CITY OF NEWARK GREEN INFRASTRUCTURE PROGRAM

Green Infrastructure Guidance Manual

Version 1

October 2024

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1 Introduction

The City of Newark's Department of Water and Sewer Utilities (DWSU) is committed to improving water quality by reducing combined sewer overflows (CSOs) as planned in the 2021 Long Term Control Plan (LTCP), and treating stormwater runoff in municipal separate storm sewer system (MS4) areas. To help achieve this goal, the City of Newark (City) is implementing green infrastructure (GI) citywide as part of RainReady Newark, the Newark Green Infrastructure Program (NGIP). Renderings of GI practices are shown in ***Figure 1-1.*** NGIP aims to sustainably manage stormwater by promoting the natural water cycle and implement projects that deliver community co-benefits beyond stormwater management within each of the City's five wards.

NGIP Vision

Implement sustainable, cost-effective and collaborative green infrastructure projects that will promote connectivity and equity, employ a local workforce and empower those who live and work in Newark to be champions for stormwater management and quality of life improvements.

Figure 1.1 | *Rendering of Rain Garden at Bo Porter Sports Complex*

This manual provides information to help guide the implementation of NGIP projects in Newark.

The target audiences for this manual are community partners, consultants and contractors working with the City to implement GI for the NGIP. This could include planners, engineers, surveyors, landscape architects, construction laborers, inspectors and maintenance crew members in addition to City staff involved in the design, construction, maintenance, or monitoring of GI. This manual includes technical information specific to the City and is meant to supplement existing resources.

Additional GI References

Descriptions of GI practices and how they work are available from other applicable resources, such as the **New Jersey Department of Environmental Protection (NJDEP) Stormwater Best Management Practices (BMP) Manual** and **Rutgers Green Infrastructure Guidance Manual**, and therefore not included in this manual.

Throughout this manual there will be references to other documents or resources. These references will be presented as pop-out boxes like this one.

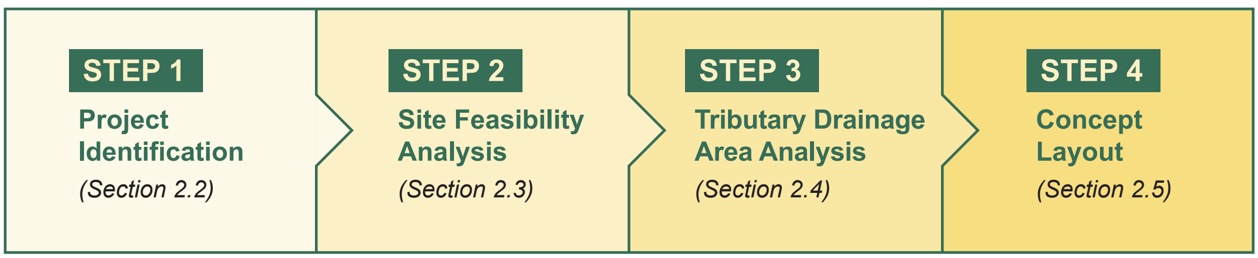
2 Siting and Planning

2.1 Summary of Chapter

Siting and planning plays an important role in the successful implementation of green infrastructure (GI) throughout the City of Newark (City). Engaging in siting and planning activities prior to initiating design allows designers to have a more holistic understanding of the site context and make informed decisions about site features.

This chapter will walk planners and designers through the major steps of the planning process (see ***Figure 2.1***).

***Figure 2.1** | GI Siting and Planning Process*



This chapter will help planners & designers:

- Understand a site's existing condition and general context within the City.
- Delineate a site's potential tributary drainage area and proposed layout of site features.
- Develop a more holistic stormwater management approach that will enhance existing resources.
- Identify opportunities to incorporate community needs and benefits similar to the Department of Water and Sewer Utilities' project ranking criteria.
- Align with ongoing City initiatives or projects.

2.2 Project Identification

Finding the appropriate location for the management of impervious acreage and the appropriate GI practice type are two of the first steps in implementing a successful GI project. To facilitate this decision-making process, the following guidelines that represent the City's priorities and ease of implementation have been developed. These guidelines are meant to be general suggestions and may shift depending on site-specific conditions. The content in this section will provide insight into the GI siting and practice types that best align with DWSU's goals.

2.2.1 Siting Preferences

Property ownership is a critical factor for siting GI. Public property is higher priority than private due to ease of construction and maintenance. (see ***Figure 2.2***)

2.2.1.1 In general, the City targets sites whose owners are amenable to partnerships with the City. For this reason, public land or land managed by community-oriented organizations is typically preferred over private land.

2.2.1.2 Site uses are based on general ease of implementation and development patterns. For this reason, site uses that allow for large open spaces are preferred for GI projects or retrofits.

2.2.2 GI Practice Type Preference

While cost and project-specific considerations often dictate practice type selection, multiple GI technologies are applicable to a site, and the preference hierarchy described below should be considered throughout siting, planning, and design.

2.2.2.1 The GI Practice Type Hierarchy shown in ***Figure 2.3*** prioritizes easy to maintain, vegetated systems that provide additional co-benefits.

2.2.2.2 When implementation of vegetated systems is not possible, planners and designers should look for opportunities to eliminate, reduce or disconnect impervious surfaces from the storm sewer network. Newly pervious surfaces require surface stabilization to prevent erosion and sedimentation. Typical stabilization options include planting, mulching, and the use of erosion control fabric.

GI Practice Types Reference

For detailed descriptions of various GI practice types and disconnection strategies see [Green Infrastructure Guidance Manual for New Jersey](), Rutgers University, Chapter 2, *Green Infrastructure Practices,* or [NJ Stormwater Best Management Practices (BMP) Manual](), NJ Department of Environmental Protection (NJDEP), Chapters 9 and 10.

Figure 2.2 | *Site Use Prioritization (in order of preference)*

1. **Schools**
2. **Park/Open Space**
3. **Public Right-of-Way**
4. **Community-Oriented Organizations** (Places of Worship, Social Organizations, etc.)
5. **Institutional** (Healthcare, Colleges, Campuses, etc.)
6. **Commercial & Industrial**
7. **Multi-Family Residential**
8. **Single-Family Residential**

Figure 2.3 | *GI Practice Type Hierarchy (in order of preference)*

TIER 1

Bioretention,
Rain Gardens,
Infiltration Basins,
Constructed Wetlands

TIER 2

Bioswales,
Stormwater Planters,
Enhanced Tree Pits,
Tree Filter Boxes

TIER 3

Downspout Planters,
Sand Filters,
Green Roofs,
Permeable Pavements,
Detention Ponds

TIER 4

Blue Roofs,
Cisterns,
Rain Barrels,
Dry Wells,
Subsurface Storage

2.3 Site Feasibility Analysis

After identifying a potential site for GI, a feasibility analysis should be conducted and used to assess a project's high-level viability and to inform future concept-level layout and tributary drainage area delineation for the proposed GI. After applying the content of this section, it should be understood if a potential GI site is suitable to move forward into the conceptual design process.

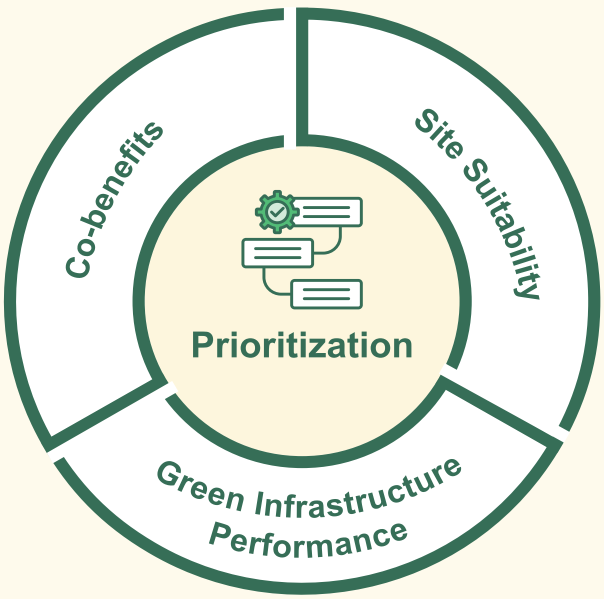
2.3.1 Site Feasibility Methodology

Information required to establish feasibility is included below. Required information can be gathered from a combination of publicly available sources (identified below)or site investigations.

2.3.1.1 Record any **known flooding issues** or signs of flooding and flooding type at potential GI sites or in close proximity. GI projects may have positive impacts on small-scale localized flooding issues, especially if they can be located upstream of recurring flooding locations. Siting GI within flood-prone areas such as floodplains may negatively impact maintenance and is not recommended.

Applicable Data Source: *Reported Flooding Locations dataset for Essex and Hudson Counties is available through the NJDEP Resilient Northeastern NJ website.*

Figure 2.4 | *Prioritization Tool*



DWSU is using a prioritization tool to decide which sites to advance to design next for continuous GI implementation. They also seek to ensure: GI sites are able to deliver different community benefits in different neighborhoods, equal distribution of GI in all of the City's Wards, and appropriate siting in CSO and MS4 areas to meet regulatory requirements.

Potential GI sites are prioritized by considering three categories of criteria: performance, co-benefits and site suitability. Criteria within each category are used to score aspects of a potential GI site. All scores are then added up to yield a total prioritization score. With this total score, potential GI sites can be quantitatively compared and ranked (see ***Figure 2.4***).

Criteria in the performance category help to evaluate the extent to which a potential GI site maximizes the area managed and achieves the City's goals. The co-benefits category focuses on additional benefits to the community other than stormwater management. Site suitability criteria rates how appropriate a potential GI site is for the construction of a GI practice.

2.3.1.2 Indicate **brownfield status** and note any other **environmental concerns**. It is important to know any environmental considerations that may prohibit or impact the construction of GI. Specifically, since certain GI concentrate infiltration, there may be adverse impacts to contaminated groundwater and, even if infiltration is avoided, excavation of contaminated soils during construction may be prohibitively expensive.

Applicable Data Source: *Brownfield sites, hazardous waste sites, and Known Contaminated Sites in the State of New Jersey are available via NJGIN Open Data.*

2.3.1.3 Note existing **land use** and **land cover** within the proposed project area. GI can be located above or below ground, and should be sited and designed as to not interrupt existing and proposed site uses including buildings, dense commercial corridors, bus stops or other programmed uses. These existing conditions may limit the potential opportunities for certain practice types. Areas with a high percentage of permeable cover or tree cover may not be ideal for locating GI practices due to the potential for limited impervious area runoff capture and root zone conflicts.

Applicable Data Source: *Land Use/Land Cover data are available via NJDEP and zoning is available to view via City of Newark Geographic Information Network (NewGIN).*

2.3.1.4 GI practices are to be designed as detention practices without infiltration. If based on USDA Natural Resource Conservation Service (NRCS) web soil survey, soil characteristics, depth to bedrock, and depth to groundwater are conducive to infiltration further investigation into feasibility of infiltration will be conducted during construction (**Chapter 6**).

Soil Properties Reference

Important soil properties and qualities are identified in the **Green Infrastructure Guidance Manual for New Jersey**, Rutgers University, Chapter 3, *Green Infrastructure Design Process*.

Applicable Data Source: *Unless site-specific testing has already been completed, soil information from the USDA NRCS web soil survey should be used.*

2.3.1.5 Record known locations of **existing utilities** that will either need to be avoided or relocated as part of the GI design. Utility locations can also be used to identify opportunities for tying in underdrains.

Applicable Data Source: *Utility locations can be assumed based on surface features such as valves, vaults, manholes and catch basins during a site visit if records are unavailable. Exact utility locations will be identified at a later stage.*

2.3.1.6 Analyze existing **site slopes** and preclude areas with excessive slopes for GI siting. Vegetated areas should not be sited in areas with slopes greater than 15% and permeable pavement systems should not be sited in areas with slopes greater than 5%.

Applicable Data Source: *10ft Digital Elevation Model and derived Slope datasets are available for the entire State of New Jersey via NJGIN Open Data.*

2.3.1.7 Record **other known site constraints** such as presence of existing tree root zones (assume 1-foot offset for every 1 inch in trunk diameter), presence of potential historical resources or known proposed development plans.

2.3.1.8 Record **other known site opportunities** such as the site being included in Green Acres Program, within an existing City park, school or business improvement district (BID), or near public transit, affording potential partnerships between DWSU and other departments or entities within the City.

2.3.2 Limitations

Through a feasibility analysis, it is possible to assess potential constraints that may impact GI implementation and what constraints will need to be investigated during future design phases. If a site advances to design phases based on desktop feasibility results, detailed investigations such as survey, utility investigation, and geotechnical investigations will confirm feasibility and design requirements for each GI project site. Because of this, the feasibility analysis is typically limited to field observations and high-level data with the goal of eliminating sites that are infeasible.

CONCLUSION OF SECTION 2.3

Completion of this section should be documented as a simple map that indicates available area for a GI system including a brief description that includes proposed practice types, potential constraints and other key siting information.

2.4 Tributary Drainage Area Analysis

Assessing site suitability often begins with determining the area that drains stormwater runoff to the site. Understanding local drainage patterns and characteristics such as size and imperviousness can help to locate and size projects in ways that will improve the performance, minimize maintenance, and integrate GI with the existing uses of the site. Applying the content of this section to a project site will allow for a planning-level delineation of the tributary drainage area which can be used to assess the feasibility and potential benefit of GI.

2.4.1 Required Information for Drainage Area Analysis

Drainage area delineations at smaller scales, such as those typically required for GI, are often most efficiently done manually. If larger sites are being assessed, automated delineation tools (such as Esri's Hydrology toolset) may be used. To manually delineate drainage areas, it is helpful to have the existing conditions data described below.

2.4.1.1 During the planning stage, detailed **topographic and field survey information** is typically not available. If topographic survey has already been completed for the site, it should be used to delineate drainage areas. If survey information is not available, elevation data in conjunction with site investigation may be used.

Applicable Data Source: *10ft Digital Elevation Model datasets are available for the entire State of New Jersey via NJGIN Open Data.*

2.4.1.2 Spatial **storm sewer network data** should be used if available. Stormwater inlets and building downspout locations can be verified as part of a site visit, photographs or online street-level viewers.

Applicable Data Source: *Storm sewer data are available upon request from DWSU.*

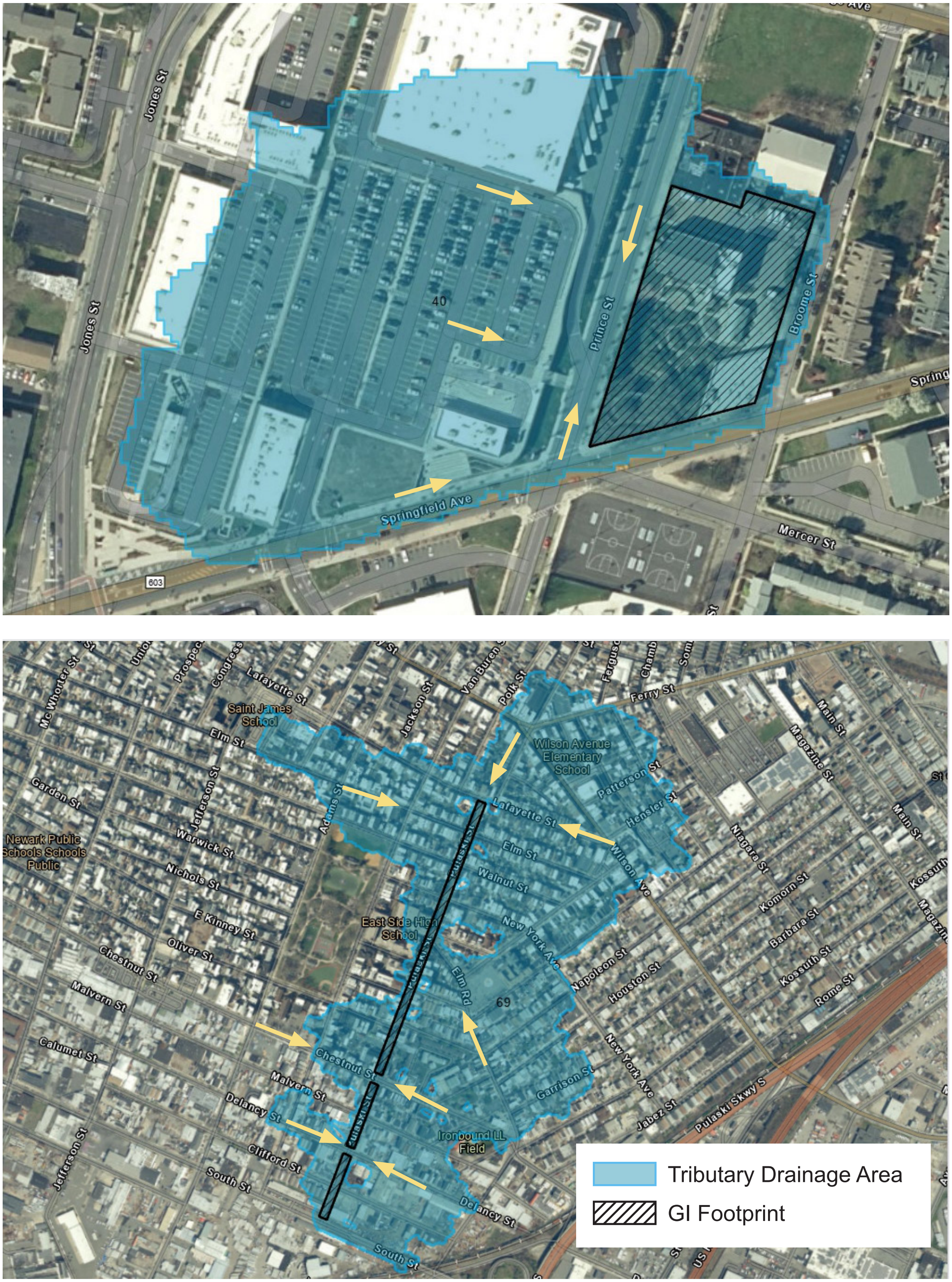
2.4.1.3 Parcel data can be used to distinguish where drainage areas are on parcels or within the right of way (ROW). Distinctions between ROW tributary drainage areas and those sourced from parcels should be noted.

Applicable Data Source: *Parcel data are available via the City of Newark Open Data website.*

2.4.1.4 Different parts of the City lie within various **sewersheds** as serviced by different types of sewers. Understanding this difference will help inform capture and conveyance strategies for tributary drainage areas. In combined sewer or CSO areas, stormwater is commingled with sanitary sewer and existing pipes and inlets cannot be rerouted directly to GI features. In separate sewer or municipal separate storm sewer system (MS4) areas, stormwater and sanitary flows are kept separate and existing storm sewers can be retrofitted to contribute directly to sites.

Applicable Data Source: *Sewershed data are available upon request from DWSU.*

Figure 2.5 *| Examples of Tributary Drainage Area Delineations*



2.4.2 Drainage Area Delineation Methodology

Delineating drainage areas should consider existing drainage patterns and be based on flow direction to stormwater inlets. For planning purposes, exact drainage areas are not necessary. Using the data collected in **Section 2.3.1**, drainage area delineations should follow this process:

2.4.2.1 Import required desktop information identified in **Section 2.4.1** into a spatial drafting environment such as ArcGIS Pro or AutoCAD.

2.4.2.2 Identify tributary drainage area collection points such as catch basins and curb cuts where drainage areas are routed to the existing sewer or proposed GI system.

2.4.2.3 Identify major topographic features such as centerline crowns, ridges, curbs and high/low points that will influence drainage. If topographic information does not contradict, it can be assumed that roads are typically crowned at the centerline resulting in a separate drainage area on each side of the road extending from the centerline to the curb and gutter line where stormwater runoff is concentrated. Sidewalks are typically graded toward the curb and gutter line.

2.4.2.4 Identify flow direction by using contours. Typically, the presence of inlets at intersections or low points can be used to indicate flow direction. If a mid-block high point is identified, flow along the ROW may be split toward opposite intersections. Indicate flow direction with arrows on drainage delineation graphics. See ***Figures 2.6*** and ***2.7*** for common tributary drainage area configurations.

Figure 2.6 | *Example of a Street with a Mid-Block Inlet Creating Two Separate Drainage Areas*

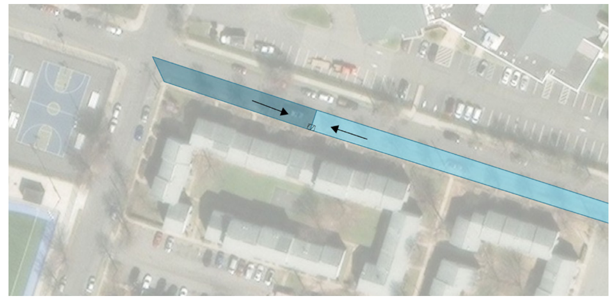
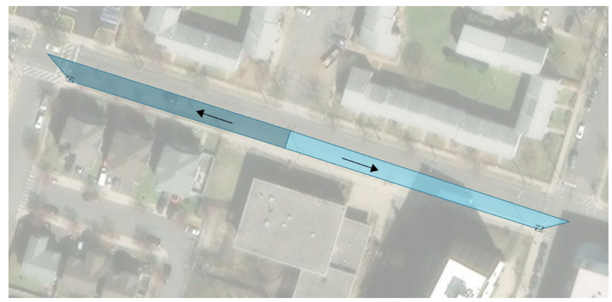
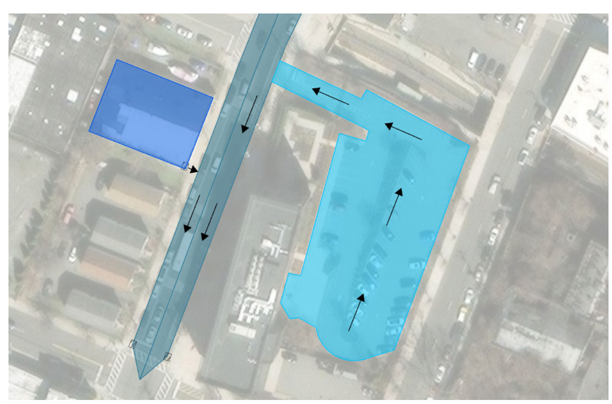


Figure 2.7 | *Example of a Mid-Block High Point Creating Two Separate Drainage Areas*



2.4.2.5 Identify other tributary drainage area contributions by using downspout and storm sewer information to identify runoff reaching the ROW from nearby parcels (see ***Figure 2.8***). If sufficient digital information is not available, a site visit will be needed to confirm these flow contributions.

Figure 2.8 | *Example of Other Tributary Drainage Area Contributions*



2.4.2.6 Assess land cover to determine the runoff potential of the drainage area. Typically, most land cover types within the ROW – streets, sidewalks, parking lanes – are considered impervious. Even small vegetated strips within the ROW are often sufficiently compacted to act like impervious surfaces during storm events.

Land Cover Methodology Reference

Percentages of each land cover type should be assigned for each drainage area following the methods in the **NJ Stormwater BMP Manual**, NJDEP, Chapter 5.

Applicable Data Source: *Land Use/Land Cover data are available via NJGIN Open Data.*

2.4.2.7 Confirm that drainage areas are not already being managed or planned on being managed by other GI systems. This may require field investigation or coordination with DWSU.

CONCLUSION OF SECTION 2.4

For record-keeping purposes, each tributary drainage area should be assigned:

- Unique identifier, e.g. DA-1234
- Total area, in feet or acres
- Percentage of each land cover type

Drainage area polygons must not overlap or have gaps.

This process is iterative as site concepts are refined and more information becomes available.

2.5 Concept Layout

A concept-level layout will be the basis for future design phases. It should demonstrate project feasibility and clearly indicate the proposed concept for discussion and decision-making purposes. Applying the content in this section will result in concept layout(s) for a site that demonstrate a preliminary understanding of tributary drainage areas and available footprint areas for a potential GI site.

2.5.1 Concept Layout Development Guidelines

The following guidelines should be used when assessing the feasibility of a concept. Exceptions will be made for site-specific circumstances especially when the project can be aligned with other community goals.

2.5.1.1 A maximum loading ratio, defined as the ratio between tributary drainage area and system footprint, of **10:1** for underground systems, **3:1** for permeable pavement and **25:1** for vegetated systems.

2.5.1.2 The combined impervious drainage areas being managed by a system should be a minimum of **3,000 square feet**.

2.5.1.3 The minimum footprint of an individual GI system should be **200 square feet**.

2.5.1.4 Systems should be at minimum **5 feet** in length and width. ROW systems should not be sited in constrained street sections where this width cannot be achieved.

2.5.1.5 Management of ROW tributary drainage areas should be prioritized over tributary drainage areas from parcels.

2.5.2 Concept Layout Development Methodology

Once site constraints are known, a maximum available GI footprint that manages each identified drainage area should be drawn. Simple assumptions about the conveyance of stormwater to the footprint should be considered during this stage.

2.5.2.1 **Footprints should be offset** from existing buildings, utilities, trees and other site constraints according to ***Table 2.1*** below. Offsets should be further refined during design (**Chapter 3**) once detailed survey information is available.

Table 2.1 | *GI Footprint Offsets*

Feature	Horizontal Offset [feet]
Property lines	5
Buildings	10
Utilities (i.e. water, sewer, electrical, hydrants, utility poles, etc.)	5
High-Risk Utilities (i.e. gas, large diameter sewers, transmission mains, etc.)	10
Buildings	10
Trees	1 for each inch of trunk diameter

2.5.2.2 Footprints proposed within the ROW should **avoid interfering with driveways and bus stops**. Parking spots should be maintained to the greatest extent possible.

2.5.2.3 Even if systems are too large for the tributary drainage area, it is helpful to know **how much space is available** for GI in case new constraints or prioritized site uses are identified as design progresses. Information about right-sizing GI practices is described in **Section 2.5.3**.

2.5.2.4 The **number of discrete GI footprints** should be minimized in order to reduce construction and maintenance costs. Look for opportunities to manage multiple tributary drainage areas with one GI footprint, as feasible.

2.5.2.5 When possible, the **length of pipe runs** should be limited by locating systems close to inlets.

2.5.2.6 Sites should maximize opportunities for **infiltration**, which will lead to improved water quality and CSO reduction benefits.

2.5.2.7 **Underground GI footprints** should use simple, generally rectangular, geometries to allow for easy construction. **Above-ground GI footprints** can be more irregular.

2.5.3 Concept Design Sizing

Concept designs should be able to clearly demonstrate the viability of a project. A concept should include a project's tributary drainage area, impervious area managed, proposed footprint, system type and total storage volume.

2.5.3.1 Prior to sizing GI, the relative elevation and position of each GI footprint should be compared to its tributary drainage areas to confirm feasible conveyance of runoff to the GI location.

2.5.3.2 Each GI system should be sized to manage the volume of runoff that is generated from a **1.25-inch storm event** over the tributary impervious drainage area at a minimum.

Design Storm Reference

The **NGIP Design Storm** equates to the volume of stormwater generated from a 1.25-inch storm event over the tributary impervious drainage area.

For more information regarding other NJ-specific design storms, see Chapter 5 of the **NJ Stormwater BMP Manual**.

2.5.3.3 The **Rutgers Cooperative Extension (RCE) Water Resources Program** has been designing GI practices to manage the **two-year design storm**, an SCS Type III 24-hr storm with 3.3" of rainfall depth. These larger systems are able to withstand more intense storms anticipated from climate change. When feasible, it is recommended to manage the two-year design storm.

2.5.3.4 **Assign a GI practice type** to each footprint. Site-specific constraints may dictate, but where possible, technologies should follow the prioritization discussed in **Section 2.2.1**.

2.5.3.5 In order to estimate volume managed, a **typical cross-section** should be developed for each GI footprint. Depths of ponding and various porous media should be developed. Assign porosity constants included in ***Table 2.2***.

Table 2.2 | *Porosity Constants*

Porosity Constants		
Ponding	n_{pond}	= 1.0
Soil	n_{soil}	= 0.2
Sand	n_{sand}	= 0.3
Stone	n_{stone}	= 0.4
Structural Storage	n_{str}	= 0.9

2.5.3.6 **Vegetated sections** require at least 24 vertical inches of soil media to facilitate plant growth. Side slopes for graded vegetated areas should not exceed 3:1.

2.5.3.7 An **Initial Storage Volume Estimate** can be calculated by multiplying the GI footprint by the amount of unit-storage provided by the typical section.

2.5.3.8 GI footprints should be refined based on **storage volume and loading ratio** requirements (see **Section 2.5.1**). While it is generally beneficial to maximize site footprint when available, cost savings may be realized by right-sizing systems. The total volume of stormwater runoff that can be managed by each practice may be limited by the total volume of runoff from the delineated drainage area.

2.5.4 Concept Details

While the concept design phase is primarily concerned with identifying the footprint and drainage area of a proposed GI system, identification of the below information will help produce a more detailed understanding of the project.

2.5.4.1 **Conveyance method** (i.e. pipe and inlet, curb cut, direct drainage, etc.) for associating each tributary drainage area to a GI footprint.

2.5.4.2 **Watershed** that the project is within. The City contains distinct watersheds. One of DWSU's goals is to construct GI across all watersheds.

Applicable Data Source: *Watershed boundaries (HUC14) are available via NJGIN Open Data.*

2.5.4.3 **Sewershed** that the project is within. Similar to watersheds, the City is serviced by many distinct sewersheds that convey stormwater. The installation of GI, especially in aggregate, may positively impact sewershed function.

Applicable Data Source: *Sewershed boundaries are available upon request from DWSU.*

2.5.4.4 Location of site within a **Green Acres Program** park or open space as coordination with the program will be required to determine feasibility.

Applicable Data Source: *Locations of all parcels participating in the Green Acres Program are available through the "State, Local and Nonprofit Open Space of New Jersey" dataset via NJGIN Open Data. To view only those participating in the Green Acres program, filter the GA Encumbered field ("ENCUMBRANCE_STATUS") field for those with a value of "Encumbered."*

2.5.4.5 Abutting **County or State roads** as coordination with these departments will be required to determine feasibility and to identify approvals needed.

Applicable Data Source: *Locations of all County and State roads are available through the "Road Centerlines of NJ, Hosted, 3424" dataset via NJGIN Open Data. This dataset contains the locations of all roadways in the State. County and State roads can be viewed by filtering the Road Jurisdiction field ("JURISDCTN") for only roads with a value of "C" (County) or "S" (State).*

2.5.5 Alternatives Analysis

At this stage of planning, it is common to be unsure of what the eventual site will look like. To facilitate discussions and make informed decisions, multiple concepts can be developed, compared and discussed with site owners or operators. This process, known as an alternatives analysis, is especially useful when trying to coordinate site designs across multiple stakeholders. Not all projects need an alternatives analysis, but gathering ideas and documenting decisions at this stage may result in more thoughtful and comprehensive future designs.

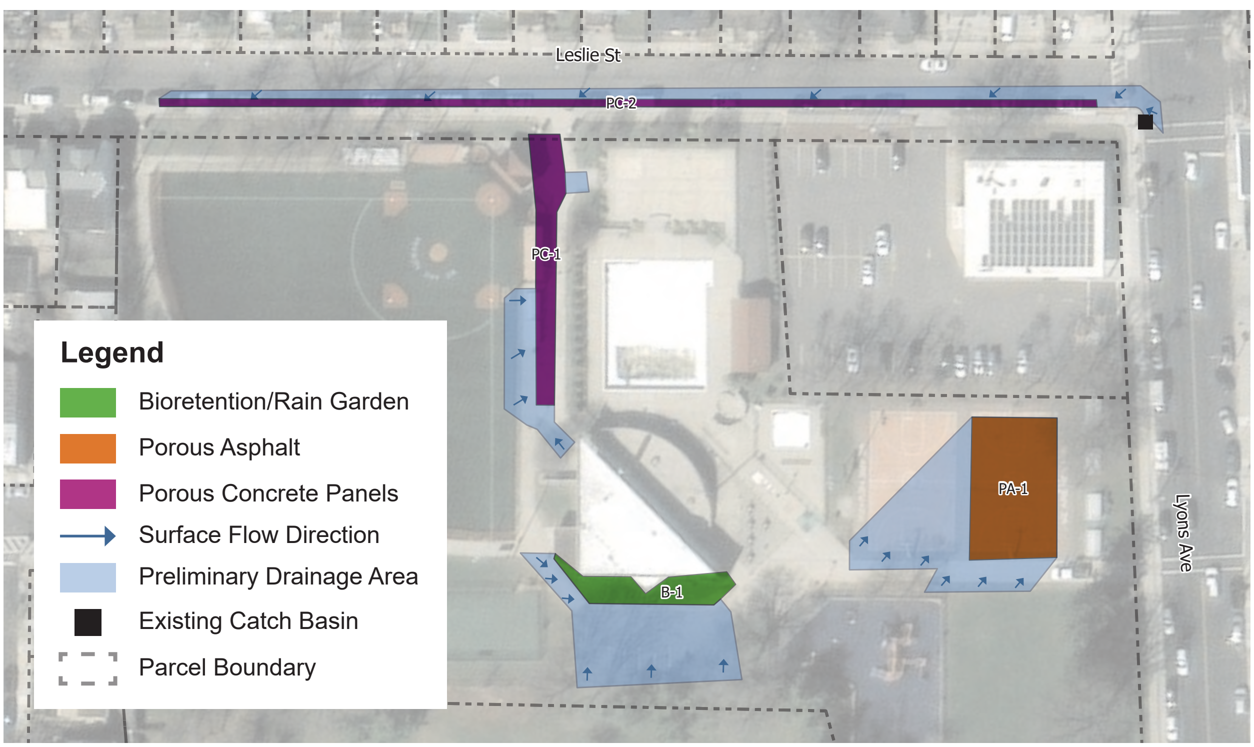
CONCLUSION OF SECTION 2.5

Upon completion of the above siting steps, conceptual designs should be formalized into a map layout that includes the following:

- Delineated tributary drainage area information from **Section 2.4**.
- GI footprints with assigned GI practice types labeled and potential stormwater management volume estimates from **Section 2.5**.
- Runoff flow arrows and conveyance methods needed to capture and convey runoff to each GI footprint from **Section 2.5.4.1**.
- Highlight of any unique conditions or potential constraints from **Section 2.5.5** that should be further investigated during the design stage.

See ***Figure 2.9*** for an example GI Concept Layout.

Figure 2.9 | *Bo Porter Sports Complex GI Concept Layout*



2.6 Additional Considerations and Context

Beyond siting GI projects in suitable locations where sufficient drainage can be routed, there are opportunities for creation of co-benefits and alignment with other City initiatives (see ***Figure 2.10***). Considering a project's overall context can lead to cost savings, increased co-benefits and heightened value to the community. The content in this section will help designers look for opportunities to provide additional benefits beyond stormwater management as part of subsequent design steps.

For example, in open space areas with existing uses, such as parks, schoolyards, or parking lots, consider how GI can be integrated into the existing function, incorporated into unprogrammed spaces or constructed below ground to maintain existing use.

Geospatial Planning Layers Reference

Geospatial planning tools such as the **EPA EJScreen Tool or Newark Environmental Resources Inventory** can be valuable when comparing multiple project opportunities, and allow for more equitable distribution of GI throughout the City.

Figure 2.10 | *Potential Co-Benefits for GI Projects*

Multi Modal Improvements

Coordinate GI with traffic calming and multimodal improvements such as separating bike and pedestrian infrastructure from vehicular travel lanes.

Habitat

Find opportunities to plant GI with native flowering vegetation that provides critical urban habitat to pollinators and other wildlife.

Water Quality

Consider the use of GI treatment trains or specialized technologies that target pollutants of concern.

Tree Canopy

Emphasize tree plantings within GI to provide shade and urban heat island reduction particularly in areas lacking canopy.

Environmental Education & Awareness

Site GI in areas visible to the community and include features such as signage or interpretive elements that will encourage engagement and education.

Nuisance Flood Reduction

Site GI upstream of areas that experience recurring nuisance flooding to reduce flood depths.

Active Recreation

Incorporate GI as an amenity within parks, along trails or near other recreational areas. Encourage connectivity between places through the cohesive use of GI features.

Visibility

Focus GI in areas with higher community visibility to get the most out of the aesthetic benefits.

Parking

Site surficial parking lane GI in areas without significant parking demand or where parking is already prohibited such as within 25 feet of crosswalks.

3 Design Process

3.1 Summary of Chapter

The design of green infrastructure (GI) projects follows from the planning process described in **Chapter 2** and includes detailed data collection and development of construction documents. By working collaboratively and carefully considering a site's potential, designers can create effective GI practices that maximize stormwater capture, are maintainable and provide community co-benefits. A design flow chart is included as **Appendix A.** This flow chart outlines NGIP's design process and includes expected check-in points with the Department of Water and Sewer Utilities (DWSU).

This chapter will help designers:

- Develop topographic survey, utility and geotechnical investigations that document existing site conditions referenced in the design and construction of GI practices.
- Design GI practices that demonstrate compliance with site-specific stormwater management requirements.
- Prioritize ease of maintenance in GI practice designs.
- Comply with City of Newark and State of New Jersey standards and requirements associated with GI design and construction.

Additional Resources

Additional information on the established Design Process for NGIP and a Design Submission Checklist example for 75% Design are included as **Appendix B** to this manual.

3.2 Survey Requirements

This section provides information on the required survey data that must be obtained when designing GI in the City of Newark (City). Surveyed information refers to topographic survey, drainage area survey, utility locations and record drawings, which are compiled into a single survey drawing.

Reference for Survey Manual

Surveys should conform to the standards established in the **NJ Department of Transportation (NJDOT) Survey Manual** except where otherwise noted.

3.2.1 Topographic Survey

Topographic survey provides information about the site's natural and manmade features such as existing grades, elevations, cover type, trees and shrubs, fences, curblines and types, depressed curbs and pedestrian ramps, street signs and other monuments at the surface of the site. Property lines should also be included in the topographic survey.

3.2.1.1 **Spot elevations** should be taken every 25 feet along the property line, top and bottom of curbline, right-of-way (ROW) centerline and at protruding features. Provide 1-foot contour lines **within the ROW**. Provide sufficient spot elevations at corners and intersections where pedestrian ramp replacement may be required or curbline changes are proposed.

3.2.1.2 Sites that are located **outside of the ROW** should provide **spot elevations** on a 25-foot grid, or as needed to provide 1-foot contour lines. Survey of areas outside of the ROW must include an established benchmark and extend to a point of connection to the sewer system.

3.2.1.3 **Label high and/or low points** within the site and flow direction. Additionally, **elevation labels** must be provided at the point of curvature (PC), point of intersection (PI) and point of tangency (PT) at the top and bottom of the curbline at intersections.

3.2.1.4 **Provide labels for streets**, **alleys,** intersecting streets and the direction of traffic on the survey.

3.2.1.5 **List the benchmark** in the upper right-hand corner of the survey drawings.

3.2.1.6 Survey should extend 25 feet up **intersecting streets**, alleys or driveways.

NJDOT Survey Reference

Additional information on survey requirements is available in the **NJDOT Survey Manual**.

3.2.2 Existing Features

The following features and conditions must be included in the survey.

3.2.2.1 **Surface expressions** of utilities, such as valve boxes, manhole covers and grates, per **Section 3.2.3**.

3.2.2.2 Material and width of the **roadway, sidewalk and curb.**

3.2.2.3 **Surface features** including structures, pavers and blocks, drainage penetrations through curbs from adjacent properties, grates, depressed curbs, driveways, stairs, steps, cellar doors, fire hydrants, parking meters, traffic signs, traffic lights, railroad tracks, curb stops, utility poles, overhead utility lines, utility access structures, utility vent and valve covers, painted markings, bus shelters, bike racks, benches, trash cans, dumpsters and other site furnishings.

3.2.2.4 Height and material of **fences and walls.**

3.2.2.5 **Overhead bridges or structures** and the elevation of the underside of the structure.

3.2.2.6 **Existing trees and stumps** within the survey area and the extents of their canopy must be shown within the survey. Canopies of trees that reach into the survey area must be shown on the survey; aerial photos may be used to determine the extents of the canopies. Label the diameter at breast height (DBH) for all trees with a DBH over 4 inches.

3.2.2.7 Landscaped, grass or **depaved areas** must be noted on the survey.

3.2.3 Utility / Record Drawings

Surveys should confirm record drawings of utilities both above and below ground, provided by utility companies, and conditions observed in the field.

3.2.3.1 Identify **existing utilities** with owner, type, size, material and cover where available.

3.2.3.2 List utilities by **diameter or width x height.**

3.2.3.3 **Show utilities** as a single line when under 12 inches in width or diameter, and double lines located at the outer walls of the utility when over 12 inches**.**

3.2.3.4 Structure type, rim and/or grate elevation, invert elevations, bottom elevation and top and bottom of curb elevation must be provided for **stormwater structures.**

3.2.3.5 If record drawings are not available, **field-testing methods** such as ground penetrating radar (GPR), closed-circuit television (CCTV) and other methods may be used to determine utility information**.**

3.2.4 Drainage Area Limited Survey

Drainage area surveys are used to accurately characterize the limits of tributary drainage areas that flow to proposed GI practices but aren't within the proposed limit of construction.

3.2.4.1 Since construction is not included within the **drainage area survey limits**, it is not necessary for drainage area survey areas to include features not relevant to stormwater flow.

3.2.4.2 **Street grades** and **street and sidewalk widths** must be shown within the drainage area survey**.**

3.2.4.3 **Roof leaders, culverts, downspouts,** drainage penetrations through curbs from adjacent properties and other infrastructure that directs stormwater into the ROW or into the drainage area must be labeled on the drainage area survey.

3.2.4.4 The drainage area survey must extend to the nearest **high point** or **catch basin.** Catch basins, high points and ridges must be labeled on the drainage area survey.

CONCLUSION OF SECTION 3.2

Survey should be provided as both a PDF and AutoCAD document that includes the following:

- Topographic survey
- Existing features survey
- Utility/record drawings
- Drainage area survey
- Civil 3D surface objects

The AutoCAD drafting style and additional survey requirements should conform to the **NJDOT Survey Manual**, unless otherwise noted.

3.3 Detailed Design

This section provides guidance and best practices for designing GI. The following guidelines are intended to supplement existing GI practice guidance presented in the **NJ Stormwater Best Management Practices (BMP) Manual**. General information on siting, sizing, grading, conveyance, landscape and level of service standards for GI practice types are presented within this section. Guidance for specific GI practice types can be found in **Chapter 4**.

Reference for Details and Specifications

Details and specifications for construction packages and bidding are available from **NJ DOT** and **DWSU**.

3.3.1 Siting and Consideration of Existing Features

During the design phase, siting criteria that are defined in **Chapter 2** should continue to be taken into consideration while refining the overall location of GI practices, maximizing both stormwater benefit and co-benefits.

To increase GI benefits, the following siting factors must be considered:

3.3.1.1 Maximizing the **tributary drainage area** to stormwater features.

3.3.1.2 Practices should be fully lined and begin with the assumption that all practices will be designed for detention, with impervious liners and underdrains that slowly release stormwater into the existing sewer system.

3.3.1.3 If **geotechnical testing during construction** shows site conditions that allow for infiltration, the design should be altered to promote infiltration, which includes removing the liner and capping the underdrain if a storage drain down time of 72 hours is achievable. The maximum allowable **surface storage drain time** is 24 hours for ponding surface features. **Section 5.4.1** provides guidance on calculating surficial drain down times.

3.3.1.4 A **minimum subsoil design permeability rate** of 0.5 inches per hour is required for infiltration practices. Geotechnical testing occurs during the construction phase and is discussed further in **Chapter 6**.

3.3.1.5 The **maximum allowable design storage drain time** is 72 hours for GI practices. Calculations for different drain down mechanisms are available in **Section 5.4**.

3.3.1.6 When possible, maximize **greening benefits,** reduce and/or convert impervious area and prioritize preserving existing trees.

3.3.1.7 Consider offset from existing features. See **Section 2.5.2.1** for **horizontal offset** guidance.

3.3.1.8 Pedestrian traffic, owner preferences and other specific site conditions must be considered when designing ponding depths for surface features. Do not exceed a **maximum ponding depth** of 12 inches.

3.3.1.9 **Replace sidewalk** in "poor" condition up to the nearest expansion or contraction joint of sidewalk that is in "good" condition when adjacent curbs and gutters are installed as part of GI construction. "Poor" condition is considered to be defects (e.g. cracks, spalling, unevenness/lifting, etc.) covering 50% or more of the area between joints. "Good" condition is considered to defects covering less than 50% of the area between joints.

3.3.2 Sizing of GI Practices

The designer should size GI practices to meet the goals of the NGIP and other regulatory requirements. This section outlines the target water quality volume and other factors that must be considered when designing GI practices.

3.3.2.1 NGIP GI practices should be designed to manage the **NGIP Design Storm**. Guidance on calculating the design storm volume is available in **Section 5.2.**

3.3.2.2 Systems should be sized the maximum contributory drainage area defined in the **NJ Stormwater BMP Manual** or the loading ratio provided in **Section 2**. Guidance on calculating the storage volume is available in **Section 5.3.**

Design Calculations Reference

Calculations for sizing typical GI practices are available in **Chapter 5** of this manual, as well as in Chapters 9 and 10 the **NJ Stormwater BMP Manual**.

3.3.2.3 Depending on the type of system that is being proposed, designers may need to consider the historic **depth of the Seasonal High Water Table (SHWT).** A minimum clearance of 3 feet must be provided between the bottom of an infiltrating practice and the SHWT.

3.3.2.4 When an individual practice is not sufficient for managing the NGIP Design Storm, designers should consider including multiple **GI practices in series.** Guidelines for arranging BMPs in series is available in **Chapter 4** of the **NJ Stormwater BMP Manual**.

3.3.3 Grading Considerations

GI surface features must consider the guidance and design requirements provided below to help reduce erosion and stabilize slopes. Designs should consider the extents of site regrading, minimizing the overall disturbance to the site and the total volumes of excavation required for the practice.

3.3.3.1 The **maximum side slope** for basins is 3H:1V, the recommended side slope is 4H:1V. Shallower slopes, 5H:1V or less, should be used for conveyance channels. Depending on the amount of flow conveyed, additional stabilization measures such as turf reinforcement matting, stone or check dams should be considered.

3.3.3.2 Systems with ponding should be designed with a level bottom of basin. If a longitudinal slope is required for the system, it must include **weirs** or **check dams** to increase storage capacity and reduce erosion within the practice. Small hummocks and micro-topographies within the bottom of the basin are acceptable within larger practices.

3.3.3.3 When a graded system is adjacent to pavement or curbline with parking, a flat-graded shoulder of 12 inches must be maintained. This space reduces the potential for undermining of the adjacent pavement and potential trip hazards and soil disturbance related to people stepping within the practice.

3.3.3.4 Minimize sheet flow into unpaved system footprints. To **prevent erosion** on slopes when a graded system will receive runoff from adjacent surfaces, redirect flow to an inlet with an energy dissipator via curbing, edging or earthen berms.

3.3.4 Conveyance Design

Inlets, pipes and other infrastructure can be used to convey stormwater to and from GI practices. Proper design of the conveyance system is essential for your GI practice's effectiveness. Conveyance systems should be designed following the guidance below to the extent practicable.

3.3.4.1 **Inlets** routed to systems should be placed five feet upstream of existing combined sewer inlets.

Conveyance Design Reference

The **NJDOT Roadway Design Manual**, Section 10, *Drainage,* provides additional requirements and criteria which must be considered when designing conveyance infrastructure.

3.3.4.2 **Pipes** will have a minimum of three feet horizontal and one foot vertical separation from the edge of existing utilities.

Table 3.1 | *Typical Piping Materials*

Material	Application
Ductile Iron (DI)	Roadways, perpendicular to the curbline
High Density Polyethylene (HDPE)	Outside of roadways
Polypropylene Pipe (PP)	Roadways, parallel to the curbline
Polyvinyl Chloride (PVC)	Outside of roadways
Reinforced Concrete Pipe (RCP)	Roadways, perpendicular to the curbline
Vitrified Clay Pipe (VCP)	Tight inlet connections where numerous bends occur

3.3.4.3 Pipes should be designed with a **minimum cover** that meets the current requirements established in the **NJDOT Roadway Design Manual**.

3.3.4.4 Common **piping materials** and their typical uses are provided in ***Table 3.1*** below. Additional guidance and requirements for choosing the appropriate pipe material is available in the **NJDOT Roadway Design Manual**.

3.3.4.5 Solid pipe runs are typically used for conveying water to and from a practice. Perforated pipe runs must be located within a practice and are used to collect (underdrain) or distribute water within a system.

3.3.4.6 Distribution pipes should be designed with a **minimum slope of 1%**. Underdrain pipes should be designed with a minimum slope of 0%.

3.3.4.7 Designers should provide inlets or other collection methods, along with **pretreatment** to reduce sedimentation and trash buildup.

3.3.4.8 Underdrains must be provided for GI practices. **Underdrains** should extend inside the system for at least 20 feet and must have a minimum diameter of six inches, or eight inches in the right of way (ROW). If geotechnical testing during construction shows that infiltration is feasible, underdrains will remain capped unless needed for dewatering purposes

3.3.4.9 **Underdrain connections** should be made to existing inlets or control structures and should always enter structures perpendicular to the structure.

3.3.4.10 Ensure that **subsurface pipes** are protected when planted within the root zone of trees and shrubs.

3.3.4.11 Where a pipe penetrates an impermeable liner (utility crossings, distribution pipes, underdrains, etc.), **boot seals** must be provided.

3.3.4.12 Set **underdrain orifice elevations** at the bottom of stone storage elevation to increase storage capacity within systems that are fully lined with impermeable liner.

3.3.5 Cleanouts and Observation Wells

Cleanouts allow for the removal of sediment, debris and other obstructions that reduce the effectiveness of GI practices. Observation wells are used for monitoring the condition and effectiveness of GI practices. Siting cleanouts and observation wells according to the guidelines below increases their effectiveness and the maintainability of the GI practice.

3.3.5.1 Cleanouts must be provided at ends of pipe runs, spaced evenly over long pipe runs at a minimum interval of every 75 feet, and upstream of complex bends. Every pipe run must be accessible from at least two points.

3.3.5.2 Cleanout sweeps should be directed upstream, except for the most upstream structure which should sweep downstream.

3.3.5.3 To the extent practicable, do not place cleanouts in roadways or parking lanes.

3.3.5.4 When feasible, it is preferred to site cleanout covers in concrete sidewalks instead of roadways or within vegetated areas. Where cleanouts must be placed within vegetated areas, they must be installed with concrete collars and with caps at elevations at least 2 inches above the ponding elevation.

3.3.5.5 GI practices with subsurface storage must include at least one observation well. Larger systems should consider inclusion of multiple observation wells. Observation wells should generally be located at the downstream portion of the system.

3.3.6 Level of Service

Practices designed and constructed as part of NGIP must provide the following level of service.

3.3.6.1 Systems storage should be designed to effectively manage the **NGIP Design Storm**.

3.3.6.2 Overflow and bypass systems must convey stormwater after the primary system has reached its capacity. Systems must provide capacity to **safely convey the 10-year, 24-hour design storm.**

3.3.6.3 Proposed GI systems must not increase or negatively impact flows to the combined sewer system during the 100-year storm.

CONCLUSION OF SECTION 3.3

Design deliverables should be developed in accordance with the above section and submitted to the DWSU Project Manager for NGIP. Design Submission Checklists, which document the required design deliverables for the 30% Conceptual Design, 75% Design, and 100% Design phases, should be used. An example is provided as **Appendix B** to this manual for 75% Design.

3.4 Designing for Maintenance

Projects must be designed and reviewed with maintenance in mind. See **Chapter 7** for additional details about maintaining GI practices. Projects must incorporate a maintenance review during the 75% Design phase. Common maintenance methods, available tools and resources should be considered during design.

3.4.1 Designing for Maintenance Best Practices

The following best practices should be followed to the extent practicable.

3.4.1.1 **Focus maintenance areas** by minimizing the number of individual systems, inflow points and pipe runs to the extent practicable.

3.4.1.2 Minimize sheet flow into systems by providing **concentrated inflow points,** level-spreaders and energy dissipators.

3.4.1.3 Prevent sediment and debris from entering the system by incorporating intentional and easily cleanable **pre-treatment** and sedimentation features at system inflows.

3.4.1.4 Include a **12-inch minimum sump** in inlets, and junction structures to allow for ease of collection of sediment and debris.

3.4.1.5 Where feasible, inlets should include a **sediment trap or hood** to reduce sediment and debris from entering the GI practice.

3.4.1.6 Consider existing **snow plowing and piling practices** for GI practices located within parking lots and design layouts to prevent piling of snow at inlets or within practice footprints. For systems in the ROW, incorporate visual cues for snowplows.

3.4.2 Maintenance Access

Planning for regular maintenance access ensures that maintenance crews can safely and efficiently manage the practice post-construction.

3.4.2.1 Design sumped maintenance ports to be accessible to maintenance vehicles. Vactor truck booms typically extend a maximum of 30 feet. **Vactor trucks** require an area 35 feet long, 12 feet wide, and with a vertical clearance of 12 feet, and require H-20 loading. Where vehicle parking is expected in grass areas, reinforced access pads must be provided at least 5 feet away from slopes.

3.4.2.2 Consider personnel **access to maintenance** features. Propose mulched areas or appropriate plant material (i.e., low ground cover) around maintenance features to help personnel identify and access maintenance features during the growing season. Minimize personnel movements along steep areas, particularly within flow paths.

Maintenance Requirements Reference

Typical maintenance requirements are included in **Chapter 7**. See **Section 7.3** for information regarding development of a maintenance plan.

CONCLUSION OF SECTION 3.4

Long term maintenance concerns for GI practices must be considered during the design phase. Following established best practices and providing adequate maintenance access ensures that GI practices will function properly. Additional guidance on GI inspections and maintenance is available in **Chapter 7**.

3.5 Design Impacts

3.5.1 Regulatory Compliance

GI practices installed in the City are subject to local, state, and federal regulations. ***Table 3.2*** includes regulations that are commonly applicable to GI projects. This list is non-exhaustive; it is the responsibility of the designer to contact the appropriate agency to confirm applicability or resolve compliance questions. Additionally, approvals and permits may also differ based on project funding including New Jersey Water Bank funding.

Table 3.2 | *Potential Agency Approvals and Permits Required*

Agency	Certification or Permit	Applicability
City of Newark Department of Water and Sewer Utilities	Sewer Connection	New sewer service connection to City sewer, or any work that directly or indirectly affects public sewer system.
City of Newark Department of Engineering	Street and/or Sidewalk Opening, Occupancy and Construction[1]	Geotechnical explorations and construction.
City of Newark Department of Public Works	Tree Trimming	For tree trimming/pruning, or any alteration to existing trees. May be required for site access during construction.
City of Newark Department of Public Works	Tree Planting	Required for new trees in the City's ROW or parks.
Hudson Essex Passaic Soil Conservation District	Soil Erosion and Sediment Control	Total amount of soil disturbance greater than 5,000 square feet.
New Jersey Department of Environmental Protection	National Pollutant Discharge Elimination System Construction Activity Stormwater General Permit	Construction activities that disturb one acre or more of land.
New Jersey Department of Transportation	Highway Occupancy	Geotechnical explorations and installation or construction of items in the state ROW.

[1] Street and/or sidewalk opening, occupancy and construction may also require onsite Police observation.

CONCLUSION OF SECTION 3.5

The specific timing for seeking permits can vary depending on the complexity and scope of your project. As a general guideline, it is advisable to begin the permit application process after the approval of your 75% Design. Additional coordination may be required for some projects. Discuss the permitting and approvals process with your DWSU Project Manager for further guidance or lessons learned.

4 Practice-Specific Design Considerations

4.1 Summary of Chapter

In addition to the general siting considerations discussed in **Chapter 2**, and the design guidelines established in **Chapter 3**, several GI practices require unique consideration in their siting, sizing, or design. Additional guidance and references for planting design, pervious paving systems, cisterns, and green roofs will be provided in this chapter.

This chapter will help designers:

- Develop planting plans.
- Design maintainable pervious paving GI practices.
- Understand best practices for cistern GI practices.
- Identify the City of Newark and State of New Jersey standards and requirements associated with green roof design.

GI Practice Types Reference

For detailed descriptions of various GI practice types and disconnection strategies see **Green Infrastructure Guidance Manual for New Jersey**, Rutgers University, Chapter 2, *Green Infrastructure Practices,* or **NJ Stormwater Best Management Practices (BMP) Manual**, NJ Department of Environmental Protection (NJDEP), Chapters 9 and 10.

4.2 Planting Design

Planting plays an important role in both the performance and perceptions of GI practices. The following guidelines should be considered when designing GI practices.

4.2.1 Vegetated Systems

Unpaved components of GI practices, such as rain gardens, stormwater planters and adjacent upland areas that drain onto GI practices, require a planting design. The following section provides guidance on plant selection, placement and reference to other guidelines that should be considered when designing GI practices with vegetation.

Planting Design Reference

Detailed landscaping requirements are provided in Chapter 7 of the **NJ Stormwater BMP Manual**. Additional practice type-specific landscaping information is included in Chapters 9 and 10 of the same manual.

4.2.1.1 When feasible, designers should select **native species** compatible with urban environments to reduce long-term maintenance needs.

4.2.1.2 Planting selections should be known to thrive in the appropriate USDA Hardiness Zone as per the USDA Plant Hardiness Zone Map. **USDA Hardiness Zone 7B** applies for most of the City.

4.2.1.3 Consider **unique site conditions** such as required sightlines, pedestrian desire lines, wet/dry tolerance, potential for road salt and sun exposure when selecting plantings.

4.2.1.4 In flow channels and sloped areas, select species with **deep root systems** that provide stabilization.

4.2.1.5 Include appropriate **mulch**, typically shredded hardwood bark for trees and shrubs or straw for seeded areas, to help stabilize soil and regulate moisture within planting beds.

4.2.1.6 When practicable, design **seeded GI practices** that allow for flow to be diverted from the practice until seeded areas are stabilized.

4.2.1.7 Ensure adequate foot and vehicular **maintenance access** is provided and is not blocked by proposed plantings.

4.2.2 Trees

Enhanced tree pits, rain gardens and other GI practices may include a proposed tree as part of the design. The following section provides guidance and best practices on selecting and siting trees that are appropriate for site conditions.

4.2.2.1 Maximize available soil volume for trees according to species size; **minimum planting pit size** should be 50 square feet. Design should consider the inclusion of suspended pavements, structural cells and structural soils where appropriate; trees without the appropriate available soil volume are more likely to disrupt adjacent paved areas.

4.2.2.2 Be aware of existing **overhead wires and utilities** when selecting potential tree species. In areas with overhead conflicts, smaller species should be selected.

4.2.2.3 Do not select trees that are known to have **long taproots** within the vicinity of side slopes or subsurface drainage facilities.

4.2.2.4 Ensure that **subsurface pipes** are protected when planted within the root zone of trees and shrubs.

4.2.2.5 Ensure trees are properly installed and stabilized if planting on **steep slopes.** Do not plant trees on slopes greater than 3:1.

Tree Pit Reference

Additional guidance on the placement of trees within tree pits is provided in the **Green Infrastructure Guidance Manual for New Jersey**.

CONCLUSION OF SECTION 4.2

Design deliverables should be developed in accordance with the above section for submittal to DWSU. In accordance with the Design Submission Checklists included as **Appendix B** to this manual, proposed plans defined by distinct hatch areas and associated plant community reference descriptions must be provided at 30% Design, and detailed proposed planting plans must be provided at 75% and 100% Design milestones.

4.3 Pervious Paving Systems

Pervious paving systems are GI practices that consist of a permeable surface course that allows stormwater runoff to move through it. The surface course is constructed over a transition layer and a storage bed of open-graded aggregate. This section provides guidance, references and best practices that must be considered when designing pervious paving systems.

4.3.1 Pervious Paving Systems Best Practices

In addition to the siting and design guidance provided in **Chapters 2 and 3**, the following best practices should be followed to the extent practicable when designing pervious paving systems. The information below describes different types of permeable pavement systems, highlights key minimum requirements and articulates some of the unique factors that must be taken into consideration when designing pervious paving systems.

4.3.1.1 **Porous asphalt, pervious concrete and permeable interlocking paver units** are all acceptable types of pervious paving system surface courses.

4.3.1.2 Pervious paving surface courses must have a **minimum infiltration rate** of 6.4 inches per hour.

Pervious Paving System Requirements Reference

Additional information on the requirements of different pervious paving system types such as minimum porosity, installation and curing requirements can be found in Chapter 9.6 of the **NJ Stormwater BMP Manual**.

4.3.1.3 It may be necessary to provide **signage** for pervious paving systems because they look similar to traditional paving. Providing signage can help prevent improper vehicle loading.

4.3.1.4 Design plans must include a **grade-separated area** that is designated for stockpiling snow and ice separate from the pervious paving system.

4.3.1.5 Avoid placing systems in **commercial or industrial areas** where there is potential for groundwater contamination or turning / stopping movements of heavy vehicles may cause rutting or displacement of the permeable surface.

4.3.1.6 Pervious Paving are susceptible to decreased functionality as **sediment clogs surfaces** and limits the ability of stormwater to infiltrate. Siting of practices should carefully consider surrounding uses, along with the potential for surface water flows to carry sediment loads. Practices should be placed to capture runoff from surrounding paved areas or roofs, avoiding runoff from unpaved surfaces.

4.3.1.7 It is recommended that the **tributary drainage area is not greater than three times the area occupied by pervious asphalt.** A ratio of 1:2 or lower is recommended for permeable concrete and asphalt, and 1:1 for permeable pavers, to extend the functionality and reduce the maintenance frequency of the permeable pavement.

4.3.1.8 Strict quality control requirements should be included in construction specifications when cast-in-place porous paving systems are used.

Maintenance Requirements Reference

Maintenance of permeable pavement requires specialized equipment and access, which should be considered during design and on the maintenance plan (see **Section 7.3**).

CONCLUSION OF SECTION 4.3

Design deliverables should be developed in accordance with the above section and submitted to the DWSU project manager. Additional coordination with City of Newark Department of Engineering may be required depending on your site.

4.4 Cisterns

Cisterns are stormwater practices that store stormwater runoff from clean rooftops that can then be reused for non-potable uses. By capturing and reusing stormwater, cisterns reduce the amount of runoff that flows into downstream facilities.

Cistern Design Stormwater Requirements Reference

Additional information on the stormwater management requirements associated with cisterns can be found in Chapter 9.1 of the NJ Stormwater BMP Manual.

4.4.1 Cistern Sizing Requirements

Cisterns have unique sizing requirements, that differ from other GI practices. The following section provides an overview of some of the design requirements that designers must keep in mind when proposing a stormwater cistern, as well as references to other codes and guidelines that must be taken into consideration.

4.4.1.1 Cisterns do not significantly improve stormwater runoff quality but can be used to manage **stormwater runoff quantity.**

4.4.1.2 Cisterns must be emptied of standing water within 72 hours of a rain event. This **minimum drain down time** allows for sufficient storage for the next rain event, and prevents anaerobic conditions, odor, and mosquito breeding. Cisterns can be emptied manually, or through the use of smart devices.

4.4.1.3 Cisterns are a stormwater management choice for sites with demand for stormwater reuse. Cisterns must be designed for the site's **water reuse demand**. If the lowest 3-day volume needed is insufficient to empty a cistern sized for the NGIP Design Storm, but demand is greater on other days, a secondary storage tank must be used.

Cistern Analysis Reference

Developed as a supplement to the NJ Stormwater BMP Manual, NJDEP has provided a **Cistern Analysis Spreadsheet** that can be used to calculate the water reuse demand for your site.

4.4.1.4 Captured stormwater can be reused for **non-potable purposes.** Some typical uses include irrigation and watering non-edible plants, toilet flushing and vehicle washing. Stormwater reuse must comply with state and local building requirements and regulations.

Plumbing Code and City of Newark Water Rules and Regulations Reference

This section does not directly address plumbing codes. Designers and reviewers should consult with the **New Jersey Plumbing Code N.J.A.C. 5.23-3.15** and the **City of Newark Zoning and Land Use Regulations**.

CONCLUSION OF SECTION 4.4

Coordinate with your DWSU project manager to ensure that you are providing the required design deliverable for a stormwater cistern. Design deliverables should be developed in accordance with the above section and in compliance with the codes and guidelines referenced above.

4.5 Green Roofs

Green roofs, or vegetated roofs, are stormwater BMPs that are covered with a growing medium and vegetation on top of a drainage layer. The green roof system intercepts and reduces the total volume of runoff through evapotranspiration.

4.5.1 Green Roof Design Requirements

Green roofs have unique structural, stormwater, and landscape architectural design requirements. The following section provides reference to codes and design guidelines that must be adhered to when designing a green roof in Newark.

4.5.1.1 As one of the more costly GI options available, green roofs are often used on sites where there is **little space available at the ground level or subsurface** or where roofs make up most of the impervious area.

4.5.1.2 Green roofs do not provide an environment where all plant species can thrive. When selecting **plantings** for a green roof, it is most important to choose plantings that have the highest prospect of establishing a healthy plant community.

Green Roof Stormwater Requirements Reference

Location, roof slope, loading capacity, and many other factors must be considered when designing a green roof. See Chapter 9.4 of the **NJ Stormwater BMP Manual** for additional information on the stormwater management requirements associated with green roof systems.

Green Roof Plant Species Reference

Although not all of the species shown in the **City of New York's Green Roof Species List** are native to New Jersey, they may still be considered when choosing a planting palette for a green roof.

4.5.1.3 Green roofs can add substantial weight to a structure. **Structures supporting green roofs** must be analyzed to ensure that they can handle the associated dead and live loads of a green roof.

4.5.1.4 **Blue roof systems**, which do not include plantings, provide stormwater detention benefits but are not considered GI in the state of New Jersey.

City and State Building Codes Reference

The structural loading capacity of the roof must be analyzed when designing a green roof. Designers must ensure that green roofs are in compliance with the requirements described in local and state building codes, including the **City of Newark Building Code**.

CONCLUSION OF SECTION 4.5

Completion of punch list items, final stabilization, and post-construction testing are important items that need to be completed prior to final acceptance. Additionally, the completion of record drawings is crucial for DWSU to have accurate records for the GI installation.

5 Calculations

5.1 Summary of Chapter

This chapter supplements **Chapters 2, 3** and **4** by providing more detail on calculation methods discussed in the manual.

This section includes calculations that will help designers:

- Determine the amount of volume that must be managed by a green infrastructure (GI) practice (see **Section 5.2**).
- Determining the volume provided by the identified GI practice type and sizing (see **Section 5.3**).
- Calculate drain down for infiltrating and detention systems (see **Section 5.4**).
- Design of conveyance infrastructure for GI practices (see **Section 5.5**).

There are many software packages readily available that perform hydraulic and hydrologic (H&H) calculations. The City of Newark's (City's) preferred software is **HydroCAD**; however, a designer may use other H&H modeling applications to perform the calculations.

HydroCAD for Stormwater Design

HydroCAD, by **HydroCAD Software Solutions LLC**, is a Windows-based program for hydrology and hydraulics of stormwater runoff. HydroCAD uses USDA Natural Resource Conservation Service (NRCS) methodologies, as well as offering other standardly used calculation methods, to produce runoff volumes, develop hydrographs, calculate time of concentration, perform routing calculations and more. **HydroCAD requires a paid license to run.**

For detailed use of HydroCAD and explanation of calculations, see the HydroCAD Reference Manual.

5.2 Design Storm Volume

As discussed in **Chapters 2** and **3**, GI practices should be sized to manage the volume of runoff associated with the rainfall depth needed to meet long term control plan (LTCP) requirements. In the case of Newark, this rainfall depth was determined to be 1.25 inches.

There are two primary methods for calculating the design storm volume: USDA NRCS Runoff Curve Number (CN) Method and the Modified Rational Method. NRCS methodology is required by the New Jersey Stormwater Management rules.

New Jersey Administrative Code (NJAC) Stormwater Management Rules Reference

Stormwater Management rules in N.J.A.C. 7:8 specify stormwater management standards that are mandatory for new major development resulting in the disturbance of 1 or more acres.

NRCS Runoff CN Method Reference

NRCS Runoff CN methodology is fully described in **NRCS Technical Release 55 (TR-55) – Urban Hydrology for Small Watersheds** and **Part 630 of the National Engineering Handbook (NEH)**, USDA, Chapter 4.

5.2.1 NRCS Methodology Overview

NRCS TR-55 methodology is one of the most widely used methods for computing stormwater runoff volumes, rates, and hydrographs. It uses a hypothetical design storm, curve number (CN) and a nonlinear runoff equation to calculate runoff.

EQN 5.1 NRCS methodology equation

$V = Q \times A$

Where

$V = runoff\ volume\ (acre - in)$

$Q = runoff\ depth\ (in)$

$A = tributary\ area\ (acres)$

$$Q = \frac{(P - 0.2s)^2}{(P + 0.8s)}$$

Where

$P = Precipitation\ (in)$
$(1.25 in\ for\ NGIP\ Design\ Storm)$

$S = maximum\ potential\ soil\ moisture\ rectition$

$$= \frac{1000}{CN} - 10$$

$CN = NRCS\ CURVE\ NUMBER$

5.2.1.1 CN table is in TR-55 and is also included within HydroCAD.

5.2.1.2 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.

5.2.1.3 Although most GI practices do not manage an area this large, NRCS methodology is not recommended for any drainage area that exceeds 20 square miles.

5.2.2 Steps for Subcatchment Calculations using NRCS Runoff Method in HydroCAD

HydroCAD offers multiple runoff methods, including **SCS TR-20**. TR-20 is an NRCS software developed for hydrology modeling and uses the TR-55 calculations. The general steps to develop runoff volume, peak runoff rate and hydrographs using **subcatchments** in HydroCAD are described below.

5.2.2.1 **Define area:** add subcatchment and specify area based on impervious tributary drainage area identified in **Section 2.4**.

5.2.2.2 **Define CN:** select appropriate CN for impervious drainage area based on NRCS CN table based on land use and soil type.

5.2.2.3 **Define time of concentration (Tc):** for larger drainage areas, several Tc calculation methodologies are provided in HydroCAD (TR-55 sheet flow, TR-55 shallow concentrated flow, channel flow and upland method). For small drainage areas (< 10,000 square feet), the minimum time of concentration is 6 minutes.

5.2.2.4 Define Rainfall depth and Distribution: the NJ Department of Environmental Protection (NJDEP) two-hour event is built into the HydroCAD software as a selection under rainfall storm types.

CONCLUSION OF SECTION 5.2

This section explained how to use NRCS methodology to calculate design storm volume. At completion of calculations, user should have a runoff volume and peak flow rate for the proposed practice.

5.3 GI Practice Sizing & Storage

After calculating the required storage volume from the NGIP Design Storm (see **Section 5.2**), it is important to next calculate the storage capacity provided by the proposed GI practice based on footprint and porosity of materials. The loading ratio should also be calculated to ensure maximum loading ratio is not exceeded (see **Section 2.5.1.1**).

5.3.1 Storage Capacity

In order to estimate storage capacity, a typical cross-section should be developed for each GI footprint. The storage capacity can be calculated as the sum of the surface ponding volume, the storage volume and the void storage volume for each porous material layer.

EQN 5.2 GI Storage Capacity

$$GI\ Capacity = V_{Ponding} + V_{storage} + \sum(\varphi_{media} \times V_{media})$$

$Where$

$V = Volume$

$n = Porosity$

5.3.1.1 Depths of each layer should be developed and compared to **footprint areas at each material or elevation change.** Porosity values are provided in ***Table 2.2***.

5.3.1.2 Using GI footprint area and appropriate porosity value, a storage volume can be calculated for each section of the practice, then summed using the equation above to determine the **overall GI practice storage.**

5.3.2 Steps for Defining Storage Capacity in HydroCAD

Storage capacity can be calculated in HydroCAD through the use of pond nodes. Exact steps may vary on GI practice type and site-specific needs, but in general the following steps should be followed.

5.3.2.1 Set the pond type to **detention pond** to enable storage.

5.3.2.2 Select **new storage type** based on shape of proposed detention. If storage has no variation in porosity, one of the **predetermined shapes** may be selected, otherwise choose **custom stage data.**

5.3.2.3 Prefabricated chamber storage options are available for a variety of manufacturers and storage models and can be added within ponds**.**

5.3.2.4 If materials and porosity vary at different layers, **custom stage data** must be selected. At each elevation, storage information can be entered as surface area (storage shape must be selected), incremental storage or cumulative storage. Also define **stage voids** at each elevation stage as a percentage**.**

5.3.3 Loading Ratio

Loading ratio is calculated as the tributary impervious drainage area (see **Section 2.4**) compared to the GI practice vegetated footprint, infiltration footprint or bottom footprint for non-infiltrating layers.

EQN 5.3 Orifice equation for circular submerged, static head calculations:

$$Loading\ Ratio = \frac{Tributary\ Impervious\ area\ (ft^2)}{GI\ practice\ footprint\ (ft^2)}$$

5.3.3.1 The infiltration footprint is the area where infiltration will occur within a system. This excludes any part of the storage that is lined with an impermeable liner.

5.3.3.2 Loading ratio should not exceed threshold of **10:1 for underground systems, 3:1 for permeable pavement** and **25:1 for vegetated systems.**

5.3.3.3 For GI practices that have both vegetated and infiltration footprints that differ, or tributary drainage areas that contribute to different footprints, **each loading ratio should be assessed independently.**

5.4 Drain Down Mechanisms

Equations to calculate drainage time for infiltration and underdrains are described below. Maximum allowable surface ponding duration is 24 hours (see **Section 3.3.1.8**) and maximum allowable storage drain time is 72 hours.

5.4.1 Detention Underdrain

Underdrains are used to convey flow from detention GI practices to existing stormwater systems. The orifice equation should be used to calculate flow through underdrains, discharging freely into the atmosphere.

EQN 5.4 Orifice equation for circular submerged, static head calculations:

$$Q = C_d\, a\sqrt{2gh}$$

$Where$

$C_d = Discharge\ coefficient$

$a = Submerged\ area$

$g = Gravitational\ constant$

$h = Effective\ head (HW - TW)$

5.4.1.1 The orifice equation should be used for submerged, static head calculations. For static head estimates, use the maximum hydraulic head associated with the GI capacity to calculate the orifice size needed to achieve a **drain down time between 24 and 72 hours,** and a maximum surface drain down time of 24 hours.

5.4.1.2 For **discharge coefficient,** values can range between 0.5 and 1.0, a **typical value of 0.6** is recommended.

5.4.1.3 For dynamic head calculations, the use of HydroCAD is recommended. Using hydraulic software, route the water quality volume through the basin to verify the actual storage volume used and the drawdown time.

5.4.2 Infiltration

When deemed appropriate based on soil conditions, infiltration can be used to drain storage. The following equation for infiltration time should be used to calculate drainage time of infiltration systems. Unless otherwise directed, the assumption is that all practice types will be sized and designed for detention (not infiltration) and that underdrains and liners can be removed from the design if soil tests during construction indicate that infiltration is appropriate.

EQN 5.5 Infiltration time

$$t = \frac{\left(\frac{V}{A_i}\right)}{i} \times 12$$

$Where$

$t = Time(hrs)$

$V = Storage\ Volume(cf)$

$A_i = Infiltration\ Footprint(sf)$

$i = Infiltration\ Rate(in/hr)$

5.4.2.1 Maximum storage volume (V) and the infiltration footprint (Ai) (see **Section 5.3.1.1**) should be used.

5.4.2.2 During design, soil infiltration rates should be determined from NRCS Web Soil Survey (see **Chapter 2**). Infiltration rates will be confirmed by geotechnical testing during the construction phase (see **Chapter 6**).

5.4.2.3 Maximum allowable **surface ponding duration** is **24 hours** and maximum allowable **storage drain time** is **72 hours** (see **Section 3.3.1.8**).

5.4.3 Steps for Drain Down Calculations in HydroCAD

After defining subcatchment parameters (see **Section 5.2.2**) and pond characteristics (**Section 5.3.2**), pond outlet information can be populated to confirm drain down time. It is most common for drain down to be calculated through orifices or as infiltration, though HydroCAD provides additional options as needed.

5.4.3.1 For slow-release systems, select **Orifice/Grate** as a new outlet device under the outlets tab of the pond editor. Provide invert elevation, orifice dimensions and discharge coefficient.

5.4.3.2 For infiltration systems, select **Exfiltration** as a new outlet device under the outlets tab of the pond editor. Provide invert elevation and infiltration rate.

5.4.3.3 After the model runs, storage can be viewed in the pond hydrograph tab to determine time after the end of the storm event that the pond reaches zero acre-feet of storage.

CONCLUSION OF SECTION 5.4

This section includes information on how to calculate drain down time for GI practices designed with infiltration and underdrain drain down mechanisms.

5.5 Conveyance Design

Overflow mechanisms should be included for flow to bypass the system when it has reached its designed capacity in order to protect the GI system and avoid worsening flooding conditions for larger events. Systems must provide capacity to **safely convey the 10-year, 24-hour design storm** (see **Section 3.3.6**).

5.5.1 Rainfall Depth for Design Storms

For major developments, New Jersey Stormwater Management rules require compliance with standards for the "current storm event" and the "projected storm event", which considers impacts of climate change. City GI projects will comply with this standard as well.

5.5.1.1 For the current storm event, the Stormwater Management rules require the use of National Oceanographic and Atmospheric Administration (NOAA), National Weather Service's (NWS) Atlas 14 Point Precipitation Frequency Estimates.

NOAA Atlas 14 Precipitation Frequency Atlas Reference

NOAA Atlas 14 rainfall data is provided by the NWS **Precipitation Frequency Data Server** (PFDS). Using location coordinates or address, select location of the proposed GI practice and determine the inches of precipitation for the 10-year average recurrence, 24-hour interval from the tabular point precipitation frequency estimates.

Future precipitation change factors can be found in ***Table 5-6*** in N.J.A.C. 7:8.

5.5.1.2 For the projected storm event, NOAA Atlas 14 Rainfall Depth is modified by multiplication with a future precipitation change factor, which project the precipitation depth for the time period from 2050 to 2099. For Essex County, the **2-, 10-, and 100-year** change factors are **1.19, 1.22, and 1.33**, respectively.

5.5.2 Pipe Flow

The Manning Equation is the most commonly used method for calculating flow in a full pipe. Manning's equation is a steady, uniform flow equation.

EQN 5.6 Manning's Equation

$$Q = \frac{1.486}{n} A - R^{2/3} \times S^{1/2}$$

$Where$

$n = manning's\ roughness\ coefficient$

$A = area\ of\ flow\ (ft^2)$

$R = hydraulic\ radius = \frac{A}{P}(ft)$

$P = wetled\ perimeter\ (ft)$

$S = Slope\ of\ hydraulic\ grade\ line\ (\frac{ft}{ft})$

5.5.2.1 Manning's roughness coefficient can be found in **HydroCAD Reference Manual** Appendix C or obtained from standard textbooks such as Open Channel Hydraulics or Handbook of Hydraulics.

5.5.3 Weir Flow

Weir equation should be used when diverting flow over an overflow weir.

EQN 5.7 Weir equation

$$Q = Cw \times L \times h^{3/2}$$

Where

$Q = weir\ flow\ (cfs)$

$Cw = weir\ coefficient$

$L = length\ of\ weir\ crest\ (ft)$

$h = head\ of\ flow\ over\ weir\ (ft)$

5.5.4 Inlet Capture

Inlets are entry points for stormwater runoff to enter GI systems. This section includes information to support inlet design as discussed in **Section 3.3.4.**

Calculation Methodology Reference

The City recommends using calculation methodology outlined in the **Federal Highway Administration (FHWA) Hydraulic Engineering Circular No. 22** (HEC-22). The basic methodology used in HEC-22 is summarized here; details and examples are provided in **HEC-22.**

5.5.4.1 Grated inlets refer to inlets located along the curbline where stormwater drops into the inlet from the gutter. A grate inlet operates as a weir at the perimeter of the grate.

5.5.4.2 Curb-opening inlets, such as trench drains back of curb inlets, are those where stormwater is directed to a vertical opening. Some curb-opening inlets can have a local depression, where the inlet is lower than curb elevations on either side. For non-depressed inlets with a uniform gutter, the length of the curb opening acts as a weir. For depressed inlets, the length of the curb plus some of the lateral width of the depression act as a weir.

5.5.4.3 Inlets with grates should assume only half of the opening is available for conveyance due to debris or organic material, therefore a **clogging factor of 0.5** is applied to the weir equation.

CONCLUSION OF SECTION 5.5

At the end of this section, user should be able to understand and use weir and pipe flow calculations for overflow and bypass design of GI practices, and understand the use of HEC-22 methodology for flow capacity of inlets for both open and grated inlets. Determining the proper inlet sizing may require iteration.

6 Construction

6.1 Summary of Chapter

Although construction of green infrastructure (GI) uses many concepts designers and contractors may be familiar with from other types of projects, there are some nuances that are important to understand for GI to function as designed. It is important that designers consider constructability in their plans and contractors understand the reasons behind GI design.

This chapter will help project teams:

- Understand the bidding solicitation and evaluation process.
- Recognize the interplay between design and construction of GI practices.
- Inform construction best practices and inspection procedures and protocols.
- Determine proper check-in points and testing requirements during construction.
- Understand roles during construction.

While this chapter provides useful information for construction, no information within this manual is meant to replace or override information present in site-specific contract documents including specifications.

Construction Details and Specifications Reference

GI should follow current New Jersey Department of Transportation (NJDOT) Standard Specifications for Road and Bridge Construction and NJDOT Standard Construction Details.

Designers should check with the **City of Newark's Department of Water and Sewer Utilities (DWSU)** for other applicable specifications and details specific to GI.

Chapter 9 of the New Jersey Stormwater Best Management Practices Manual provides Construction Requirements for individual GI practice types.

6.2 Bid Period and Evaluation

Following design approval, the Engineer alongside DWSU compiles a project bid package including Contract Documents to convey details of GI construction to Contractors. The City of Newark (City) is transitioning from receiving paper bids and responses to a fully electronic procurement system; bidders should reference bid advertisement information to determine how to access bid packages and submit bids. Once the bid period closes, received bids will be evaluated and the contract will be awarded. **All bidding requirements should follow the City of Newark's Procurement Guidelines, unless otherwise noted in the Bid Documents.**

6.2.1 Bid Period

DWSU will issue a bid advertisement via the Star Ledger and/or other newspaper or online publication. Bid advertisements will also be available online at [Procurement Portal].

6.2.1.1 The bid advertisement will provide instructions to view and obtain copies of the Bid Documents. These documents will include drawings and specifications for the project.

6.2.1.2 As applicable, the Bid documents will include pre-bid meeting information. It will detail if a pre-bid meeting is being conducted and if it is mandatory.

6.2.1.3 All questions about the meaning or intent of the Contract Documents shall be received in writing by the Engineer at least ten (10) days (Saturdays, Sundays and legal holidays excluded) before the date set for the opening of bids. No oral answers will be given to any inquiries regarding the intent or meaning of the Contract Documents.

6.2.1.4 Bids will need to be submitted prior to the due date noted in the advertisement.

6.2.1.5 Each bid will need to be submitted in accordance with the Instructions to Bidders and be accompanied by a Bid Security in the form of a bid bond, cashier's check, or a certified check made payable to the City of Newark in an amount equal to ten percent (10%) of the amount of the total bid, but not in excess of $20,000.00.

6.2.1.6 Received bids will be opened publicly at the date, time and location noted in the Bid Documents. A virtual option may be provided.

6.2.2 Bid Evaluation and Award

Received bids will be evaluated by DWSU and the Engineer.

6.2.2.1 Received bids will be evaluated to verify unit price calculations within each bid, compliance with any requirements outlined in the Bid Documents, and consistency with the City's Bid Document Submission Checklist.

6.2.2.2 The City's Affirmative Action requirements for minimum minority business enterprise (MBE)/ women's business enterprise (WBE) participation and/or additional socially and economically disadvantaged (SED) small business requirements may apply dependent on project funding.

6.2.2.3 If all calculations are verified and all bids meet the bid requirements, DWSU will award the contract to the lowest responsive or responsible bidder.

DWSU Bid Portal Reference

DWSU bids are available on the City of Newark E-Procurement Portal.

CONCLUSION OF SECTION 6.2

The bid period and evaluation process will vary slightly depending on the project. The Bid Documents for a specific project are the best resource for this information.

6.3 Roles in Construction and Inspection

Prior to beginning construction, the project team should understand who will be performing construction administration (CA), construction inspections, environmental inspections, engineering reviews and approvals and compliance with funding requirements, as applicable. As the owner, DWSU will identify these roles and responsibilities in-house or appoint an Owner's Representative and clearly communicate this information during the Pre-Construction Meeting. The contractor will need to closely coordinate with the person assigned the CA role.

6.3.1 Pre-Construction Meeting

A Pre-Construction Meeting should be held prior to the start of construction. This meeting is conducted by the Owner or Owner's Representative and is often held prior to issuing a Notice-to-Proceed to the selected Contractor. A separate Pre-Construction Meeting may also be required by the New Jersey Department of Environmental Protection (NJDEP) if New Jersey Water Bank funding is used for the project.

6.3.1.1 All stakeholders should be present at this meeting, including DWSU, the engineer-of-record, Contractor and those responsible for the other roles identified above. Depending on the location and scope of the project the meeting may also need to include property owners, other departments within the City or others, and a site visit may be recommended following the meeting.

6.3.1.2 The Contractor should discuss their access plans to and from the site, along with means for delivering and storing materials and removing waste. They should show that all the activities on site fall within the limits of disturbance associated with the project. These plans should comply with any permits received for the project.

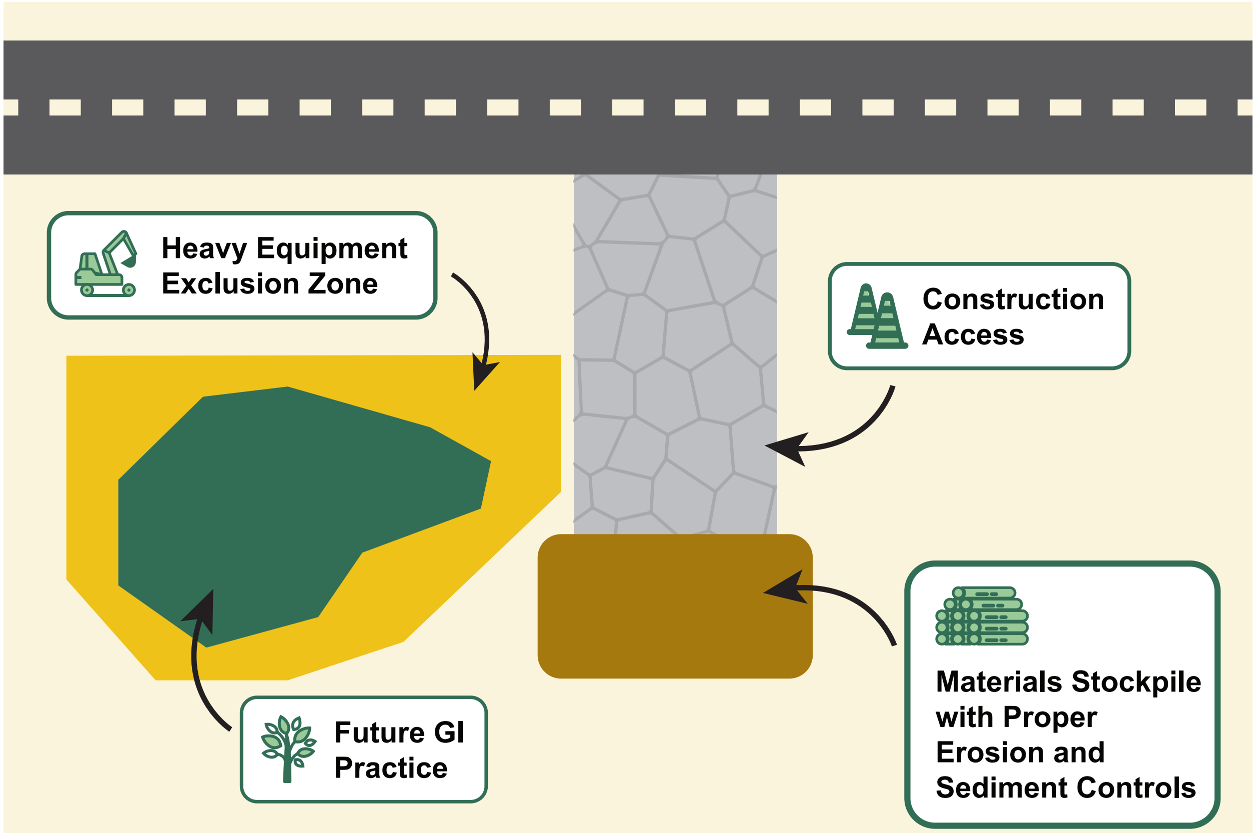
6.3.1.3 There are a few GI-specific items to be covered during the meeting that are unique to, or play a greater role in, GI projects. These items include:

- Confirmation of hydraulic elevations.
- Maintenance of pedestrian and vehicular traffic during construction, and signage, as needed.
- Dewatering and outflow considerations.
- Erosion and sediment control around GI.
- GI-specific inspection hold points and acceptance/testing requirements.
- Impact of compacted media and heavy equipment exclusion zones, see ***Figure 6.1***.

6.3.1.4 The proposed project schedule should be discussed, including recommended construction paving and planting periods.

6.3.1.5 No work should begin until all parties agree on the proposed coordination methods discussed at the Pre-Construction Meeting.

Figure 6.1 | *Heavy Equipment Exclusion Zones*



National Green Infrastructure Certification Program Reference

The National Green Infrastructure Certification Program (NGICP) provides base-level skills necessary for entry-level workers to properly construct, inspect and maintain GI. Several Newark residents have obtained this certification. Other interested local residents and laborers can learn more at NGICP - EnviroCert.

DWSU, in collaboration with the Newark Workforce Development Board, NewarkDIG, Rutgers University and its design consultants are developing construction roles to promote GI jobs for local residents and using training programs such as NGICP and the City's on-the-job training programs to connect local residents with the pipeline of GI construction projects anticipated. DWSU should be contacted to learn more about contractor requirements and training programs as these are developed.

6.3.2 Construction Administration

CA services will be performed by the Engineer or Owner's Representative.

6.3.2.1 CA services include reviewing submittals, responding to Requests for Information (RFIs), confirming payment applications, monthly progress report and meeting reviews, and coordinating with the Contractor and Owner regarding any change orders.

6.3.2.2 A CA process chart is included as **Appendix C** to this manual.

6.3.3 Construction Inspection

Construction inspections are needed to verify that installed GI components meet specified requirements, allowing the GI practice to function as designed.

6.3.3.1 An Owner's Representative should be onsite to observe construction, provide oversight and confirm that the specifications and industry standards noted in **Section 6.4** or Contract Documents are being followed. It is important that the Owner's Representative be in close communication with both the Owner and Contractor throughout the project. An additional DWSU-appointed Environmental Inspector may also be required, dependent on project funding.

6.3.3.2 Inspection hold points will be used at critical junctures to confirm that GI components are installed as designed. Inspection hold points serve as a checkpoint for construction, requiring approval from the Owner's Representative before any subsequent construction activities can commence.

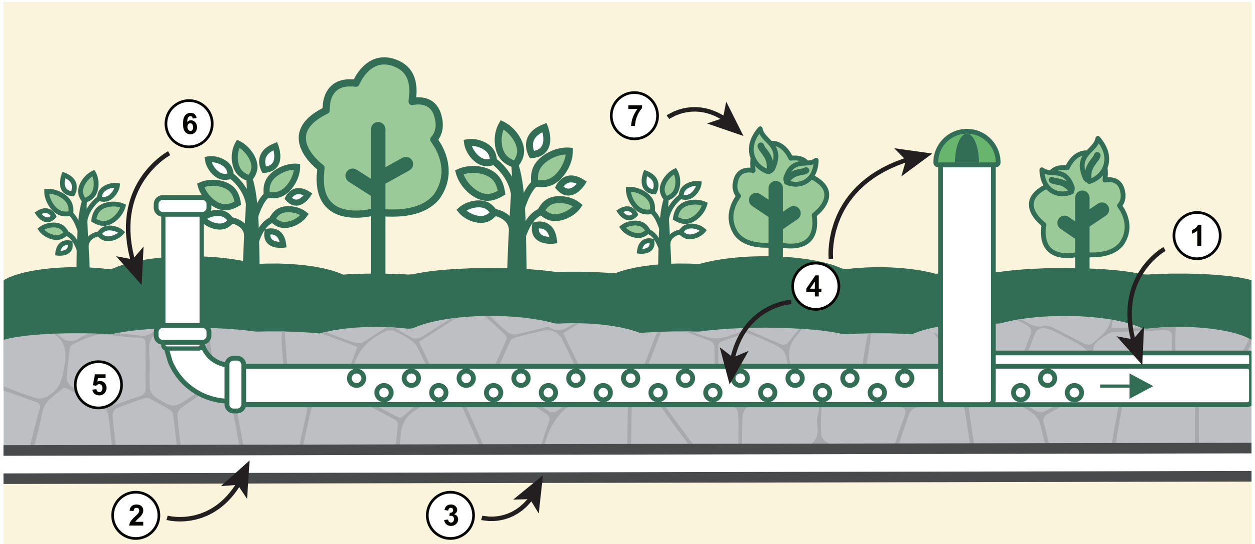
6.3.3.3 Contractor will be responsible for providing Owner with certified reports for any structural or geotechnical third-party inspections conducted, if required by the Contract Documents.

6.3.3.4 If the Owner's Representative believes construction activities threaten to compromise the GI practice's design, construction should be halted and necessary remediation efforts should be made.

Inspection hold points are project-specific as outlined in the Contract Documents, a graphical representation of a selection of typical inspection hold points can be seen in ***Figure 6.3.***

References to these typical inspection hold points that match the figure are indicated throughout **Section 6.4**.

Figure 6.3 | *Common Inspection Hold Points*



Legend

1. **Field survey to confirm control elevations that would impact design hydraulics.**
2. **Excavation to the GI footprint.**
3. **Installation of geotextile and impermeable liner.**
4. **Installation of drainage structures, piping or sewer connections.**
5. **Placement of stone storage layer.**
6. **Placement of soil backfill.**
7. **Installation of plants.**

CONCLUSION OF SECTION 6.3

Exact requirements for construction administration and inspections will vary depending on the project. The above section only details examples of these requirements. Contract Documents should be the main source for project-specific requirements.

6.4 Construction Sequencing

The sequence of construction for GI varies greatly depending on the existing conditions, type of GI being installed permitting considerations and coordination needed with other projects. Typical elements of a construction sequence are detailed below. This sequence does not supersede project-specific construction requirements included in Contract Documents.

6.4.1 Erosion and Sediment Controls

The NJ Soil Erosion and Sediment Control Act requires most construction activities greater than 5,000 square feet to be developed in accordance with a plan to control erosion during construction. Contractors should make sure all work activities comply with the Erosion and Sediment Control Plan within the Contract Documents, and a certification for the plan has been obtained from Hudson Essex Passaic Soil Conservation District. Additional standards information and best practices are listed below.

6.4.1.1 **Locate staging areas and access points** and install any rock construction entrances prior to installation of erosion and sediment control measures.

6.4.1.2 **Install and maintain adequate tree protections** and erosion and sediment controls to divert runoff around the disturbed area, prevent migration of excavated materials and filter runoff leaving the disturbed area during construction. Do not use systems designed for infiltration as temporary sediment basins or traps during construction.

6.4.1.3 All **GI footprints and existing conveyance structures downstream** of construction activities must be protected from erosion and sedimentation.

6.4.1.4 All **inflow points** must be blocked to prevent water from entering the GI until the GI construction is complete and any vegetation has been stabilized.

Erosion and Sediment Controls Reference

The design practices used in the erosion control plans shall be installed and maintained during construction in accordance with the Contract Documents and the latest edition of The Standards for Soil Erosion and Sediment Control in New Jersey.

See submittal checklist and application here: A2-App-Disclosure-checklist-2019.pdf

GI Standard Construction Details Reference

For example Construction Details for various GI elements, see Green Infrastructure Guidance Manual for New Jersey, Rutgers University, Chapter 4.

6.4.2 Protection of Existing Utilities

Record drawing and survey information of existing utilities used for design is not always accurate. The Contractor should mitigate the potential for existing utilities to impact construction.

6.4.2.1 At least 3 business days prior to any earth disturbance activities, the **New Jersey One Call System must be notified** at 800-272-1000 for the location of existing underground utilities.

6.4.2.2 The Contractor will **examine and field verify** all existing and given dimensions and conditions with those shown on the plans. In case of any discrepancy, the Contractor should immediately notify the Owner's Representative.

6.4.2.3 The Contractor may conduct test pitting or potholing to confirm the locations of existing utilities, as directed by the Owner's Representative. All test pits should comply with **City of Newark Green Infrastructure Specification 31 09 19 (Test Pits)**.

(1) ***Inspection Hold Point***

6.4.3 Excavation

Proper excavation and handling of the subgrade is critical in the construction of all GI, but particularly for GI involving infiltration. The excavation to the final design elevation of the storage bed may only occur after all construction within its contributory drainage area is completed and the drainage area is stabilized. Contractors should work to promote proper excavation practices throughout the project.

6.4.3.1 All excavation shall comply with **NJDOT Standard Specification 202** and the notes below.

6.4.3.2 During clearing and grading of the site, measures must be taken to **eliminate soil compaction** at the location of any proposed GI involving infiltration. Excavation and construction must be performed using equipment placed outside the limits of the GI footprint.

6.4.3.3 Excavate to a **uniform, level subgrade** free from rocks and soft material such as muck. If non-uniform material is found, over-excavate a minimum of 14 inches to remove unsuitable soils and backfill with suitable material.

6.4.3.4 For infiltrating GI practices, **infiltration tests** should be conducted upon completion of excavation to confirm feasibility of infiltration. If infiltration rates are low, GI should be constructed as a detention practice.

(2) ***Inspection Hold Point***

6.4.4 Construction Testing

Onsite construction testing is performed to confirm that existing conditions are similar to design assumptions and that materials used for the GI project match design values.

6.4.4.1 Contractor should document that **planting soils, bioretention media, stone, pavement and structural components** conform to the design specifications. Contractor shall supply documentation from supplier or perform testing on site while Owner's Representative is present.

6.4.4.2 **Infiltrometer testing** should be performed according to specifications.

6.4.4.3 **Test soil and groundwater** (where applicable) and dispose of excavated soil in accordance with all applicable federal, state and local regulations. Develop and follow a Health and Safety Plan (HASP) during testing and installation. The HASP must be submitted and approved prior to commencement of field work.

6.4.5 Geotextile and Impermeable Liner

Geotextile may or may not be required on a GI project. Refer to Contract Documents to determine if geotextile is required. Contractors should promote proper placement of geotextile when required.

6.4.5.1 When specified in design, place **geotextile** along the bottom and sides of the bed and wrap geotextile around all perforated pipes. Geotextile should be non-woven, consist of polypropylene fibers and meet required specifications. Heat-set and heat-calendared geotextiles are not permitted.

6.4.5.2 **Impermeable liner or geomembrane,** when required, will be placed along the bottom and sides of the bed. Impermeable liner shall be placed with continuous contact with native soils.

6.4.5.3 Geotextile and impermeable liner shall be placed in accordance with the manufacturer's specifications. Overlap between strips of material should be a **minimum of 16 inches** and the geotextile should be secured at least four feet outside of the bed area. Once soil contiguous to the bed on-site has been fully stabilized, excess material may be cut back to the edge of bed.

6.4.5.4 Care must be taken to **not puncture materials during installation**. Damage to geotextile or geomembrane must be repaired prior to backfill in accordance with engineer and manufacturer requirements.

③ ***Inspection Hold Point***

6.4.6 Hydraulic Structure Placement

Due to constraints found in the urban environment, GI practices often must be designed with little vertical margin. During construction, particular care must be paid to setting hydraulic structures at the proper elevations and discouraging future movement or settling of these structures.

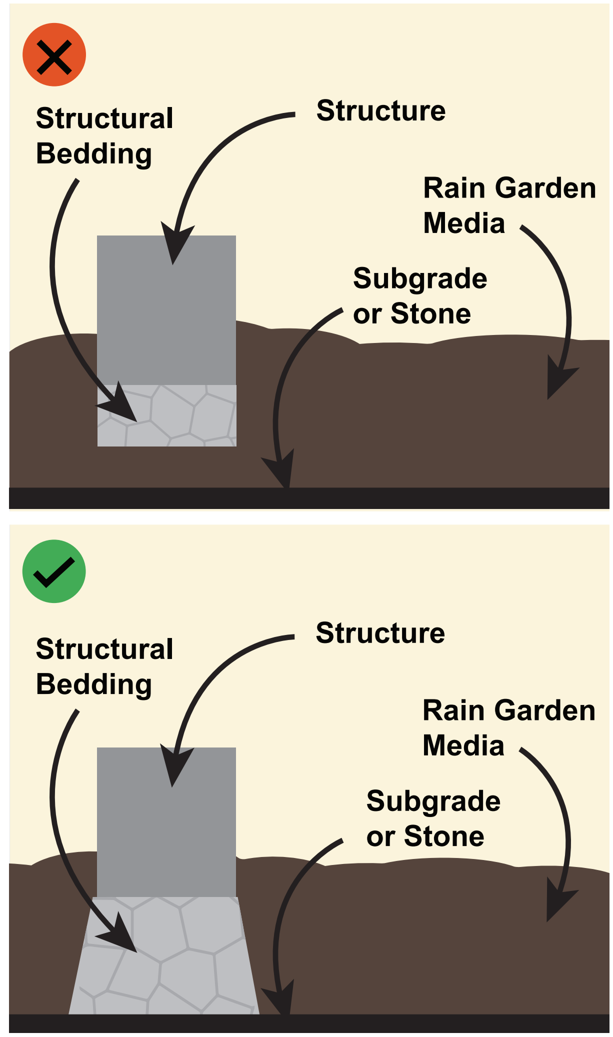
6.4.6.1 **Structural bedding** should be placed and compacted beneath hydraulic structures, cleanouts and other elements at risk of settling.

6.4.6.2 **Hydraulic structures** shall not be placed on uncompacted porous media such as rain garden soil. Where hydraulic structures are to be placed in these environments, compacted structural bedding should extend to the stone or subgrade below, see ***Figure 6.4.*** Identified heavy equipment exclusion zones should be respected during this process.

④ ***Inspection Hold Point***

6.4.6.3 Install inlet, pretreatment and outlet control structures; subsurface systems; observation wells, manholes and clean-outs; piping to sewer connections; and all other necessary system components as specified in the **engineering design documents**.

Figure 6.4 | Bedding Beneath Structures



6.4.6.4 As needed for placement of pipes or structures at proper elevations, **lifts of media** may be placed (See **Section 6.4.7**).

6.4.7 Media Placement

GI designs involve multiple media types that each have different construction considerations. Contractors should work to promote proper placement of media to the extent possible.

6.4.7.1 **Stone storage layers** may be used as part of the GI backfill material. It is important that any stone used for storage be clean and free of debris. The void spaces between the stone must be available for stormwater storage which cannot occur if the voids are filled with fines.

5 ***Inspection Hold Point***

6.4.7.2 Stone storage layers should be installed in lifts defined within the Contract Documents. Each layer shall be compacted according to specifications, minimizing equipment movement over storage bed native soils. Aggregate shall be installed to grades indicated in the Contract Documents.

6.4.7.3 Prior to the placement of sand or soil, **adequate choker layers or geotextile** should be placed to prohibit migration of fine media into stone storage.

6 ***Inspection Hold Point***

6.4.7.4 **Sand layers** should be installed in lifts defined within the Contract Documents. Each layer shall be lightly compacted with equipment, minimizing equipment movement over storage bed native soils. Sand should be installed to grades indicated in the Contract Documents.

6.4.7.5 Bioretention media material shall be as defined in **City of Newark Green Infrastructure Specification 32 90 05 (Planting Media)**. Placement of the media shall also meet the requirements outlined in 32 90 05.

6.4.7.6 **Bioretention media** must be evenly placed to the thickness and configuration as directed by the Engineer or as shown on the plans. Bioretention media must be placed by gravity with no additional compaction. The Owner's Representative must confirm final elevation**.**

6.4.8 Vegetation and Planting

In GI practices that include vegetation, plants should be installed only after other construction activities have been completed. Contractors should work to promote proper establishment of vegetation to the extent possible.

6.4.8.1 **All plants must meet sizes and species** identified in the Contract Documents. If alternates are proposed, they must first be approved by the Owner's Representative.

7 ***Inspection Hold Point***

6.4.8.2 Delivery, installation, planting schedule and establishment period for plants shall comply with **City of Newark Green Infrastructure Specification 32 90 00 (Planting)**.

6.4.9 Precast GI Products

Manufactured GI products such as tree boxes, porous panels and subsurface detention may also be used. These products should be installed per the Contract Documents and manufacturer recommendations.

CONCLUSION OF SECTION 6.4

Construction of GI should follow the general sequencing guidelines noted above, but Contract Documents should be referenced for requirements related to project-specific sequencing and inspection hold points.

6.5 Final Acceptance

Following substantial completion of the GI construction, a few items must be completed before DWSU's final acceptance.

6.5.1 Punch List

Prior to final stabilization and acceptance of GI, the Owner's Representative and Owner will compile a list of outstanding issues that need corrected by the Contractor. The Contractor should document the completion of these items and have the Owner's Representative sign off on each activity completed.

6.5.2 Final Stabilization

Following completion of the punch list items, erosion and sediment controls can be removed and the site can be stabilized to its final condition.

6.5.3 Record Drawings

The Contractor will submit Record Drawings documenting any changes between the design plans and the constructed GI. Record Drawing format should follow what is specified in the Contract Documents.

6.5.4 Post-Construction Testing

Post-construction testing shall be performed to ensure that the as-built system functions as designed.

6.5.4.1 Testing must comply with the **City of Newark Green Infrastructure Specification 33 05 05 (Infiltrometer Testing)**.

6.5.4.2 This testing includes **determination of the permeability rates of the soil bed** and **hydraulic capacity of the underdrain,** or the permeability of the subsoil, depending on the GI practice type. If the time it takes to fully infiltrate the design storm runoff is longer than designed, corrective action must be taken to bring the GI within the appropriate drain time.

CONCLUSION OF SECTION 6.5

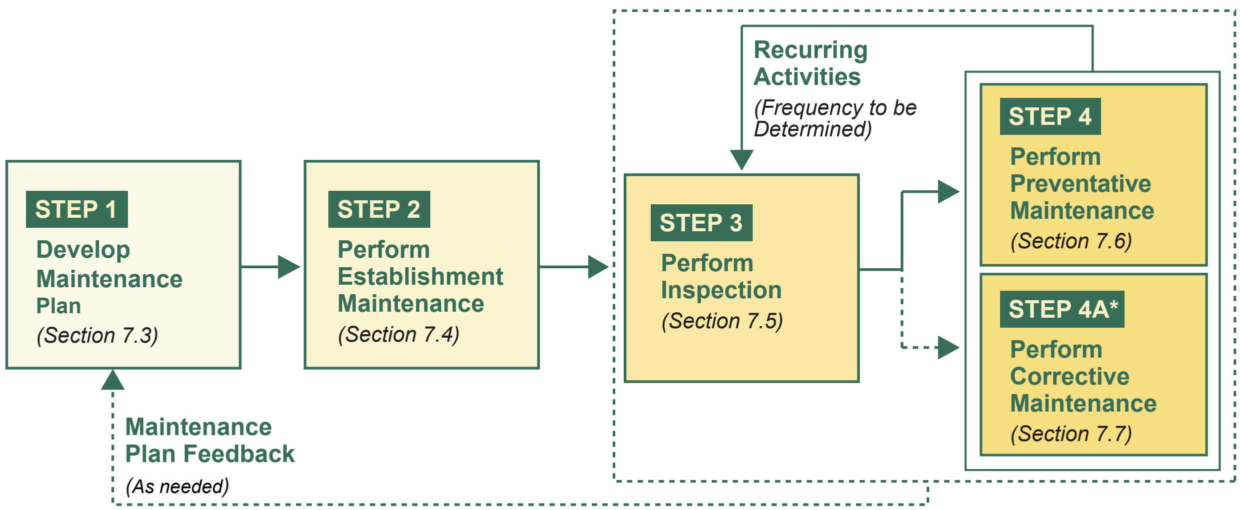
Completion of punch list items, final stabilization, and post-construction testing are important items that need to be completed prior to final acceptance. Additionally, the completion of Record Drawings is crucial for DWSU to have accurate records for the GI installation.

7 Inspection and Maintenance

7.1 Summary of Chapter

Regular inspection and maintenance of green infrastructure (GI) systems is necessary for the long-term success of the GI program in the City of Newark (City). Properly maintained systems are safer, provide more benefits to water quality and the community and look better. Maintenance of GI is challenging given the dynamic nature of the urban environments in which they are often sited. This chapter will explain the suggested inspection and maintenance practices that can help support a sustainable long-term GI maintenance program (see ***Figure 7.1***).

Figure 7.1 | *GI Maintenance Process*



This chapter will help inspectors and maintenance personnel:

- Understand the importance of maintenance and the effect that proper maintenance may have on GI systems.
- Cross-reference available maintenance resources.
- Determine necessary maintenance tasks and frequencies depending on GI features present at a given site.
- Identify and prioritize issues with GI systems based on regular inspections.
- Plan for potential maintenance issues that are not commonly observed or may be a larger undertaking than items presented within this chapter.

Common maintenance activities for GI practice types discussed in **Chapter 2** are provided in ***Table 7.1***, along with references to the **NJ Department of Environmental Protection (NJDEP) Best Management Practices (BMP) Manual** that includes additional detail on specific maintenance considerations for each practice. Site-specific maintenance requirements will vary.

Table 7.1 | *GI Practice Types with Relevant Maintenance Information*

GI Practice Type	Establishment Maintenance Section 7.4	General Care Section 7.6.1	Vegetative Maintenance Section 7.6.2	Minor Repairs Section 7.6.3	Permeable Pavement Maintenance Section 7.6.4	Subsurface Maintenance Section 7.6.5	NJDEP Reference Section 7.6.5
Bioretention	X	X	X	X		X	**Chapter 9.7** and **Chapter 10.1**
Rain Gardens	X	X	X	X			
Infiltration Basins	X	X	X	X			**Chapter 9.8** and **Chapter 10.2**
Constructed Wetlands	X	X	X	X			**Chapter 10.4**
Bioswales	X	X	X	X		X	
Stormwater Planters	X	X	X	X		X	
Enhanced Tree Pits	X	X	X	X		X	
Tree Filter Boxes	X	X	X	X		X	
Downspout Planters	X	X	X	X			
Sand Filters		X		X		X	**Chapter 9.9**, **Chapter 10.3**, and **Chapter 11.4**
Green Roofs	X	X	X	X			**Chapter 9.4**
Permeable Pavements		X		X	X	X	
Detention Ponds	X	X	X	X			**Chapter 11.2**
Blue Roofs		X		X			**Chapter 11.1**
Cisterns		X		X			**Chapter 9.1**
Rain Barrels		X		X			
Dry Wells		X		X		X	**Chapter 9.2**
Subsurface Storage		X		X		X	**Chapter 11.5**

7.2 Maintenance Event Procedures

Maintenance events are defined as any time that personnel perform maintenance activities at a GI site. During maintenance events, all maintenance personnel should adhere to procedures outlined in site-specific maintenance plans and suggestions set forth in this chapter.

7.2.1 General Guidelines

More specific guidance for maintenance tasks is included in later sections. The following considerations should be used at all sites as best practices during maintenance.

7.2.1.1 A minimum of **one maintenance event should be conducted at each site annually.** Additional events should be considered as required by maintenance plans or where additional maintenance events are needed to improve site safety, functionality or aesthetics; see suggested frequency in **Section 7.6**.

7.2.1.2 **Minimize disturbance to the ground surface and vegetation** within GI practices. Avoid stepping on or placing tools or equipment on vegetation. Restrict the use of vehicles or heavy equipment over infiltrating surfaces to avoid compaction of porous media.

7.2.1.3 Unless performance of maintenance is critical to improving safety in an emergency situation (See **Section 7.7**), **maintenance should not be performed when soils are saturated**.

7.2.1.4 Some maintenance activities, such as access, material disposal or certain repairs, **may require State permits**. NJDEP provides an overview of potentially relevant permits under their **Maintenance Guidance**.

7.2.1.5 When applicable, **minimize disruptions** to site users, pedestrians and vehicular traffic.

7.2.1.6 Upon completion of maintenance, **clean vehicles and equipment** to avoid tracking sediment away from the site. Remove sediment and debris from impervious areas.

7.2.1.7 All necessary maintenance event **documentation should be completed promptly** upon completion of maintenance.

7.2.2 Health and Safety

Maintenance activities and equipment operations will be conducted in accordance with all applicable laws and regulations including but not limited to:

- Jurisdictional laws – United States, State of New Jersey, City of Newark.
- Occupational Safety and Health Administration (OSHA).
- Any applicable owner/operator Health and Safety Plans (HASPs).

City Stormwater Control Ordinance Health and Safety Requirements Reference

Health and safety requirements for the Newark Stormwater Control Ordinance can be found in the **City of Newark Title XLI Zoning and Land Use Regulations**.

In addition, the following health and safety considerations should be followed during all maintenance.

7.2.2.1 Maintenance personnel must use **appropriate personal protective equipment (PPE)**, as applicable, including but not limited to the list included in ***Figure 7.2***.

7.2.2.2 **First aid materials** must be kept on all maintenance vehicles.

7.2.2.3 Only maintenance personnel with a **valid confined space entry certification** may enter combined spaces such as manholes or access ports. All personnel entering such structures must follow OSHA confined space entry protocols and use air quality monitors whenever entering confined spaces.

7.2.3 Access Requirements

Confirming proper site access prior to performing GI maintenance will minimize site disruptions and limit down time during maintenance events.

7.2.3.1 For sites located on private property, access should be coordinated with the property owner at least 48 hours in advance of maintenance events. Access to any locked or barred areas should be confirmed prior to arrival onsite.

7.2.3.2 Maintenance plans should be reviewed prior arriving onsite to identify sensitive areas, parking and access points.

Figure 7.2 | *Personal Protective Equipment*

7.2.4 Equipment and Materials

Equipment and materials that are commonly used during maintenance events and should be included for most regular maintenance events are listed below.

Routine Maintenance Equipment List

Landscaping tools

- Flat headed shovel
- Spade
- Leaf/garden rake
- Hoe
- Push broom

Hand Tools

- Pry bar
- Dustpan and brush
- Pruning shears
- Loppers
- Garden scissors
- Rubber mallet
- Hand saw

Power Equipment

- Leaf blower
- String trimmer
- Edger

Miscellaneous

- Tape measure
- Ladder
- Stakes
- Tarps
- Water hose
- Wheelbarrow
- Flashlight
- 5-gal buckets

Routine Maintenance Materials List

- Heavy-duty garbage bags
- Compost
- Rain garden media
- Hardwood stakes
- Mulch
- Paper bags
- Staking ribbon
- Clean stone
- Topsoil

In addition, the following guidance should be followed during all maintenance.

7.2.4.1 Keep work areas **neat and orderly during maintenance events**. Be aware of the locations of all tools during maintenance events. When tools are no longer needed, they should be properly stowed.

7.2.4.2 Additional equipment, such as traffic cones, barricades or warning signs should be used to **direct traffic away from maintenance activities** that are located close to vehicular traffic.

7.2.5 Personnel Requirements

Personnel completing maintenance activities should be trained on utilizing maintenance plans, safety, and record keeping. It is suggested that maintenance personnel receive certification from the National Green Infrastructure Certification Program (NGICP).

Stormwater Management Maintenance Training Reference

NJDEP provides a two-part Stormwater Management Maintenance training via recorded video that is intended to give an overview of stormwater BMP functions and the maintenance requirements within the Stormwater Management rules and the municipal separate storm system (MS4) permits. Videos are on the **NJDEP website**. **Part 1** is an introduction to stormwater management and stormwater BMPs. **Part 2** details maintenance of stormwater BMPs and reviews example maintenance issues using a checklist.

CONCLUSION OF SECTION 7.2

At the end of this section, user should understand the necessary guidelines and protocols necessary for every maintenance event. This includes health and safety practices (**Section 7.2.1**), how to approach site access (**Section 7.2.3**), what equipment and materials may be necessary for different maintenance activities (**Section 7.2.4**), and personnel requirements (**Section 7.2.5**).

7.3 Developing a Maintenance Plan

Maintenance plans can be helpful in assisting staff in organizing and tracking maintenance tasks and history. If GI is being constructed as part of the regulatory requirements for a major development, all NJDEP requirements, including the development of a maintenance plan, must be followed. Even if not required, it is recommended that maintenance plans are developed for each GI project during the design phase. Maintenance plans help guide different maintenance personnel and organize maintenance information in one place. As site maintenance is conducted, these plans should be updated based on lessons learned.

Recommended maintenance plan content includes:

- List of **preventative maintenance tasks** relevant to the applicable GI and suggested maintenance schedule with frequency for each task (see **Section 7.6**).
- **Inspection checklist** (See **Section 7.5**) identifying key items for inspections.
- List of all **equipment** to be included for all maintenance events (see **Section 7.2.4**).
- Suggested procedure for identifying, assigning, and carrying out **corrective maintenance tasks** (see **Section 7.7**).
- Site-specific **healthy and safety** and **access** considerations (see **Section 7.2.2** and **Section 7.2.3**).
- **Maintenance log** to document dates and notes from all routine and corrective maintenance events.
- **Contact information** for GI owner/operator.
- Relevant **as-built plans**, **warranties** and **permits**.
- For vegetated GI practices, include a list with photos of plants included in the project-specific planting plan alongside photos of weeds to be removed.

Maintenance Plan Development Reference

NJDEP provides a template for maintenance plans, as well as field manuals with basic check-lists, in the **Post-Construction Stormwater Management Maintenance Guidance**. Additional maintenance plan contents and considerations can be found in **Chapter 8 of the NJ Stormwater BMP Manual**.

CONCLUSION OF SECTION 7.3

At the end of this section, user should understand the importance of a maintenance plan to the success of GI maintenance and understand the necessary components of a maintenance plan.

7.4 Establishment Maintenance

For GI involving plantings, vegetation may take two growing seasons or longer to establish after planting. During this establishment period, extra maintenance is typically required in order to ensure growth is not disrupted and a properly functioning plant community is able to establish without weeds or other undesirable species. ***Table 7.2*** includes common tasks associated with establishment maintenance.

Table 7.2 | *Establishment Maintenance Tasks with Suggested Timing and Frequency*

Task	Suggested Frequency and Timing	Reference
Establishment watering	Every month	7.4.1
Establishment weed control	Every month	7.4.2

7.4.1 Establishment Watering

Watering vegetation is essential and should be done with increased frequency during the establishment period to improve plant community survival.

7.4.1.1 **Limit subjecting establishing plants to erosive flows** by blocking or diverting flow paths.

7.4.1.2 The following guidance applies to **all watering activities**:

- Watering can be accomplished by installing a permanent irrigation system or using a portable water truck.
- **Direct water towards the base of plants** to avoid high pressure flow toward delicate plant stems or leaves.
- **Allow water to soak into the ground** and move slowly throughout each section, spending on average 5 minutes for every 100 square feet.

7.4.1.3 The following guidance applies to **tree watering**:

- For any trees planted within the last two years or any trees that are specifically stressed, **water bags** should be used when possible. Water bags should be deployed April through the end of October. Water bags should be filled once for every 7 days without rain.
- If **watering trees manually**, direct water toward the base of the tree and water each tree for 5 minutes, or until soil is thoroughly saturated. Afterwards, restore any mulch disturbed by watering.

7.4.1.4 The following guidance applies to **herbaceous vegetation**:

- For vegetation planted within the last 24 months, watering should occur **every 4 days** without significant rain between April and October.
- For more **drought-tolerant species**, watering can stretch up to 7 days without significant rain. Mulch should be removed and replaced annually in April for planter beds less than 2 years old.

7.4.2 Establishment Weed Control

Weeding should be done with increased frequency, at least every month, during the establishment period to prevent weeds from establishing themselves over desired vegetation. Weed control can include physical or chemical forms of weed removal or the application of pre-emergent treatments (described in **Section 7.4.2.3**).

Weed Identification Reference

Weeds are defined as plants listed by **Rutgers New Jersey Weed Gallery**, plants listed by the U.S. Department of Agriculture (USDA) on the **Federal Noxious Weed List** or plants otherwise determined undesirable by the GI owner.

7.4.2.1 The following guidance applies to **mechanical removal of weeds**:

- Try and remove as much of the root mass as possible. For smaller plants, pull from the base of the stem. For larger rooted weeds, use a shovel or spade to loosen the soil around the stem.
- Fill in any holes created from plant removal with soil.
- Bag and remove all plant material and dispose at offsite location.

7.4.2.2 The following guidance applies to **all chemical removal of weeds**:

- Chemicals should only be applied during dry periods, at least 24 hours since the last rain event, and with minimal wind. If rain is anticipated in the next four hours, or timeline as specified by chemical labels, chemicals should not be applied.
  - Foliar treatments should only be performed in temperatures above 60 degrees Fahrenheit.
  - Cut-and-treat stem and basal bark treatments should only be performed in temperatures above freezing.
- All herbicides should be applied in compliance with all label sheets and Material Safety Data Sheets (MSDS), and all other applicable codes and regulations.
- Prepare all herbicide solution prior to arriving on site.

7.4.2.3 The following guidance applies to **specific chemical treatments**:

Cut stem treatments

- Horizontally cut stems at or near ground level; cuts should be level and smooth.
- Immediately apply appropriate herbicide to the outer 20% of the stump.

Foliar treatments

- Apply appropriate herbicide with a backpack sprayer equipped with a flat spray tip or adjustable cone nozzle using a lower pressure (20-50 psi).
- Apply herbicide to leaves and stems of target plants using back and forth motion in order to consistently apply to foliage.
- In public areas it may be necessary to close the treated areas off to people until the herbicide has completely dried (at least 3 hours).

Pre-emergent treatments

- Apply pre-emergent treatments herbicide in early spring, late summer or early fall, or immediately following cultivation.
- Thoroughly remove weed residues and debris prior to treatment.
- Apply pre-emergent herbicide in granular form using a small handheld spreader, or in liquid form using a hand-held or backpack sprayer.

- Apply evenly to bare soil, avoiding any areas seeded with non-weed species.
- Following application of granular herbicide, apply approximately ¼ inch or more of water evenly across treatment area (rainfall is also acceptable).
- Do not apply more than 600 pounds per acre within a 12-month period.

Basal bark treatments

- Apply herbicide with a backpack sprayer using low pressure (20-40 psi) with a straight stream of flat fan tip.
- To control vegetation with a stem diameter of less than 3 inches, apply a translocated herbicide-oil mixture on one side of the stem to a height of 6 inches from the base.
- For stems with a diameter of greater than 3 inches, or stems with thick bark, treat both sides of the stem to a height of 12 to 24 inches from the base.

CONCLUSION OF SECTION 7.4

At the end of this section, user should understand that additional watering and weeding is required for GI practice types with plants during the establishment phase and know typical frequency and guidance for completing establishment maintenance activities.

7.5 Inspection

Regular inspection of GI practices help inform owners and the GI program management team of their function. Performing inspections also help identify and communicate necessary maintenance tasks. Inspections are most commonly conducted prior to routine maintenance activities to facilitate maintenance feedback, alongside maintenance crews to decrease the number of trips to each practice or following storm events to confirm GI function.

7.5.1 Routine Inspections

Routine inspections are performed by trained inspectors and aim to confirm the function, aesthetics and public safety of GI practices. Routine inspections are limited to visible features, and do not require access to underground structures.

7.5.1.1 **Inspection checklists** should be developed as part of a site maintenance plan (See **Section 7.3**) and be used to standardize inspections protocols and recordkeeping.

Example Checklist Reference

The Port Authority of New York and New Jersey (PANYNJ) provides an example inspection checklist in Appendix H of their **Green Infrastructure Design Manual**.

7.5.1.2 Routine inspections should be conducted a **minimum of once annually**. More frequent inspection is suggested for sites with more complex features or where previous inspection and maintenance suggests that the site may benefit from more frequent inspection.

7.5.1.3 Inspectors **must understand how GI practices work**. This knowledge can be obtained through schooling, experience or trainings such as the NGICP. Depending on site-specific considerations, inspectors may need additional qualifications such as landscaping or arboricultural experience.

7.5.1.4 Inspections may result in **follow-up preventative or corrective maintenance tasks** that need to be completed by maintenance crews to confirm safety or function of a GI practice. These necessary follow-up tasks should be communicated to the owner and differentiated from other inspection results.

7.5.2 Subsurface Inspections

Subsurface inspections are inspections of subsurface features performed by trained inspectors using CCTV camera equipment. They compliment routine inspections to confirm the function of features that cannot be inspected without CCTV equipment.

7.5.2.1 Subsurface inspection checklists should identify access points and pipe runs to be inspected (See **Section 7.3**).

7.5.2.2 Subsurface inspectors need training on the use of **CCTV pipe inspections**, such as certification by National Association of Sewer Service Companies (NASSCO).

7.5.2.3 In order to identify defects, subsurface inspections must be performed when pipes **do not contain standing water** or other obstructions. If pipes are not clean during inspections, they must be re-inspected following maintenance (see **Section 7.6.5**).

CONCLUSION OF SECTION 7.5

At the end of this section, user should understand the need for regular inspections and necessary information to be identified during inspections.

7.6 Preventative Maintenance Tasks

Preventative maintenance, or routine maintenance, should be performed on a regular basis in order to ensure proper functioning of the GI and prevent larger issues from developing. Maintenance activities are required through various regulations, including the New Jersey Pollutant Discharge Elimination System (NJPDES) rules, N.J.A.C. 7:14A. Maintenance crews should be prepared to complete all relevant preventative maintenance activities described below at every maintenance event.

The following sections list the most common preventative maintenance tasks with frequency and references to additional detail. While one maintenance event is required annually, site-specific circumstances may necessitate more frequent maintenance.

Frequency is a general recommendation and should be adjusted as necessary based on observations at inspections and maintenance events.

7.6.1 General Care

The following general care tasks should be completed regularly for most, if not all, GI maintenance events. ***Table 7.3*** provides a summary of general care maintenance tasks and suggested frequency and timing, which may vary depending on site-specific circumstances.

Table 7.3 | *General Care Maintenance Activities*

Task	Suggested Frequency and Timing	Reference
Trash and Organic Debris Removal	Every other month	7.6.1.1
Sediment Removal	Every other month	7.6.1.2

7.6.1.1 Trash and organic debris removal

PURPOSE:

Ensure functioning of the GI and prevent damage from large debris. Trash removal also helps maintain intended aesthetics of the GI and prevent complaints from the public.

GUIDANCE:

- Small quantities of trash/sediment/organic debris can be removed using hand tools, rakes or mowers.
- Large deposits should be removed from paved structures or turf-covered storage areas using a mini-excavator or portable vacuum excavator.
- Mechanized equipment such as skid-steers or mini loaders should not be used on infiltration areas in order to avoid soil compaction

7.6.1.2 Sediment removal

PURPOSE:

Prevent buildup of material that can compromise GI functions and capacity.

GUIDANCE:

- Remove sediment from pretreatment device, hardscape and vegetated areas.
- For pretreatment devices, if there is standing water, remove using a pump prior to lifting. Invert and shake or gently tap the device until all material has been removed. Clean the fabric using a scrub brush or pressure washer to remove fine sediment from fabric pores, taking care not to tear or damage the material.
- For hardscaped areas, sediment can be removed from hardscaped areas using brooms or dust pans.
- For vegetated areas, sediment can be removed using rakes and shovels.

7.6.2 Vegetative Maintenance

For GI practice types with above-ground vegetation, including but not limited to bioretention and rain gardens, infiltration basins, constructed stormwater wetlands, bioswales, planters, enhanced tree pits or green roofs, landscaping specific maintenance is required. Maintenance crews should be prepared to complete the following routine maintenance tasks at most maintenance events. ***Table 7.4*** provides a summary of vegetative maintenance tasks and suggested frequency and timing, which may vary depending on site-specific circumstances.

Table 7.4 | *Vegetative Maintenance*

Task	Suggested Frequency and Timing	Reference
Watering	As needed after vegetative establishment based on weather conditions	7.4.1 and 7.6.2.1
Weed Control	Twice annually during the growing season	7.4.2 and 7.6.2.2
Pruning	Once annually during the fall	7.6.2.3
Replanting	As needed	7.6.2.4
Mowing	As needed, typically once annually	7.6.2.5
Pest Management	As needed when observed	7.6.2.6
Mulching	As needed, typically once during the spring	7.6.2.7

7.6.2.1 Watering

PURPOSE:

Preserve vegetation through drought conditions.

GUIDANCE:

- Watering may be required outside of establishment period if there is persistent drought causing vegetative stress.
- See **Section 7.4.1** for detailed descriptions and protocols for watering.

7.6.2.2 Weed control

PURPOSE:

Remove undesired vegetation so intended plant species can establish for proper functioning and aesthetics of the GI practice.

GUIDANCE:

- Weeding may be required outside of establishment period if invasive or undesirable species are outcompeting plants that are intended for the treatment of the stormwater.
- See **Section 7.4.2** for detailed descriptions and protocols for weed control.

7.6.2.3 Pruning

PURPOSE:

Keep vegetation within designated GI footprint, promote proper plant growth and remove any dead vegetation or branches.

GUIDANCE:

- For trees and woody shrubs, complete selective pruning using pruning shears, loppers or a hand saw in order to maintain visibility, access and desired tree shape. Complete pruning in late fall and do not remove more than 25% of total free foliage annually.
- For herbaceous vegetation, cut back dormant herbaceous species annually using pruning tools or trimmer to maintain shape.
- Remove and dispose of any plant material at an appropriate off-site location per owner/operator.

7.6.2.4 Replanting

PURPOSE:

Replace vegetation that didn't survive to maintain vegetative cover, typically 85% cover.

GUIDANCE:

- Any vegetation planted should be consistent in genus, species, variety, size and quality with the vegetation identified for planting during design or with concurrence of the owner/operator.
- During the planting process, do not store vegetation in direct sunlight and roots should be kept moist.

7.6.2.5 Mowing

PURPOSE:

Maintain aesthetics of GI, promote redistribution of seed and prevent excess growth from harboring pests.

GUIDANCE:

- Mow cool season native grasses to a height of 3-4 inches.
- Mowing of perennial herbaceous grasses and wildflowers, especially once seed heads have set, promotes redistribution of seed for this self-sustaining system.

7.6.2.6 Pest management

PURPOSE:

Eliminate pests from GI for safety of public and maintenance staff.

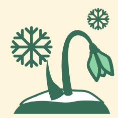
GUIDANCE:

- For pest insects and fungi, treat vegetation with chemical pest control, such as insecticidal soap or pest-specific spray oils, to remove or destroy pests.
- Apply chemical pest control a minimum 24 hours before or after a rain event and with little to no wind. Apply pesticide per label instruction.
- Remove infected leaves, twigs, branches, needles and cones around the base of trees and shrubs to remove disease from the site.
- For small pest mammals, if animal borrows are present, fill with stone and compact. If more than 2-3 borrows are present or repeated animal sitings (e.g. rate, mice, moles, etc.) are present. contact GI owner.

Figure 7.3 | *Recommended Planting Timing*

Seeding

Spring (***March 1 – May 15***) or fall (***August 15 – October 15***).

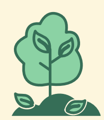


Ground cover, herbaceous perennials and plugs

In spring after danger of frost is past (typically ***April 15 – May 30***) or late summer/early fall at least 30 days before first frost (typically ***September 15 – October 31***).

Bulbs

September 15 – October 31 planting (soil temperature less than 55°F, but before soil freezes).



Deciduous trees and shrubs

Early spring and late fall when plants are dormant (typically ***March 15 – May 30*** and ***September 15 – October 31***).

Evergreen trees and shrubs

Early spring and late summer/early fall (typically ***April 15 – May 30*** and ***September 15 – October 31***). Soil temperatures for fall planting must not be less than 60°F.

7.6.2.7 Mulching

PURPOSE:

Properly maintain mulch to help improve moisture retention, cool soil and roots, suppress weeds and prevent erosion.

GUIDANCE:

- Remove existing mulch from tree pits and replace with fresh mulch. If mulch is within 3 inches of tree trunk, rake excess mulch away from trunk.
- For planter beds, apply mulch to the perimeter for beds older than 2 years.

7.6.3 Minor Repairs

Maintenance crews should be prepared to make minor repairs to GI infrastructure at most preventative maintenance events. ***Table 7.5*** provides a summary of minor repair maintenance tasks and suggested frequency and timing, which may vary depending on site-specific circumstances. For more major repairs, see **Section 7.7**.

Table 7.5 | *Minor Repair Maintenance Activities*

Task	Suggested Frequency and Timing	Reference
Minor Concrete Repairs	As needed when observed	7.6.3.1
Settling/Undermining	As needed when observed	7.6.3.2
Minor Erosion Repair	As needed when observed	7.6.3.3
Hardware Care	As needed when observed	7.6.3.4

7.6.3.1 Minor concrete repairs

PURPOSE:

Repair minor concrete issues to improve safety and prevent further damage. If concrete repair is greater than 50 square feet or more than 10% of the total paved area, secure any unsafe areas and contact the owner/operator.

GUIDANCE:

- To repair hairline/cosmetic cracks in concrete, apply a concrete crack repair product. If crack is large enough to accumulate debris, clean out debris before filling.
- Maintain protective measures during the 5- to 7-day curing period of concrete and follow all manufacturer's instructions for temperature and rain.

7.6.3.2 Setting/undermining

PURPOSE:

Repair minor settling to improve safety and prevent further damage. If settling is affecting stability of the structure or safety, secure any unsafe areas and contact the owner/operator.

GUIDANCE:

- Remove by hand any material, plant or stone, over the settled area in order to access.
- Excavate using hand tools to the bottom of the depression and fill excavated area with clean fill material (clean stone or soil, in the case of landscaped areas) and compact with hand tamper.
- Replace any hardscape subbase to match existing surface.

7.6.3.3 Minor erosion repair

PURPOSE:

Repair minor erosion to improve functioning and prevent further damage. If erosion is recurring or larger than what can be managed with routine maintenance equipment (approximately 20 square feet), secure any unsafe areas and contact the owner/operator.

GUIDANCE:

- Fill eroded area, if necessary, with material matching that of the surrounding area. Grade material with hoe, rake, or other hand tool to match the grade of the surrounding undamaged surface. Install erosion blanket using method described below and following manufacturer's instructions.
- Ensure that the upslope edge of the erosion fabric is securely embedded and anchored into an anchor trench above the entry point of water into the GI.
- If multiple pieces of erosion blankets are necessary to cover an eroded area, ensure that no bare soil is left exposed by overlapping the fabrics at the seams.
- At the downstream end, anchor the edge of the erosion fabric in an anchor trench at a minimum of 3 feet downstream of the eroded area to provide sufficient coverage.
- If appropriate, seed the area per **Section 7.6.2.4**, or if outside of typical seeding window, plant a temporary cover crop.

7.6.3.4 Hardware care

PURPOSE:

Ensure proper functioning of GI hardware.

GUIDANCE:

- Remove and nuts, bolts or locks from hardware and clean and lubricate as necessary.
- Replace or rethread any bolts with noticeable damage or warping. Avoid mixing metals (e.g. stainless steel, iron, or aluminum) as this can lead to corrosion.

7.6.4 Permeable Pavement

Permeable pavements require careful maintenance, particularly with regard to sediment control. If they remain unmaintained for too long, sediments may get lodged too deeply into the material for sweepers to remove, eventually reducing the function of the GI practice. ***Table 7.6*** provides a summary of permeable pavement maintenance tasks and suggested frequency and timing, which may vary depending on site-specific circumstances.

Table 7.6 | *Permeable Pavement Maintenance Tasks*

Task	Suggested Frequency and Timing	Reference
Trash and Debris Removal	Minimum four times per year	7.6.4.1
Vacuum Washing	Minimum four times per year, or after rain events greater than 1 inch	7.6.4.2
Vacuum Sweeping	Minimum four times per year, or after rain events greater than 1 inch	7.6.4.3
Winter Care	After snow events greater than 2 inches	7.6.4.4

7.6.4.1 Trash and debris removal

PURPOSE:

Ensure functioning of the GI and prevent damage from large debris. Trash removal also helps maintain intended aesthetics of the GI.

GUIDANCE:

- Large trash and debris can be removed manually.
- Debris removal should be performed in the fall after leaves have fallen.

7.6.4.2 Vacuum washing

PURPOSE:

Use high pressure water, vehicle-mounted or standalone pressure washer to dislodge fine soil and sediment.

GUIDANCE:

- Systematically use vacuum washer to dislodge sediment across the entire surface. If there are indications of slow drainage, spend additional time dislodging sediment.
- Ensure washer does not have enough pressure to compromise structural integrity of the pavement by checking manufacturer specifications and/or performing test spot.
- Vacuum washing must be used with vacuum sweeping (See **Section 7.6.4.3**) in order to remove soil and sediment from the site.

7.6.4.3 Vacuum sweeping

PURPOSE:

Remove soil and sediment and maintain infiltration capacity of the pavement.

GUIDANCE:

- Inspect the pervious paving system after every storm greater than 1 inch of rainfall to remove mud or sediment.
- Vacuum sweeping should take place after all water has been drained from the surface and there is no ponding. If surface is not draining corrective action may be needed.
- Vacuum sweeping must be followed by either air blowing or high-pressure power washing performed per manufacturer directions.
- Any material dislodged by vacuum sweeping must be removed and properly disposed of per owner/operator.

7.6.4.4 Winter care

PURPOSE:

De-ice and plow during the winter to maintain function.

GUIDANCE:

- In the winter, de-icer should be applied to the surface for snow events greater than 0.25 inches and any event with sleet or freezing rain, as well as after plowing.
- De-icers should not be used on permeable pavements less than a year old, and sand and de-icers with magnesium chloride, calcium magnesium acetate or potassium acetate should never be used.
- Plowing should occur every 3 hours during any storm event greater than 2 inches. Plows should be equipped with rubber edge. Plowing should be performed carefully and with enough clearance (minimum half an inch) from the ground so as to not damage permeable surface.

Figure 7.4 | *Porous Pavement and Subsurface Maintenance Equipment*

7.6.5 Subsurface Maintenance

GI practice types with subsurface components (See ***Table 7.1***) require specific care with specialized equipment in order to maintain function. Jetting and vacuuming, often used in combination, are two methods of cleaning stormwater drainage of accumulated sediment and other blockages. ***Table 7.7*** provides a summary of subsurface maintenance tasks and suggested frequency and timing, which may vary depending on site-specific circumstances.

Table 7.7 | *Subsurface Maintenance Tasks*

Task	Suggested Frequency and Timing	Reference
Pipe jetting	At least once per year.	7.6.5.1
Vacuum cleaning	At least once per year.	7.6.5.2

7.6.5.1 Pipe jetting

PURPOSE:

Jetting is the process of pumping high-pressure water through piping infrastructure, typically using a vehicle-mounted cleaning system, in order to clear blockages and wash away accumulated soil and sediment.

GUIDANCE:

- Pipe jetting should not take place within 48 hours of a storm event, or while standing water is present within non-sumped structures.
- Capped underdrains, if present, require removal prior to performance of maintenance.
- If access structures contain more than one pipe, all pipes other than the one being maintained must be plugged.
- As necessary, loosen compacted sediment with a high-velocity air lance during vacuuming.
- Access structures, including sumps, must be cleaned upon completion of pipe jetting.

7.6.5.2 Vacuum cleaning

PURPOSE:

Vacuum cleaning typically uses vehicle-mounted cleaning device to collect sediment and other material into a collection tank that is eventually disposed of off-site.

GUIDANCE:

- Vacuum cleaning should not take place within 48 hours of a storm event, or while standing water is present within non-sumped structures.
- For subsurface storage, vacuum clean trash, sediment and organic debris from structures and pretreatment devices.
- Vacuumed spoils must be disposed of properly.

CONCLUSION OF SECTION 7.6

At the end of this section, user should understand what tasks are expected to be completed at typical preventative maintenance visits and general guidance for completing preventative maintenance tasks.

7.7 Corrective Maintenance

Corrective maintenance is any maintenance that falls outside of the routine maintenance tasks defined above or as part of a maintenance plan. Commonly these types of maintenance events will be conducted as a result of an observation that something is impacting safety, performance and/or aesthetics of the GI. Corrective maintenance, particularly when it involves major site retrofits, may be more complex, expensive and time-consuming when compared to routine maintenance. This section presents the suggested process that should be undertaken to right site issues, and some scenarios that may require corrective maintenance.

7.7.1 Corrective Maintenance Procedure

The need for corrective maintenance can stem from inspections, community observations, complaints or issues noted by the maintenance crew during a routine maintenance event. It is recommended that the following process is followed to address site issues to be remediated by corrective maintenance.

7.7.1.1 **Identified issues should be communicated** to the site owner, Department of Water and Sewer Utilities (DWSU) or other responsible parties.

7.7.1.2 **If issues that may present a safety hazard (e.g. sinkholes, settling, downed trees)** are present, the site should first be secured to reduce safety risk.

7.7.1.3 A **corrective maintenance plan** should be developed for the work to be completed. This plan should consider whether design services, specialized personnel, equipment or materials are needed to complete the maintenance.

7.7.1.4 Identified issues should be remediated **as soon as possible** and should not wait for the next scheduled routine maintenance event.

7.7.1.5 In certain cases, **significant retrofits or replacements** of GI practices **may be required.**

7.7.1.6 Records should be kept of corrective maintenance performed. Future inspection and maintenance events should **confirm that corrective actions were effective** and that issues are not resurfacing.

7.7.1.7 If corrective maintenance results in significant changes to site layout, features or function, **updates should be made to the maintenance plan** (see **Section 7.3**).

7.7.2 Potential Corrective Maintenance Scenarios

The table on the following page lists potential observations from GI and corrective actions that may be taken. Given space constraints, the list of issues and possible actions below is not comprehensive. Issues listed may vary in scale and complexity and other issues or responses may arise.

Table 7.8 | *Potential Site Observations and Corresponding Corrective Actions for GI Maintenance*

Observation	Corrective Actions
Standing water in sediment forebays or storage areas after 72-hr drainage period	• Clear and remove debris or sediment via pipe jetting/vactoring/dewaterring. • Check for clogging of drainage infrastructure or consider adding drainage infrastructure if it doesn't exist. • Perform soil testing and remediate soil
Algae blooms in standing water	• Remove algae by hand-pulling and raking and dispose of off-site. • If recurring, investigate possible causes to determine appropriate method for prevention.
Significant erosion	• Repair erosion, install erosion control matting or improve vegetation at eroding areas. • If erosion is occurring downstream of energy dissipator, consider extending energy dissipator. • Consult design engineer to use riprap or other solutions as necessary to prevent further erosion.
Significant sedimentation	• Perform sediment removal using specialized equipment. • Install pretreatment devices to limit sediment reaching the GI system. • Consult design engineer to determine possible solutions if problem is recurring.
Sinkholes or settling	• Perform sinkhole repair. • Compact settled areas. • Assess soil properties with geotechnical investigation, or perform dye testing if problem is recurring.
Dead, fallen or unhealthy trees	• Remove dead trees. If trees are large or interfering with electrical lines an arborist should be consulted. • Prune unhealthy limbs. • Replace trees.
Dead, diseased, or problematic vegetation	• Apply treatments to affected vegetation. • Replace vegetation. • Remove noxious or invasive species. • Assess vegetation size and placement and consider changes to the planting plan.
Concrete, pavement or structural damage	• Perform patching to damaged structures. • For significant damage, consult an engineer for possible re-design and a construction contractor to perform repairs.
Mosquito, bee/wasp or other pest infestation	• Remove pests or apply control measures such as traps, pesticides or mosquito dunks. • Retrofit system to limit standing water.
Soil degradation, significant salt accumulation or soil compaction	• Remove and replace surficial layers of soil where problem is most concentrated. • Aerate soil. • Investigate and limit possible sources.
Stormwater bypassing inlet or curb cut during events	• Check for blockages or paving issues. • Consult design engineer for inlet modification.

CONCLUSION OF SECTION 7.7

At the end of this section, user should understand how to identify issues that need corrective maintenance, what procedure to follow when corrective maintenance needs are identified and potential solutions for different issues.

8 Post-Construction Monitoring

8.1 Summary of Chapter

Incorporating monitoring into the NGIP allows for a better understanding of how green infrastructure (GI) is functioning compared to design and program goals. This chapter describes the key aspects and timing of monitoring GI. While every project may not require post-construction monitoring, the Department of Water and Sewer Utilities (DWSU) should be consulted early during the design phase to determine if a NGIP project should include post-construction monitoring.

This chapter will help monitoring staff:

- Understand the role monitoring plays in understanding GI performance
- Identify which monitoring methods should be used for different GI practice types
- Determine how monitoring can inform remedial action at GI practices

8.2 Monitoring Objectives and Approach

It is important to establish clear objectives and monitor GI to track performance over time. Similar to a maintenance plan (see **Section 7.3**), a site's monitoring approach will vary depending on the type of GI installed. A general approach that can be used as a starting point is described below. An example monitoring plan layout is included as ***Figure 8.1***.

8.2.1 Objectives

The objective of GI monitoring is to confirm site compliance with the original design and program intent and regulatory standards, diagnose unexpected changes in performance, identify corrective and adaptive management actions and inform future design, construction and maintenance practices.

8.2.2 Site Knowledge

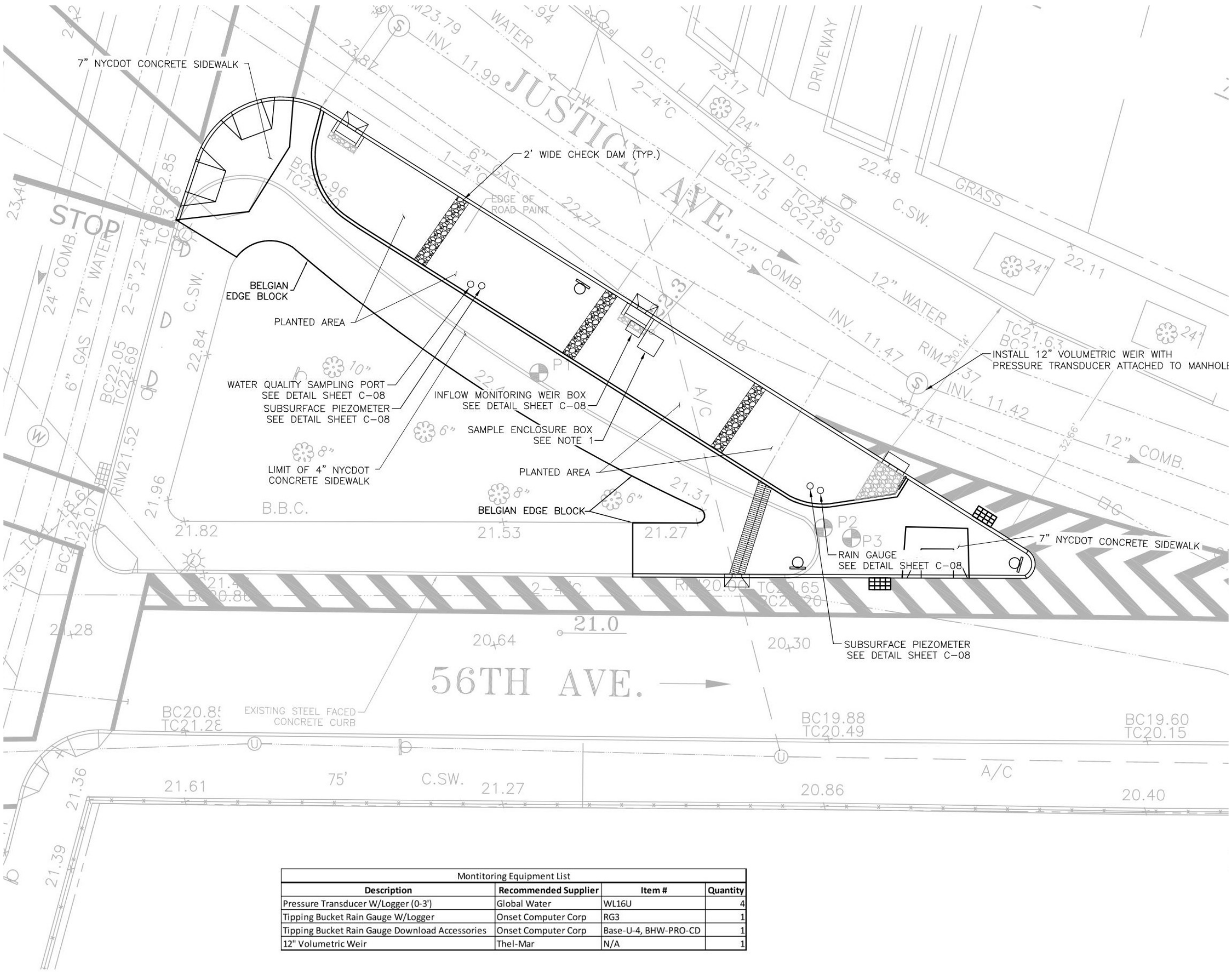
Prior to beginning any monitoring activities, monitoring staff should have a contextual understanding of how the site functions as a whole with respect to hydraulic network and characteristics of nearby GI practices. This may include reviewing construction drawings, specifications and as-built drawings, as well as understanding any monitoring equipment currently installed at the site.

8.2.3 Instrument Handling

Instruments must be calibrated and maintained per the manufacturer's instructions to achieve accurate outputs. While monitoring equipment will vary by site, details of several potential pieces of monitoring equipment are shown in ***Figure 8.1.***

8.2.3.1 **Manufacturer calibrations** performed in the factory are not permanent and equipment may migrate away from the calibrated value. It is important to perform and document periodic calibrations.

Figure 8.1 | *Example Monitoring Plan Layout*



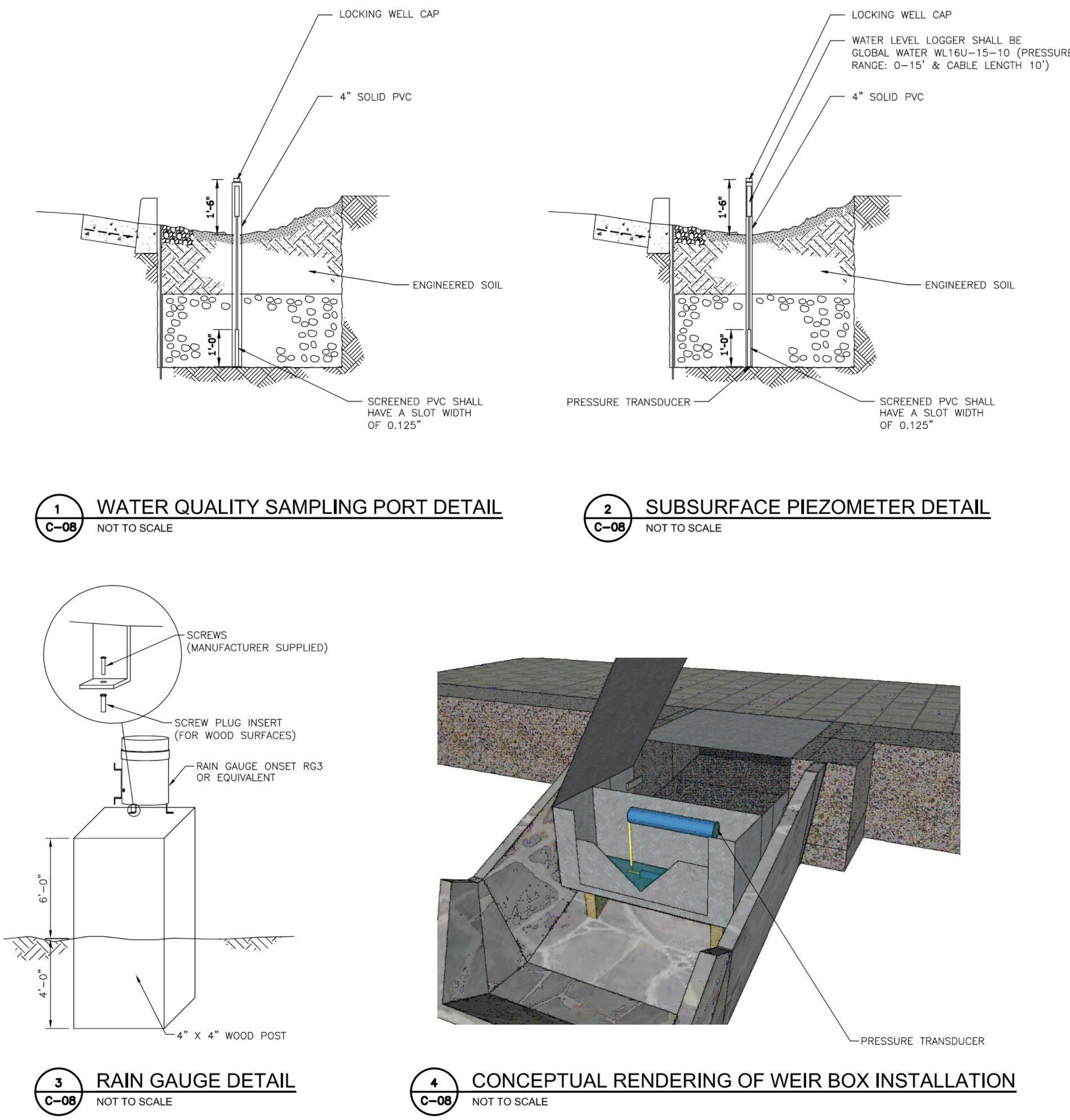
Montitoring Equipment List			
Description	**Recommended Supplier**	**Item #**	**Quantity**
Pressure Transducer W/Logger (0-3')	Global Water	WL16U	4
Tipping Bucket Rain Gauge W/Logger	Onset Computer Corp	RG3	1
Tipping Bucket Rain Gauge Download Accessories	Onset Computer Corp	Base-U-4, BHW-PRO-CD	1
12" Volumetric Weir	Thel-Mar	N/A	1

8.2.3.2 Sensors can be calibrated by **using a known value** (standard) and recording a measured value in a calibrating software typically provided by the instrument manufacturer.

8.2.3.3 Prior to installation of equipment, an **in-situ verification** and, if needed, calibration, is recommended to assure that the instrument is functioning.

8.2.3.4 Where **custom equipment** is needed, user manuals will be developed and updated.

***Figure 8.2** | Example Monitoring Equipment*



CONCLUSION OF SECTION 8.2

Clear monitoring objectives and expectations should be set for each GI practice and the program as a whole. In addition to evaluating performance of the GI practice, monitoring data can be leveraged to inform program decisions and adapt design and program standards.

8.3 Performance Testing Timeline

Performance testing should be performed at critical points during a GI practice's life. Field acceptance testing is performed during construction, baseline performance testing upon establishment and ongoing field performance testing at recurring intervals throughout the GI practice's life.

8.3.1 Field Acceptance Testing

The goal of field acceptance testing is to test if GI practices were constructed in a way that manages stormwater as designed.

8.3.1.1 It is necessary for **coordination between the monitoring staff and the Contractor** to occur during field acceptance testing.

8.3.1.2 The City of Newark (City) and its Engineer will coordinate with the Contractor to perform and document the field acceptance testing.

8.3.2 Baseline Performance Testing

Baseline performance testing should be completed once a site is established (see **Section 7.5**).

8.3.2.1 The goal of baseline performance testing is to establish the baseline performance of GI projects to **track the change in performance over time**.

8.3.2.2 Performance of GI can be impacted by sediment accumulation, traffic, erosion, plant health and lack of maintenance.

8.3.2.3 When completing baseline testing of surface infiltration, it is crucial to take **seasonal variations in soil permeability** into account when establishing a baseline surface infiltration rate. It is recommended that two baseline measurements be taken, one at the beginning and one at the end of the growing season.

8.3.3 Ongoing Field Performance Testing

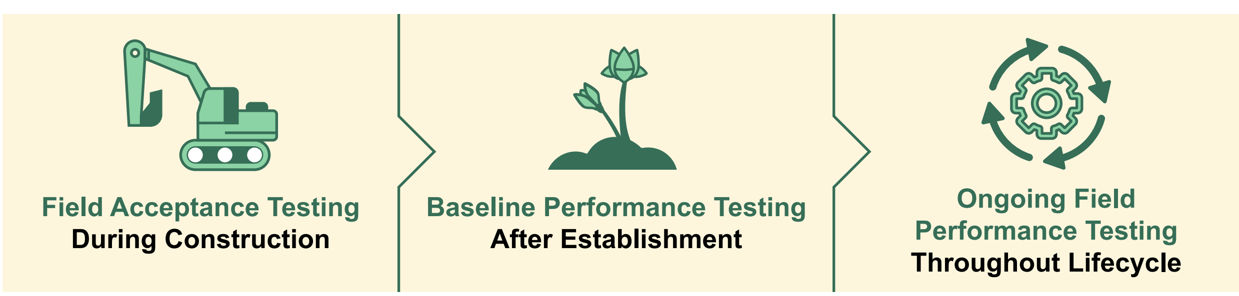
Ongoing field performance testing is used to determine the performance of a GI practice over time and monitor changes from the baseline performance.

8.3.3.1 Field performance testing can help the City determine modifications to designs or maintenance requirements that can enhance the performance of existing and future GI facilities.

8.3.3.2 Field performance testing should be conducted at least once every 5 years at each GI practice.

8.3.3.3 Performance during these testing periods will be compared to baseline performance to determine if there are any changes in performance.

Figure 8.3 | *Performance Testing Timeline*



CONCLUSION OF SECTION 8.3

Establishing a structured monitoring lifecycle allows for an effective understanding of changes to performance over time.

8.4 Testing Methods

Testing methods will vary depending on the type of GI practice and how stormwater enters and leaves the practice. Some common testing methods that will be used in the City are summarized below, but additional methods may need to be considered depending on the GI practice.

8.4.1 Water Level Testing

Continuous water level testing allows DWSU to understand how much water is getting into and out of GI practices and to better understand storage provided as it relates to experienced storm events.

8.4.1.1 GI practices should be designed with **observation wells with lockable caps** (see **Section 3.4.4**) to allow for ease of installation of monitoring equipment and sensors.

8.4.1.2 **Piezometers** can be installed temporarily during a singular monitoring event or left in place to measure and collect data over time.

8.4.2 Surface Infiltration Testing

It is important that the actual infiltration rate through the GI is determined so that it can be compared to the designed infiltration rate.

8.4.2.1 **Two infiltration tests** are required at GI practices with a footprint of <1000 square feet and **four infiltration tests** are required at green infrastructure practices ≥1000 square feet.

8.4.2.2 For vegetated GI practices such as rain gardens, a **double-ring infiltrometer test** is typically used. However, faster methods such as the Cornell Sprinkle Infiltrometer Test could be suitable alternatives.

Infiltration Testing Methods in Vegetated Areas Reference

The double-ring infiltrometer testing method is outlined in the **City of Newark Green Infrastructure Specification 33 05 05**.

The Cornell Sprinkle Infiltrometer testing method is outlined in the **user manual**.

8.4.2.3 For **permeable pavement and pavers,** the testing method consists of adhering a 12-inch infiltration ring to the permeable surface and applying water to pre-wet the area. After the media is saturated, a specified mass of water is poured into the ring and the time for the water to be infiltrated is used to calculate a surface infiltration rate.

Infiltration Testing on Permeable Surfaces Reference

Monitoring must be in accordance with the following standards: **ASTM C1781/ C1781M-15 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems** and **ASTM C1701/ C1701M−17a Standard Test Method for Infiltration Rate of In Place Pervious Concrete.**

8.4.3 Simulated Runoff Test

Simulated runoff tests, or "hydrant tests", should be performed to understand if stormwater runoff is reaching the system as designed.

8.4.3.1 A simulated runoff test verifies that **stormwater enters and exits** the GI practice and that the designed storage volume is being used.

8.4.3.2 The test is performed by **applying a measured flow of water from a nearby fire hydrant** upstream of the GI, while monitoring water levels within the system.

8.4.3.3 During a simulated runoff test, it is important to **measure flow that returns to the sewer system,** since it is used to determine the correct volume of runoff managed by the GI practice.

8.4.3.4 Monitoring staff measures the hydrant output and performs a **water balance equation to calculate how much runoff the practice stores,** the rate of infiltration into the engineered soil, and the drain down time of the GI system.

CONCLUSION OF SECTION 8.4

It is important that a consistent and appropriate testing method be used throughout the monitoring period. The testing method used will be based on the type of GI practice.

8.5 Reporting, Data Management, Quality Control

Monitoring efforts are summarized with data collection and reports that can help understand performance and inform programmatic improvements. **Chapter 9** provides additional information about data management.

8.5.1 Reporting

It is important that the results of performance testing be reported consistently and shared with individuals taking part in the design, construction and maintenance of GI practices.

8.5.1.1 All monitoring performed should be recorded using a **standard monitoring log** that includes GI practice name, location, date, time, names of monitoring staff, weather, test performed and test results.

8.5.1.2 Comprehensive results of monitoring should be stored in a **digital database** to allow for interpretation of data.

8.5.1.3 Reporting should assess performance of GI practices individually, as well as on a sewershed-scale.Conclusions from monitoring should be provided as feedback to decision makers in a summary memo. **Monitoring summary memos should be developed annually,** or as-needed.

8.5.2 Remedial Actions

Depending on the results of performance testing, remedial action may need to be taken by designers or maintenance staff.

8.5.2.1 Maintenance staff should be notified if there is **shift from baseline performance** during ongoing performance testing. This may include updates to the maintenance plan to include more frequent maintenance visits (see **Section 7.3**) or corrective maintenance (see **Section 7.7**).

8.5.2.2 Monitoring may also provide insight into programmatic improvements to future GI implementations such as adjusting design criteria or increasing maintenance frequencies (see **Chapters 3** and **7** respectively).

8.5.3 Quality Control

As the results of performance testing will be used to inform changes in design and maintenance, it is important that testing is conducted to achieve quality performance testing results.

8.5.3.1 Perform a **consistent application** of monitoring procedures across sites, monitoring staff and monitoring seasons.

8.5.3.2 Adhere to all **ASTM Standards.**

8.5.3.3 Maintain **calibration and upkeep** of field equipment.

8.5.3.4 Perform consistent **quality control** for data management, analysis, and reporting.

8.5.3.5 **Train all involved individuals** on conducting monitoring procedures, using instrumentation and reporting.

CONCLUSION OF SECTION 8.5

As a result of monitoring, DWSU is able to make necessary changes at specific sites and better understand how designs and maintenance procedures can be modified to better serve future sites. Using the guidance presented above and in **Chapter 9** will help standardize data management and quality standards and promote a more consistent interpretation of monitoring results.

9 Project Data Tracking

9.1 Summary of Chapter

The Department of Water and Sewer Utilities (DWSU) must be able to easily monitor, report on and summarize the status of green infrastructure (GI) projects within their program, as needed. This is especially important if the development of GI practices is tied to the City's Long Term Control Plan (LTCP) or municipal separate storm sewer system (MS4) permit. Furthermore, proper data tracking will allow community partners, consultants and contractors to report project status and milestones and infer other metrics quickly for regulatory agencies and municipal officials.

This chapter will help GI program management staff:

- Understand the importance of project data tracking.
- Develop a project data tracking database .
- Gain an appreciation and knowledge of the types of data to include in a GI data tracking database.
- Understand best practices for storing monitoring data.

9.2 Fields and Values

9.2.1 General GI Project Data

Data for each GI project proposed, designed and constructed should be compiled and tracked in a database by project teams. Whether the data is tracked in a relation database such as Microsoft Access, an enterprise database using SQL Server, a geographic information system (GIS) or simple Microsoft Excel table, the concept is the same.

The database can be set up to track many aspects of a GI practice. The following broad categories or fields should be considered:

9.2.1.1 **Description** - Information about the GI sites names, locations and types. Data such as the street and cross street, neighborhood, parcel, drainage area, type of GI practice and date of survey.

9.2.1.2 **Selection** - Data about the selection and ranking of proposed sites. For DWSU projects, this may include prioritization scores, ranking and environmental screening information based on desktop analysis.

9.2.1.3 **Status** - The developmental stage of a GI site or project including proposed, concept or final design.

9.2.1.4 **Performance** - Metrics on the operational characteristics of designed or built sites such as drainage area managed and impervious area managed and/or removed. Results and status of monitoring (as discussed in **Chapter 8**) should also be tracked and recorded.

9.2.1.5 **Financials** - The costs of GI practices, including proposed costs, final bid costs, funding status, and impervious acres and gallons managed per dollar.

9.2.1.6 **Additional Information** - Space for recommendations specific to a GI site and/or additional comments as narrative text.

9.2.2 Project Tracking Database Example

A well-designed project tracking database must prioritize consistent and high quality data collection yet be adaptable as projects move from siting, planning and design to construction, as new project sites are proposed and as NGIP grows and evolves. ***Table 9.1*** lists the fields that should be included in the NGIP Project Tracking Database. Information should be added to the database and updated throughout a GI project.

This information is critical as DWSU will need to access comprehensive NGIP data to calculate percent (%) of LTCP goal achieved based on impervious area managed information provided by each project in addition to other program metrics.

Table 9.1 | *Project Tracking Database*

Field Type	Field Name	Data Type	Field Description
Description	GI ID	Integer	GI Practice Number (sequential)
	Site	Text	Name of Site
	Address	Text	Number and Street Name
	Location (Other)	Text	Cross Street(s), etc.
	Latitude/Longitude	Decimal	Location of Site
	Site Type	Text	GI Site Type
	Drainage Type	Text	Combined Sewer Overflow (CSO) or MS4 Drainage
	GI Practice Type	Text	GI Practice Types to be Constructed
	Ward	Text	City Ward
	Survey	Month/Day/Year	Survey Completion Date
Selection	GI Performance Score	Integer	Prioritization Score (as applicable)
	Co-Benefits Score	Integer	Prioritization Score (as applicable)
	Site Suitability Score	Integer	Prioritization Score (as applicable)
	Total Score	Integer	Total Prioritization Score (as applicable)
	Rank	Integer	Sort List by Total Score then Performance, then Co-Benefits, then Suitability to Assign Rank
	Environmental Screening	Text	Status of Desktop Environmental Screening (as applicable)

Status	Status	Text	Status of GI Site at Date of Data Entry
	Year Completed	Year	Year of DWSU Final Acceptance
Performance	GI Area	Decimal	Total Footprint Area of GI Practice (square feet)
	Managed Area	Decimal	Total Tributary Drainage Area Managed (square feet)
	Impervious Area Managed	Decimal	Impervious Tributary Area Managed (square feet)
	Impervious Area Removed	Decimal	Impervious Area Converted to Pervious (square feet)
	Volume of Runoff Capacity	Integer	Calculated Volume based on Design (gallons)
	Monitoring Status	Month/Day/Year	Monitoring Start Date (if applicable)
Financial	Funding	Text	Type of Project Funding
	Estimated Cost	Dollars	Estimated Cost of Project at Final Design
	Bid Cost	Dollars	Selected Bidder's Cost
	Actual Cost	Dollars	Actual Cost of Project at DWSU Project Acceptance
Additional Information	Geotechnical Results	Text	Depth to Groundwater (feet) and Infiltration Rate (inches per hour)
	Recommendations	Text	Eliminate or Defer GI at a Site with Explanation
	Comments	Text	Additional Comments

9.2.3 Data Validation

Using "valid values" for each non-numerical categorical field will facilitate data review, analysis and reporting.

Table 9.2 lists initial valid values for the NGIP Project Tracking Database.

9.3 Database Management

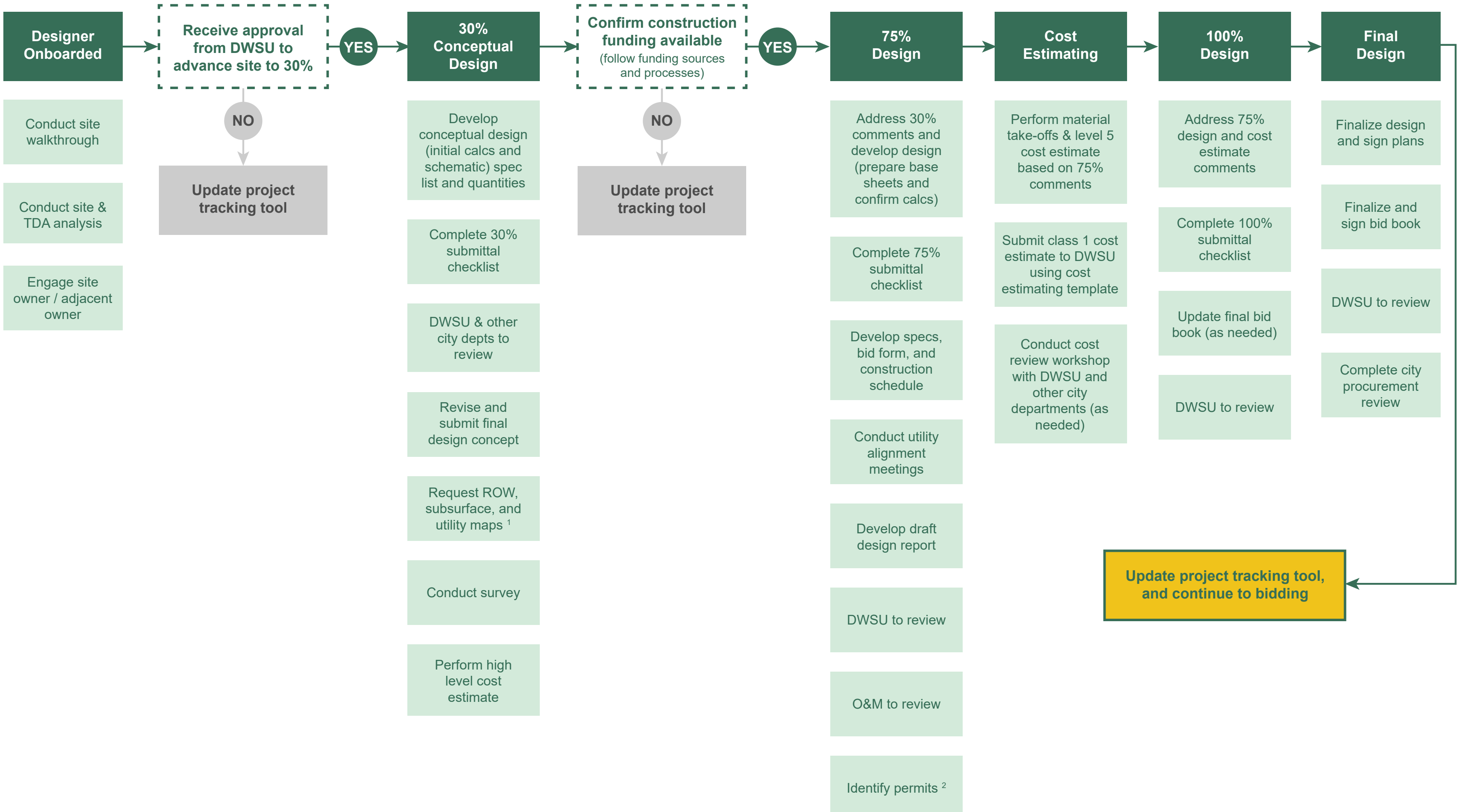
In order to keep data up to date, consistent and accessible project data should be stored in a location accessible by project teams but editable by a limited number of team members only. Changes such as the addition and deletion of fields or valid values should be documented either in an external file or within the database or spreadsheet itself. Printouts and exports of data from the database should be tagged with the source of the data and date in order to facilitate retrieval of new data or quality checks.

Table 9.2 | *Valid Non-Numerical Data Values*

Field Type	**Valid Values**	
Site Type	Park	School
	Parking Lot	Vacant Lot
	Public Housing	Municipal Facility
	Road Right of Way	Public Facility
Drainage Type	CSO	
	MS4	
GI Practice Type	Rain Gardens	Stormwater Planters
	Bioretention	Cisterns & Rain Barrels
	Bioswales	Permeable Pavements
	Downspout Planters	Tree Filter Boxes
	Infiltration Basins	Constructed Wetlands
	Tree Filter Boxes	Sand Filters
	Green Roofs	Detention Ponds
	Blue Roofs	Dry Wells
	Subsurface Storage	
Ward	North	East
	South	West
	Central	
Desktop Environmental Screening	Pending	Passed
	Under Review	Failed
Status	Proposed	
	30% Conceptual Design	
	75% Design	
	100% Design	
	Bid	
	Construction	
	DWSU Project Acceptance	
Funding	NJ Water Bank	City of Newark
	State Grant	Private
	Federa Grant	Mixed
	Other Grant	Not Funded

Appendices

Appendix A City of Newark Green Infrastructure Program Design Process



1 DWSU to provide prior to survey initiation.

2 Anticipated permits during construction: NJDEP (various), Soil Conservation District, City of Newark Tree Work (Trimming and Planting), Sewer Connection, and Site Plan Approval.

Appendix B Example 75% Design Checklist

Project Name:		**Project Number:**	
Dept./Firm Name:		**Date:**	
No.	**Item**	**Provided and Correct**	**Comment** Note: A comment must be provided to explain all items checked 'No'
1	Conceptual design checklists completed.	☐ YES ☐ NO ☐ N/A	
2	Comments from 30% design have been addressed and comment response log completed.	☐ YES ☐ NO ☐ N/A	
3	Internal 75% QA/QC performed, and comment response log completed before submittal to DWSU.	☐ YES ☐ NO ☐ N/A	
4	Updated calculations and stormwater volume managed table.	☐ YES ☐ NO ☐ N/A	
5	Construction documents in PDF prepared to submit to DWSU.	☐ YES ☐ NO ☐ N/A	
6	Findings from additional environmental surveys are reflected in the design.	☐ YES ☐ NO ☐ N/A	
7	Demolition and removal plans included.	☐ YES ☐ NO ☐ N/A	
8	Tree protection plans included.	☐ YES ☐ NO ☐ N/A	
9	Erosion and sedimentation control plan included.	☐ YES ☐ NO ☐ N/A	
10	Site layout plan included.	☐ YES ☐ NO ☐ N/A	

11	Profile and section views created for all major project elements including pipes, BMPs, and drainage structures.	☐ YES ☐ NO ☐ N/A
12	Standard details referenced on all appropriate sheets.	☐ YES ☐ NO ☐ N/A
13	Non-standard details included.	☐ YES ☐ NO ☐ N/A
14	City and non-City utilities requiring relocation identified and contacted at DWSU PM's direction.	☐ YES ☐ NO ☐ N/A
15	Materials plan included.	☐ YES ☐ NO ☐ N/A
16	Maintenance and Protection of Traffic Plans, as needed.	☐ YES ☐ NO ☐ N/A
17	Construction access and staging areas identified and provided on plans.	☐ YES ☐ NO ☐ N/A
18	Location and size of work areas, equipment and material storage, truck routes, equipment set up areas, stockpiling, and disposal of excess soil discussed with City and included in construction documents, if necessary.	☐ YES ☐ NO ☐ N/A
19	Specifications to include updated Table of Contents, Special Provisions, Edited Guide Specifications, and Engineer-developed Specifications.	☐ YES ☐ NO ☐ N/A
20	Invert elevations, slopes, and sizes included on design documentation for all structures, piping, and flow control devices.	☐ YES ☐ NO ☐ N/A

21	Materials and tie-ins or anchors for structures, structural GI/BMPs and furnishings identified.	☐ YES ☐ NO ☐ N/A
22	GI/BMPs have sufficient hydraulic head to operate by gravity and meet required drain-down times.	☐ YES ☐ NO ☐ N/A
23	All major structures and/or structural GI/BMP details have been referenced or incorporated into the design set.	☐ YES ☐ NO ☐ N/A
24	Landscape plans including plant size, species, quantity, and landscape details included for all vegetated BMPs and landscaped areas.	☐ YES ☐ NO ☐ N/A
25	Access provided for maintenance (vegetation and sediment).	☐ YES ☐ NO ☐ N/A
26	Utility crossings shown on profile.	☐ YES ☐ NO ☐ N/A

Reviewer

Name: Signature:

Title: Date:

Project Manager

Name: Signature:

Title: Date:

Appendix C City of Newark Green Infrastructure Program Construction Process