGE VOLUME REQUIREMENTS, WATER QUALITY REQUIREMENTS, AND OTHER PARAMETERS. DESIGNERS ARE RESPONSIBLE FOR CONFORMING THE DRAWINGS AND SPECIFICATIONS TO MEET REQUIRED REGULATIONS AND SITE PARAMETERS.
6. DESIGNERS SHOULD APPLY PANYNJ STANDARD SPECIFICATIONS WHERE AVAILABLE AND SHOULD DEVELOP CUSTOM SPECIFICATIONS FOR ANY COMPONENTS NOT INCLUDED IN THE STANDARD SPECIFICATIONS.
7. DESIGNER SHOULD INCLUDE AT LEAST ONE CLEANOUT PORT FOR ALL PRACTICES WITH AN UNDERDRAIN OR SUBSURFACE STORAGE SYSTEM.
8. ALL PRACTICES SHOULD INCLUDE AN OVERFLOW SYSTEM TO PREVENT SURFACE FLOODING WHEN THE DESIGN STORM QUANTITY IS EXCEEDED.
9. DESIGNERS SHOULD CONSIDER PRETREATMENT SYSTEMS IN CASES WHERE TRIBUTARIES ARE EXPECTED TO CONTRIBUTE EXCESSIVE DEBRIS OR SEDIMENT.
10. THE MINIMUM DEPTH FROM THE BOTTOM OF AN INFILTRATION PRACTICE TO THE TOP OF BEDROCK OR THE SEASONALLY HIGH GROUNDWATER TABLE IS 3 FEET UNLESS OTHERWISE APPROVED BY PANYNJ.
11. MAXIMUM EXCAVATION DEPTH IS 5 FEET UNLESS OTHERWISE APPROVED BY PANYNJ.

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GENERAL NOTES

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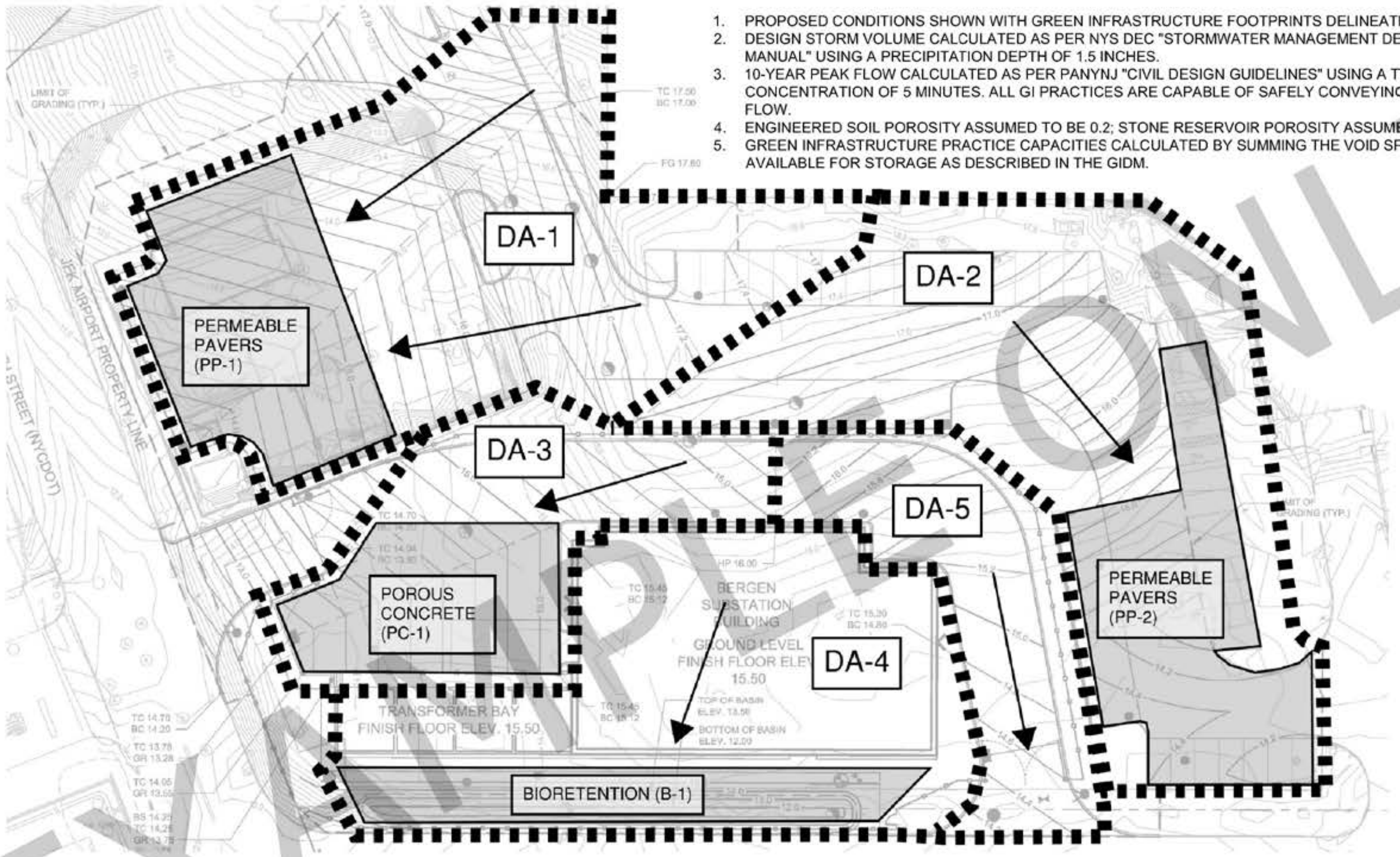
TRIBUTARY DRAINAGE PLAN



NOTES

1. PROPOSED CONDITIONS SHOWN WITH GREEN INFRASTRUCTURE FOOTPRINTS DELINEATED.
2. DESIGN STORM VOLUME CALCULATED AS PER NYS DEC "STORMWATER MANAGEMENT DESIGN MANUAL" USING A PRECIPITATION DEPTH OF 1.5 INCHES.
3. 10-YEAR PEAK FLOW CALCULATED AS PER PANYNJ "CIVIL DESIGN GUIDELINES" USING A TIME OF CONCENTRATION OF 5 MINUTES. ALL GI PRACTICES ARE CAPABLE OF SAFELY CONVEYING THE PEAK FLOW.
4. ENGINEERED SOIL POROSITY ASSUMED TO BE 0.2; STONE RESERVOIR POROSITY ASSUMED TO BE 0.4.
5. GREEN INFRASTRUCTURE PRACTICE CAPACITIES CALCULATED BY SUMMING THE VOID SPACES AVAILABLE FOR STORAGE AS DESCRIBED IN THE GIDM.

DA-1	
TOTAL AREA (SF)	27,525
IMPERVIOUS AREA (SF)	18,364
PERVIOUS AREA (SF)	9,161
DESIGN STORM VOLUME (CF)	2,273
10-YR PEAK FLOW (CFS)	2.96

DA-2	
TOTAL AREA (SF)	32,671
IMPERVIOUS AREA (SF)	28,112
PERVIOUS AREA (SF)	4,559
DESIGN STORM VOLUME (CF)	3,332
10-YR PEAK FLOW (CFS)	4.52

DA-3	
TOTAL AREA (SF)	9,126
IMPERVIOUS AREA (SF)	8,816
PERVIOUS AREA (SF)	310
DESIGN STORM VOLUME (CF)	1,044
10-YR PEAK FLOW (CFS)	1.41

DA-4	
TOTAL AREA (SF)	19,451
IMPERVIOUS AREA (SF)	14,678
PERVIOUS AREA (SF)	4,773
DESIGN STORM VOLUME (CF)	1,781
10-YR PEAK FLOW (CFS)	2.58

DA-5	
TOTAL AREA (SF)	9,824
IMPERVIOUS AREA (SF)	9,244
PERVIOUS AREA (SF)	580
DESIGN STORM VOLUME (CF)	1,117
10-YR PEAK FLOW (CFS)	1.33

PERMEABLE PAVERS (PP-1)	
FOOTPRINT AREA (SF)	8,210
TRIBUTARY/FOOTPRINT RATIO	3.4:1
STONE RESERVOIR DEPTH (IN)	18
GI PRACTICE CAPACITY (CF)	4,926

PERMEABLE PAVERS (PP-2)	
FOOTPRINT AREA (SF)	10,284
FOOTPRINT/TRIBUTARY RATIO	3.2:1
STONE RESERVOIR DEPTH (IN)	18
GI PRACTICE CAPACITY (CF)	6,170

POROUS CONCRETE (PC-1)	
FOOTPRINT AREA (SF)	4,504
FOOTPRINT/TRIBUTARY RATIO	2.0:1
STONE RESERVOIR DEPTH (IN)	18
GI PRACTICE CAPACITY (CF)	2,702

BIORETENTION (B-1)	
FOOTPRINT AREA (SF)	3,134
FOOTPRINT/TRIBUTARY RATIO	6.2:1
ENGINEERED SOIL DEPTH (IN)	18
STONE RESERVOIR DEPTH (IN)	12
PONDING VOLUME (CF)	783
GI PRACTICE CAPACITY (CF)	2,977

NO GREEN INFRASTRUCTURE

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EXAMPLE TRIBUTARY DRAINAGE PLAN

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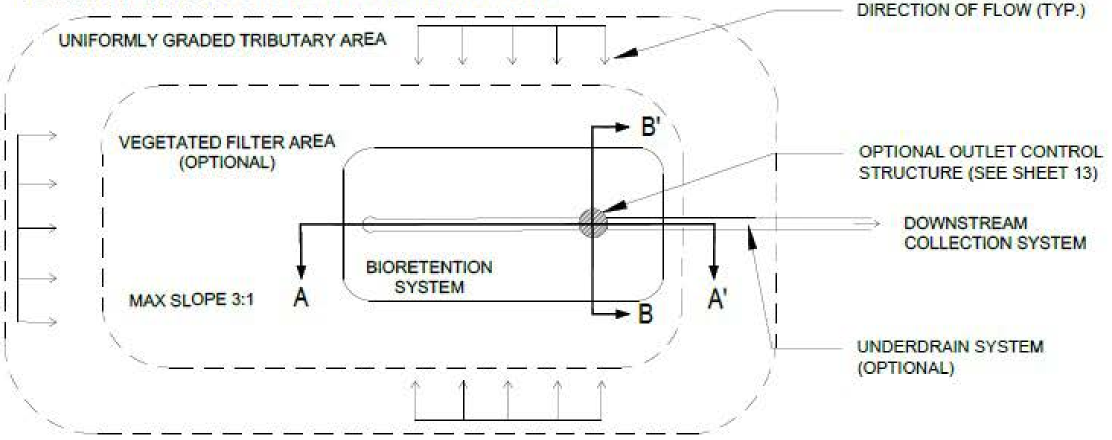
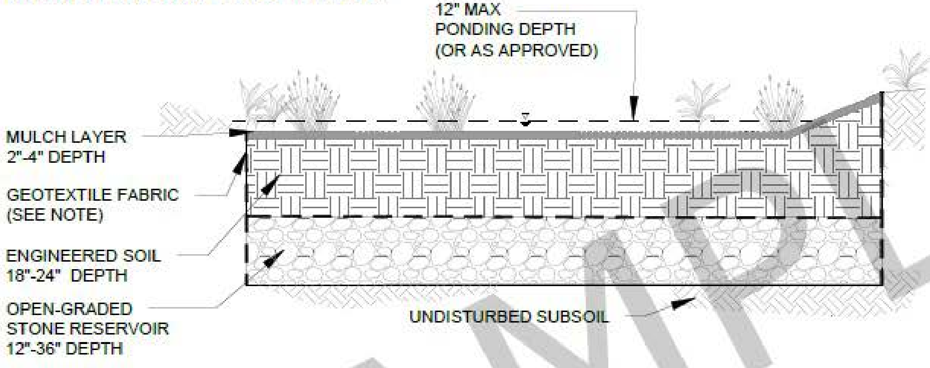
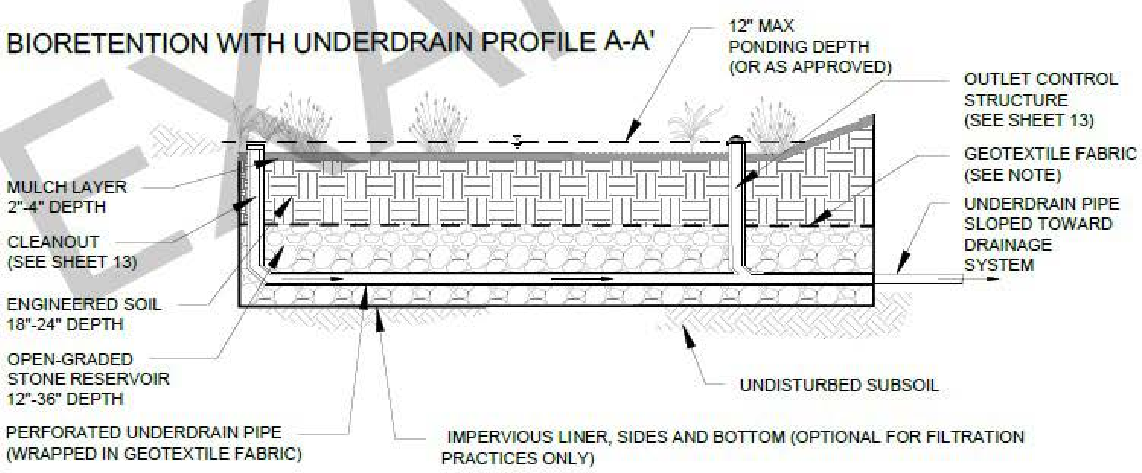
BIORETENTION SCHEMATIC PLAN VIEW



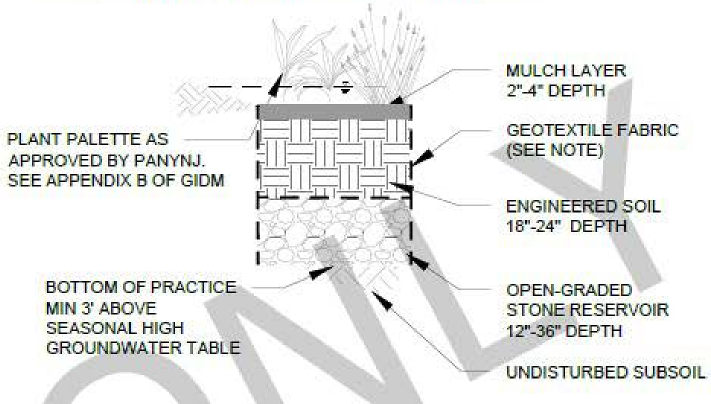
BIORETENTION PROFILE A-A'



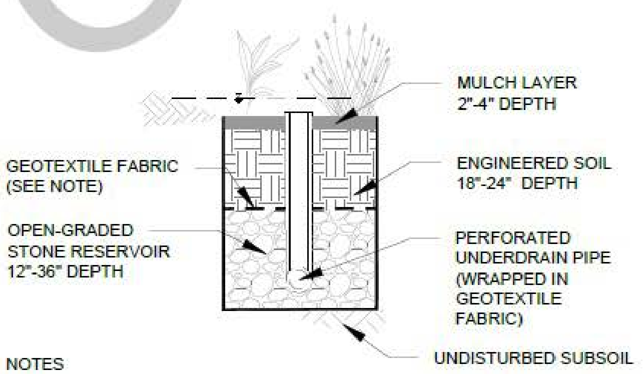
BIORETENTION WITH UNDERDRAIN PROFILE A-A'



BIORETENTION CROSS-SECTION B-B'



BIORETENTION WITH UNDERDRAIN PROFILE B-B'



NOTES

1. GEOTEXTILE FABRIC MUST BE PLACED AROUND THE SIDES OF THE PRACTICE. ENGINEER TO DETERMINE IF REQUIRED BETWEEN DRAINAGE MEDIA LAYERS. GEOTEXTILE FABRIC SHOULD NOT BE PLACED AT THE BOTTOM OF THE EXCAVATION EXCEPT FOR FILTRATION-ONLY PRACTICES. GEOTEXTILE FABRICS MUST NOT EXCESSIVELY RESTRICT HYDRAULIC FUNCTION OF THE PRACTICE.
2. PRETREATMENT, INFLOW, AND OUTFLOW CONFIGURATIONS MUST ACCOMMODATE THE DESIGN STORM PEAK FLOW.
3. STORAGE VOLUME OF THE PONDING AREA, ENGINEERED SOIL, AND OPEN-GRADED STONE RESERVOIR MUST EQUAL DESIGN STORM VOLUME, AT A MINIMUM.
4. SUBSOIL INFILTRATION RATE MUST BE 0.5 IN/HR AT A MINIMUM FOR INFILTRATION PRACTICES.

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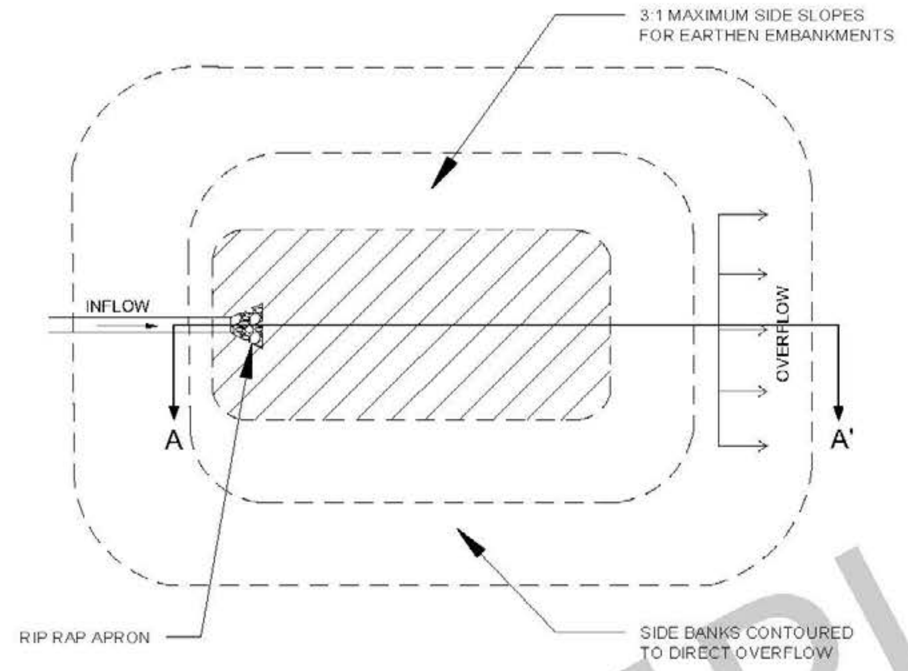
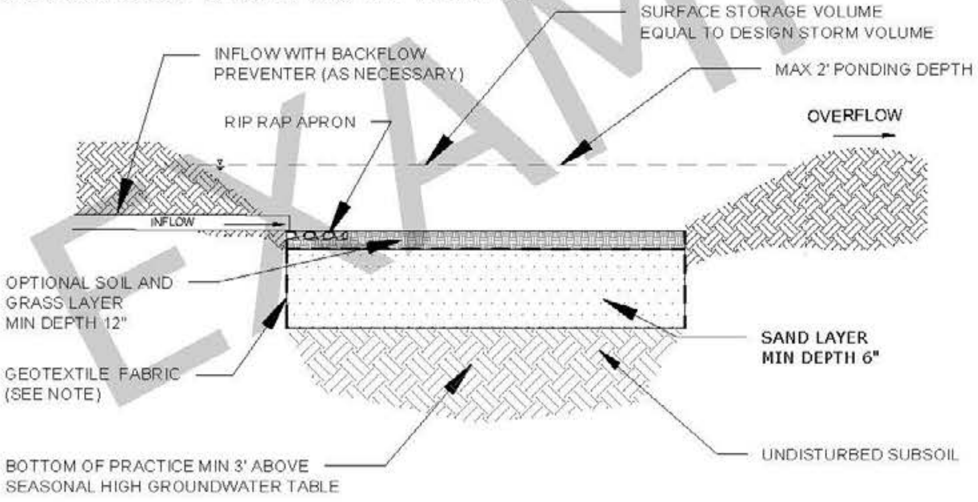
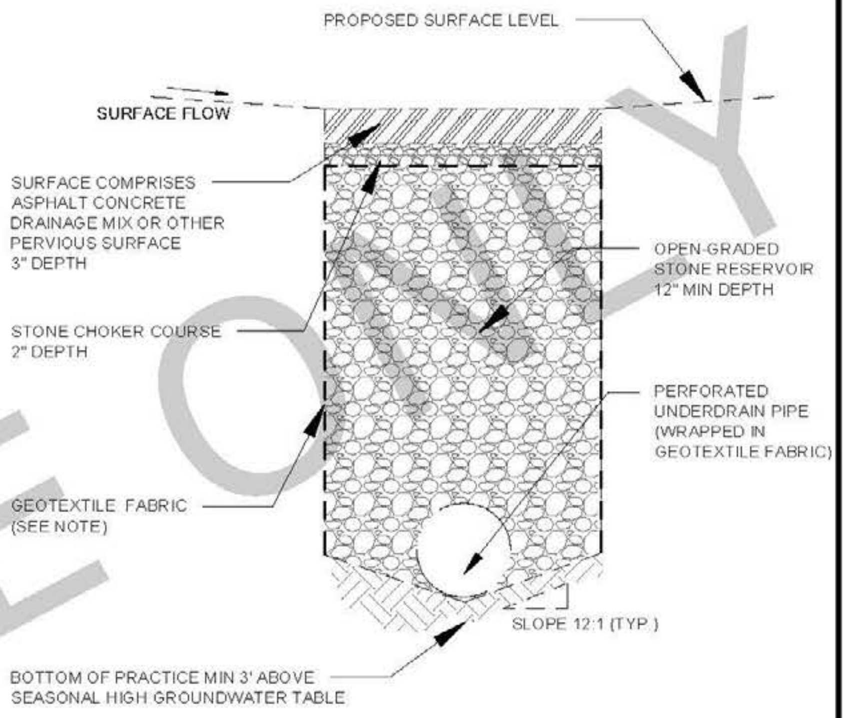
INFILTRATION BASIN SCHEMATIC PLAN VIEW



INFILTRATION BASIN PROFILE VIEW A-A'



INFILTRATION TRENCH CROSS-SECTION



NOTES

1. GEOTEXTILE FABRIC MUST BE PLACED AROUND THE SIDES OF THE PRACTICE. ENGINEER TO DETERMINE IF REQUIRED BETWEEN DRAINAGE MEDIA LAYERS. GEOTEXTILE FABRIC SHOULD NOT BE PLACED AT THE BOTTOM OF THE EXCAVATION EXCEPT FOR FILTRATION-ONLY PRACTICES. GEOTEXTILE FABRICS MUST NOT EXCESSIVELY RESTRICT HYDRAULIC FUNCTION OF THE PRACTICE.
2. PRETREATMENT, INFLOW, AND OUTFLOW CONFIGURATIONS MUST ACCOMMODATE THE DESIGN STORM PEAK FLOW.
3. STORAGE VOLUME OF THE PONDING AREA, ENGINEERED SOIL, AND OPEN-GRADED STONE RESERVOIR MUST EQUAL DESIGN STORM VOLUME, AT A MINIMUM.
4. SUBSOIL INFILTRATION RATE MUST BE 0.5 IN/HR AT A MINIMUM FOR INFILTRATION PRACTICES.

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INFILTRATION BASIN
AND
INFILTRATION TRENCH
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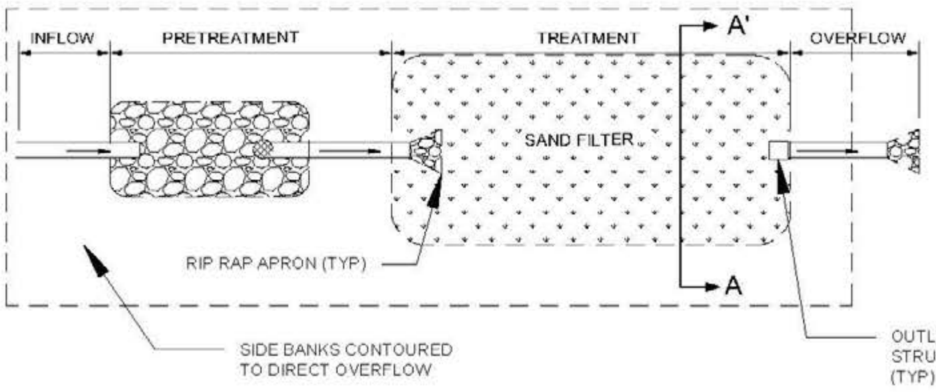
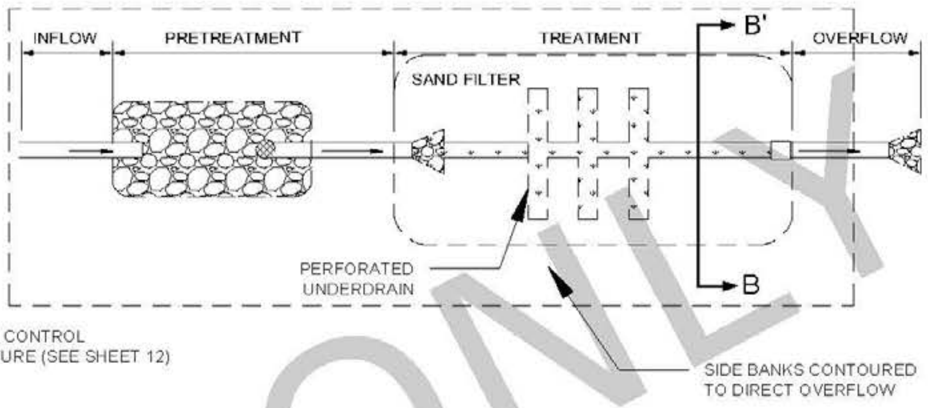
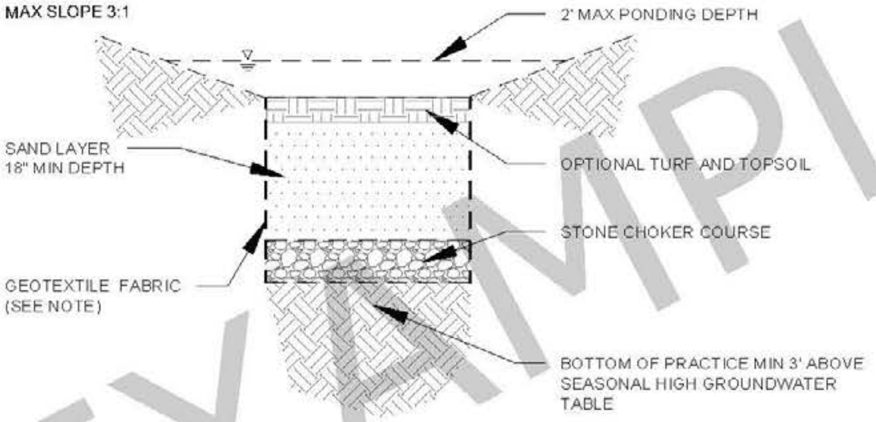
SAND FILTER SCHEMATIC PLAN VIEW



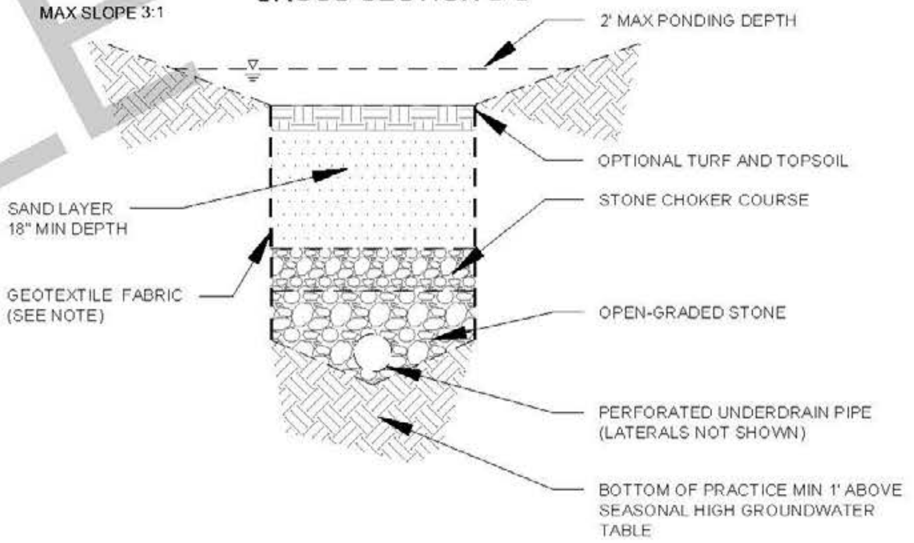
SAND FILTER WITH UNDERDRAIN SCHEMATIC PLAN VIEW



SAND FILTER
CROSS-SECTION A-A'



SAND FILTER WITH UNDERDRAIN
CROSS-SECTION B-B'



NOTES

1. GEOTEXTILE FABRIC MUST BE PLACED AROUND THE SIDES OF THE PRACTICE. ENGINEER TO DETERMINE IF REQUIRED BETWEEN DRAINAGE MEDIA LAYERS. GEOTEXTILE FABRIC SHOULD NOT BE PLACED AT THE BOTTOM OF THE EXCAVATION EXCEPT FOR FILTRATION-ONLY PRACTICES. GEOTEXTILE FABRICS MUST NOT EXCESSIVELY RESTRICT HYDRAULIC FUNCTION OF THE PRACTICE.
2. PRETREATMENT, INFLOW, AND OUTFLOW CONFIGURATIONS MUST ACCOMMODATE THE DESIGN STORM PEAK FLOW.
3. STORAGE VOLUME OF THE PONDING AREA, ENGINEERED SOIL, AND OPEN-GRADED STONE RESERVOIR MUST EQUAL DESIGN STORM VOLUME, AT A MINIMUM.
4. SUBSOIL INFILTRATION RATE MUST BE 0.5 IN/HR AT A MINIMUM FOR INFILTRATION PRACTICES.

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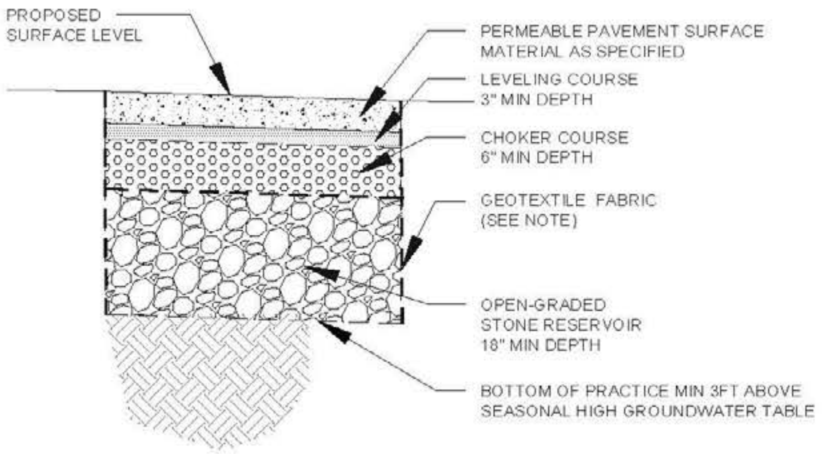
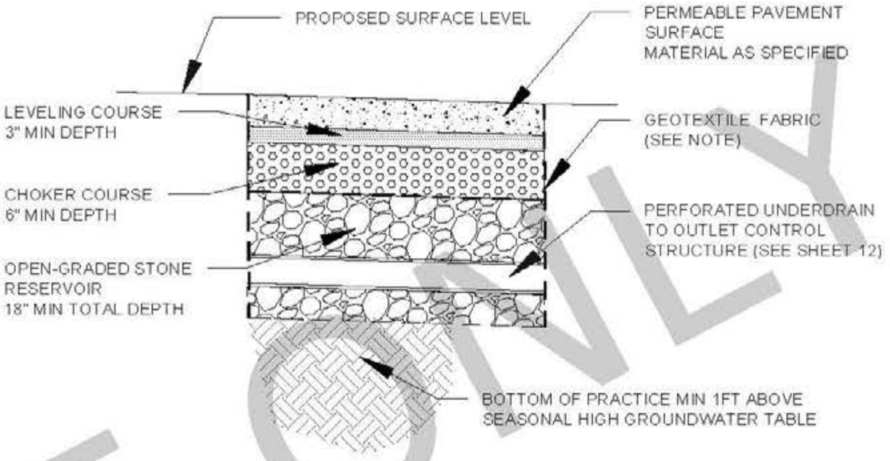
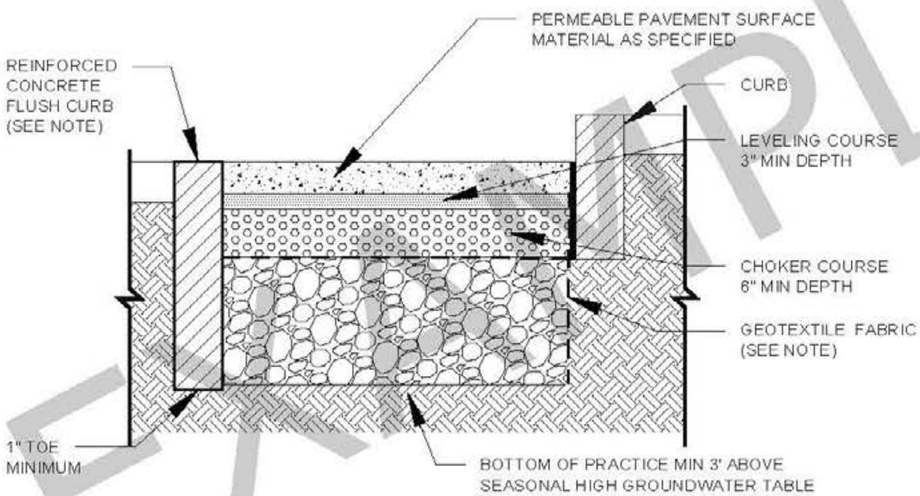
PERMEABLE PAVEMENT CROSS-SECTION



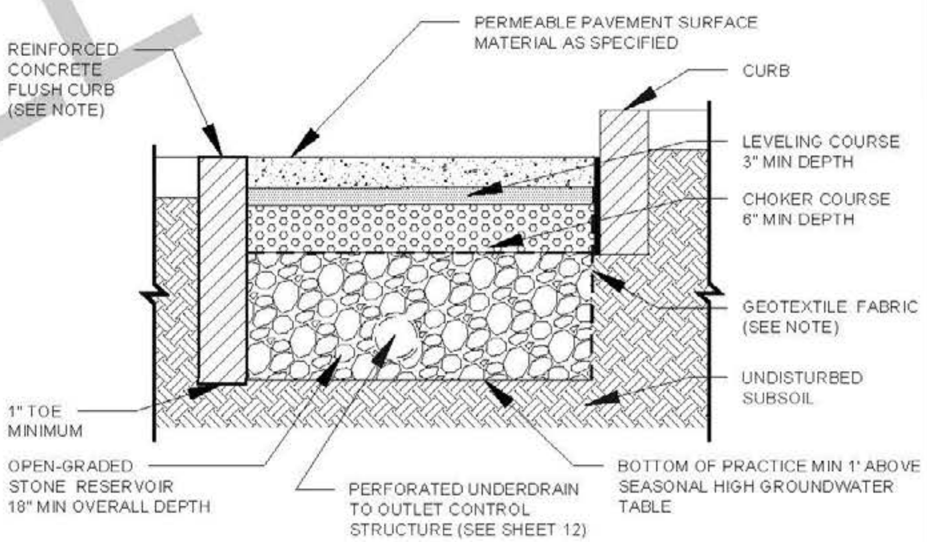
PERMEABLE PAVEMENT WITH UNDERDRAIN CROSS-SECTION



PERMEABLE PAVEMENT IN ROADWAY SHOULDER



PERMEABLE PAVEMENT WITH UNDERDRAIN IN ROADWAY SHOULDER



NOTES

1. REINFORCED CONCRETE FLUSH CURB DIMENSIONS TO BE DETERMINED BY PANYNJ TO PROTECT ADJACENT SUBBASE AS NEEDED.
2. GEOTEXTILE FABRIC MUST BE PLACED AROUND THE SIDES OF THE PRACTICE. ENGINEER TO DETERMINE IF REQUIRED BETWEEN DRAINAGE MEDIA LAYERS. GEOTEXTILE FABRIC SHOULD NOT BE PLACED AT THE BOTTOM OF THE EXCAVATION EXCEPT FOR FILTRATION-ONLY PRACTICES. GEOTEXTILE FABRICS MUST NOT EXCESSIVELY RESTRICT HYDRAULIC FUNCTION OF THE PRACTICE.
3. PRETREATMENT, INFLOW, AND OUTFLOW CONFIGURATIONS MUST ACCOMMODATE THE DESIGN STORM PEAK FLOW.
4. STORAGE VOLUME OF THE PONDING AREA, ENGINEERED SOIL, AND OPEN-GRADED STONE RESERVOIR MUST EQUAL DESIGN STORM VOLUME, AT A MINIMUM.
5. SUBSOIL INFILTRATION RATE MUST BE 0.5 IN/HR AT A MINIMUM FOR INFILTRATION PRACTICES.
6. PERMEABLE PAVEMENT WITH UNDERDRAIN REQUIRES OUTLET STRUCTURE PER SHEET 09.

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PERMEABLE PAVEMENT DETAILS

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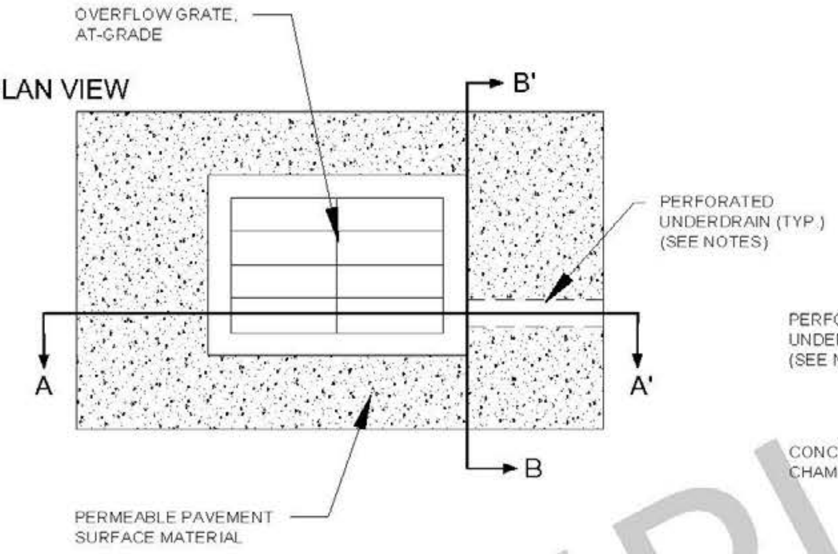
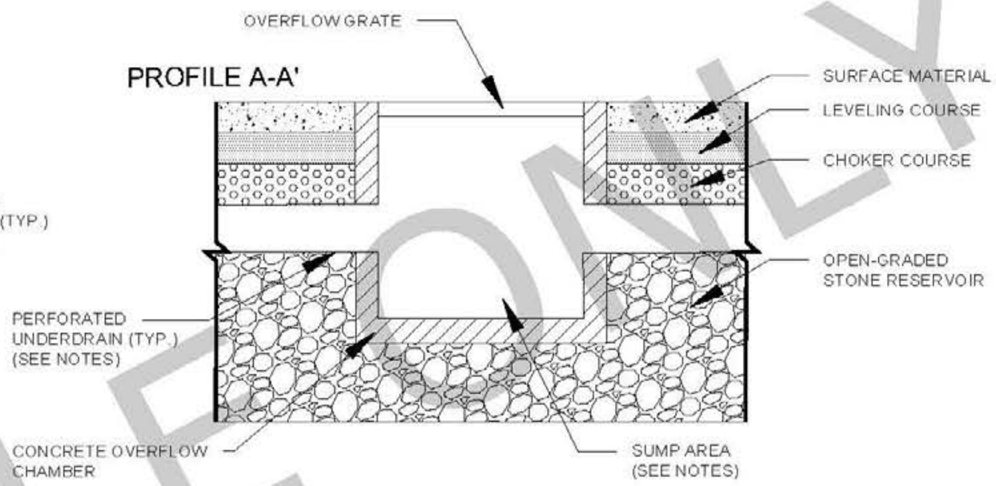
PERMEABLE PAVEMENT OVERFLOW STRUCTURE

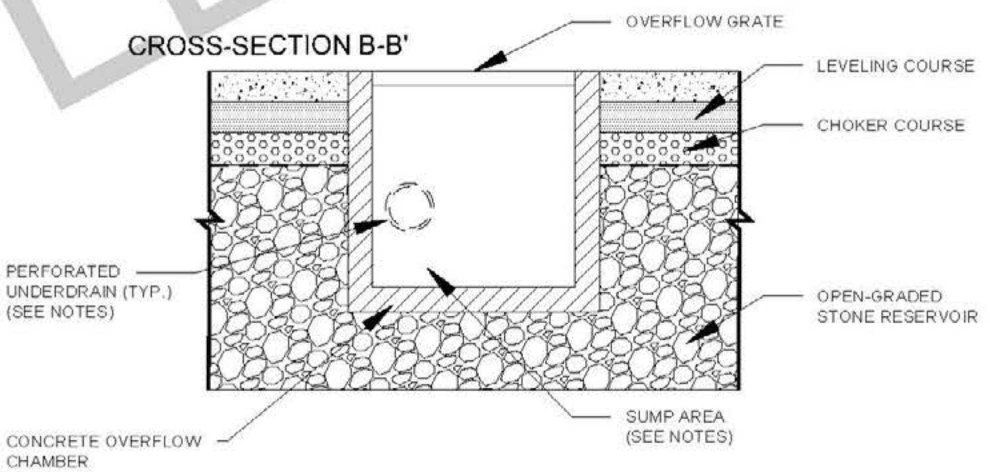
PLAN VIEW



PROFILE A-A'



CROSS-SECTION B-B'



NOTES

1. OVERFLOW GRATE IS OPTIONAL IF PRACTICE DOES NOT HAVE OVERLAND OVERFLOW PATH.
2. UNDERDRAIN ELEVATION DEPENDS ON HYDRAULIC CHARACTERISTICS OF THE GI PRACTICE.
3. SUMP DEPTH AS REQUIRED FOR MAINTENANCE PURPOSES.
4. DESIGNER MUST CONFIRM CONNECTION REQUIREMENTS ARE MET.

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PERMEABLE PAVEMENT
OVERFLOW STRUCTURE
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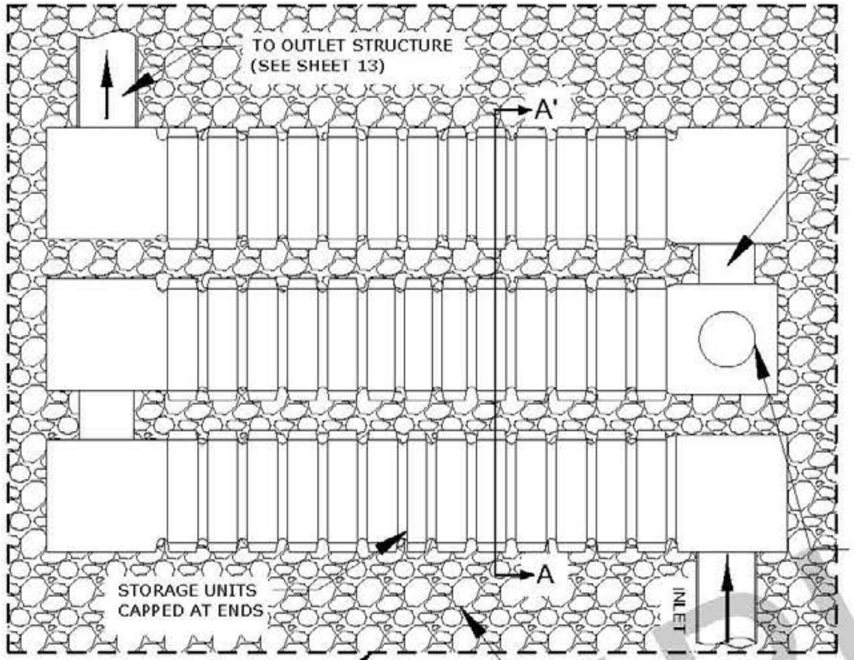
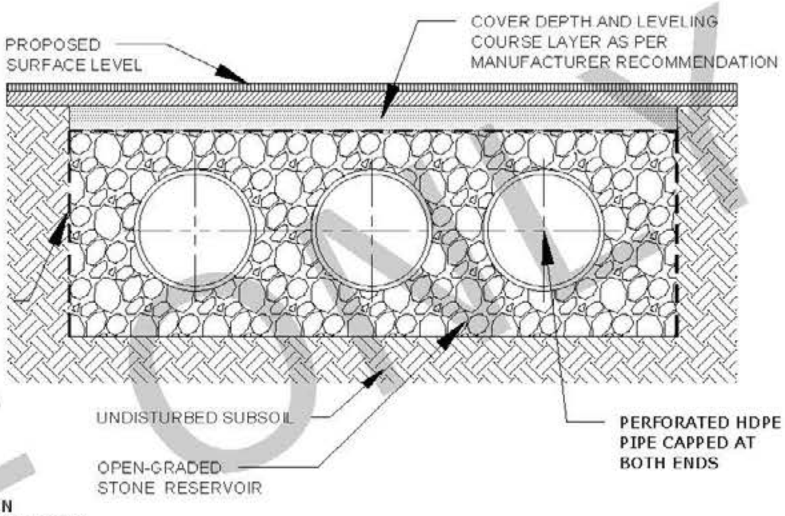
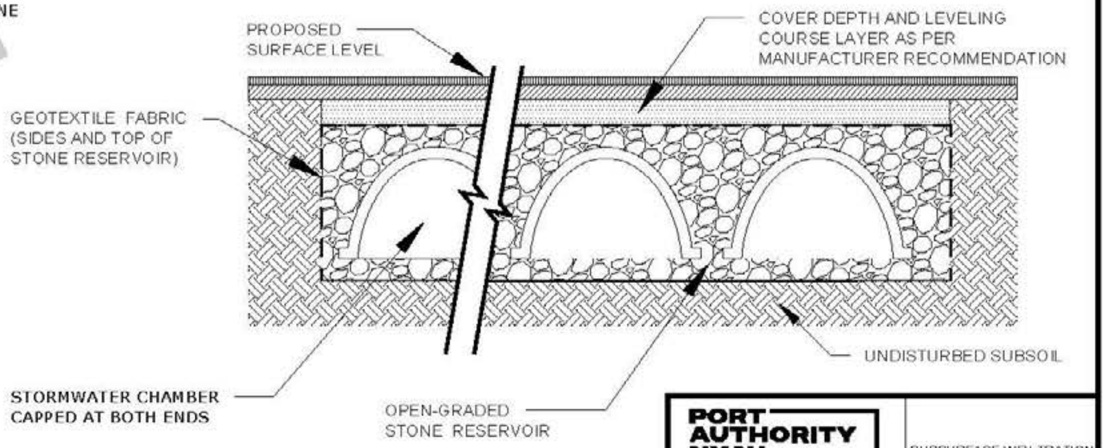
SUBSURFACE PIPES & CHAMBERS SCHEMATIC PLAN VIEW



SUBSURFACE PIPES CROSS-SECTION A-A'



SUBSURFACE CHAMBERS CROSS-SECTION A-A'



NOTES:

1. PRETREATMENT, INFLOW, AND OUTFLOW CONFIGURATIONS MUST ACCOMMODATE THE DESIGN STORM PEAK FLOW. DESIGNER TO CONFIRM OUTFLOW RATE IS APPROPRIATE FOR DOWNSTREAM DRAINAGE SYSTEM.
2. INLET AND OUTLET STRUCTURES MUST BE DESIGNED AS PER MANUFACTURER SPECIFICATIONS TO ACCOMMODATE REGULAR MAINTENANCE.
3. STORAGE VOLUME OF THE STORAGE UNITS AND OPEN-GRADED STONE RESERVOIR MUST EQUAL DESIGN STORM VOLUME, AT A MINIMUM.
4. FOR INFILTRATION PRACTICES, SUBSOIL INFILTRATION RATE MUST BE 0.5 IN/HR AT A MINIMUM.
5. SPACING BETWEEN STORAGE UNITS, CLEARANCE TO EDGE OF EXCAVATION, COVER DEPTH, AND STONE BASE DEPTH AS PER MANUFACTURER RECOMMENDATIONS.
6. CONNECTION CONFIGURATIONS BETWEEN STORAGE UNITS TO BE DETERMINED BY DESIGNER TO OPTIMIZE STORMWATER MANAGEMENT.
7. GEOTEXTILE OVERLAPS SHALL BE MINIMUM 24" LONG.

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SUBSURFACE INFILTRATION DETAILS

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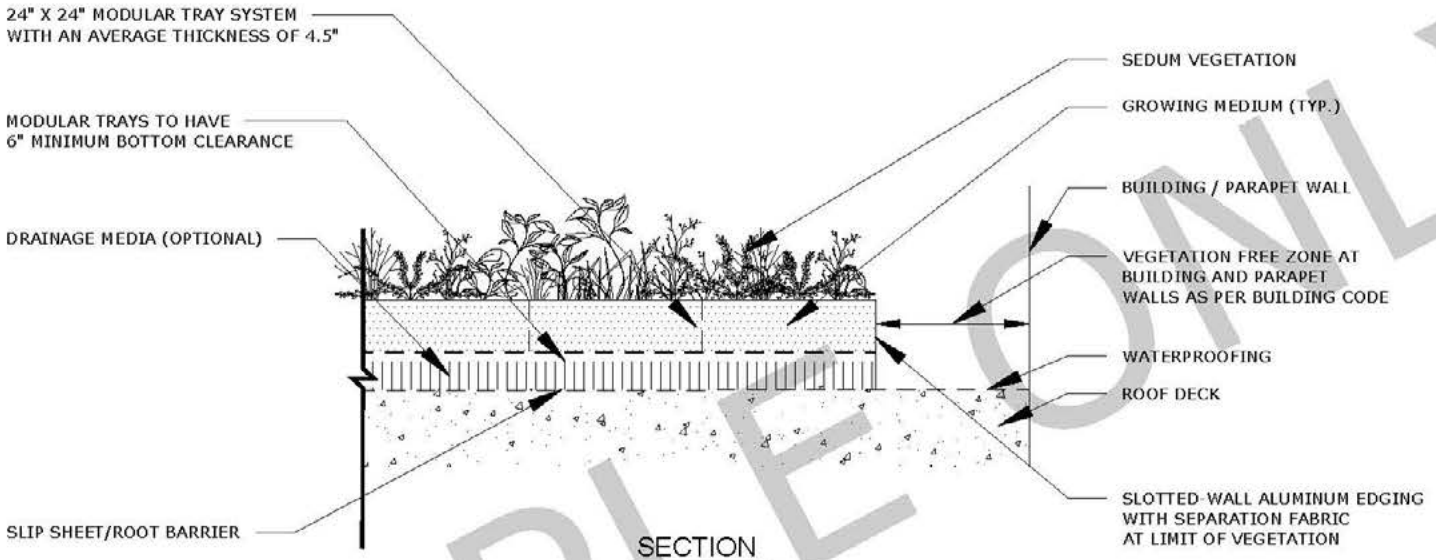
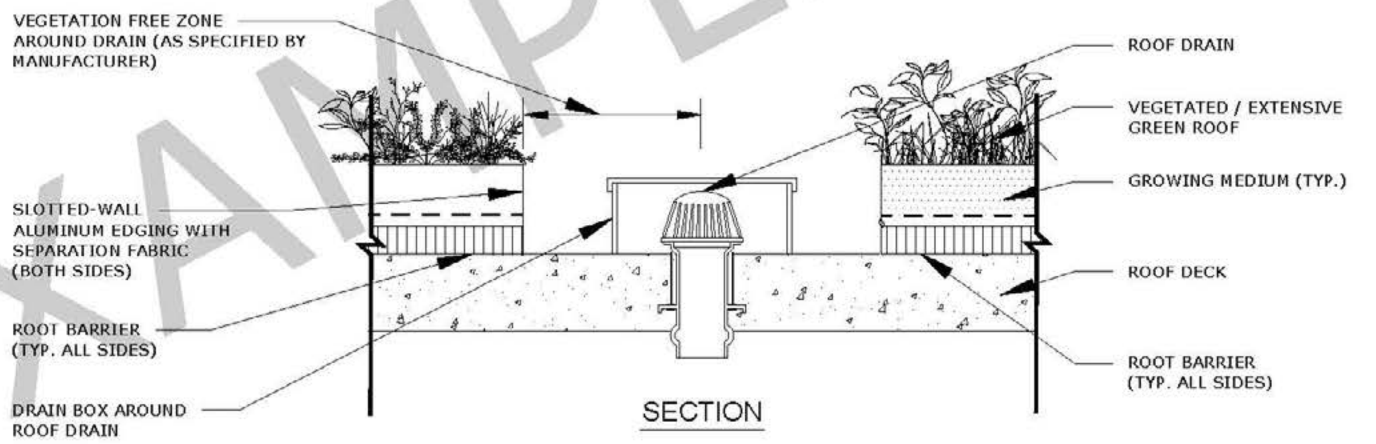
EXTENSIVE GREEN ROOF: MODULAR SEDUM TRAY SYSTEM



SECTION



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EXTENSIVE GREEN ROOF DETAILS

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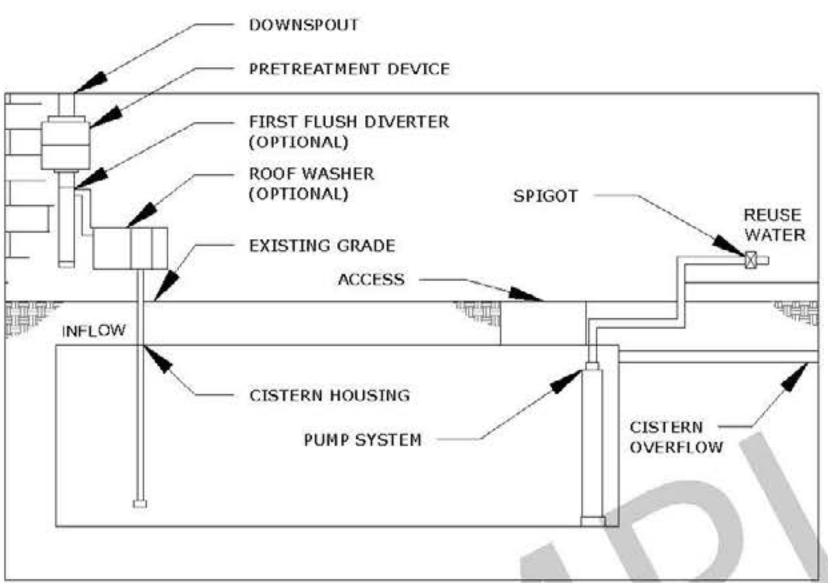
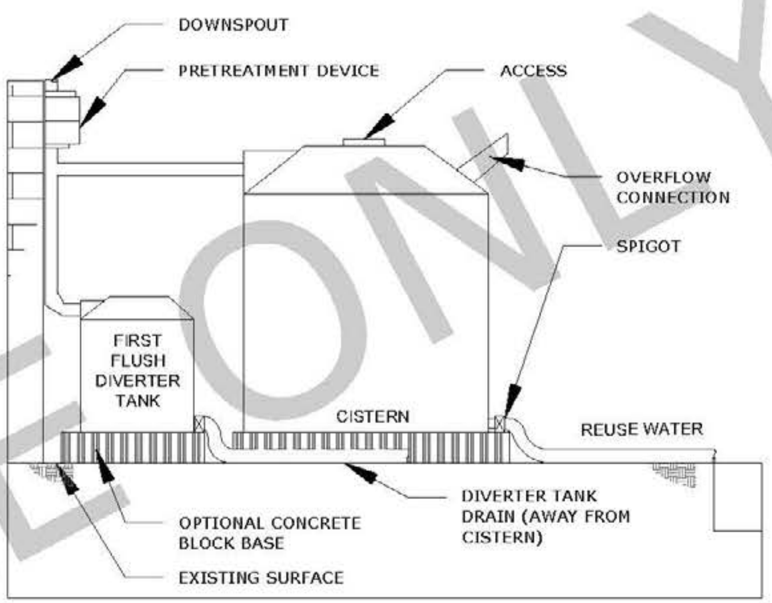
RAINWATER HARVESTING: SUBSURFACE CISTERN EXAMPLE SCHEMATIC PLAN



RAINWATER HARVESTING: SURFACE CISTERN EXAMPLE SCHEMATIC PLAN



NOTES

1. CISTERN STORAGE VOLUME MUST BE SUFFICIENT TO CONTAIN THE DESIGN STORM VOLUME WITHOUT OVERFLOW.
2. PRETREATMENT IS REQUIRED UPSTREAM OF ALL CISTERNS TO REMOVE COARSE MATERIAL AT A MINIMUM. CISTERNS MAY ALSO INCLUDE ROOF WASHERS TO REMOVE FINER PARTICLES.
3. FIRST FLUSH DIVERTERS MAY BE USED TO ROUTE THE INITIAL RUNOFF FLOW AWAY FROM THE CISTERNS. THE FIRST FLUSH TYPICALLY INCLUDES HIGHER SEDIMENT AND DEBRIS LOADING AND MAY REQUIRE MORE FREQUENT MAINTENANCE IF PASSED INTO CISTERN.
4. NO STANDING WATER MAY REMAIN IN CISTERN 72 HOURS AFTER RAIN EVENT.
5. SECONDARY STORAGE TANKS ARE REQUIRED IF THE 3-DAY WATER REUSE DEMAND IS NOT SUFFICIENT TO DRAIN CISTERN IN 72 HOURS. THE SECONDARY STORAGE TANK HOLDS WATER FOR REUSE WHILE THE PRIMARY TANK IS EMPTIED TO PREPARE FOR THE NEXT STORM.
6. CISTERNS THAT USE PUMPS, VALVES, OR OTHER CONTROLS TO AUTOMATE OR REGULATE FLOW MUST INCLUDE ALARMS OR OTHER MEASURES TO DETECT FLOWS AND FAILURE CONDITIONS. SUCH SYSTEMS MAY ALSO REQUIRE EMERGENCY SHUTOFF AND BACKUP POWER.
7. ROOF GUTTERS, LEADERS AND RAINWATER COLLECTION PIPING SHALL SLOPE CONTINUOUSLY TOWARD COLLECTION INLETS WITH A SLOPE GREATER THAN 1/8" PER FOOT ALONG THEIR TOTAL LENGTH.
8. CISTERN VENTS SHALL BE PROTECTED FROM CONTAMINATION WITH A U-BEND INSTALLED WITH THE OPENING DIRECTED DOWNWARD OR AN APPROVED CAP. THE VENT OUTLETS SHALL EXTEND A MINIMUM OF 4" ABOVE GRADE TO PREVENT SURFACE WATER FROM ENTERING THE STORAGE TANK.
9. ANY WATER SERVICE PIPING, NON-POTABLE OR POTABLE, CONTAINING RAINWATER NEEDS TO BE SEPARATED FROM THE BUILDING SEWER BY 5' OF UNDISTURBED EARTH. THE WATER SERVICE PIPES SHALL NOT BE LOCATED IN, UNDER, OR ABOVE CESSPOOLS, SEPTIC TANKS, SEPTIC TANK DRAINAGE FIELDS, OR SEEPAGE PITS.

PORT AUTHORITY NY NJ

RAINWATER HARVESTING SCHEMATICS

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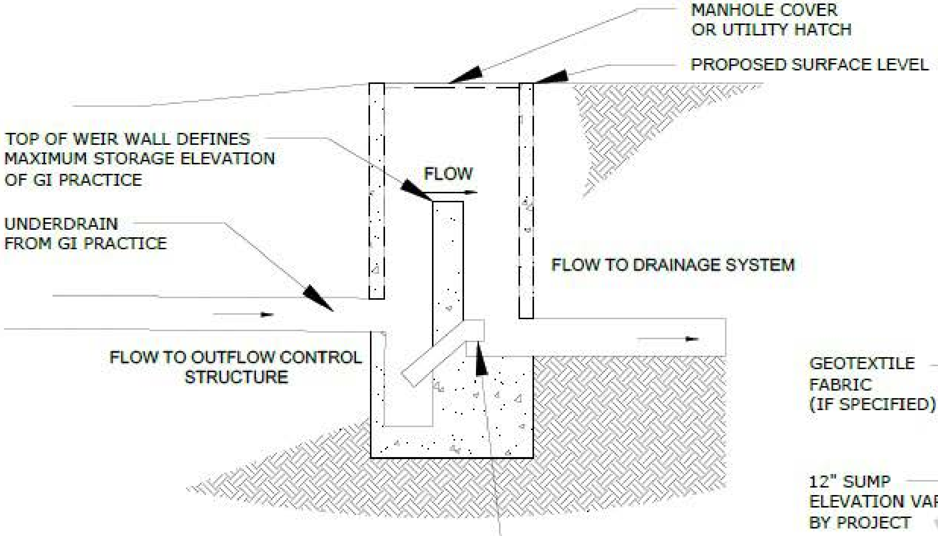
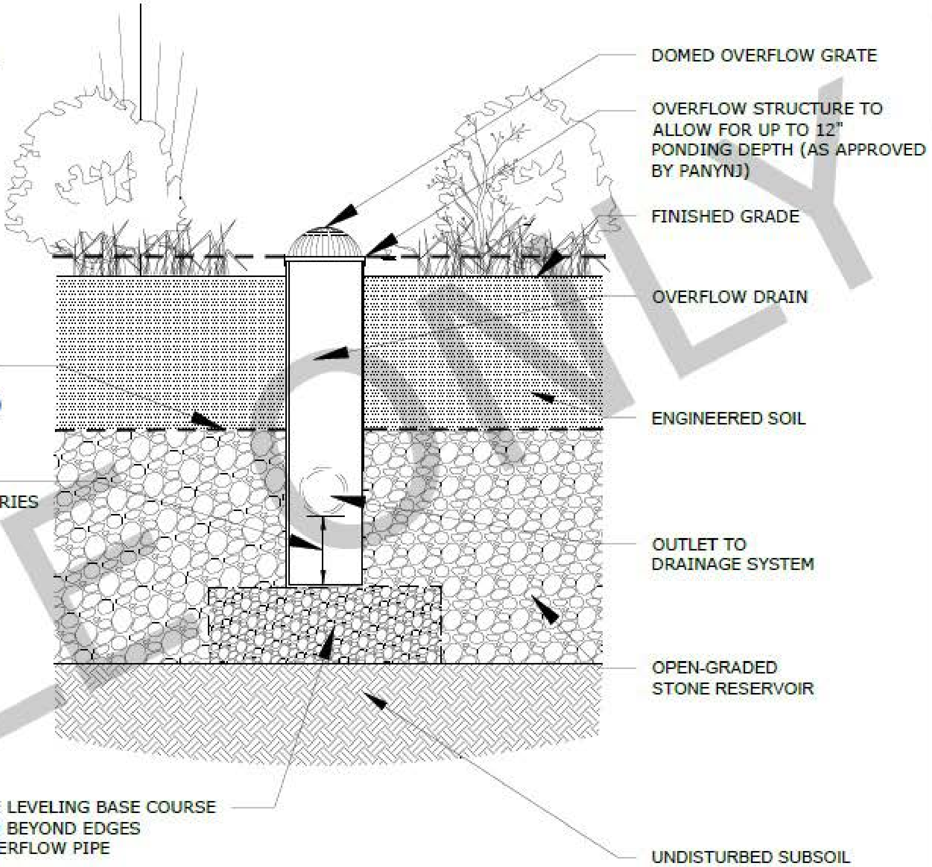
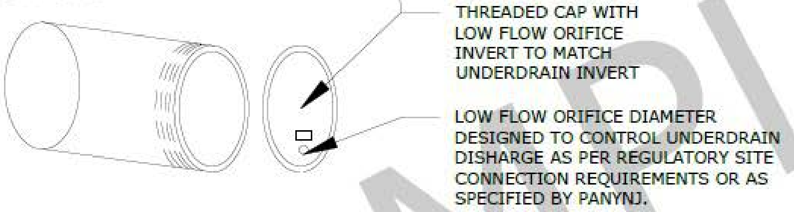
OUTLET CONTROL STRUCTURE



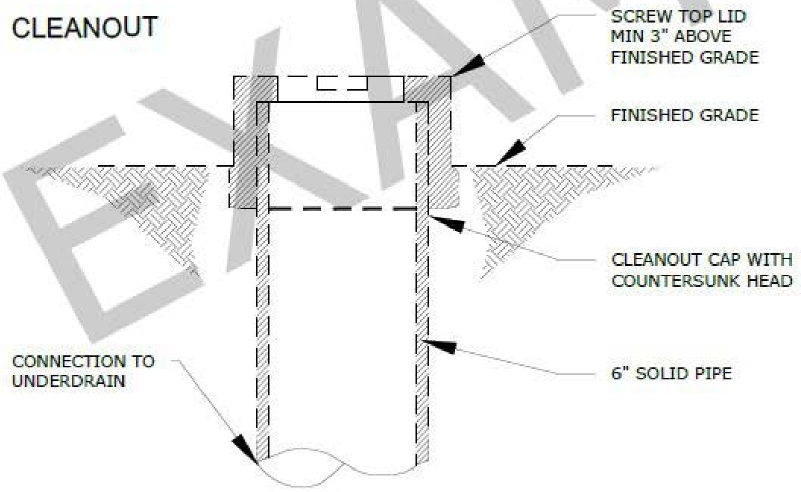
SURFACE OVERFLOW STRUCTURE



LOW FLOW ORIFICE



CLEANOUT



CLEANOUT NOTES

1. FOR UNDERGROUND FLUSH MOUNTED CLEANOUT, PROVIDE PIPE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST 3' LONG WITH MIN. INTERNAL DIAMETER OF 6"
2. CLEANOUT SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH IMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

PORT AUTHORITY NY NJ

MISCELLANEOUS
DETAILS

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13 OF 13

Appendix D: Example Construction Specifications

Example Specifications:

AGGREGATES FOR GREEN INFRASTRUCTURE D-2

ENGINEERED SOIL FOR GREEN INFRASTRUCTURE D-12

UNDERDRAIN SYSTEM FOR GREEN INFRASTRUCTURE D-18

PERVIOUS CONCRETE PAVING D-24

PRECAST POROUS CONCRETE PAVING SLABS D-31

Additional Resources:

LIST OF EXISTING PANYNJ SPECIFICATIONS FOR GREEN INFRASTRUCTURE D-41

Disclaimer

Note that the resources provided in this appendix are for example purposes only. Designers are responsible for ensuring their design drawings and specifications meet all PANYNJ and regulatory requirements

DIVISION 32

SECTION XXXXXX

AGGREGATES FOR GREEN INFRASTRUCTURE

PART 1. GENERAL

1.01 SUMMARY

This Section specifies requirements for aggregate for green infrastructure including stone reservoirs, choker courses, leveling courses, and sand layers.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American Association of State Highway and Transportation Officials (AASHTO)

AASHTO M 6	Standard Specification for Fine Aggregate for Hydraulic Cement Concrete

American Society for Testing and Materials (ASTM) International

ASTM C 33	Standard Specification for Concrete Aggregates
ASTM C 88	Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.
ASTM C 131	Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
ASTM D 698	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
ASTM D 1556	Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.
ASTM D 1557	Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN m/m^3)).
ASTM D 1883	Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils.
ASTM D 2167	Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.
ASTM D 2434	Standard Test Method for Permeability of Granular Soils (Constant Head)
ASTM D 3665	Practice for Random Sampling of Construction Materials.
ASTM D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM 5856-95	Standard Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter
ASTM D 6938	Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.03 DESIGN AND PERFORMANCE REQUIREMENTS

A. Site Conditions
   1. Subgrade for infiltration-based green infrastructure practices shall be uncompacted and scored to maximize infiltration rates.
   2. Do not place or spread aggregate unless subgrade is free of frost and standing water.
   3. Do not place aggregate when ground water level is above a plane two feet below the bottom of the base course. This condition would be indicated by existing water level readings, known site conditions or by the results of probes performed by the Contractor before placement of aggregate for green infrastructure. Contractor shall notify the Engineer if such conditions exist.
   4. When necessary, lower and maintain ground water below the required plane by methods approved by the Engineer.

B. In-Place Requirements
   1. Surface of the aggregate shall be within plus or minus 1/2 inch of elevations shown on the Contract Drawings and free of depressions or projections greater than 3/8 inch when tested with a 16-foot straight edge applied parallel with or at right angles to the centerline.
   2. Thickness of aggregate at any point shall not be deficient by more than 1/2 inch from the required thickness shown on the Contract Drawings.

1.04 QUALITY CONTROL AND QUALITY ACCEPTANCE INSPECTION AND TESTING

A. Quality Control Plan
   1. Establish and maintain a Quality Control Plan (hereinafter called the "Plan") along with all the personnel, equipment, supplies and facilities necessary to obtain samples, perform and document tests and meet Specification Section requirements. For contracts requiring 500 cubic yards of green infrastructure aggregate or greater, the Plan is required. For contracts requiring less than 500 cubic yards of green infrastructure aggregate, the Plan is at the Contractor's option.
   2. Describe the Plan in a written document. Submit the written Plan to the Authority's Chief of Materials Engineering, Materials Engineering Unit for review at least 28 calendar days prior to the start of any green infrastructure Work.
   3. In the absence of an approved Quality Control Plan, the Authority will make no payments for aggregates which are subject to specific quality control.
   4. The Plan may be implemented wholly or in part by the Contractor, or by an independent organization engaged by the Contractor, but it shall in all cases remain the responsibility of the Contractor.
   5. Organize the Plan to address at a minimum the following items:
      a. Quality control organization chart.
      b. Quality control organization names and qualifications of personnel.
      c. Area of responsibility and authority of each individual.
      d. Names and qualifications of personnel as required by 1.04 A.7.d.
      e. A listing of any outside organizations such as testing laboratories that will be used by the Contractor and a description of the services they will provide.

- f. A testing plan which lists the tests required to be performed by the Contractor or organization engaged by the Contractor, the frequencies of testing, sampling locations and the location of the testing facilities.
- g. Procedures for ensuring that tests are taken in accordance with the testing plan, that tests are documented and that proper corrective actions are taken when necessary.
- h. Procedures for ensuring that testing equipment is available, that it complies with specified standards, and that it has been calibrated against certified standards.
- i. Procedures for verifying that tests are taken in accordance with the appropriate ASTM standards.
- j. Procedures for daily submittal of test results to the Engineer.
- k. An action plan detailing procedures to be used to correct unsatisfactory production processes and construction practices when tests indicate that the aggregate is failing to meet the following:
  - (1) Aggregate gradation.
  - (2) In-place density.
  - (3) Surface smoothness.
  - (4) Grades.

6. The Plan shall address all elements which affect the quality of the green infrastructure aggregate including at a minimum:
   - a. Aggregate gradation.
   - b. Quality of materials.
   - c. Stockpile management.
   - d. Placement and compaction.
   - e. Surface smoothness and grades.

B. Noncompliance

1. In cases where quality control activities do not comply with either the Plan or the Contract provisions, or where the Contractor fails to properly operate and maintain an effective Plan, the Engineer may order the Contractor to replace ineffective or unqualified quality control personnel.

C. Engineer's Sampling and Testing

1. The Engineer may inspect, test and approve aggregate at the source. At least five days prior to delivery of green infrastructure aggregate to the instruction site, notify the Engineer. If the source or the supplier of the aggregate material changes, resubmittals for approval must be made in accordance with all submittal requirements.

2. Aggregate for green infrastructure delivered to the construction site may be sampled and tested by the Engineer for conformance to the requirements specified in 2.01. A copy of the test analyses will be on file with the Engineer. The samples will be taken from stockpiles on site, prior to material placement operations. Typical testing frequencies will be as follows:

Aggregate for Green Infrastructure	
Gradation	1 test per Lot
Moisture-Density (Proctor) Test	1 test per Lot

A Lot shall be defined as one day's production but no more than 400 cubic yards.

3. The Engineer may check aggregate layer thickness at least once every 2,500 square feet.
4. The Engineer may determine in-place density of aggregate from in-place density tests. Frequency of testing will be at least one test every 2,500 square feet per lift. Locations of random sampling shall be determined in accordance with ASTM D 3665. The in-place density shall be determined in accordance with ASTM D 6938, or ASTM D 2167 or ASTM D 1556.
5. The Engineer may check conformance to elevations required by the Contract Drawings and required tolerance for surface straightness.

1.05 SUBMITTALS

See Appendix "A" for submittal requirements.

PART 2. PRODUCTS

2.01 MATERIALS

A. Description

1. Virgin stone aggregate for green infrastructure shall be quarry processed, crushed dolomite, granite, limestone, gneiss or trap rock. Stone shall be double washed and free from stone dust, clay clods or balls, silt, organic matter, debris, refuse, cinders, slag, and other unwanted material which may hinder storage and permeability.
2. Sand material shall be clean medium-aggregate concrete sand.

B. Gradation for green infrastructure aggregate shall be as follows:

Stone Reservoir	Choker Course	Leveling Course	Sand Layer
AASHTO No. 2 or No. 3 Stone	AASHTO No. 57 Stone	AASHTO No. 8 Stone	Clean medium-aggregate concrete sand in accordance with AASHTO M 6 or ASTM C 33

C. Soundness of Aggregates

1. Aggregate shall not have more than 5% of flat or elongated pieces (>5:1) as specified in ASTM D 4791.
2. Material shall have a California bearing ratio (CBR) or at least thirty (30) as determined by laboratory test on a four (4) day-soaked sample in accordance with ASTM D 1883.

3. Loss limitation shall not be more than 10 percent loss by weight, using sodium sulfate for 5-cycle test period, or not more than 15 percent loss by weight, using magnesium sulfate for a 5-cycle test period as determined in accordance with ASTM C 88.

D. Permeability / Hydraulic Conductivity

1. Saturated hydraulic conductivity of sand and tone shall be not less than 10 inches per hour according to ASTM D 5856-95 when compacted to a minimum of 95% Standard Proctor, ASTM D 698.

E. Resistance to Degradation

1. Percentage loss between the original weight and the final weight of the test sample, shall not exceed 45 percent as determined in accordance with ASTM C 131.

F. Environmental Compliance

1. For crushed stone from a native source (quarry/mine) submit to the Engineer the following:

    a. A copy of the State quarry or mine facility permit.

    b. A notarized certification that the material excavated from undisturbed geologic formations, obtained from the licensed quarry/mine, is not known or suspected of being contaminated, and is not affected by conditions or processes that would result in the introduction of or increase in concentration of contaminants already present in the quarry/mine.

2. At the Engineer's discretion, the Engineer will perform quality assurance testing of aggregate material brought to the site to confirm compliance with the specified requirements. Remove and replace, at no additional cost to the Authority, material determined by the Engineer to be not in compliance.

PART 3. EXECUTION

3.01 INSTALLATION

A. Equipment

1. Placing and spreading equipment shall be approved by the Engineer and be capable of spreading material without segregation.

2. All compaction equipment, including rollers, mechanical tampers, and plate compactors, is subject to review and approval by the Engineer.

B. Preparation of Subgrade

1. Verify that site conditions specified in 1.03 A. have been met and there are no high points in the subgrade which would interfere with meeting the tolerance requirements specified in 1.03 B.

2. Subgrade shall not be compacted for green infrastructure practices where a minimum subgrade permeability rate is specified (i.e., infiltration-based practices).

3. For green infrastructure practices where no minimum infiltration rate is specified for the subgrade, Contractor shall be allowed to perform subgrade compaction, and can utilize geotextile fabric or impermeable liners as specified in the Contract Documents.

4. Perform any subgrade compaction operations at or near optimum moisture content. In areas where use of a roller is impractical, compact subgrade with approved mechanical tampers.

5. Provide grade control as follows:
    a. Set grade stakes on a rectangular grid not more than 25 feet on centers.
    b. After firmly driving stakes, offset mark each 6 inches above the top of aggregate layer.
    c. Maintain stakes during placement and compaction of aggregate layers.

C. Placement and Compaction

1. Upon completion of subgrade work, the Engineer shall be notified and shall inspect the subgrade before the Contractor continues installation. Engineer shall have the option to perform infiltration testing on the subgrade to verify minimum infiltration rates at the Contractor's expense where specified on the Contract Documents.
2. Any accumulation of debris or sediment which takes place after approval of the subgrade shall be removed prior to installation at no extra cost.
3. Place geotextile fabric, impermeable liner, underdrain pipe, and aggregate as required by Contract Documents immediately after approval of subgrade.
4. Place the aggregate evenly over the prepared subgrade with approved spreading equipment. In multi-layer construction, clean the previously constructed layer of loose of foreign material prior to placing the next layer of the aggregate. Keep the surface of the compacted aggregate moist until it is covered by the next layer.
5. When spread, the aggregate shall be at or near optimum moisture content and of a thickness such that the maximum depth of a compacted layer shall be 6 inches. In multi-layer construction, place the aggregate in approximately equal-depth layers.
6. Moisten and roll each lift of aggregate with a 10-ton roller, keeping equipment movement over exposed sub-grades to a minimum. Roll each lift between 4 and 6 passes. If a required depth of aggregate in a lift exceeds ten (10) inches, the aggregate layer shall be rolled in ten (10) inch lifts.
7. In areas where use of rollers is impractical, compact with manually operated equipment while at or near optimum moisture content.
8. Maintain the aggregate layers in a condition that will meet all requirements specified herein until the Work is accepted. Equipment used in the construction of an adjoining section may be routed over completed portions of the aggregate layers, provided no damage results including rutting or uneven compaction.
9. As determined by the Engineer, if the in-place density of the compacted aggregate has been affected due to exposure to precipitation, drain off all freestanding water and compact the aggregate until in-place density requirements are met, all at no additional cost to the Authority.

3.02 QUALITY CONTROL

A. Testing Requirements for Aggregates for Green Infrastructure

Testing will include quality control testing by the Contractor and, possibly Quality Acceptance Inspection and Testing by the Engineer. Testing frequencies are dependent on the type of aggregate, the nature and size of the installation, and the structural significance of the installation.

1. Quality Control Testing by the Contractor
   - a. Implement and maintain quality control plans and procedures that ensure all aggregate material for green infrastructure and completed construction conform to 1.04 herein. The Engineer shall be permitted access to the field operations at all times for checking compliance with the approved quality control procedures. Provide labor and equipment to take samples as directed and assist the Engineer in other tests. Repair all areas from which samples are taken to meet all requirements of this Section.
   - b. Perform quality control consisting of in-place density testing to determine densities achieved after compaction efforts. The frequency of testing shall be as follows, unless otherwise shown on the Contract Drawings:

In-Situ Field Testing - Per Lift:

In-place Density	1 test / 2,500 sq. ft.
In-Place Density - Trenches	1 test / 50 ft. of trench

   - c. The size of the stockpiles shall be as shown on the Contract Drawings.
2. Quality Acceptance Inspection and Testing by the Engineer
   - a. At the discretion of the Engineer, Quality Acceptance Inspection and Testing to verify field densities may be performed by the Engineer after compaction operations. Test methods may be either sand-cone (ASTM D 1556), rubber balloon (ASTM D 2167) or nuclear device with moisture content (ASTM D 6938). Tests will measure the density of the layer immediately below each compacted layer and the density of the uppermost or final layer.
   - b. Quality Acceptance Inspection and Testing may also include periodic sampling and testing of aggregate materials to verify continued conformance with the requirements of 2.01 and to verify the value of maximum density used as the control value, as per Engineer’s direction.
   - c. When performing Quality Acceptance Inspection and Testing, the Engineer will determine the density of compacted fill or backfill by in-place density tests or from undisturbed samples cut from the compacted fill or backfill as required. Notify the Engineer 72 hours prior to start of filling or backfilling to allow the Engineer time to make provisions for such testing.
   - d. To evaluate whether material has been compacted to the specified density, the Engineer will compare results of in-place density tests with results of control tests on material of the same designation using Procedure C of ASTM D 1557.
   - e. If aggregate has not been sufficiently compacted as determined by in-place density tests, the Contractor shall continue compaction effort and shall adjust the moisture content as necessary until the specified compaction is obtained, at no additional cost to the Authority.

3.03 ADJUSTING

A. Adjustment of Deficiencies

1. Remove and replace any aggregate that does not meet the requirements, as determined by the Engineer, as specified herein and place and compact as specified in 3.01 C. herein.
2. Do not add thin layers of aggregate to the top layer of aggregate to meet grade. If the elevation of the top layer is 1/2 inch or more below grade, scarify the top layer of the aggregate base to a minimum depth of 3 inches, place additional aggregate, and the layer shall be cut back to grade and compacted as specified in 3.01 C. herein.

END OF SECTION

SECTION XXXXXX

AGGREGATES FOR GREEN INFRASTRUCTURE

APPENDIX "A"

SUBMITTALS

Submit the following in accordance with the requirements of "Shop Drawings, Catalog Cuts and Samples" of Division 01 - GENERAL PROVISIONS:

A. Product Data

1. Submit to the Chief of Materials Engineering, Materials Engineering Unit, Port Authority Technical Center, 241 Erie Street, Jersey City, NJ 07310-1397, the material supplier, source, and certified test data for gradation and composition of the aggregate for green infrastructure. The gradation report shall be current and representative of the material that will be actually incorporated into the Work. The virgin aggregate material shall come from a source approved by either NYDOT or NJDOT. The Engineer will approve or disapprove within 10 days after receipt of submittal. Do not deliver virgin aggregate material until the Engineer has approved of the source.
2. Submit specifications for equipment that will be used for spreading and compaction, as specified in 3.01 A.1 and 3.01 A.2.
3. Submit all environmental compliance documents for fill material specified in 2.01 H. Provide such documents at least three weeks prior to delivery of material to the site.

B. Quality Assurance-Quality Control

1. Submit to the Chief of Materials Engineering the Quality Control Plan within 28 calendar days prior to the start of any aggregate for green infrastructure Work.

END OF APPENDIX "A"

SECTION XXXXXX

AGGREGATES FOR GREEN INFRASTRUCTURE

INSTRUCTIONS TO ENGINEER/ARCHITECT

A. Contract Drawings

Ensure that the Contract Drawings show the following items specified in the text:

(1.03 B.1)	Required aggregate layer elevations.
(1.03 B.2)	Required thickness of aggregate layers.
(1.04 A.6.c; 1.04 C; 2.01 F; 3.02 A.1.c)	Location(s) of stockpile area, if an area will be provided. If the stockpile area is combined with the "Area Available for Contractor's Use" then relabel such area as "Area Available for Contractor's Use and Stockpile Area".
(3.02 A.1.b)	Minimum frequency of quality control testing by the Contractor, if other than specified.

END OF INSTRUCTIONS

DIVISION 32

SECTION XXXXXX

ENGINEERED SOIL FOR GREEN INFRASTRUCTURE

PART 1. GENERAL

1.01 SUMMARY

This Section specifies requirements for the supplying, testing, and installation of engineered soil.

1.02 DESIGN AND PERFORMANCE REQUIREMENTS

A. As a guide to determine local weather predictions for testing, use the National and Local Forecast, Hurricane, Radar and Report website at http://www.weather.com as published by the Weather Channel.

B. Soil Testing Procedures shall be as per "Recommended Soil Testing Procedures For The Northeastern United States, Current Edition, Northeastern Regional Publication No. 493 as provided by the Agricultural Experiment Stations of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and West Virginia.

1.03 ENVIRONMENTAL REQUIREMENTS

A. Obtain soil samples only during the following weather conditions:

1. There shall be no frost in the ground and the soil temperature shall be above 32 degrees F.
2. There shall be no form of precipitation falling or forecast to fall within the next two hours. Following a period of precipitation, resume operations only after the soil has drained.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Verify that the laboratory performing the laboratory testing of this Section is a certified testing laboratory such as the Rutgers Soil Testing Laboratory, Rutgers Cooperative Research & Extension, New Jersey Agricultural Experiment Station, Milltown, NJ 08850 or an approved equal in either the State of New Jersey or New York, that it has experience in soil testing for soil properties important for plant and turf management and that is capable of performing a "Landscape Topsoil Evaluation" https://njaes.rutgers.edu/soiltestinglab/services.asp as specified in 2.01 and as outlined on Appendix B of this Section.
2. Verify that the entity and its workers performing the Work of this Section are experienced in landscaping and have been engaged in work of a complexity similar to that required under this Section for a period of at least three years.

B. Test Requirements

1. Prior to delivery to the construction site, submit a representative sample of engineered soil for analysis to a certified independent laboratory to ensure conformance to requirements specified in 2.01. No substitutions for testing parameters will be permitted. Submit test results to the Engineer, in accordance with 2.01 and Appendix “B” of this Section. All green infrastructure practices with engineered soil shall have a minimum of one test.
2. Any analysis of which the date of testing by the certified independent laboratory is in excess of one month prior to the actual date of delivery to the construction site will not be accepted.
3. Prior to delivery of engineered soil to the construction site, submit to the Engineer the following: 1) The location and the source of the engineered soil, 2) A certified analysis of the engineered soil that it meets this specification, 3) A “Landscape Topsoil Evaluation”, including completing the “Soil Test Questionnaire and identifying that the engineered soil shall be used for planting trees, shrubs and seeding of Tall Fescue, 4) A two pound sample to the Chief of Materials Engineering, Materials Engineering Unit, Port Authority Technical Center, 241 Erie Street, Jersey City, NJ 07310-1397, and 5) One sample for up to each 100 Cubic Yards of engineered soil delivered to the construction site. In the event that the sample does not conform to the specified requirements, submit additional samples until the results do conform to the specifications, all at no additional cost to the Authority.
4. Do not deliver engineered soil to the construction site until the Engineer has approved the submittal in writing.
5. After delivery of engineered soil to the construction site, submit a representative sample for analysis to a certified, independent laboratory to ensure conformance to requirements specified in 1.04 B 3 and 2.01. Submit test results to the Engineer for approval. In the event that the delivered sample is not consistent with the sample approved prior to delivery, remove the delivered engineered soil from the construction site and replace it with material that does conform, all at no additional cost to the Authority.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Do not deliver the engineered soil to the construction site until the Chief of Materials Engineering has approved in writing the test results for the representative sample.

1.06 SUBMITTALS

See Appendix "A" for submittal requirements.

PART 2. PRODUCTS

2.01 MATERIALS

A. Engineered soil

Supplier-certified to conform to the following:

1. Engineered soil shall be a uniform mix, free of stones, stumps, roots, hard clods, sods, or other similar objects larger than one inch. No other materials or substances shall be mixed or dumped within the green infrastructure area that may be harmful to plant growth or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of noxious weeds.
2. Engineered soil shall be free from lime, cement, ashes, slag, concrete, tar residues, tarred paper, boards, chips, sticks, glass or any other undesirable material.
3. Engineered soil shall meet the following criteria:
    a. pH range 5.2 - 7.0
    b. organic matter 3.0 – 5.0%
    c. magnesium 35 lb./ac
    d. phosphorus P2O5 75 lb./ac
    e. potassium K2O 85 lb./ac
    f. soluble salts not to exceed 500 ppm
4. Maximum particle size shall be one inch. The maximum amount of material retained on the 2mm (No. 10) sieve is 15% by weight of total sample.
5. Engineered soil shall consist of the following, based on dry (air-dried only) weight of sample and the mechanical analysis of the soil as determined by the Bouyoucous Hydrometer method:

a.	Sand	75% - 90%, inclusive;
b.	Silt	10% - 15%, inclusive;
c.	Clay	5% - 10%, inclusive.

6. Engineered soil shall have a minimum permeability rate of 10.0 inches per hour as measured in situ within each green infrastructure practice in accordance with ASTM D2434.

2.02 ENVIRONMENTAL PARAMETERS

A. Verify that the concentration of environmental parameters in all soil mixes does not exceed the NYSDEC Technical and Administrative Guidance Memorandum #4046 Determination of Soil Cleanup Objectives and Cleanup Levels: Criteria for Recommended Soil Cleanup Objectives.

PART 3. EXECUTION

3.01 PREPARATION

A. Green Infrastructure Practices
1. Excavate to desired depth and install open-graded stone reservoir material and/or geotextile fabric as required by this Contract.
2. Examine conditions and correct any deficiencies such as improper elevations or construction debris in the excavation area prior to installing engineered soil.
3. The contractor or soil supplier shall not work soil when the moisture content is less than 60% nor more than 100% of optimum moisture content as determined by AASHTO T-99 for all planting soils. Apply water, if necessary, or dry the soil to bring soil within the acceptable moisture content range.

B. Erosion Control and Sedimentation Measures

Apply erosion and sediment control measures at all times as required by this Contract and the governing regulatory agencies.

3.02 APPLICATION

A. Placing and spreading over prepared open-graded stone reservoir and/or subgrade.

1. Place and spread approved engineered soil over prepared stone reservoir or subgrade in a uniform layer of such thickness to meet grades and elevations shown on the Contract Drawings following settlement.
2. Inundate practice with clean water to achieve final settlement of engineered soil. Add layers of engineered soil and inundate as required until required depths and elevations are met.
3. Contour the surface level of the engineered soil as shown on the Contract Drawings.

END OF SECTION

SECTION XXXXXX

ENGINEERED SOIL FOR GREEN INFRASTRUCTURE

APPENDIX "A"

SUBMITTALS

Submit the following in accordance with the requirements of "Shop Drawings, Catalog Cuts and Samples" of Division 1 - GENERAL PROVISIONS:

A. Qualifications

1. Submit qualifications of the entity performing the laboratory testing of this Section to the Engineer in accordance with 1.04 A. Include the name, address and telephone number of the Testing laboratory performing the Work of this Section.
2. Submit qualifications of the entity and its workers performing the Work of this Section to the Engineer in accordance with 1.04 A. Include names of clients, telephone numbers, and contract amounts for work performed in the last three years and experience records of workers performing the Work of this Section.

B. Products

1. Submit a complete "Product List", listing the product to be used under this Section.
2. Submit the location of the source of the engineered soil and a two-pound representative sample of engineered soil (as many as required) to the Chief of Materials Engineering, Materials Engineering Unit, Port Authority Technical Center, 241 Erie Street, Jersey City, NJ 07310-1397, in accordance with 1.04 B.

C. Test Reports

Submit laboratory analyses of engineered soil and the results of the "Landscape Topsoil Evaluation" to the Engineer in accordance to 1.04 B and Appendix B.

1. Submit to the Engineer the test results for "Landscape Topsoil Evaluation" as specified in 1.04 B. of this Section.
2. Submit to the Engineer the test results for the nutrient controls as recommended in the "Landscape Topsoil Evaluation" as specified in 1.04 B. of this Section.

END OF APPENDIX "A"

SECTION XXXXXX

ENGINEERED SOIL FOR GREEN INFRASTRUCTURE

APPENDIX "B"

The following is a sample testing form to be used by the Contractor:
Material: Engineered soil
Specification: Section XXXXXX – Engineered Soil for Green Infrastructure
Source of Sample:
Contract or P.O.#:

Quality Characteristics:	Spec.		
Visual Examination:	No hard clods, etc.		
Nutrients: Inorganic Nitrogen-Nitrate (ppm)			
Nutrients: Inorganic Nitrogen-Ammonium (ppm)			
Total Kjeldahl Nitrogen (%)			
Nutrients: P (pounds/acre)			
Nutrients: K (pounds/acre)			
Micro Nutrients: Zinc (ppm)			
Micro Nutrients: Copper (ppm)			
Micro Nutrients: Manganese (ppm)			
Micro Nutrients: Boron (ppm)			
Micro Nutrients: Iron (ppm)			
Organic Matter: (Loss of Ignition)	Min. 3.0% Max. 5.0%		
Soluble Salts: - PPM	Max. 500		
pH:	5.2 - 7.0		
Mechanical Analysis: Passing - 1"	100%		
Passing - 1" Retain 2 mm (#10)	Max. 15%		
Bouyoucous Hydrometer Test of Material:			
Total Percent - Sand	75%-90%		
Total Percent – Silt	10%-15%		
Total Percent – Clay	5%-10%		

END OF APPENDIX “B”

DIVISION 33

SECTION XXXXXX

UNDERDRAIN SYSTEMS FOR GREEN INFRASTRUCTURE

PART 1. GENERAL

1.01 SUMMARY

A. This Section specifies requirements for perforated polyvinyl chloride (PVC) and high-density polyethylene (HDPE) underdrain systems for green infrastructure practices.

B. Definition of terms relating to plastic pipe shall be in accordance with ASTM F412.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American Association of State Highway and Transportation Officials (AASHTO)

AASHTO M 105	Gray Iron Castings
AASHTO M 252	Standard Specification for Corrugated Polyethylene Drainage Pipe
AASHTO M 278	Standard Specification for Class PS46 Polyvinyl Chloride (PVC) Pipe
AASHTO M 288	Standard Specification for Geotextiles

American Society for Testing and Materials (ASTM)

ASTM C 33	Concrete Aggregates
ASTM D 1785	Specification for Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120
ASTM D 2729	Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
ASTM D 3034	Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
ASTM F 2306	12 to 60 in. [300 to 1500 mm] Annular Corrugated Profile-Wall Polyethylene (PE) Pipe and Fittings to Gravity-Flow Storm Sewer and Subsurface Drainage Applications

ASTM D 2321	Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity Flow Applications
ASTM F 2648	2 to 60 Inch [50 to 1500 mm] Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications
ASTM D 3212	Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
ASTM F 412	Standard Terminology Relating to Plastic Piping Systems
ASTM F 477	Elastomeric Seals for Joining Plastic Pipe

1.03 QUALITY ASSURANCE

A. Any entity performing the Work of this Section shall have at least three years of installation experience on projects with piping systems of types and sizes similar to that required under this Contract.

B. Pipe will be visually inspected by the Engineer when delivered to the construction site. Damaged material or material not meeting the requirements of this Section shall be removed from the construction site and replaced at no cost to the Authority.

C. Pipe may be inspected at the place of manufacture by the Engineer.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Comply with manufacturer's instructions for unloading, storing and moving pipe.

B. Plastic pipe that is stored at the construction site shall remain covered, in a manner approved by the Engineer, until pipe installation is performed.

C. Care shall be taken when storing pipe and appurtenances so as not to damage Authority or other public or private property and any property so damaged shall be repaired at the Contractor's expense.

1.05 SUBMITTALS

See Appendix "A"

PART 2. PRODUCTS

2.01 MATERIALS

Use any of the pipe systems specified below unless otherwise shown on the Contract Drawings.

A. Perforated High-Density Polyethylene (HDPE) Pipe.

Six-inch perforated HDPE (AASHTO M 252) pipe, with 3/8- inch perforations at 6 inches on center, solid connectors.

B. Perforated Polyvinyl Chloride (PVC) Pipe.

Six-inch schedule 40 PVC (ASTM D 1785 or AASHTO M 278) rigid pipe, with 3/8” perforations at 6 inches on center, 4 holes per row.

C. Geotextile Wrap (sock): Pipe with circular perforations, and pipe with slotted perforations greater than 1/16" least dimension, shall be furnished with manufacturer's recommended geotextile wrap (sock) to prevent entry of aggregate through the perforations.

D. Geotextile (fabric) shall meet the physical requirements of Class 1 for Drainage applications of AASHTO M 288 and shall be in accordance with Section 313218 entitled "GEOTEXTILES."

E. Unless otherwise specified, washed Aggregate shall be crushed stone conforming to ASTM C33 size No. 6, 67, 7 or an approved equal with maximum size of 25 mm (1") and minimum size of 2.36 mm (No. 8).

F. Fittings shall be PVC and installed as indicated on Contract Drawings

G. Cleanout: cleanout cover assembly shall be cast iron and have an adjustable housing with a scoriated cast iron cover.

H. Screw Cap: threaded PVC with 2-inch square lug.

I. Gate Valve: manual slide valve, PVC plastic body and hubs with 304 stainless steel shaft and paddle and die cast aluminum handle.

J. Backflow Valve: backflow flapper valve type as approved by Engineer.

PART 3. EXECUTION

3.01 EXAMINATION

Where the underdrain is to cross existing utilities, the Contractor shall verify their elevation and horizontal location through excavation of the test pits.

3.02 INSTALLATION

A. Excavation

1. Excavate pipe trench in accordance with Section 312323 entitled "EXCAVATION, BACKFILLING AND FILLING" in the location and to the depth shown on the Contract Drawings.
2. If ground water is encountered, prevent accumulation of water in trench by methods approved by the Engineer.

B. Underdrain Installation

1. Prior to the start of construction, the method for control of alignment and grade shall be submitted for approval. The method shall be a laser system or grade board setup to establish a reference grade and alignment control directly above or within the pipe. Use of other equipment may be substituted if, in the opinion of the Engineer, the alternate system produces equivalent accuracy.
2. Place geotextile (fabric) in trench and then place washed aggregate in maximum 6-inch lifts to the invert elevations shown on the Contract Drawings. Compact each lift of washed aggregate with two passes of a vibrating pad compactor.
3. Immediately prior to placement in the trench, all pipe shall be inspected in the presence of the Engineer to verify that it is internally clean and free of damage. Damaged units shall be removed from the construction site and replaced to the satisfaction of the Engineer and at no additional cost to the Authority.
4. Lay pipe with bell or grooved end up grade and with perforations down.
5. Pipe shall be laid at a minim 0.5% slope or as indicated on the Contract Drawings
6. When lowering pipe into the trench and joining the units, take precautions to ensure that the interior of the pipeline remains clean.
7. Make up pipe joints in accordance with the manufacturer's instructions. Do not cover pipe until the Engineer has approved the installation.
8. Place the balance of the washed aggregate in maximum 6-inch lifts to the elevation shown on the Contract Drawings. Compact each lift with two passes of a vibrating pad compactor.
9. Complete geotextile (fabric) encasement of the washed aggregate as shown on the Contract Drawings and in accordance with the Section 313218 entitled "GEOTEXTILES."
10. Complete field connections to manhole or other new or existing drainage infrastructure as per Contract Drawings. Engineer must approve connection before backfilling.
11. Close all openings in the pipeline with watertight plugs when pipelaying is stopped at the conclusion of the work period or interrupted for any reason.

C. Cleanout Installation

1. Install cleanouts as per Contract Drawings at a maximum interval spacing of 100 feet on center.
2. In paved areas: Provide frame and cover over cleanout riser pipes as indicated in the Contract Drawings. For locations in permeable pavement, frames and covers shall be located within the permeable pavement area surrounded by an edge curb. Connect riser to underdrain piping.
3. In non-paved areas: Provide screw cap covers. Covers shall be set 6-inches above final grade. Connect riser to underdrain pipe.

D. Pipe Installation

Installation of underdrain shall be in accordance with the applicable provisions of ASTM D 2321.

E. Backflow Preventer Installation

Backflow preventer assembly to be located per the Contract Drawings and as directed by the Engineer at a location upstream of proposed drainage field connection and downstream of perforated underdrain pipe. Provide PVC riser pipe to protect PVC access sleeve pipe. Connect assembly to underdrain piping, using the appropriate reducer and tee fittings.

F. Gate Valve Installation

Gate valve shall be located per the Contract Drawings and as directed by the Engineer within an accessible catch basin or overflow riser and upstream of proposed drainage field connection and downstream of perforated underdrain pipe. The incoming non-perforated PVC pipe shall extend into the catch basin or overflow riser a sufficient distance to allow for connection of the valve as well as sufficient operation of the valve handle but not more than a distance of 8 inches. Valves may also be placed within valve boxes as per plans and specifications and as directed by the Engineer. Catch basins, overflow risers and/or valve boxes must have sufficient depth to allow for the height of the valve when in its fully open position plus at least 3 inches at the top.

3.03 PROTECTION

A. Care shall be taken not to damage or displace installed pipes during construction.

B. Where pipe is damaged or displaced, replace or take remedial measures as directed by the Engineer at no additional cost to the Authority.

3.04 TESTING

When construction is complete, Contractor shall test all completed underdrain systems for continuous, unimpeded flow.

A. Suggested test methods for each underdrain pipe run are as follows:

1. At highpoint or upstream end of underdrain pipe, open cleanout and insert hose from water source.
2. Turn on water
3. Acceptance of pipe run consists of free flow of water through drain outlet into the existing storm sewer structure.

B. Any sections of the underdrain that are clogged or crushed shall be repaired at the Contractor’s expense.

END OF SECTION

SECTION XXXXXX

UNDERDRAIN SYSTEMS FOR GREEN INFRASTRUCTURE

APPENDIX "A"

A. Submit certificates from manufacturers of the following items certifying that the following materials comply with the requirements specified in this Section:

1. Perforated High Density Polyethylene Pipe (HDPE)
2. Perforated Polyvinyl Chloride Pipe (PVC)
3. Geotextile (Fabric)
4. Gate Valve
5. Backflow Valve
6. Fittings, caps, and covers

B. Submit to the Chief Materials Engineer, Materials Engineering Unit, Port Authority Technical Center, 241 Erie Street, Jersey City, New Jersey 07310-1397, certified test data covering gradation and composition of the washed aggregate proposed for use, together with one 75-pound representative sample of the material.

1. Submit the sample in a clean, sturdy container or bag which shall not permit loss of any of the material.
2. Clearly label the container or bag of the sample with: Contract location, title and number; the name of the material supplied; and location of the source.
3. The Engineer will approve or disapprove the proposed material within 21 days after receipt of the sample.
4. Do not deliver material to the construction site from any source until the Engineer has approved the material from that source.

C. Submit Catalog Cuts of pipes and geotextile (fabric) for the Engineer's approval.

D. Submit for Engineer's approval methods for prevention of accumulation of groundwater and alternate methods of line and grade control where applicable.

E. Submit "As-Built" drawings in accordance with Section of Division 1 entitled "Utility Record Drawings."

END OF APPENDIX "A"

DIVISION 32

SECTION XXXXXX

PERVIOUS CONCRETE PAVING

PART 1. GENERAL

1.01 SUMMARY

This Section specifies requirements for pervious concrete paving.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American Society for Testing and Materials (ASTM)

ASTM C 33	Specification for Concrete Aggregates
ASTM C 42	Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 94 / C 94 M	Standard Specification for Ready-Mixed Concrete
ASTM C 171	Standard Specification for Sheet Materials for Curing Concrete
ASTM C 140	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C 150 / C 150 M	Standard Specification for Portland Cement
ASTM C 595	Standard Specification for Blended Hydraulic Cements
ASTM C 1077	Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C 1688	Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete
ASTM C 1701	Standard Test Method for Infiltration Rate of In Place Pervious Concrete
ASTM D 75	Standard Practice for Sampling Aggregates
ASTM D 545	Standard Test Methods for Preformed Expansion Joint Fillers for Concrete Construction (Nonextruding and Resilient Types)
ASTM D 3385	Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
ASTM E 329	Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

ASTM E 548	Standard Guide for General Criteria Used for Evaluating Laboratory Competence

American Concrete Institute (ACI) Standards

ACI 522.1	Specifications for Pervious Concrete Paving

1.03 QUALITY ASSURANCE

A. Manufacturer Qualifications:
  1. Manufacturer of ready-mixed concrete products in compliance with ASTM C 94/C 94M requirements for production facilities and equipment.
  2. Manufacturer certified according to National Ready Mixed Concrete Association's (NRMCA) "Certification of Ready Mixed Concrete Production Facilities."

B. Installer Qualifications:
  1. Submit evidence of two successful pervious concrete pavement projects including: the project name and address, owner's name, contact information and size of each project.
  2. Submit one of following criteria for minimum certification for each placement crew and submit verification of NRMCA Pervious Concrete Certification with bid.
    a. No less than one (1) NRMCA Certified Pervious Concrete Craftsman must be onsite, actively guiding and working with each placement crew during pervious concrete placement.
    b. No less than three (3) NRMCA Certified Pervious Concrete Installers must be onsite, actively guiding and working with pervious concrete for projects.
    c. No less than three (3) NRMCA Certified Pervious Concrete Technicians and one (1) Certified Pervious Concrete Installer must be onsite, actively guiding and working with pervious concrete for projects.

C. Testing Agency Qualifications:
  1. Independent agency qualified in accordance with ASTM C 1077 and ASTM E 329 for testing indicated, as documented in accordance with ASTM E 548.

D. Construction minimum standards as per respective State Department of Transportation Standards

E. Should conflicts arise between standard specifications of government agencies mentioned herein and Contract Documents, Contract Documents shall govern.

F. Where a particular type of material or method is specified, no other type of material or method will be permitted, except as approved by the Engineer.

1.04 TESTING

A. Test mockup for density of fresh concrete as described in ASTM C 1688.
  1. Results will be used as a reference for future tests.

B. Mockups shall have three (3) cores taken from each panel in accordance with ASTM C 42 at a minimum of seven (7) days after placement of the pervious concrete.
  1. Cores shall be measured for thickness, void structure, unit weight and density as described in ASTM C 140.
    a. Average of production cores shall not be less than specified design thickness.

2. After thickness determination, trim cores and measure for unit weight in saturated condition as described in ASTM C 140. Immerse trimmed cores in water for 24 HRS, allow to drain for one (1) minute, surface water removed with a damp cloth, and weigh immediately.
3. Upon completion of initial curing, test mock up for initial baseline infiltration in accordance with ASTM C 1701.
    a. Rate shall be a minimum of 100 inches per hour.
    b. Results of this test will be used to set acceptable values for subsequent density tests.
4. Test each delivery for density of fresh concrete as described in ASTM C 1688.
    a. Range of satisfactory unit weight values is +/- 5 PCF of design unit weight.
5. Remove three (3) cores from each lot of 5000 FT2 in accordance with ASTM C 42, not less than 7 days after placement of pervious concrete.
    a. Test in same manner as mockup.
    b. Range of satisfactory hardened density values is +/- 5 PCT of design density.
    c. Fill cores taken for testing with conventional concrete or pre-blended grout.

C. Preinstallation Conference: Contractor shall meet with the Engineer prior to commencement of installation activities to confirm procedure, approve materials, and verify optimal conditions.

1.05 SUBMITTALS

For Submittals, see Appendix "A".

PART 2. PRODUCTS

2.01 MANUFACTURERS

Manufacturer of pervious concrete materials shall be approved by either the New York State Department of Transportation or the New Jersey Department of Transportation.

2.02 MATERIALS

A. Pervious concrete:
1. For vehicular paving:
    a. Portland cement Type I or II conforming to ASTM C 150/C 150 M or Portland cement Type IP or IS conforming to ASTM C 595.
        i. Cement Color: Natural gray.
    b. Air entrainment admixtures as per manufacturer’s recommendations.
    c. 0.5-inch max aggregate size.

B. Pervious Paving Subgrade Aggregate Material:
1. ASTM C 33 No. 57 Crushed Stone Aggregate Gradation.

Opening	Percent Finer, by weight
2 1/2 inch	- -
2 inch	- -
1 1/2 inch	100
1 inch	95 to 100
¾ inch	- -
1/2 inch	25 to 60
3/8 inch	- -
No. 4	0 to 10
No. 8	0 to 5

C. Subgrade:
  1. Compose top 6 inches of subgrade of granular soil and predominantly sandy with no more than a moderate amount of silt or clay.
  2. Subgrade shall be determined in accordance with ASTM D 3385.
  3. Compact subgrade to a minimum 90% and a maximum 95%.
  4. Fill material:
     a. Clean and free of deleterious materials.
     b. Place in 6-inch maximum layers.
     c. Compact to minimum density of 90% and a maximum density of 95%.
  5. Subgrade moisture content shall be 1% to 3% above optimum.

D. Admixtures:
  1. Admixtures:
     a. Use according to manufacturer’s directions.
  2. Admixtures which may adversely affect quality of installed pervious concrete not allowed.

E. Expansion Joint Filler:
  1. ASTM D 545, flexible foam.
  2. Vehicular paving: 3/4 inch thick.
  3. Walks: 1/2 inch thick.

F. Sealant:
  1. Use self-leveling type where appropriate.
  2. Use gun grade, non-sag type for vertical joints.

G. Bond Breaker:
  1. Liquid membrane, plastic film or asphalt saturated felt or paper.

H. Geotextile Filter Fabric:
  1. Place under the sub-base and up the sides of the sub-base and forms.
  2. Geotextile fabric shall be tested for the ability to prevent migration of silts and clay fines from the subgrade and allow water to readily penetrate the fabric.

I. Moisture-Retaining Cover:
  1. As per ASTM C 171; 6mil polyethylene sheet or white burlap-polyethylene sheet.

J. Water:
  1. Potable.

PART 3. EXECUTION

3.01 PREPARATION

A. Examine exposed subgrades and sub-base surfaces for compliance with requirements for dimensional, grading, and elevation tolerances.

B. Install geotextile filter fabric.

C. Compact the surface of the sub-base aggregate to provide a firm and level surface for placement of the pervious concrete mix.

D. Moisten sub-base to provide a uniform dampened condition at time concrete is placed. Do not place concrete around manholes or other structures until they are at required finish elevation and alignment.

E. Install concrete pavement only after nonconforming conditions have been corrected and base is ready to receive pavement.

F. Installation indicates acceptance of substrates and responsibility for performance.

3.02 APPLICATION

A. Edge Forms and Screeds

1. Use metal or wood forms that are straight and suitable in cross-section, depth, and strength to resist springing during depositing and consolidating the concrete.
2. Form tolerance: 1/8 inch in 10 feet, horizontal or vertical direction.
3. Use flexible or curved forms for forming radii.
4. Set, brace, and secure edge forms, bulkheads, and intermediate screed guides for pavement to required lines, grades, and elevations.
5. Install forms to allow continuous progress of work.
6. Retain forms in place 24 hours minimum after concrete placement.
7. Clean forms after each use and coat with form-release agent to ensure separation from concrete without damage.
    a. Do not apply form-release agent to previously placed concrete.

B. Joints

1. Form expansion and control joints and tool edgings true to line with faces perpendicular to surface plane of concrete.
    a. Construct transverse joints at right angles to centerline, unless otherwise indicated.
    b. When abutting existing pavement, place transverse joints to align with previously placed joints, unless otherwise indicated on approved jointing plan.
    c. Locate end of each day’s work or any line where work must be suspended for more than 15 minutes along a designated control joint or expansion joint.
    d. 20 feet maximum joint spacing.
    e. Largest dimension of panel shall not exceed smallest dimension by more than 125%.
2. Provide longitudinal and transverse control joints in locations indicated.
    a. Saw cut, 1/8 inch by minimum 0.25 depth of slab.
    b. Fill joint with sealant.
3. Provide expansion joints in locations indicated.
    a. Provide expansion joints where paving abuts other structures or stationary items such as manholes.

    b. 3/4-inch wide by full depth of pavement with 1/4-inch radius edges at top.
    c. Set joint filler to within 1 inch of surface.
    d. Seal joint with sealant.
4. Tool edges of slabs in concrete to a 1/4-inch radius after initial placement.
    a. Eliminate tool marks on concrete surfaces.

C. Pervious Concrete Placement

1. On properly compacted sub-base, install thickness of concrete as shown on drawings.
2. Distribute and strike off concrete in a manner that will maintain density and pervious structure.
3. Provide expansion and control joints in locations indicated.
4. Provide thickened edge at drive entrances and abutting slabs.
    a. 1.5 times normal thickness and slope bottom to normal thickness in 3 feet.

D. Protection and Curing

1. Provide final protection and maintain pervious concrete paving shall be without damage at time of Substantial Completion.
2. Protect freshly placed concrete from premature drying and excessive cold or hot temperatures.
3. Mist surfaces of pervious concrete with plain water to prevent excessive drying of surface prior to placement of plastic sheeting.
4. Apply 6.0 mil polyethylene sheeting to concrete surface immediately after screeding pervious concrete paving.
5. Place sheeting in widest practicable width, with sides and ends lapped at least 12 inches.
6. Seal with waterproof tape or adhesive.
7. Repair holes or tears during curing period using cover material and waterproof tape or adhesive.
8. Retain cover in place a minimum of seven (7) days.
9. Remove and replace broken, damaged, or defective concrete pavement or that which does not comply with requirements in this Section.
10. Protect concrete from damage.
    a. Exclude traffic from pavement fourteen (14) days minimum after placement.

3.03 CORRECTIONS OF DEFICIENCIES

A. Deficiencies in Surface Smoothness and Grade Tolerances of Pervious Concrete

1. In the event surface smoothness and surface grades fail to comply with the Contract Drawings, make corrections as specified below at no additional cost to the Authority.
2. The area of deficiencies in surface smoothness and/or surface grade tolerance shall be defined as the area enclosed by a line of points halfway between the grade in excess of the specified tolerance and the next finished grade shown on the Contract Drawings that meets the specified tolerance, both longitudinally and transversely. The area will be determined by the Engineer from the field survey.

END OF SECTION

SECTION XXXXXX

PERVIOUS CONCRETE PAVING

APPENDIX "A"

SUBMITTALS

A. Submit to the Manager, Engineering Materials Division, Port Authority Technical Center, 241 Erie Street, Jersey City, New Jersey, 07310-1397, for approval, all Job Mix Formulae with from each plant and each new source of material at least 10 days prior to the start of production.

B. Submit certified test data, location of each type aggregate to be used and quantities to be obtained from each location and make arrangements for the Engineering Materials Division, to obtain samples from each such location for checking against the samples submitted. Take all samples in accordance with requirements of ASTM D 75.

C. If requested, submit to the Manager, Engineering Materials Division, samples of each type aggregate to be used and from each source with proper identification as to source, type of aggregate and Contract number. Submit in clean, sturdy bags and in the following amounts for each sample:

Aggregate:	25 lbs.
Sand:	25 lbs.

D. Submit to the Manager, Engineering Materials Division for approval four one-quart samples of the pervious concrete proposed for use together with the following data:

1. The name of the supplier.
2. An analysis of such pervious concrete by the supplier, certifying that the results of tests comply with the requirements of Section 1.04 of this specification.

   Resubmit the above data each time pervious concrete from a different source is proposed.

E. Submit quality control plan to the Manager, Engineering Materials Division for approval at least 5 days prior to the start of production.

END OF APPENDIX "A"

DIVISION 32

SECTION XXXXXX

PRECAST POROUS CONCRETE PAVING SLAB

PART 1. GENERAL

1.01 SUMMARY

This Section specifies the following:

A. Labor, materials, tools, equipment, and services for the installation of Precast Porous Concrete Paving Slab, as indicated, in accordance with provisions of Contract Documents.

   1. Installation shall include planning the work, horizontal and vertical layout, fine grading of subgrades, installing impermeable membrane and/or geotextile in accordance with the respective manufacturer's recommendations, placing and compacting crushed stone reservoir storage (subbase), place and screed crushed stone leveling course (base), installation of edge restraint, and placing precast porous concrete paving slabs.

B. Coordinate with work of other trades.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American Society for Testing and Materials (ASTM) International

ASTM C 33	Standard Specification for Concrete Aggregates
ASTM C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 1688	Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete
ASTM C 1701	Standard Test Method for Infiltration Rate of In Place Pervious Concrete
ASTM D 882	Standard Test Method for Tensile Properties of Thin Plastic Sheeting
ASTM D 1204	Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
ASTM D 1557	Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort
ASTM D 1599	Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
ASTM D 1751	Standard Specification for Performed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D 1754	Standard Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)

ASTM D 1790	Standard Test Method for Brittleness Temperature of Plastic Sheeting by Impact

American Concrete Institute (ACI)

ACI 522 R	Report on Pervious Concrete

1.03 QUALITY ASSURANCE

A. Manufacturer Qualifications:
  1. Company specializing in the manufacture of concrete porous paving slabs for period of at least five (5) years.

B. Installer Qualifications:
  1. Installation Contractor (Superintendent and Foreman) shall be certified and/or approved by the manufacturer to install precast porous concrete paving slab. Approved/certified personnel shall be responsible for reviewing the manufacturer’s handling and installation manual with laborers under their employ. A certified/approved individual shall be onsite providing supervision during all phases of the installation, including the reservoir course and leveling course installations.
  2. The installation contractor shall use adequate forces including equipment and skilled workers. Workers shall be trained and experienced in the necessary crafts and completely familiar with the specified methods needed for proper performance of this Specification.
  3. All materials, methods of installation and workmanship shall conform to requirements of ASTM, ACI, Department of Transportation, or other applicable Standards.

C. Concrete porous paving slabs shall:
  1. Comply with ACI 522R Guidelines

D. Leveling Course and Reservoir Stone shall:
  1. Comply with ASTM C 136 and related Specifications.

1.04 SUBMITTALS

A. Product Data:
  1. Shop drawings; including installation plan showing layout of each full and partial precast porous concrete paving slab, individual slab drawings detailing lifting points in surface and all dimensions, edge restraint detail(s), and geotextile manufacturer data specification sheets.
  2. Test results performed by an independent testing laboratory of the following:
    a. Particle-size analysis in accordance with ASTM C 136/136M Testing methods for Sieve Analysis of Fine and Coarse Aggregates for the crushed stone storage reservoir (subbase) and un-compacted/screed crushed stone levelling layer with source(s) of supply(s) noted.
    b. Infiltration rate of Precast Porous Concrete Paving Slabs in accordance with ASTM C 1701/C 1701M Standard Test Method for Infiltration Rate of In Place Pervious Concrete

    - c. Density and void content results for the Precast Porous Concrete Paving Slabs in accordance with ASTM D1754/1754M Standard Test Method for Density and Void Content of Hardened Pervious Concrete.
    - d. Results of other tests specified by the Engineer.

B. Samples:
  1. Four 6” diameter samples for approval prior to delivery to site.
  2. Install minimum 100 SQFT mock-up of paving system on-site (utilizing specified pattern) for approval by Engineer prior to continuing work.

C. Project Information:
  1. Installer to submit list of three successfully completed projects of similar scope for reference check.

PART 2. PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Precast Porous Concrete Paving Slab:
  1. Precast Porous Concrete Paving Slab shall meet or exceed the Specifications herein.
  2. The Precast Porous Concrete Paving Slab shall be supplied by a manufacturer having at least five (5) years of experience in the manufacture and sale of the product.

2.02 MATERIALS

A. Precast Porous Concrete Paving Slab:
  1. Permanent lifting points shall be imbedded in the slab surface for ease of slab installation, maintenance, removal and reinstallation.
  2. Slabs shall be reinforced with Monofilament Microsynthetic microfibers such as BASF MasterFiber M 100 or approved equal.
  3. Typical dimensions of precast porous concrete slabs provided shall be as below, unless otherwise approved by the Engineer;
     - a. 5 ft. by 4 ft.
     - b. 5 ft. by 2 ft.
     - c. 4 ft. by 2.5 ft.

  4. All slabs shall be 6” thick unless otherwise specified. Refer to project specific drawing(s) for required Precast Porous Concrete slab sizing and numbers.
  5. Slabs shall be manufactured for field placement with butt joints. Ship-lap joints shall not be permitted.
  6. A minimum average infiltration rate of 250 in./hr. shall be demonstrated in accordance with ASTM C 1701/C 1701M..
  7. Slabs shall have a void ratio of 15-25% when tested in conformance with ASTM C 1688: Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.
  8. Concrete average unit weight shall be 124 LB/CF (+/- 4%) when tested in conformance with ASTM C 1688: Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.
  9. Each individual Precast Porous Slab shall be weighed, and the unit shall be labelled with the weight, size and date of manufacture.

10. The slab unit shall include a minimum of 2 imbedded lifting permanent lifting points in the surface of the unit.
11. Precast porous concrete slabs shall be cured by the manufacturer's approved methods.
12. All slabs shall be provided with a self-stick adhesive label which includes the date of manufacture and slab weight.
13. All slabs shall be provided with 1/8" spacers (preventing slab to slab contact) and approved ½" dia. lifting swivels for use with the imbedded lifting points.
14. All slabs shall be provided with lifting point protection caps for use in covering the imbedded lifting points.
15. Precast porous concrete shall be cast upside down against a steel form and shall be vibrated throughout their entire section during the manufacturing process.

B. Crushed Stone Reservoir (Subbase) and Leveling Course:
  1. Use of screened rounded gravel is prohibited.
  2. All crushed stone shall be double-washed and clean and free of all fines and debris.
  3. Compacted crushed stone for storage reservoir (subbase) shall conform to ASTM C 33 Size No. 57 Grading Requirements for Coarse Aggregates or as specified on Contract Drawings. Minimum thickness of compacted storage reservoir (subbase) layer shall be 6 inches.
  4. Un-compacted/screed crushed stone for leveling course (base) shall conform to ASTM C 33 Size No. 8 Grading Requirements for Coarse Aggregates. Thickness of un-compacted/screed leveling course layer shall be 2 inches.

C. Impermeable Liner:
  1. Impermeable liner shall be stored and placed in a manner to eliminate any possibility of puncture or penetration.
  2. Material Type: 30 mil Grey Poly Vinyl Chloride sheeting, 30 +/- mil., 73 lbs/in Tensile Strength, 8 lbs. tear strength, 3%-Dimensional Stability, Low Temperature Impact -20 degrees F.
  3. Manufacturer: as approved by Engineer.
  4. Material Standards: Thickness Conforming to ASTM D-1599, Tensile Strength ASTM D-882, Tear Strength ASTM D-882, Dimensional Stability ASTM D 1204, Low Temperature Impact ASTM D-1790

D. Geotextile:
  1. Subgrade shall not be compacted or permanently covered with geotextile unless approved by the Engineer and shall be as follows:
    a. Trevira Spunbond S1127 or approved equal.

E. Geogrid:
  1. Tensar Triax 130S or approved equal.

F. Edge Restraint/Joint Filler:
  1. Provide as detailed on Contract Drawings.
  2. Edge restraint installed at exterior sides of precast porous concrete paving slabs shall be as follows:
    a. Material: 1/2 –inch thick pre-molded expansion joint filler conforming to ASTM D1751 or joint filler consisting of closed cell foam backer rod and polyurethane non-sag elastomeric sealant
    b. Manufacturer: as approved by Engineer

PART 3. EXECUTION

3.01 INSTALLATION

Note:

3.02 INSPECTION

A. Verify acceptability of subgrade to accept installation.
   1. Check for improperly compacted trenches, debris and improper gradients.

B. Report deficiencies to Engineer.

C. Do not start installation until unsatisfactory conditions are corrected.

D. Installation constitutes acceptance of subgrade conditions and responsibility for satisfactory performance.

E. The contractor shall obtain all Federal, State and/or Municipal approvals that may be required for this project.

F. Contractor’s installation plan shall be reviewed in a pre-construction meeting with Precast Porous Concrete Panel manufacturer’s representatives, paving slab installation contractor, general contractor, and Engineer.

3.03 SITE PREPARATION

A. Verify that all field infiltration and permeability testing of the subgrade has been performed, that test results meet the project design requirements and excavation and preparation of the subgrade has been approved by the Engineer.

B. The subgrade under all infiltration areas shall not be compacted or permanently covered with geotextile unless approved by the Engineer.

C. Prepared subgrades shall not be subject to construction equipment traffic.

D. Temporary haul roads consisting of crushed stone over a reinforcing geotextile shall be provided as required to prevent the over-compaction of subgrade soils.

E. Where erosion has caused accumulation of sediment or ponding on the subgrade, remove sediment with light equipment (and/or manually). Scarify the underlying soils to a minimum depth of 6 inches with a York rake, or equivalent equipment, and a small/light tractor.

F. Restore any subgrade areas damaged by erosion, ponding, or traffic compaction to design line and grades prior to installation of filter fabric, impermeable line, or store storage reservoir layer.

G. Prior to placing the stone reservoir material, the subbase surface tolerance shall be +/- 3/8 in. under a 10 ft. straight edge compared to the elevation in the Contract Drawings.

H. For detention or non-infiltration systems beneath light-duty parking lots and pedestrian sidewalks compaction of aggregate shall be to a minimum of 95% ASTM D 1557 relative compaction.

3.04 GENERAL INSTALLATION INSTRUCTIONS

A. Any excess thickness of soil placed over the soil subgrade to trap sediment transported by runoff from adjacent construction areas shall be removed before placement of impermeable liner or storage reservoir layer.

B. Keep area where precast porous concrete paving slabs are to be installed free of sediment during the entire construction period. Geotextiles and stone storage reservoir material contaminated with sediment shall be removed and replaced with clean materials.

C. Do not damage drainpipes, underdrains, observation wells, roadway boxes, manholes or any other utilities during installation. Report any damage immediately to the Engineer. Any damage shall be replaced or repaired as part of the bid price of this item at the Contractor’s expense.

3.05 GEOTEXTILES, IMPERMEABLE LINER AND GEOGRID

Install the below materials only as shown in the Contract Drawings or as approved by Engineer.

A. Place geotextile on prepared subgrade and/or along sides of excavation and secure in place to prevent wrinkling.

B. Overlap geotextile edges in accordance with the manufacturer’s requirements, and a minimum of 12 in. in the direction of drainage flow.

C. Place impermeable liner as shown on Contract Drawings after all material that may potentially puncture the liner have been removed from the excavated area.

D. Overlap impermeable liner a minimum of 12 in. in the direction of drainage flow.

E. Firmly secure the impermeable liner at the top of excavation prior to the placement of stone reservoir material.

F. Place geogrid 6” below bottom of screeding stone (leveling course) in stone reservoir layer.
    1. Geogrid shall be required at the discretion of the Engineer. The Engineer may require geogrid reinforcement where weak, disturbed and/or saturated subgrade soils are present.

3.06 INSTALLATION OF RESERVOIR (SUBBASE) LAYER

A. Coordinate and construct all required concrete footings and foundation for all utility posts and signage posts with inserted post sleeves.

B. Place open-graded stone base/reservoir conforming to ASTM C33 No. 57 (or as shown in Contract Drawings) washed crushed stone over prepared subgrade; spread and level evenly by raking to specified thickness. Do not disturb prepared subgrade or shift, wrinkle or fold the geotextile. Place crushed stone to protect geotextile from tearing under equipment tires and tracks.

C. Compact reservoir storage layer, with a minimum of two complete coverages, one pass each in mutually perpendicular directions, with a 1 to 3 ton smooth, double or single, drum roller operated in vibratory mode. Following vibratory compaction, apply two complete coverages, one pass each in mutually perpendicular directions, with the roller operated in static mode. Continue static rolling until there is no visible movement, weaving or deflection in the surface of the storage reservoir layer. In areas that are too small to permit the use of a 1- to 3-ton drum roller a walk behind plate compactor shall be used on each lift of 6”. Compaction using the plate compactor shall require four complete coverages, two passes each in mutually perpendicular directions.

D. The surface tolerance of the compacted storage reservoir layer shall be +/- 3/4 in. under a 10 ft. straightedge compared to the elevation in the Contract Drawings.

E. Compacted storage reservoir area shall not substantially exceed that which is covered by paving slabs by the end-of-day.

F. In all cases reservoir stone shall be placed and compacted against rigid lateral boundaries, i.e., in situ, undisturbed native soils, fill materials compacted to 98% Standard Proctor density or concrete curb and headers. Compaction of reservoir stone against any flexible boundaries shall not be allowed.

3.07 INSTALLATION OF SCREEDED LEVELING COURSE

A. Place and spread ASTM C 33 Size Number 8 (3/8”) crushed stone evenly over screed rails to achieve a thickness of 2 inches minimum. Level the surface of crushed stone with a screed.

B. Do not compact or disturb screeded leveling course.

C. The surface tolerance of the screed leveling course shall be + 1/4 in. under a 10 ft. straightedge compared to the elevation in the Contract Drawings.

D. Screed leveling course placed shall not substantially exceed that which is covered by paving slabs by the end-of-day.

3.08 PRECAST POROUS CONCRETE PAVING SLAB INSTALLATION

A. Lay slabs in pattern(s) shown on approved drawings and manufacturer’s layout plan. Cut slabs as indicated to complete pattern.

B. For gutter applications, slabs shall be placed perpendicular to the adjacent curb. The angle between the curb and slab shall be greater than or equal to 90 degrees.

C. Slabs shall only be lifted and placed using lifting swivels and spreader chains. Chains, cables or slings should never be wrapped around slabs for lifting under any circumstances. Lifting swivel bolts shall be securely bolted snug but not over-tightened to avoid damage to the surface.

D. Place porous concrete slabs without using metal hammers, pry bars or drift pins. Make horizontal adjustments to placement of laid slabs with wood wedges and levers, and rubber mallets as needed.

E. Adjacent slabs shall be separated from each other by 1/8”. Manufacturer supplied spacers shall be used to ensure proper joint spacing.

F. The porous concrete panels shall be installed so that there is no lippage or surface unevenness greater than 1/8" difference in height between slabs and adjacent surfaces.

G. Joints between adjacent rows of slabs shall be staggered when possible.

H. Joints shall never be filled with loose material including but not limited to sand, stone dust, stone chips, etc.

I. Horizontal joint lines shall not deviate more than ±½ in. over 50 ft. from string lines.

J. Fill gaps at the edges of the paved area with properly-sized cut slabs.

K. Cut end slabs to be placed along the edge or corners with a diamond blade masonry saw. Cut units shall be no narrower than 18" and cutting shall occur so that a minimum distance of 8" is maintained between embedded lifters and cut edges.

L. Core drill or cut slabs as may be necessary to fit over, and/or around, existing utility structures or poles, and signposts prior to slab placement.

M. Cut Slabs using hand-held, or machine-driven diamond cut off saw having the required blade diameter to safely cut slabs.

N. Protect adjacent slabs surfaces from dust infiltration when cutting slabs.

O. Seal outside edges and around installed new concrete footing and foundations, utility structures or poles, and signposts as indicated on the approved Permit Plans with approved materials as per Section 2.02 F. Edge Restraint/Joint Filler of these Specifications.

P. Adjust bond pattern at pavement edges such that cutting of edge slabs is minimized. Do not expose cut slabs to vehicular traffic. Cut slabs at edges as indicated on the drawings

Q. Keep skid steer and forklift equipment off unrestrained paving slabs.

R. After an area is completely paved, set the precast porous concrete slabs into the screed crushed stone leveling course layer by trafficking with light rubber-tired equipment.

S. Remove and replace any slabs cracked or damaged during installation with new ones at Contractor's expense. Reset slabs not in conformance with specified installation tolerances at Contractor's expense.

T. Installer shall warranty for a period of one year from the date of installation that installed slabs shall be free of rocking or pumping evidenced by visible vertical movement. Any slabs observed to be moving shall be removed and the screeded leveling course shall be re-screeded and the slabs reset at Contractor's expense.

U. Check final surface elevations of set slabs for conformance to Contract Drawings. The final surface tolerance from grade elevations shall not deviate more than ± 1/4 in. under a 10 ft. straightedge.

V. The surface elevation of set slabs shall be flush with manholes or the top of utility structures.

W. Hairline cracks in placed slabs shall be considered as to not interfere with the proper functioning or performance of the system. Where approved by the Engineer, larger cracks or occasional imperfections may be repaired under the direction of the manufacturer. The repairs must be properly finished and cured. The color of the repair area must match as closely as possible with the rest of the element color. Repairs shall be made with a mixture of sand and cement, as directed by the manufacturer

3.09 PROTECTION

A. Immediately after precast porous concrete slabs have been placed; use provided (by manufacturer) plastic caps to fill imbedded lifting points. Care should be taken to make sure the plastic caps are flush with the surface; do not press caps down into the imbedded lifting points.

B. After work in this section is complete, the Contractor shall be responsible for protecting the precast porous paving slab system from damage, contamination and/or clogging with sediment, mud, dirt, grass cuttings, accumulation of foliage and other debris.

C. The surface of the precast porous paving slabs shall be covered during the placement of adjacent soils or paving materials.

3.10 CLEAN UP

A. Upon completion of work covered in this section, clean up porous paving system work areas by removing debris, surplus material and equipment from site.

END OF SECTION

SECTION XXXXXX

PRECAST POROUS CONCRETE PAVING SLAB

SUBMITTALS

APPENDIX “A”

Submit the following in accordance with the requirements of “Shop Drawings, Catalog Cuts and Samples” of Division 1 – General Provisions:

A. Qualifications:

1. Submit qualifications of the entity and its workers performing the Work of this Section to the Engineer. Include names of clients, telephone numbers and contract amounts for work performed in the last five (5) years and experience records of workers performing the Work of this Section.

2. Submit qualifications of the entity performing herbicide application. Include a copy of a valid state pesticide applicator’s license.

B. Products:

1. Product Data: Submit manufacturer’s technical data for each manufactured product listed in this Section, including certification that each product complies with specified requirements.

2. Submit shop drawings showing layout of paving slab and setting details, including all sizes, dimensions, patterns and profiles.

3. Samples for Verification Purposes: Submit four (4) 6” diameter samples from actual precast porous concrete paving slab in each color, finish and type. Include in each set of samples the full range of exposed color and texture to be expected in the completed Work.

4. Submit to the Engineer one copy of the US Department of Labor Material Safety Data Sheets (MSDS) for all hazardous chemicals utilized during the Work of this Section.

C. Mock-up:

1. Construct for inspection a 10-foot x 10-foot (100 SQFT) paving slab area mock-up for pattern shown on the Contract Drawings.

D. Certification:

1. Submit the name of the entity installing the precast porous concrete paving slab and details of at least three (3) previous precast porous concrete paving slab installation projects of comparable scope.

END OF APPENDIX ‘A’

LIST OF EXISTING PANYNJ SPECIFICATIONS FOR GREEN INFRASTRUCTURE:

PANYNJ implements the below standard and custom specifications which may apply to green infrastructure practices. This list is not exhaustive.

Standard Specifications:

033100 CONCRETE FORMWORK

036115 GROUTING (NON-METALLIC)

055313 GRATINGS

075216 STYRENE-BUTADIENE-STYRENE (SBS) MODIFIED ARCHITECTURAL BITUMINOUS ROOFING

075423 THERMOPLASTIC POLYOLEFIN (TPO) ROOFING SYSTEM

312323 EXCAVATION, BACKFILLING AND FILLING

313218 GEOTEXTILES

321123 AGGREGATE BASE COURSE

321244 ASPHALT CONCRETE DRAINAGE MIX

321374 PAVEMENT JOINT SEALING

330131 CLEANING STORM DRAINAGE AND SANITARY SEWER SYSTEMS

334160 EXTERIOR WATER SUPPLY SYSTEM (INFILTRATION/E•FILTRATION TESTING NOT REQUIRED)

334610 SUBDRAINAGE SYSTEM

334914 MANHOLE AND DRAINAGE STRUCTURES

Custom Specifications:

C-077277 EXTENSIVE VEGETATED ROOF TRAY ASSEMBLY

C-312325 CLEARING, EXCAVATION AND GRADING

C-321412 CONCRETE BLOCK PAVERS

C-321423 ASPHALT BLOCK PAVERS

C-321550 GRAVEL MULCH

C-323118 ALUMINUM LOUVERED FENCES AND GATES

C-323120 ORNAMENTAL STEEL FENCES AND GATES

C-327100 TIDAL WETLAND PLANTING

C-329110 SOIL TESTING

C-329120 SCREENED LOAM SOIL

C-329219 SEEDING

C-329219 SEEDING – PREPACKAGED SEED MIX

C-329300 TREES, SHRUBS, AND GROUNDCOVER IN GROUND (NEW JERSEY)

C-329400 TREES, SHRUBS, AND GROUNDCOVER IN GROUND (NEW YORK)

C-329720 MAINTENANCE OF PERMANENT PLANTING AND HARDSCAPE (NEW JERSEY)

C-329720 MAINTENANCE OF PERMANENT PLANTING AND HARDSCAPE (NEW YORK)

C-329735 TIDAL WETLAND MAINTENANCE AND MONITORING

Appendix E: Regulatory Guidance Summary

E.1 Primary State Guidance Manuals

Designers should use the most recent version of the below guidance manuals as the primary design reference for meeting the respective state regulations:

- **New Jersey Stormwater Best Management Practices (BMP) Manual**
  New Jersey Department of Environmental Projection developed this manual to provide guidance for meeting the requirements of Stormwater Management Rule N.J.A.C. 7:8. It details structural and non-structural green infrastructure strategies and procedures for completing the hydrologic and hydraulic calculations. The manual includes fact sheet chapters for most common GI types. Designers can use the methods in the BMP Manual without need for additional documentation to address the performance standards in the N.J.A.C. 7:8. **(Updated March 2, 2021)**

- **New York State Stormwater Management Design Manual**
  This manual provides design standards for meeting the State Pollutant Discharge Elimination System (SPEDES) requirements and protecting the waters of New York from the adverse impacts of urban stormwater runoff. The manual provides design standards on the most effective stormwater management approaches including incorporating green infrastructure design and implantation of standards stormwater management practices, and implementation of maintenance programs.

E.2 Additional Regulations & Guidelines

In addition to the above, designers should confirm the applicability of the below regulations to their projects.

1. **New Jersey**
    - **New Jersey State Pollution Discharge Elimination System (SPDES) Permit:** project must confirm to most recent applicable permit governing the project site.
    - **State of New Jersey Stormwater Management Rules, N.J.A.C. 7:8 (June 2016)**: includes general requirements for stormwater management (NJ BMP Manual detailed above will satisfy most of these requirements).
    - **Stormwater Management Rules, N.J.A.C. 7:8, Green Infrastructure**: these regulations from New Jersey Department of Environmental Protection ***go into effect on March 2, 2021***. They place higher emphasis on using green infrastructure and natural systems for stormwater management.
    - **State Open Waters/Freshwater Wetlands (N.J.A.C. 7:7A et. seq.):** permitting requirements for working in and around qualifying open water and freshwater wetlands in New Jersey.
    - **New Jersey Coastal Zone Management Rules** and **Living Shorelines Guidance:** NJ DEP Administrative Code for permitting and development within coastal zones. Also includes recommendations and guidelines for living shorelines.
    - **New Jersey Flood Hazard Area (FHA) Control Act Rules (N.J.A.C 7:13):** states that any alteration of typography through excavation, grading and/or placement of fill within the 100-year flood plain will require a Flood Hazard Area Permit.

2. **New York**

- **New York State Pollution Discharge Elimination System (SPDES) Permit:** must confirm to most recent applicable permit governing the project area.
- **NYC Climate Resiliency Design Guidelines (September 2020):** New York City Mayor's Office of Recovery & Resiliency incorporates forward-looking climate data from the New York City Panel on Climate Change (NPCC) into the design of all City of New York capital projects. Includes guidance on planning for increased sea level rise, increased temperature, and increased precipitation.
- **Guidelines for the Design and Construction of Stormwater Management Systems (July 2012):** developed by the New York City Department of Environmental Protection (DEP) in consultation with the New York City Department of Buildings (DOB), provides guidance to the New York City's development community and licensed professionals for the planning, design, and construction of on-site source controls within the combined sewer network. This will affect Port Authority projects when establishing site connections with the NYC sewer system.

Note: *NYC is consolidating their combined sewer and MS4 guidance into a Unified Stormwater Rule in 2021*. The new manual will apply to all cases where 20k square feet of land is disturbed or 5k square feet of new impervious area is added. It will prioritize green infrastructure retention practices for both water quality and quantity. There will also be a new site connection rule and calculation procedure.

- **Flood Zone Compliance BC 1204.29 and BC G105:** if the building is in a special flood hazard zone, a Special Inspection Agency must verify construction complies with NYC Building Code Appendix G, locating all new equipment (excluding the AC disconnect) above the DFE (Design Flood Elevation)
- **New York City Local Law 94 of 2019:** amends the NYC Building Code to require green roofs and/or solar panels on 100% of the area of all new and substantially renovated roof decks. Enacted on November 15, 2019.
- **New York City Waterfront Revitalization Program (WRP):** authorized by New York State's Waterfront Revitalization of Coastal Areas and Inland Waterways Act, the WRP establishes the City's policies for waterfront planning, preservation, and development projects to ensure consistency over the long term. The goal of the program is to maximize the benefits derived from economic development, environmental conservation and public use of the waterfront, while minimizing any potential conflicts among these objectives.
- **NYS DEC Living Shoreline Regulations and Guidance:** NYS Department of Environmental Conservation compilation of codes, rules, and regulations pertaining to the Division of Water Resources. The DEC provided guidance encourages the appropriate use of natural shoreline protection measures in place of hardened or man-made approaches to coastal erosion controls. In addition, the guidance provides information on types of living shorelines, reviews how tidal wetland and protection of waters permit standards relate to living shorelines, and speaks to proper siting, maintenance, and monitoring considerations.

3. **Federal & National**

- **U.S. Department of Transportation (USDOT), Federal Aviation Administration (FAA), Advisory Circular No. 150/5200-33B, dated 8/28/2007, entitled “Hazardous Wildlife Attractants on or Near Airports:** this Advisory Circular (AC) provides guidance on certain land uses that have the potential to attract hazardous wildlife on or near public-use airports. It also discusses airport development projects (including airport construction, expansion, and renovation) affecting aircraft movement near hazardous wildlife attractants. Appendix 1 provides definitions of terms.

- **Energy Independence and Security Act (EISA) Section 438:** this Act helps increase US energy security, develop renewable energy production, and improve vehicle fuel economy. Section 438 addresses stormwater management for Federal projects which exceed 5,000 SF. These projects must maintain pre-development hydrology and ensure changes in runoff temperature, volume, durations, and rates do not negatively impact receiving waters.

- **American Society of Civil Engineers (ASCE)** standards and guidelines.

- **American Association of State Highway and Transportation Officials (AASHTO)** standards and guidelines.

Appendix F: References

F.1 PANYNJ Green Infrastructure Design Tools

- **PANYNJ Green Infrastructure Screening Tool**
  GIS-based tool for planning-level site analysis. Considers topographical and geotechnical data and vicinity to flood zones, wetlands, and surface waters.

- **PANYNJ Green Infrastructure Calculator**
  Excel-based tool assists with estimating the design volume, peak flow, and GI footprint area based on general assumptions. Calculator should be used for Stage I planning purposes only. Designer is responsible for final design calculations in Stage III.

F.2 PANYNJ Design Guidance Manuals

- **PANYNJ Sustainable Building Guidelines**
  Gives direction for optimizing building project sustainability through integrated design practice, with the complementary goals of enhancing cost effectiveness, extending the project lifespan and, in some cases, reducing operational and/or maintenance costs. References USGBC's LEED credit system

- **PANYNJ Sustainable Infrastructure Guidelines**
  Gives direction for optimizing infrastructure project sustainability through integrated design practice, with the complementary goals of enhancing cost effectiveness, extending the project lifespan and, in some cases, reducing operational and/or maintenance costs. Guidelines align with the Institute for Sustainable Infrastructure's Envision rating system.

- **PANYNJ Climate Resilience Design Guidelines**
  Gives guidance to maximize the long-term safety, service, and resilience of the Port Authority's assets as climate conditions change. Includes sea level rise, rising temperature, and increased precipitation.

- **PANYNJ Civil Design Guidelines**
  The primary design guidance for stormwater management in the Engineering Division. The general rule is to comply with regulating agency if it affects drainage outside Port Authority jurisdiction. Includes sections on water quality, water quantity, maintenance, and design guidance.

- **PANYNJ Aviation Landscape and Sustainable Design Criteria**
  Manual covers the criteria for designing vegetated infrastructure in the vicinity of aviation facilities. Includes chapters on design parameters/recommendations, design criteria for bird deterrents, plant palette, irrigation, hardscape/maintenance, and reducing construction impacts.

F.3 PANYNJ Green Infrastructure Design Reports

- **AECOM; Investigation of Green Infrastructure Stormwater Management Solutions at the Holland and Lincoln Tunnels; 2017.**
  Report compares grey ("business as usual") and green infrastructure options for stormwater management at two tunnel parking lot locations. Analysis includes examples for calculating design storms and peak flows and selecting the most suitable green and grey practices.

F.4 External Green Infrastructure Design References

- **New Jersey Stormwater Best Management Practices (BMP) Manual**
  New Jersey Department of Environmental Projection green infrastructure guidance manual for meeting the requirements of Stormwater Management Rule N.J.A.C. 7:8.

- **New York State Stormwater Management Design Manual**
  New York State Department of Environmental Conservation's green infrastructure guidance manual for meeting State Pollutant Discharge Elimination System (SPEDES) requirements and protecting the waters of New York from the adverse impacts of urban stormwater runoff.

- **New York City Green Infrastructure On-site Design Manual (May 2019)**
  New York City Department of Environmental Protection's (NYC DEP) guidance manual for designing site-specific green infrastructure within NYC parks and the campuses of City-owned property. Includes guidance on siting, survey, geotechnical investigations, and detailed design.

- **NYC DEP Right-of-Way Standards – Standard Designs and Guidelines for Green Infrastructure Practices (July 2017)**
  NYC DEP's standard design drawings for green infrastructure within the City-owned right-of-way. Includes standard plan views and cross-sections of bioswales, permeable pavement, and other green infrastructure components. Also includes planting plans for various urban and residential tributary scenarios.

- **High Performance Landscape Guidelines 21st Century Parks for NYC (2010)**
  NYC Parks and Recreation's manual for the design and construction of sustainable parks and open space. The guidelines intend to improve quality of life by reducing the city's impact on the earth, improving air quality, absorbing stormwater, reducing urban heat island effect, providing habitat, and addressing the challenges of climate change.

F.5 External Green Infrastructure Design Tools and Resources

- **NJ DEP Cistern Water Reuse Calculator**
  NJ DEP's Excel-based calculation spreadsheet takes inputs such as roof area and water reuse rates and outputs the suitability of rainwater harvesting and the necessary storage configuration.

- **NJ DEP Stormwater Manufactured Treatment Devices Guidance Webpage**
  List of NJ DEP-certified MTDs with certified total suspended solid removal rate and maintenance plans. List includes which devices they do and do not consider "green infrastructure".

F.6 Rainwater Harvesting Filtration and Treatment Tables

Table F.1 - Rainwater Treatments Per End Use Tier

End Use Tier	Category	Potential for Human Contact	End Uses	Treatment Method
1	Non-Potable	Low	• Trap primers • Spray irrigation (restricted access/ exposure) • Surface/subsurface irrigation • Fire suppression • Ice rinks	• Screen • First flush • Vortex/centrifugal
2	Non-Potable	Medium	• Toilet/urinal flushing • Laundry • HVAC evaporative cooling* (cooling tower, evaporative condenser, spray cooler, direct and indirect evaporative cooling) • Rooftop thermal cooling	• Screen • First flush • Vortex/centrifugal • Cartridge filters • Automated sand filters • Ultraviolet light • Ozone
3	Non-Potable	High	• Hose bibbs • Pressure washing • Decorative fountains • Vehicle washing • Spray irrigation (non-restricted access/ exposure)	• Screen • First flush • Vortex/centrifugal • Cartridge filters • Automated sand filters • Ultraviolet light • Ozone
4	Potable	High	• Human consumption • Oral care • Food preparation • Dishwashing • Bathing, showering, hand washing • Pools, hot tubs, spas and splash pads • Misting stations • Swamp coolers	• Screen • First flush • Vortex/centrifugal • Cartridge filters • Automated sand filters • Ultraviolet light • Ozone • Membrane filtration • Reverse osmosis (RO) • Nanofiltration • Chlorination as required

Source: Adapted from ASPE Plumbing Engineering Design Handbook (2008) and ICC B805 Table 5.1

Table F.2 - Rainwater Treatment Locations and Purposes

Treatment Type	Treatment Method	Location	Purpose
Screening	Leaf screens and strainers	Gutters and downspouts	Prevents leaves and debris from entering tank
Settling	Sedimentation	Within tank	Settles out particulates
	Activated charcoal	Before tap	Removes chlorine*
Filtering	Roof washers	Before tank	Removes suspended material
	Inline multistage cartridge	After pump	Sieves sediment
	Activated charcoal	After sediment filter	Removes chlorine* and improves taste
	Slow sand filters	After tank	Traps particulates
Microbial Treatment/ Disinfection	Boiling/distilling	Before use	Kills microorganisms
	Chemical treatment (chlorine or iodine)	Within tank or at pump (liquid, tablet, or granular) before activated charcoal	Kills microorganisms
	Ultraviolet light	After activated charcoal filter and before tap	Kills microorganisms
	Silver ionization	After activated charcoal filter and before tap	Kills microorganisms
	Ozonation	After activated charcoal filter and before tap	Kills microorganisms
	Nanofiltration	Before use, polymer membrane (10^3-10^4 pores)	Removes molecules
	Reverse osmosis	Before use, polymer membrane (10^3-10^4 pores)	Removes ions (contaminants) and microorganisms

*Should be used if chlorine has been used as a disinfectant

Source: Adapted from ASPE Plumbing Engineering Design Handbook (2008)

F.7 Benefits and Co-benefits Summary

Table F.3 - Benefits Overview

Benefits	Description	Typical Results
Water Quality	Removal of pollutants from stormwater runoff	Improvements to public and ecological health
Water Volume	Reduction of runoff volume and/or peak flow leaving the site	Flood mitigation and increased longevity of downstream drainage infrastructure
Peak Flow Reduction	Reduction of the maximum runoff flow rate	Flood mitigation and decreased wear and tear on downstream infrastructure
Groundwater Recharge	Replenishment of the groundwater table	Maintains healthy and sustainable water cycle and river levels
Co-Benefits	**Description**	**Typical Results**
Water Use Reduction	Reuse of stormwater as a replacement for potable water	Reduces potable water use and associated metering costs
Wildlife Preservation	Provides habitats and ecosystem functions	Provides support to local fauna
Air Quality	Removal of pollution from the atmosphere	Improvements to public and ecological health; reduced rates of respiratory illnesses and conditions
Heat Island Reduction	Use of vegetation and low solar reflectance materials to reduce the ambient temperature in urban environments	Improvements to public and ecological health; decreased heat-based mortality rates
Aesthetic Improvement	Beautification of the project and community	Increased property values, improved mental health, and higher quality of life
Increased Infrastructure Durability	Use of materials that protect or replace traditional infrastructure, thus increasing its lifespan	Lower lifecycle costs for repairing and/or replacing infrastructure
Decreased Site Maintenance	Use of materials and technologies which require less maintenance than traditional alternatives	Lower lifecycle costs for maintaining infrastructure

Appendix G: Example Construction Inspection Checklist

Disclaimer

These materials are for demonstrative purposes only. Project teams should customize these forms and references to suit the GI type, size, location, and configuration. Word versions of the forms are located here.

GREEN INFRASTRUCTURE CONSTRUCTION INSPECTION CHECKLIST 01-22

[Supplement to form PA 0327]

Contract Name:	Inspector Report No.:

TYPE(S) OF GREEN INFRASTRUCURE INSPECTED

☐ Bioretention	☐ Biofiltration	☐ Infiltration Basin	☐ Sand Filter
☐ Permeable Pavers	☐ Permeable Asphalt	☐ Pervious Concrete	☐ Subsurface Chamber
☐ Green Roof	☐ Rainwater Cistern	☐ Hydrodynamic Separator	☐ Media Filters

CONSTRUCTION SCOPE

Excavation	**Comments**
☐ Runoff is diverted from excavation and/or GI inlet	
☐ Excavation is at proper depth	
☐ Bottom of excavation is uncompacted as specified	
☐ Infiltration testing is complete as specified	
Drainage Components	**Comments**
☐ Manufactured components conform to specifications	
☐ Soil, sand, and stone are tested as required	
☐ Drainage media is installed to correct depths	
☐ Drainage media is not over compacted	
☐ Subsurface components are approved prior to backfill	
☐ Inlets and outlets installed at correct elevation	
☐ Surface contours/flow paths are correctly constructed	
Permeable Pavement	**Comments**
☐ Choker course is even and level	
☐ Pavement is installed in suitable climate conditions	
☐ Installed pavement is tested and approved	
Vegetation	**Comments**
☐ Vegetation conforms to planting plan and/or specs	
☐ Vegetation is installed in suitable climate conditions	
Construction Completion	**Comments**
☐ Upstream tributary is clean and stabilized	
☐ Post-construction drainage tests are complete	
☐ Commissioning for alarms, pumps, controls complete	

ADDITIONAL COMMENTS (attach photos to form PA 0327)

SCAN FOR GIDM

Inspector's Signature: ______________________ **Reviewed By:** _____________________ **Date:** ___________

[Print Name] [RE/ARE]

Appendix H: Example Maintenance Resources

Example Maintenance Resources:

APPENDIX H-1: EXAMPLE MAINTENANCE LOG H-2

APPENDIX H-2: EXAMPLE MAINTENANCE CARD H-3

Disclaimer

These materials are for demonstrative purposes only. Project teams should customize these forms and references to suit the GI type, size, location, and configuration. Word versions of the forms are located here.

GREEN INFRASTRUCTURE MAINTENANCE LOG 01-22

GI Type/ID:	Facility:
Date/Time:	Weather/Temp:
Maintenance Staff:	

PREVENTATIVE MAINTENANCE

General	Comments
☐ Structural Inspection	
☐ Drainage Component Inspection	
☐ Surface Cleaning/Sweeping	
☐ Surface Contouring/Regrading	
☐ Inlet/Outlet Cleaning	
Vegetation	**Comments**
☐ Watering	
☐ Weeding	
☐ Structural Pruning	

Removals	Quantity	Comments
☐ Trash Removal		
☐ Sediment Removal		
☐ Leaf/Lawn Debris Removal		

CORRECTIVE MAINTENANCE

Task	Comments
☐ Vegetation Replacement	
☐ Underdrain Flushing/Cleaning	
☐ Hardscape Repair/Replacement	
☐ Drainage Component Repair/Replacement	
☐ Other	

MATERIALS USED

Materials	Quantity	Comments
☐ Engineered Soil		
☐ Stone Aggregate		
☐ Mulch		
☐ Vegetation		

OBSERVATIONS/ACTION ITEMS

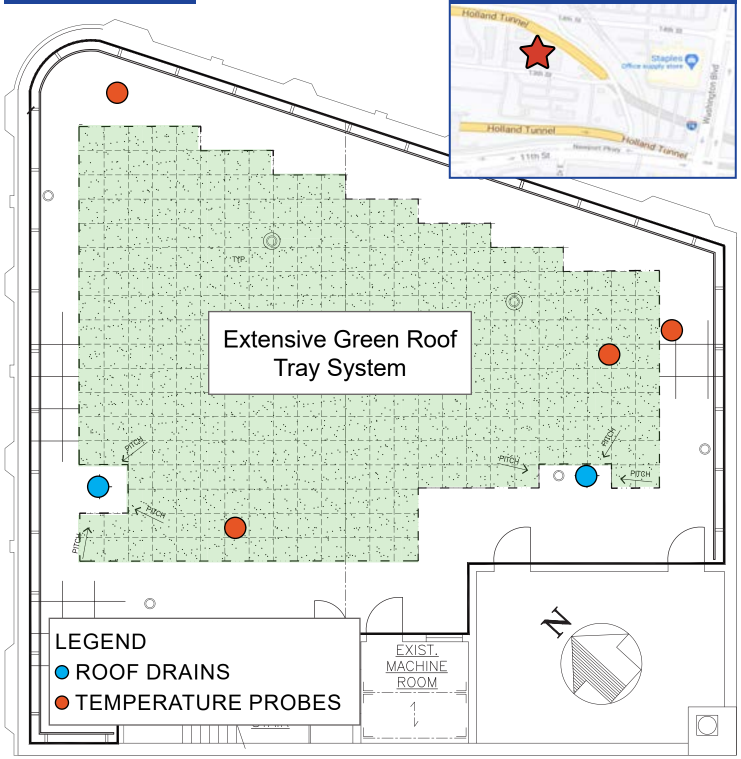
SCAN FOR GIDM

Maintenance Lead Signature: ________________________ **Date:** ____________ ☐ Photo Attachments

Holland Tunnel Green Roof | Maintenance Card (Example)

Plan View

Location Map



General Information

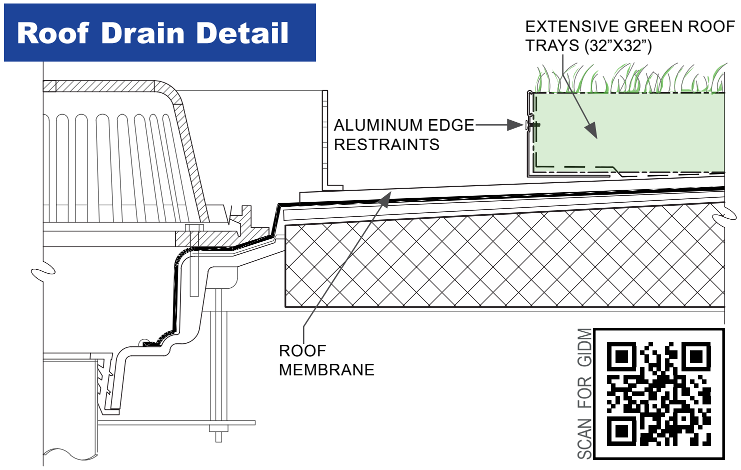
The site consists of a 1,400 SF extensive green roof system (32”x32” trays) with sedum vegetation and aluminum edge restraints. Roof drains are 12” clear of green roof assembly and should be free of sediment and debris. There are also four temperature probes (two on roof surface and two in green roof) that should not be disturbed during maintenance activities.

Preventative Maintenance Schedule

Task	Frequency	Notes
General Inspection	Quarterly*	Check all components for corrective maintenance needs
Clear Roof Drains	Quarterly*	Remove any sediment and debris inhibiting drain functions
Clean Rubbish	Quarterly*	Remove rubbish and debris from roof
Prune Overgrowth	Quarterly	Cut detrital vegetation to four/six inches
Remove Weeds	Quarterly	Remove undesirable vegetation

*or after severe wind or rain events

Roof Drain Detail



SCAN FOR GIDM

Corrective Maintenance (As-Needed)

Task	What to Look for
Replace/Restore Vegetation	Dead, dying, or missing sedum plants
Repair/Replace Green Roof Tray	Damage to modular green roof trays that affects drainage or vegetation health
Inspect Waterproofing Membrane	Rips, tears, or abrasions to membrane (report to manufacturer for repair)
Flush Out Drainage Media	Standing water, heavy sedimentation, and/or clogging of the drainage layers/pipes


Dead Vegetation

(www.sky-garden.co.uk)


Weeds

(flickrcc: SamSaunders)


Clogged Drain

(www.frost-roofing.com)