# Appendix B1
# Passaic County Green Infrastructure Plan:
## GSI/LID Reference Document Review

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## Introduction & Executive Summary

The current *Passaic County Green Infrastructure Study* is not the first green stormwater infrastructure/low impact development (GSI/LID) initiative in the County, State of New Jersey, or the nation. Accordingly, the plan process will be informed by the efforts of others through a desktop review of existing plans and technical documents from government and nonprofit entities in the NY–NJ–PA region. This review of the background documents listed below includes a description of the document purpose and goals; summary of relevant GI/LID content; and examples of illustrative tables, drawings, and other relevant figures.

The review will inform the planning process in two ways. First, the review of existing Passaic County documents will determine where and how GI/LID is already addressed. Where it is already incorporated into Passaic County documents, the project team will be cognizant of potential conflicts, and make recommendations to rectify any conflicts in the final report. Moreover, the existing document review will also alert the project team to areas where GI/LID can and should be incorporated into existing docs in order to ensure consistency in the County's commitment to and implementation of GI/LID.

The second way the document review will inform the planning process is through the insights gained from other existing resources in New Jersey and the NY–NJ–PA region. The best management practices and standards of communities already implementing GI/LID will be presented to the Technical Advisory Committee (TAC) and Inter-agency Team (IT) as starting points for discussion as to how the County could implement GI/LID. Further, best management practices, design specifications, and other information gathered from these documents will serve as examples for inclusion in the County's *Green Infrastructure Implementation Element*.

### Passaic County Resources

- Moving Passaic County – Transportation Element of the Passaic County Master Plan, Passaic County Department of Planning and Economic Development, October 2012
- Passaic County Multi-Jurisdictional Hazard Mitigation Plan, Passaic County Office of Emergency Management, August 2010
- Highlands Element of the Passaic County Master Plan and Exhibits, Passaic County Planning Department, May 2011
- Highlands Environmental Resource Inventory for Passaic County and Exhibits, Passaic County Planning Department, May 2011
- Little Falls Green Infrastructure Feasibility Study, Passaic County Sewerage Commission and Rutgers Cooperative Extension Water Resource Program
- Paterson Public School #5 Green Infrastructure Information Sheet, Passaic Valley Sewerage Commission, 2015

### New Jersey Resources

- Green Infrastructure Guidance Manual for NJ, Rutgers Cooperative Extension Water Resource Program, March 2016
- NJ Developers' Green Infrastructure Guide, NJ Future and NJ Builders Association, April 2017
- Tier A MS4 NJPDES Permit Presentation and GIS Initiatives for Stormwater Infrastructure Presentation, NJ Department of Environmental Protection, March 2016
- Hudson County Land Development Review Regulations for Smart Growth & Sustainable Development, Hudson County Planning Board, June 2016

- Newark Greenstreets Initiative Report and Technical Appendix, Together North Jersey, March 2015
- Hoboken Green Infrastructure Strategic Plan, Together North Jersey, October 2013

### United States Comparative Resources

- City of Philadelphia Stormwater Management Guidance Manual, Version 3.0, Philadelphia Water Department, July 2015
- City of Philadelphia Green Streets Design Manual and Appendix, Philadelphia Water Department and Philadelphia Streets Department, 2014
- A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds, Philadelphia Water Department, August 2009
- NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways, NYC Department of Environmental Protection, September 2010

The review of existing resources identified a number of key items that the project team will use in external and internal communications, and/or take under consider during Plan creation:

*Moving Passaic County - the Transportation Element Update of the Passaic County Master Plan* (the Plan) outlines the policies, priorities, and projects for all modes of transportation within the County.

- While not specifically identified for green infrastructure in the *Transportation Element Update*, the priority corridors for bicycle, pedestrian, and river access are prime opportunities for green streets.
- In the typical cross sections of the County's five street types, only the Highlands Regional Street type specifically recommends the installation of green streets as a means to minimize the impacts of street runoff.
- The existing Green Streets section of the Complete Streets Guidelines provides an overview of the County's goals and objectives related to green streets, including stormwater management, maintaining drinking water supply, improving the environment, public health, and quality of life, and decreasing capital costs for public infrastructure. The section includes a nontechnical description of typical design elements for roadways, public transit, and on site facilities (driveways, parking lots, etc.).
- Ultimately, this project will produce comprehensive Green Streets Guidelines, which will bolster the existing green infrastructure aspects of the Transportation Element.

The *Multi-Jurisdictional Hazard Mitigation Plan* (the *Plan*) is Passaic County's response to the Federal Emergency Management Agency (FEMA) Interim Final Rule (IFR) related to the Disaster Mitigation Act of 2000. The purpose of the Plan is to identify hazards, conduct a risk assessment, and recommend mitigation actions.

- The most significant hazard to which Passaic County is exposed is flooding. The goals and expectations of this project and the impending *Green Infrastructure Implementation Element* are in alignment with the goals of the *Plan*.
- The *Plan* recognizes that County and municipalities' land use planning and development review processes are areas where flood mitigation measures can be incorporated and implemented. Although most of the recommendations related to planning and development have to do with the location of development relative to flood plains and

building codes to mitigate flood damages, GI techniques can also be applied to reduce stormwater runoff flows that may contribute to some flooding issues.

- The Municipal Action section of the *Plan* includes action items of particular relevance to GI, in that they include specific improvements to stormwater management systems and stream corridors in the County, which may be opportunities to target GI projects.
- The Municipal Action section of the *Plan* identifies potential repetitive loss buy-out areas, which could be opportunities to implement GI techniques during the restoration phase after building(s) have been demolished.

The *Highlands Element of the Passaic County Master Plan* (the *Highlands Element*) meets the requirements of Plan Conformance to the Highlands Regional Master Plan (RMP), and identifies policies to guide future land use and development for the Preservation Area of the County.

- The regulatory requirements of the *Highlands Element* apply only to areas where the County has jurisdiction over site plan and subdivision review along County roads and where the development impacts County stormwater facilities, as well as County capital improvement projects in the Highlands Preservation Area.
- Many of the goals outlined in the *Highlands Element* are related to water quality and control of flow. Moreover, LID is specifically mentioned as a strategy to address many goals within the *Highlands Element*. Accordingly, the goals and expectations of this project and the impending *Green Infrastructure Implementation Element* are in alignment with the goals of the *Highlands Element*.

The *Highlands Environmental Inventory* (*ERI)* is intended to provide background information about Passaic County's natural and cultural resources to support its planning efforts related to the *Highlands Regional Master Plan* (RMP).

- The *ERI* includes a series of environmental maps that depict areas of degradation related to water quality and quantity control. These maps may serve as the basis for targeting GI/LID techniques.

The *Little Falls Green Infrastructure Feasibility Study* is a nontechnical guide for Little Falls to implement green infrastructure (GI) practices and provide public education and awareness about the benefits of GI.

- The *Little Falls Green Infrastructure Feasibility Study* provides educational graphics that may be adapted by the County for its own community outreach purposes.
- Little Falls provides examples of community engagement best practices, including its rain barrel and "Stormwater in Your Schools" programs.
- Because of its demonstrated commitment to GI/LID practices, it is of particular interest to have a representative from Little Falls participate and provide their expertise on the TAC.

The *Green Infrastructure Guidance Manual for New Jersey* (the *Manual*) was created to provide guidance for identifying locations and implementing green infrastructure (GI) projects throughout NJ. The *Manual* provides information about the fundamental function and benefits of select GI practices, as well as technical design standards. It describes the design process for GI practices, and guides the user through the process from site identification to implementation.

- The *Manual* provides examples and design specifications for GI practices that the County may consider including in the *Green Infrastructure Implementation Element.*

The *New Jersey Developers' Green Infrastructure Guide* (the *Guide*) was created by the NJ Developers' Green Infrastructure Task Force convened by the NJ Future and NJ Builders Association to address basic questions about green stormwater infrastructure for the New Jersey real estate development community, and to help inform decisions about where and how green stormwater infrastructure (GSI) would be most useful on a project. The *Guide* serves as a primer on urban hydrology (impervious cover and stormwater runoff), and the most widely used GI practices. It is not a design manual, and thus, does not provide engineering details, calculations, or specifications.

- The *Guide* provides examples of GI practices that the County may consider including in the *Green Infrastructure Implementation Element.*
- The *Guide* discusses two tools available to support decision making through cost–benefit analysis, including the Green Infrastructure Co-Benefits Calculator (http://www.nycgicobenefits.net/) and the National Green Values Calculator (http://greenvalues.cnt.org/national/calculator.php), both of which may be used by the County and its municipalities to estimate GI costs.
- The Guide includes a FAQ section to address common concerns and misperceptions about GSI, the relevant portions of which the County may consider including in its outreach materials.

The New Jersey Department of Environmental Protection (NJDEP) gave a series of *Tier A MS4 NJPDES Permit Presentations* to municipal officials explaining their responsibilities under the New Jersey Pollutant Discharge Elimination System (NJPDES) rules.

- Of particular relevance to GI/LID are NJDEP's regulations related to post-construction stormwater management. Municipalities must enforce NJDEP's minimum standards for stormwater runoff quantity, water quality, and groundwater recharge. Moreover, the NJPDES design and performance standards are enforced through municipal ordinances. Because GI/LIP best practices conform to NJDEP standards; they may be incorporated into the municipal land development review process.

The Hudson County Land Development Regulations (LDR) establish standards for site plan and subdivision reviews for which the County has jurisdiction. This most recent edition of the LDR includes Green Stormwater Infrastructure (GSI) regulations that reflect and incorporate post-Sandy regulatory changes, as well as the County's continued efforts in support of resiliency.

- With the exception of a few of references in the Street Design Element encouraging or allowing green stormwater infrastructure with relation to sidewalks and planting strips, the Circulation and Road Design Standards are largely silent regarding GSI and low impact development (LID).
- The LRD's Stormwater Management Design Standards require the use of green infrastructure and nonstructural best management practices in addition to the regular standards "to the maximum extent possible." Specifically, developments with 5,000 square feet of disturbance or less are required to include one GSI practice, and those

with 5,000 square feet of disturbance or more must include two GSI practices. The GSI practice must, at a minimum, handle runoff for 50% of the total disturbance. The project team will include this standard in the list of those for consideration by the TAC, IT, and the County.
- The GSI standards also include a "Quick Reference Guide" to demonstrate where the green stormwater management practices are most suitable, which serves an example the County may consider for inclusion in the *Green Infrastructure Implementation Element.*

The *Newark Greenstreets Initiative: Planning & Implementing Green Stormwater Infrastructure* includes best management practices, implementation recommendations, and an appendix of technical specifications. The Report provides guidance to Newark staff through a review of the City's existing Green Stormwater Infrastructure (GSI) specifications; identification of potential pilot locations; concept-level designs with stormwater diversion estimates, cost estimates, and contracting recommendations; and preparation of a horticulture manual.

- Key recommendations of the report that Passaic County may consider in its own *Green Infrastructure Implementation Element*.
    - Streets and City-owned properties provide abundant implementation opportunities.
    - Pilot selection should overlap with community priorities, be deemed feasible based on physical suitability, should be linked to outfalls with a history of CSO incidences, and consider cost reasonableness.
    - Establishing a cross-departmental team to implement the pilot projects
- The report includes examples of regulations and design specifications from communities throughout the US, as well as draft regulation and design specifications. The County may consider including a similar manual in the *Green Infrastructure Implementation Element*.
- The report's Horticultural Manual provides guidelines to identify appropriate vegetation and soil characteristics suitable for GSI techniques, as well as advice related to installation and maintenance. The County may consider including a similar manual in the *Green Infrastructure Implementation Element*.

The City of Hoboken's *Green Infrastructure Strategic Plan* (the Plan) addresses the impacts of more intense and frequent severe weather and flood events on the City's stormwater infrastructure system.

- The Plan includes a sewershed level analysis that organized the City into three zones based on the carrying capacity of the underlying land.
- The Plan provides examples of best management practices, including an analysis of both capital and maintenance costs.
- The Plan includes the following recommendations for innovative implementation strategies that Passaic County may consider in its own *Green Infrastructure Implementation Element*.
    - Incorporate performance based standards that include minimum standards for stormwater management without prescriptive language about how the standard is attained, thus allowing for flexibility of design. It further recommends incentive

zoning that gives bonuses to encourage retention greater than the minimum standard.
    - Establish a Stormwater Trust Fund to collect funds from individual development projects where specific site conditions limit the ability to incorporate GI. Instead of forcing ineffective GI applications, the City can collect funds to construct more effective solutions offsite.
    - Conduct a further study to determine the feasibility of other financial incentive programs such as a Stormwater Management Tax Credit, rebates, and installation financing.

The *Philadelphia Stormwater Management Guidance Manual, v. 3.0* (the *Manual*) is a comprehensive resource to help the real estate development community navigate the Stormwater Plan Review process and demonstrate compliance with the City's Stormwater Regulations.

- Philadelphia Water (PWD) Stormwater Regulations require onsite stormwater management for development projects that cause 15,000 square feet (5,000 in certain watersheds) or more of earth disturbance. Other types of construction activities may also trigger portions of the Stormwater Regulations, including demolition and voluntary stormwater retrofit projects.
- The Manual provides examples of substantive content, exhibits, best management practices, and design standards the County may want to include in the *Green Infrastructure Implementation Element*.

The *Philadelphia Green Streets Design Manual* (the Manual) provides guidance for designing, constructing, and maintaining green stormwater infrastructure (GSI) in the City right-of-way (i.e., "green streets").

- Streets represent 30% of the City's impervious cover. Accordingly, like Newark, Philadelphia sees streets as a prime opportunity to incorporate GSI.
- The Manual provides examples of substantive content, exhibits, best management practices, and design standards the County may want to include in the *Green Infrastructure Implementation Element*.

*A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds* (the Report) was prepared to provide PWD with a more complete understanding of the "implications of the green and traditional infrastructure approaches in terms of their respective ability to provide environmental, social, public health, and other values." A triple-bottom line (TBL) approach recognizes that there are external benefits to society not captured in a cash flow financial analysis.

While a triple bottom line assessment is beyond the scope of this project, some key findings for consideration by the County include:

- Compared with LID approaches, traditional control measures do not provide environmental, social, and public health benefits to the community beyond water quality improvement.

- Traditional infrastructure-based measures may not address the root causes of impairment streams, where the primary causes of impairment are modified flow patterns and habitat degradation.
- Infrastructure-based measures are typically focused on removing loads of specific pollutants rather than restoring natural flow conditions and habitat.
- Under LID-based options, recreational opportunities increase; property values increase; urban heat island effect decreases; water quality and aquatic ecosystems improve; wetlands are created and/or enhanced; local green jobs reduce poverty; shade and insulation from GI save energy and reduce carbon footprint; air quality improves; and the level of construction and maintenance-related disruption decreases.

The *NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterway*s (the Plan) applies alternative "green" approaches to improving water quality, particularly by reducing flows into the City's combined sewer overflow (CSO).

- The Plan includes specific attainment goals the County may consider including in the *Green Infrastructure Implementation Element*.
    - reducing CSO volume by a specific amount quantified in billions of gallons per year (bgy);
    - capturing rainfall from 10% of impervious surfaces in CSO areas over 20 years; and
    - providing substantial and quantifiable sustainability benefits, including cooling the city, reducing energy use, increasing property values, and cleaning the air.
- The Plan recommends implementation of a sewer charge for stormwater to provide a dedicated funding source for green infrastructure projects.

## Moving Passaic County – Transportation Element of the Passaic County Master Plan

Passaic County Department of Planning and Economic Development, October 2012

*Moving Passaic County - the Transportation Element Update of the Passaic County Master Plan* (the Plan) outlines the policies, priorities, and projects for all modes of transportation within the County. Having prepared its last Transportation Element in 1982, the County produced this Plan to reflect the vast changes in demographics, land use, and regulation, as well as contemporary thought about transportation planning.

The Plan includes four broad goals *(language from the Plan)*:

- *Bring the County's transportation system in line with current and anticipated future needs.*
- *Help the County become more transit-friendly and reduce reliance on the automobile;*
- *Integrate transportation with local land-use plans to better support each community's vision for its future.*
- *Work toward the creation of "Complete Streets" so that the roadways better serve all users, including pedestrians, bicyclists, transit users, senior citizens, and persons with disabilities.*

The Plan also includes six key themes:

- Complete Streets: Provides context-based typologies for improvements that provide a safe and efficient street system for all users. The Complete Streets Guidelines also encourage "green streets" to mitigate the impacts of stormwater runoff and flooding.
- Bicycle, Pedestrian and River Access: Encourages alternative means of transportation as a sustainable practice that has positive impacts on the environment, public health, and overall community connectivity, and includes a framework for priority corridors to enhance bicycle, pedestrian, and river access.
- Moving Goods and People: Recognizes the economic benefit of freight movement through the County; and thus, includes recommendations that prioritize roadways and corridors for freight supportive improvements, as well as identifies rail improvements to increase this mode's share of freight movements within the County.
- Public Transportation: Addresses the importance of the public transportation system within the County, and recommends improvements to the existing system and enhancements to allow new service to reach underserved populations, increase system efficiency, and promote redevelopment.
- Motor Vehicle Circulation: Discusses the roadway system, which moves both people and goods within and through the County. Many of the higher level functional class roadways are owned and maintained by the County. The Plan includes recommendations for the efficient maintenance of the County's roadway system, recognizing the rational link between capital improvements and land use.

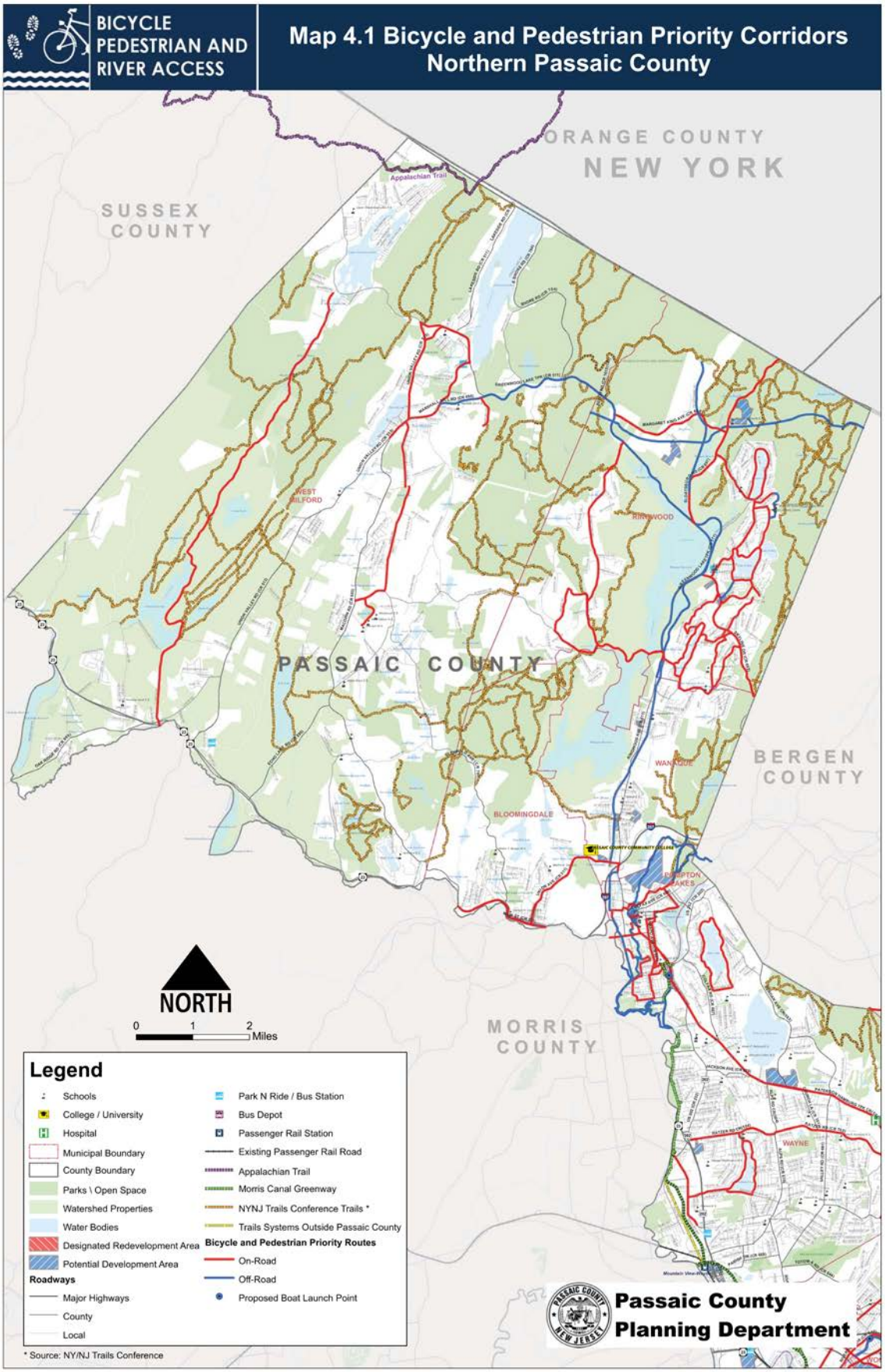
*Source: Moving Passaic County – Transportation Element of the Passaic County Master Plan, Oct 2012*

- Scenic and Historic Byways: The Plan identifies and makes recommendations to protect and enhance corridors that contribute to the County's historic, cultural, and scenic character.

The Plan includes a look at community demographic, employment and economic trends, travel patterns, land use, and environmental considerations to put the transportation network in context in terms of past demand, current need, and future expectations. The Plan also includes scenario planning to test outcomes based on variable land use, demographics, transportation mode share, and policy mixes.

While not specifically identified for green infrastructure in the Plan, the priority corridors for bicycle, pedestrian, and river access are prime opportunities for green streets *(See Map 4.1 and 4.2)*.

*Source: Moving Passaic County – Transportation Element of the Passaic County Master Plan, Oct 2012*



*Source: Moving Passaic County – Transportation Element of the Passaic County Master Plan, Oct 2012*

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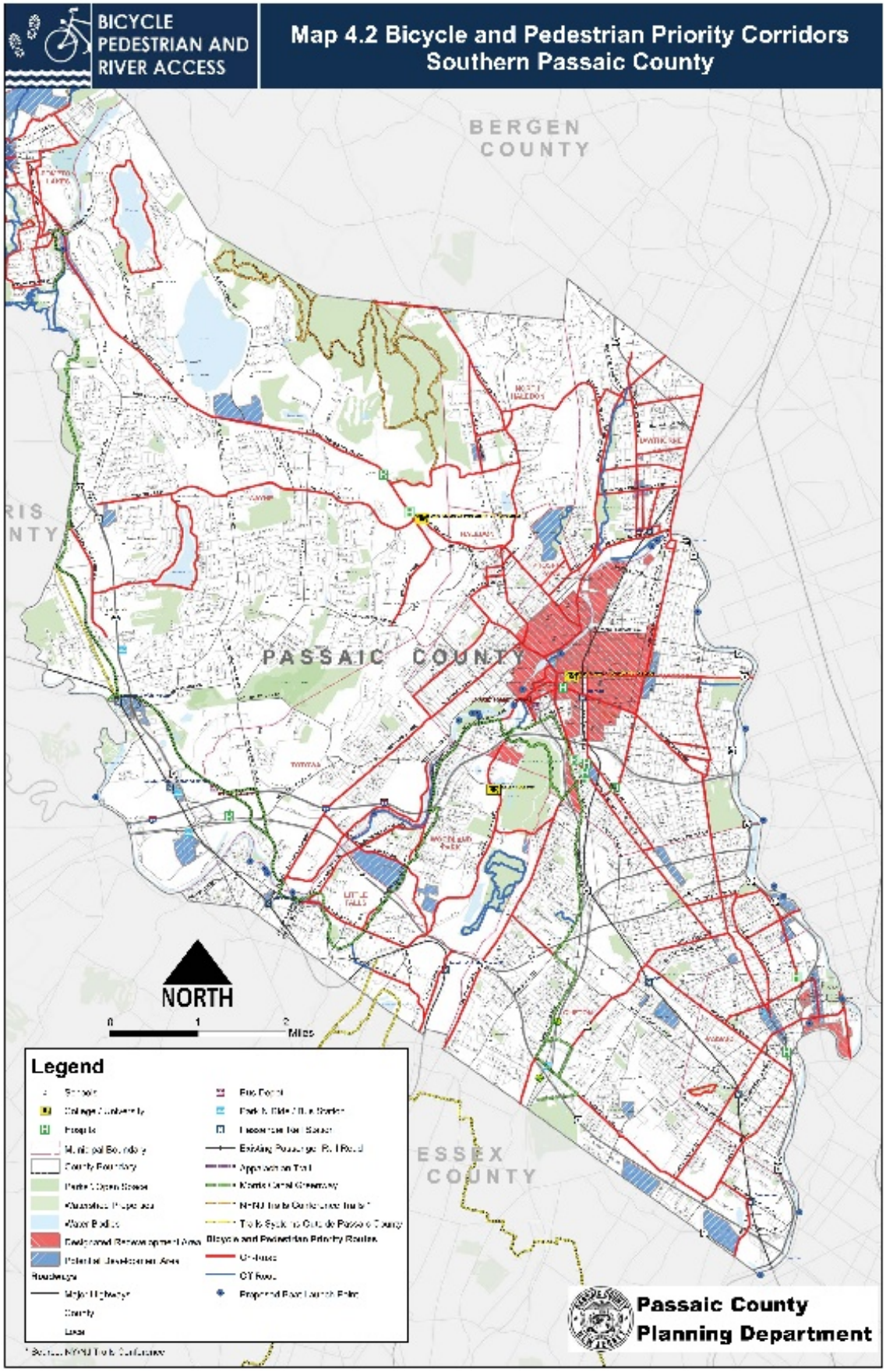


Complete Streets section of the Plan establishes a new County Roadway Classification System based on street typologies that recognize the context of the surrounding landscape, as well as priority users, and the street hierarchy within the roadway network. The County has five street types:

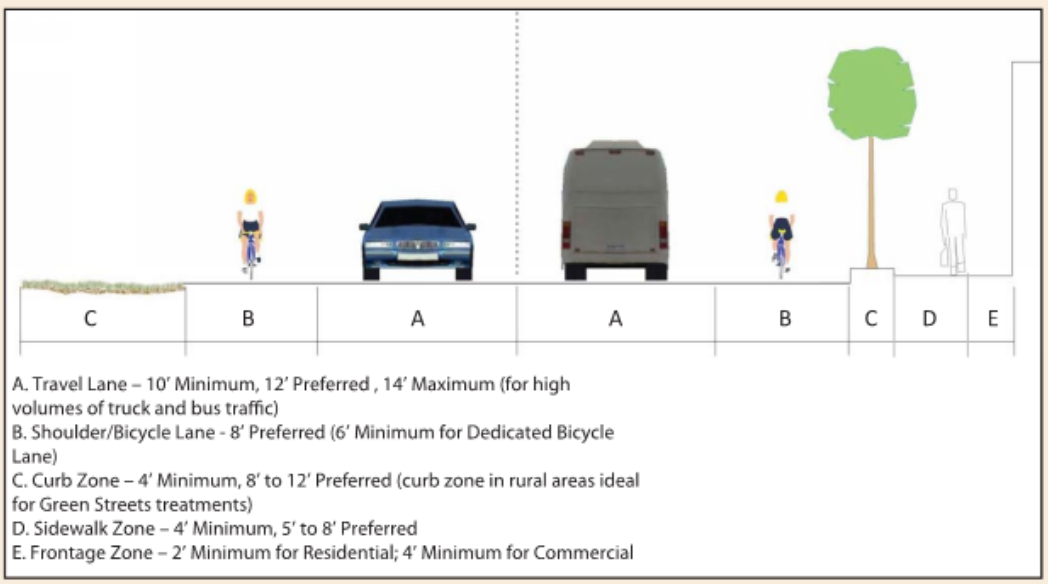
- Regional Streets are "major travel routes that handle the highest volume of traffic on County roadways, supporting all modes of transportation."
- Highlands Regional Streets "serve the same type of transportation needs as a Regional Street except that it is located within the New Jersey Highlands Region", and are seen as priority for green streets.
- Downtown Streets are "[c]ounty roadway corridors characterized by mixed-use commercial and traditional downtown services and activities."
- Community Streets "provide connections for local communities to reach regional through-routes and local commercial and downtown centers."
- Neighborhood Streets "are walkable roads that typically serve the residents or local businesses located along the street and no other users."

The Complete Streets section of the Plan also includes a brief discussion about the opportunity for roadways to incorporate low impact design, as well as structural and nonstructural green infrastructure to capture stormwater. The Plan recommends that best management practices be developed for each street classification.

## Appendix A - Complete Streets Guidelines

The Complete Streets Guidelines, includes as an appendix to the Plan, which provides more detailed descriptions and typical cross sections of the County's five street types. Only the Highlands Regional Street type specifically recommends the installation of green streets as a means to minimize impacts of street runoff on the Region's water quality *(Figure 3.2)* and references the Green Streets section of the Complete Streets Guidelines for examples and guidance.

**Figure 3.2 - Highlands Regional Street Typical Cross-Section**




A. Travel Lane – 10' Minimum, 12' Preferred , 14' Maximum (for high volumes of truck and bus traffic)
B. Shoulder/Bicycle Lane - 8' Preferred (6' Minimum for Dedicated Bicycle Lane)
C. Curb Zone – 4' Minimum, 8' to 12' Preferred (curb zone in rural areas ideal for Green Streets treatments)
D. Sidewalk Zone – 4' Minimum, 5' to 8' Preferred
E. Frontage Zone – 2' Minimum for Residential; 4' Minimum for Commercial

*Source: Moving Passaic County – Transportation Element of the Passaic County Master Plan, October 2012*

### Green Streets

The Green Streets section of the Complete Streets Guidelines provides an overview of the County's goals and objectives related to green streets, including stormwater management, maintaining drinking water supply, improving the environment, public health, and quality of life, and decreasing capital costs for public infrastructure.

The section also includes a nontechnical description of typical design elements for roadways, public transit facilities, and on site (driveways, parking lots, etc.)  Within the streetscape, the Green Streets sections recommends the installation of street trees, stormwater planters, pervious pavers for sidewalks, vegetated swales, bicycle facilities, and energy efficient lighting.

## Passaic County Multi-Jurisdictional Hazard Mitigation Plan

Passaic County Office of Emergency Management, August 2010

The *Multi-Jurisdictional Hazard Mitigation Plan* (the Plan) is Passaic County's response to the Federal Emergency Management Agency (FEMA) Interim Final Rule (IFR) related to the Disaster Mitigation Act of 2000. The purpose of the Plan is to identify hazards, conduct a risk assessment, and recommend mitigation actions.

The risk assessment determined that Passaic County's most likely and costly hazards are flooding, high wind–straight-line winds, earthquake/geological, dam failure, and severe storm–winter weather *(see Table 2.3.2-1)*.

**Table 2.3.2-1:**
**Summary of Countywide Natural Hazard Risks in Passaic County**
**By Asset and Hazard Type (100-Year Horizon)**
(Sources: 2000 US Census, HAZUS)

| Hazard | Asset | Risk (100-Year Horizon) | Risk Per SF (1) | Risk Per Capita (2) |
|---|---|---|---|---|
| Flood | Repetitive loss properties (residential) | $32,287,476 | $16.21 | $12,966 |
| Flood | Severe repetitive loss properties | $18,306,811 | $45.99 | $36,760 |
| Flood | Deaths and Injuries | Not Determined | NA | NA |
| High Wind–Straight-Line Winds | All assets | $200,053,412 | $0.93 | $409 |
| High Wind–Straight-Line Winds | Deaths and injuries | Not Determined | NA | NA |
| Severe Storm–Winter Weather | All assets, direct damages (3) | $4,024,497 | NA | $14 |
| Severe Storm–Winter Weather | Deaths (monetized) (4) | $1,027,440 | NA | NA |
| Severe Storm–Winter Weather | Injuries (monetized) | $45,664 | NA | NA |
| Dam Failure | All assets, direct damages | See Section 7.3.4 | NA | NA |
| Earthquake/Geological | All assets | $312,476,989 | $1.46 | $639 |
| Earthquake/Geological | Deaths (monetized) | $1,272,563 | NA | NA |
| Earthquake/Geological | Injuries (monetized) | $48,878,104 | NA | NA |

*Source: Passaic County Multi-Jurisdictional Hazard Mitigation Plan, August 2010*

The goals of the Plan include the following *(language from the Plan)*:

- *Improve education and outreach efforts regarding potential impacts of hazards and the identification of specific measures that can be taken to reduce their impact.*
- *Improve data collection, use, and sharing to reduce the impacts of hazards.*
- *Improve capabilities, coordination, and opportunities at municipal and county levels to plan and implement hazard mitigation projects, programs, and activities.*
- *Pursue opportunities to implement projects including mitigation of repetitive and severe repetitive loss properties and other appropriate programs, and activities.*

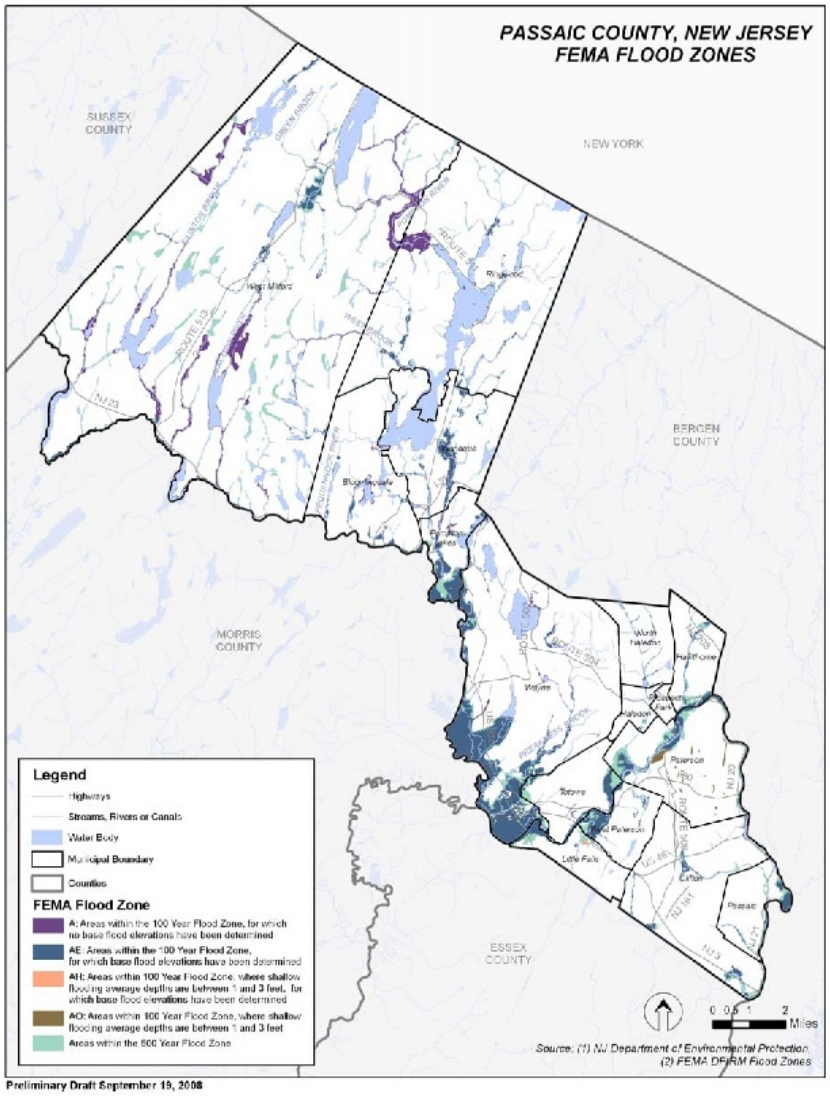
The stated objectives of the Plan most relevant to green infrastructure include the following *(language from Plan)*:

- *Support increased integration of municipal/county hazard mitigation planning and floodplain management with effective municipal/county zoning regulation, subdivision regulation, and comprehensive planning.*
- *Facilitate development and timely submittal of project applications meeting state and federal guidelines for funding for repetitive and severe repetitive loss properties and hardening/retrofitting infrastructure and critical facilities with highest vulnerability rankings.*

- *Maintain and enhance local regulatory standards including full and effective building code enforcement, floodplain management, and other vulnerability-reducing regulations.*

The most significant hazard to which Passaic County is exposed to is flooding. The County has a well-established history of localized flooding during storm events, as well as severe flooding and flood damage in the County's urban areas, and periodic flooding from the overflow of streams in low-lying areas. Continued development has increased the frequency and severity of flood events in the Passaic River Basin, affecting the Boroughs of Bloomingdale, Prospect Park, Totowa, Woodland Park, and Hawthorne; the Townships of Little Falls and Wayne; and the Cities of Clifton, Passaic and Paterson. *Figure 6.3.7-1* depicts the County's flood hazard areas.

**Figure 6.3.7-1**
**Floodplain Map of Passaic County**
(Sources: FEMA and NJDEP)




Preliminary Draft September 19, 2008

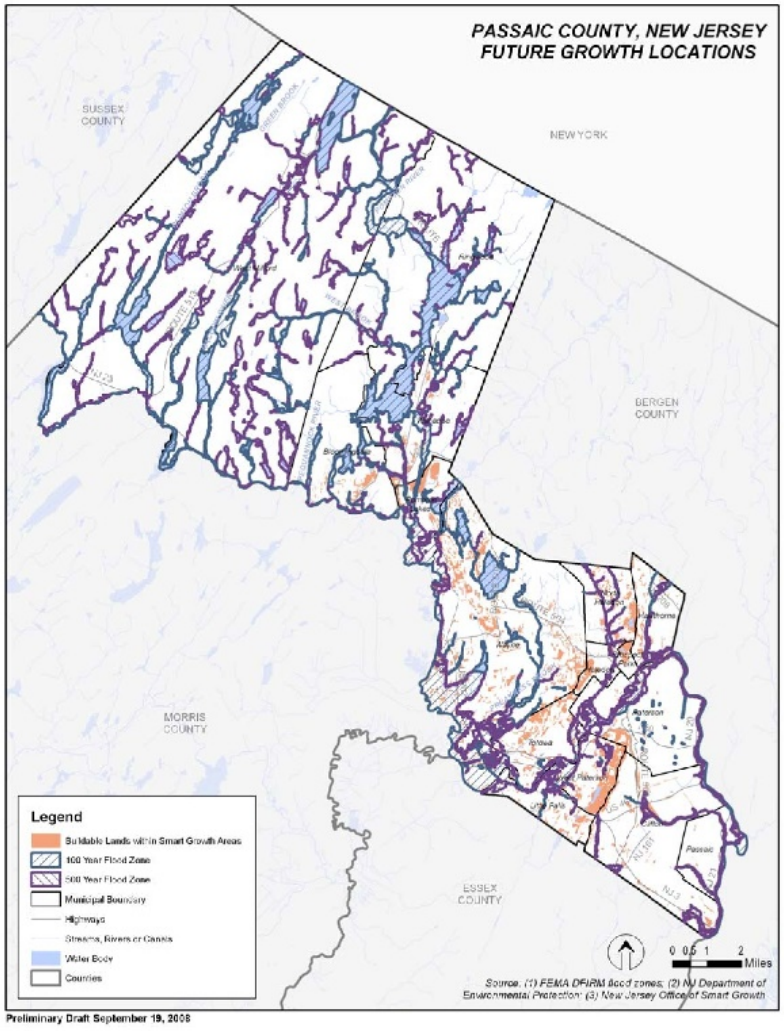
The flood zone designations are defined as follows:



*Source: Passaic County Multi-Jurisdictional Hazard Mitigation Plan, August 2010*

The Plan identifies areas of high risk that are also susceptible to future development by overlaying the NJ State Plan Policy Map growth areas with FEMA mapped 100- and 500-year floodplains, as depicted in *Figure 7.5-1* and *Table 7.5-1*. These may be areas to target green infrastructure techniques.

**Figure 7.5-1**
**Passaic County Future Growth Locations**
(Sources: 2001 New Jersey State Development and Redevelopment Plan, FEMA, NJDEP)






*Source: Passaic County Multi-Jurisdictional Hazard Mitigation Plan, August 2010*

**Table 7.5-1**
**Passaic County Buildable Land (in acres) by Flood Zone, Ranked by Municipality**
(Sources: 2001 New Jersey State Development and Redevelopment Plan, FEMA)

| Municipality Name | Acres within 100-year Floodplain | Acres within 500-year Floodplain | Acres Outside 500-year Floodplain | Grand Total |
|---|---|---|---|---|
| Wayne Township | 366 | 52 | 1,324 | 1,742 |
| Woodland Park Borough | 31 | 5 | 609 | 645 |
| Totowa Borough | 36 | 23 | 434 | 492 |
| Clifton City | 46 | 38 | 392 | 476 |
| North Haledon Borough | 14 | 6 | 343 | 363 |
| Pompton Lakes Borough | 35 | 2 | 280 | 317 |
| Paterson City | 49 | 11 | 192 | 252 |
| Hawthorne Borough | 29 | 11 | 195 | 235 |
| Little Falls Township | 8 | 7 | 195 | 209 |
| Wanaque Borough | 15 | 3 | 170 | 188 |
| Haledon Borough | 4 | 2 | 155 | 161 |
| Bloomingdale Borough | 1 | 0 | 145 | 146 |
| Prospect Park Borough | 2 | 0 | 105 | 107 |
| Passaic City | 17 | 12 | 26 | 55 |
| Ringwood Borough | 0 | 0 | 0 | 0 |
| West Milford Township | 0 | 0 | 0 | 0 |
| **Total** | **652** | **170** | **4,565** | **5,387** |

*Source: Passaic County Multi-Jurisdictional Hazard Mitigation Plan, August 2010*

The Capability Assessment section of the Plan discusses the capacity to implement mitigation measures at all relevant levels of government. The County and municipalities' land use planning and development review processes are seen as areas where mitigation measures can be incorporated and implemented. Although most of the recommendations related to planning and development have to do with the location of development relative to flood plains and building codes to mitigate flood damages, green infrastructure techniques can also be applied to reduce stormwater runoff flows that may contribute to some flooding issues. In addition, the County's role in economic development and capital improvement planning can incorporate hazard management and mitigation activities.

The Plan includes specific actions that various levels of government can implement related to education and outreach, capital improvements, and land planning and regulation. The municipal action items include action items of particular relevance to green infrastructure, in that they include specific improvements to stormwater management systems and stream corridors in the County, which may be opportunities to target green infrastructure projects. The relevant recommendations are as follows *(language from the Plan)*:

- *Bloomingdale: Construct new and upgrade existing culverts and retention basin and flood ponds along Vandam Brook and Post Brook along Brandt Lane*
- *Clifton: Installation of storm-water management culverts for the Department of Public Works building on East 7th Street*
- *Clifton: Storm-water management system upgrade along Route 46 at Main Avenue overpass*
- *Clifton: Storm-water management system upgrade along Route 3 and Hepburn Road*
- *Clifton: Upgrade culvert on Sylvan Avenue and Main Avenue*

- *Hawthorne: Stream bank stabilization and bank augmentation of the Goffle Brook to protect private residences on Brookside Avenue and First Avenue*
- *Little Falls: Stream bank stabilization to protect Department of Public Works building along the Peckman River on Sindle Avenue.*
- *Little Falls: Stream bank stabilization along Peckman River from Tulip Gardens and Passaic Valley High School to Route 46.*
- *Little Falls: Upgrade of storm-water pumping station facilitating water removal in various locations*
- *North Haledon: Stream bank stabilization and bank augmentation along the Molly Ann Brook*
- *Passaic: Stream bank stabilization and augmentation along the Passaic River located at 8th, 9th, and 10th streets near Passaic Street and River Drive*
- *Paterson: Riverbank augmentation of the Passaic River Corridor along the River Street area*
- *Pompton Lakes: Engineering study to determine mitigation actions for the various streets*
- *Pompton Lakes: Improved drainage along Sunset Road*
- *Ringwood: Upgrade and improvement of storm-water culverts along McGee Road.*
- *Wanaque: Storm-water management culvert upgrade and improvement along Crescent Road and Treemont Terrace*
- *West Milford: Upgrade and improve storm-water culverts along Burnt Meadow Road*
- *West Milford: Stream bank stabilization of banks by High Crest Dam*
- *West Milford: Upgrade storm drainage system on Cherry Ridge Road*
- *Woodland Park: Work with Passaic County to improve storm drainage carrying capacity, confluence (straighten out to reduce debris), adjust to address bridge and culvert replacement issue on McBride Avenue and/or Browertown Road*

The Municipal Action section of the Plan also identifies potential repetitive loss buy-out areas, which could be opportunities to implement GI techniques during the restoration phase after building(s) have been demolished.

## Highlands Element of the Passaic County Master Plan

Passaic County Planning Department, May 2011

The *Highlands Element of the Passaic County Master Plan* (the Highlands Element) meets the requirements of Plan Conformance to the Highlands Regional Master Plan (RMP), and identifies policies to guide future land use and development for the Preservation Area of the County. The regulatory requirements of the Highlands Element apply only to areas where the County has jurisdiction over site plan and subdivision review along County roads and where the development impacts County stormwater facilities, as well as County capital improvement projects in the Highlands Preservation Area.

Green infrastructure and low impact development (GI/LID) can support the goals of the Highlands Element with regard to stormwater and flood retention and mitigation, water quality management, and other environmental outcomes. The Highlands Element highlights related GI/LID are as follows *(language from Highlands Element)*:

- Development in the Preservation Area must comply with the density requirements within the various zones and subzones of the Highlands Land Use Capability Zone (LUCZ) Map, including the development or expansion of County facilities.

- GI/LID can support the following Highlands Open Waters and Riparian Area goals:
    - *To seek opportunities to restore the functional value of Highlands Open Waters buffers where existing development or land uses have reduced or impaired their quality.*
    - *To limit disturbance of existing natural vegetation or increases in impervious area within High and Moderate Integrity Riparian Areas in all other Zones and Sub - Zones to the minimum feasible in areas beyond Highlands Open Waters buffer requirements; protect the water quality of adjacent Highlands Open Waters; and maintain or restore habitat value of the Riparian Area.*
    - *To require use of Low Impact Development Best Management Practices for any development activity proposed within a Riparian Area to minimize both alteration of natural vegetation and increase in impervious area and to provide for mitigation through restoration of impaired Riparian Areas in the same HUC14 subwatershed.*

- GI/LID can support the following Steep Slope goals:
    - *Land disturbance within all Steep Slope Protection Areas should incorporate Low Impact Development techniques to minimize the extent of such disturbance and the potential negative impacts resulting from it.*

- GI/LID can support the following Critical Habitat goals:
    - *To promote the restoration and enhancement of impaired lands in Critical Habitat.*
    - *Prohibit indirect impacts from activity that is off - site, adjacent to, or within Critical Habitat that will jeopardize the continued existence of, or result in the likelihood of the destruction or adverse modification of Critical Habitat…*

- GI/LID can support the following Lake Management goals:
    - *To prevent degradation of lake water quality, protect lake ecosystems, and promote lake area aesthetic values in the Lake Community Sub - Zone.*

- *To protect lake water quality and associated ecosystems for all lakes from the impacts of present and future development. Applicable management strategies should address direct and proximate potential impacts from such activities as shoreline modification and development…*

- GI/LID can support the following Water Resource Availability goals:
  - *To require and incorporate the use of water conservation, recycling and reuse methods (where appropriate) and devices for any redevelopment or development activity, including renovations to existing buildings, to minimize consumptive water use. This should include mandatory collection and use of stormwater to serve non-agricultural irrigation needs and to the extent feasible, other non-potable purposes.*

- GI/LID can support the following Prime Groundwater Recharge Area goals:
  - *To require use of Low Impact Development and other Best Management Practices to maximize natural ground water recharge and minimize the need for engineered recharge methods.*
  - *To restrict land use and development activities that reduce natural ground water recharge volumes in PGWRAs or that may contribute to or result in degradation of ground water quality, whether directly or indirectly.*
  - *To avoid disturbance of lands identified as PGWRAs to the maximum extent feasible, and to minimize such disturbance where it cannot be avoided. Where disturbances do occur in PGWRAs, to require mitigation measures to enhance pre - construction recharge volumes.*
  - *To identify and implement opportunities for the restoration or enhancement of recharge in PGWRAs and other lands through such means as the retrofit or rehabilitation of stormwater recharge facilities, land management improvements, and reforestation.*
  - *To achieve a net improvement in ground water volume and quality through enhanced infiltration, pretreatment and other available means.*

- GI/LID can support the following Water Quality goals:
  - *To adopt and implement stormwater management controls through a Stormwater Management Plan.*
  - *To require use of applicable Low Impact Development and Best Management Practices to protect the quality of ground and surface waters.*

- GI/LID can support the following Wellhead Protection goals:
  - *To ensure that stormwater management plans pertinent to both county development projects and county-wide planning, address wellhead protection requirements.*
  - *To encourage stormwater reuse for non-agricultural irrigation and other non-potable water purposes to minimize the volume of stormwater discharges (other than from clean sources) within a Tier 1 or Tier 2 Wellhead Protection Area.*
  - *"o ensure that development activities and existing land use activities implement best management practices to protect the quality of ground water within Wellhead Protection Areas.*

- Further, the Highlands Element includes specific policies and best management practices for Low Impact Development as follows:

1. *Stormwater management LID standards that preserve or mimic the natural hydrologic features and characteristics of the land.*
    a. *Use of stormwater management features that maintain, restore and enhance the pre-existing natural drainage patterns of the site.*
    b. *Limitations on impervious coverage allowances to maximize stormwater infiltration and reduce runoff.*
    c. *Requirements for site-specific hydrologic studies which identify the velocity, volume and pattern of water flow into, through and flowing from a parcel proposed for development.*
    d. *Requirements that stormwater management systems employ a "design with nature" approach by use of grass channels, dry swales, wet swales (vegetated channels designed to retain water or marshy conditions that support wetland vegetation), infiltration basins, bio - swales and water gardens, constructed wetlands, green roofs, and other low impact approaches to attenuate and control stormwater and provide multiple environmental benefits.*
2. *LID practices that minimize land disturbance during construction activities.*
    a. *Requirements for site - specific analysis of environmental features and constraints as an integral component of site design.*
    b. *Limitations on site disturbance, soil compaction, clearing and grading to the minimum necessary to allow for permissible development.*
    c. *Provisions to minimize soil erosion and airborne dust during construction and to protect streams and other water bodies from silt and sedimentation.*
3. *LID best management practices where any development application proposes disturbance of a Highlands Area resource, including but not limited to Steep Slope Protection Areas, Forest Areas, Critical Habitat Areas, Highlands Open Waters and Riparian Areas, and Prime Ground Water Recharge Areas.*
    a. *Highlands Area resources should be identified as a first step in site planning.*
    b. *To the maximum extent practicable Highlands Area resources should be avoided or their disturbance minimized through site design.*
    c. *The quality and value of Highlands Area resources located on development sites should be maintained by use of LID strategies that minimize the impacts of development to the maximum extent possible.*
4. *LID practices in design of sites, buildings, structures and roadways. Development and redevelopment projects should follow a prescribed conservation design planning process that considers existing site features and site context; maximizes opportunities for open space and connections to open space systems; and incorporates LID practices in all aspects of stormwater management, site layout and resource protection. In addition to the previously listed items (1 - 3, above) these include but are not limited to the following:*
    a. *Use of water conservation measures in site layout and structures, including but not limited to such practices as water efficient landscaping (including use of native and drought - tolerant non - invasive plant species), rain collection systems, use of gray water, and water - efficient landscape irrigation.*
    b. *Use of low maintenance landscaping that encourages retention and planting of native vegetation and minimizes lawn areas and use of fertilizers and pesticides.*
    c. *Use of pervious paving materials and minimization of impervious surfaces.*
    d. *Use of micro - climate conditions to maximize solar gain for winter heating and minimize solar gain during high temperature summer conditions.*

e. *Re - use and recycling of building materials.*
f. *Inclusion of energy - efficient features in site layouts and buildings.*
g. *Roadway design standards (subject to Residential Site Improvement Standards limitations) that incorporate LID techniques to address stormwater management, limit impervious coverage, ensure planting of native and drought - resistant vegetation, and integrate other "green street" design initiatives.*

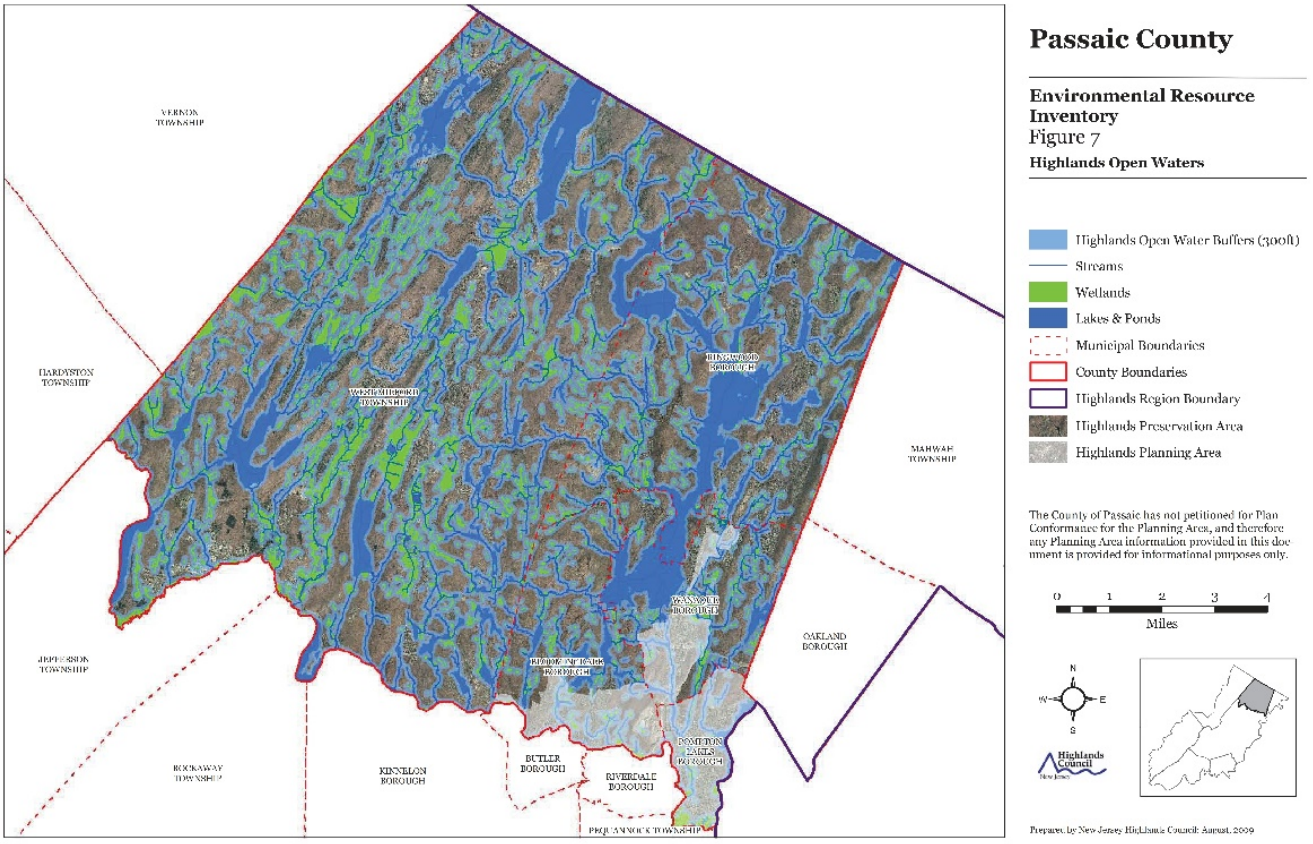
- GI/LID can support the following goals of the County Facilities and Infrastructure Plan Element:
  - *To consider stormwater management, LID and scenic and historic resources (specifically bridges and scenic byways as defined and delineated in the Highlands Region Historic and Cultural Resources Inventory and the Highlands Scenic Resources Inventory in the Historic Preservation Plan below) in the design and construction of any county roadways, bridges and related facilities.*
  - *To promote storm water management controls in the Passaic County Stormwater Management Plan for county drainage facilities.*
  - *To identify for all county facilities, as applicable, realistic options to enhance energy efficiencies, incorporate "green" building materials and technologies, reduce pollutant emissions, and minimize "carbon footprints;" and to develop a county strategy for implementing them.*
  - *To promote all feasible LID techniques in the design, development, operation and management of existing and proposed county facilities and infrastructure.*

## Highlands Environmental Resource Inventory for Passaic County

Passaic County Planning Department, May 2011

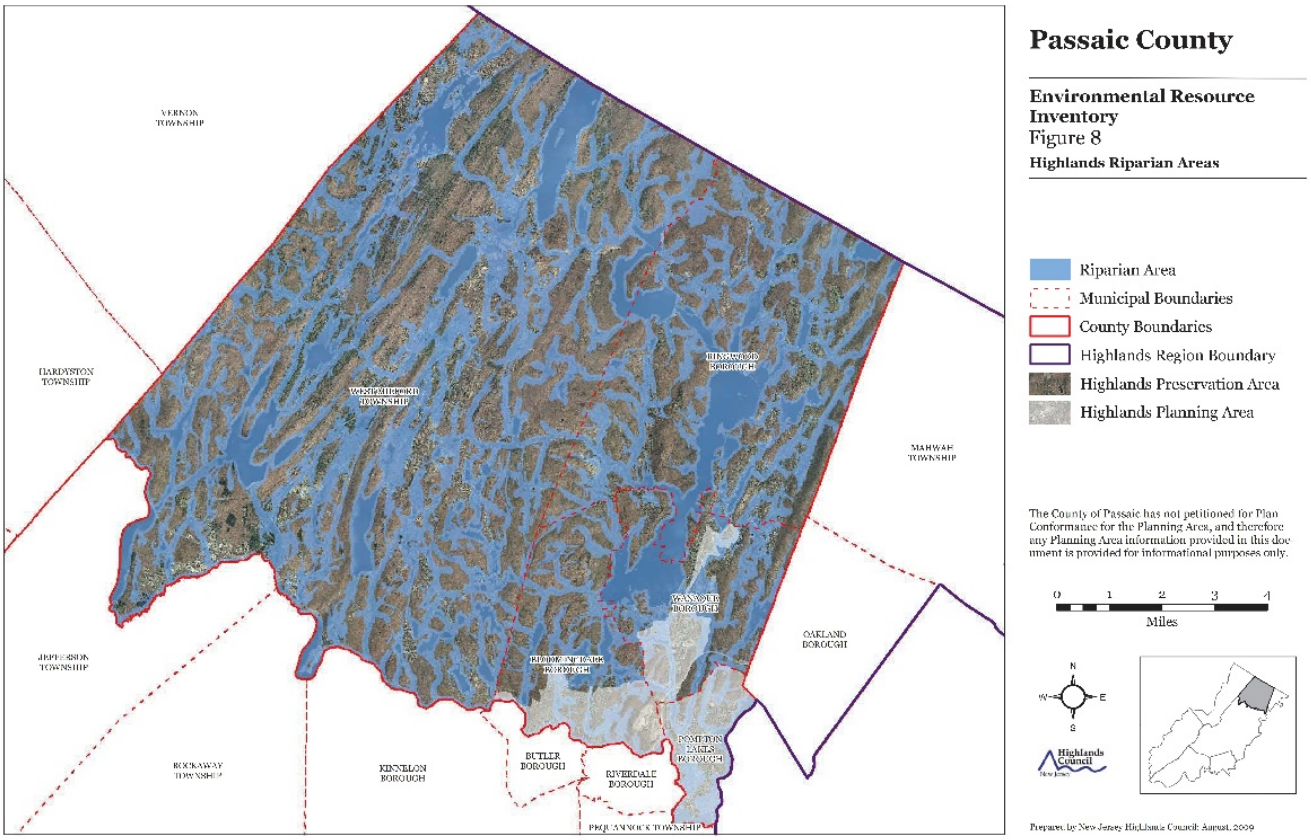
The *Highlands Environmental Inventory* (ERI) is intended to provide background information about Passaic County's natural and cultural resources to support its planning efforts related to the *Highlands Regional Master Plan* (RMP). Green infrastructure is often thought of in an urban or suburban context, but rural and environmentally sensitive areas with diminished or threatened environmental integrity are prime locations to implement green infrastructure techniques where land has been or is planned to be disturbed. Highlights regarding Passaic County's environmental resources are as follows:

- Passaic County includes portions or the entirety of 22 HUC14 subwatersheds, 18 of which are in the Highlands Preservation Area and 4 of which are in the Highlands Planning Area.
- Passaic County contains 77,987 acres of Highlands defined "Forest Resource Area," including over 61,000 acres of "total forest." All of the HUC14 subwatersheds in Passaic County's Preservation Area are deemed to have "high" forest integrity.
- *ERI Figure 7* depicts Passaic County's Highlands Open Waters and their buffer areas, which include all springs, wetlands, streams and bodies of water in the Highlands Region, as well as a 300-foot buffer that provides habitat, stormwater retention and filtration, water quality protection, and other environmentally beneficial qualities.



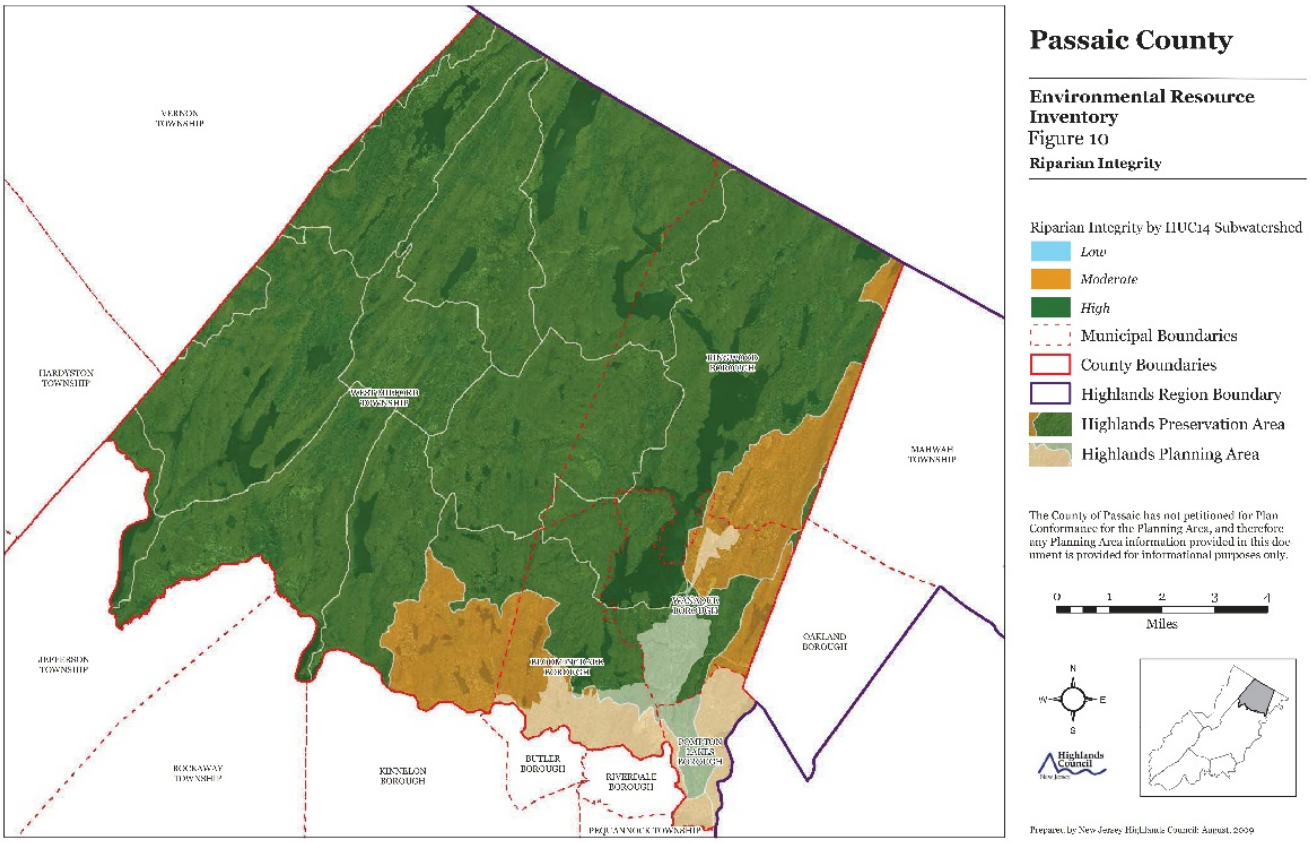

*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

- *ERI Figure 8* depicts Passaic County's riparian areas, which are the interface between surface water and the surrounding terrestrial ecosystem. Riparian areas provide many ecological benefits related to water quality, habitat, and stormwater/flood retention and infiltration.



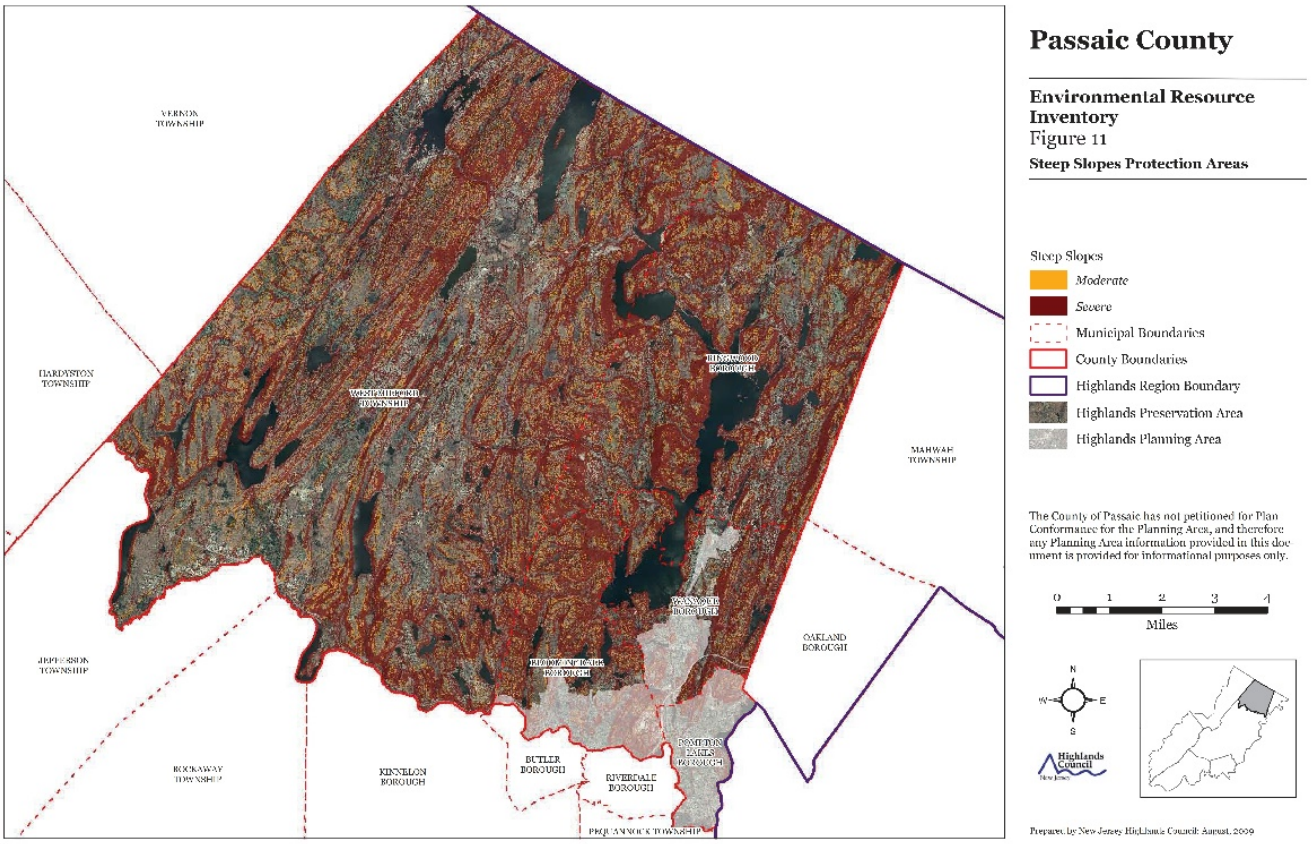

*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

  - Further, *ERI Figure 10* depicts Riparian Integrity. Areas of moderate riparian integrity could serve as places to target green infrastructure solutions.




*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

- As depicted in *ERI Figure 11*, Passaic County includes nearly 48,000 acres of Highlands defined Moderate Constrained Slopes and nearly 34,000 acres of Severely Constrained slopes, where disturbances could result in erosion and sedimentation.

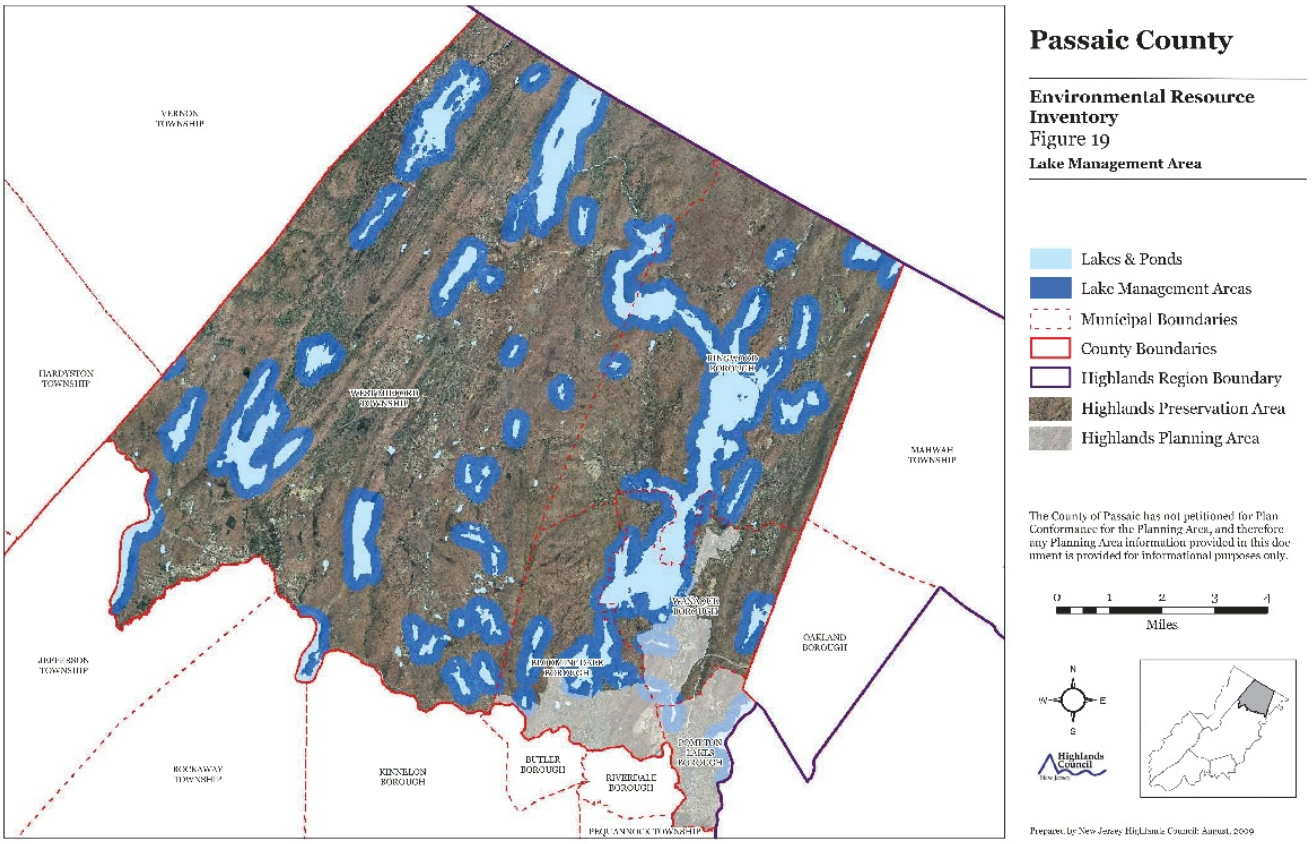



*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

- Passaic County contains 68,388 acres of Critical Wildlife Habitat suitable for rare, threatened, and endangered species, just over 67,000 of which is in the Preservation Area.
- Passaic County contains over 29,000 acres of Highlands Preserved Lands as follows:

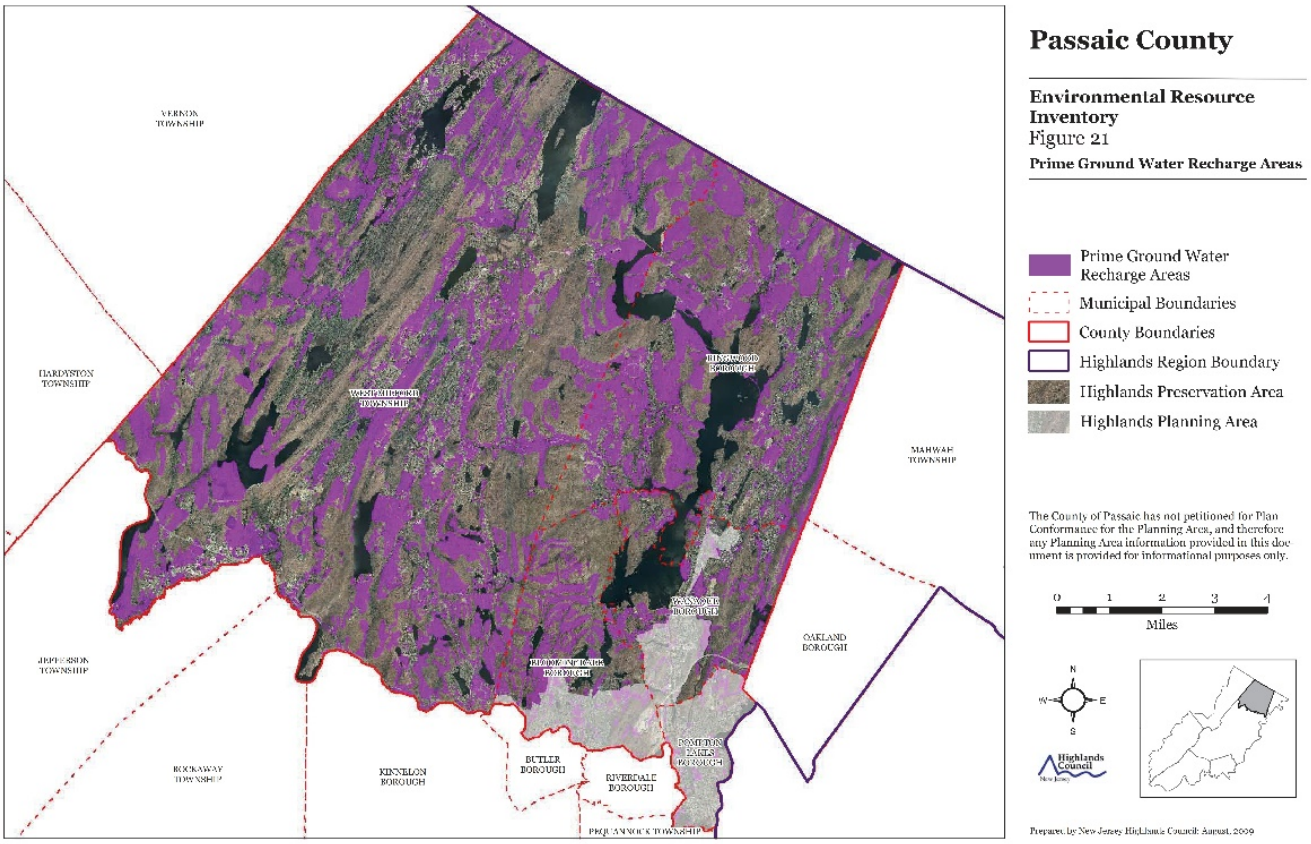
| Preserved Land Category | Acres |
|---|---|
| Preserved Farmland | 64.32 |
| Federal | 22.5 |
| State | 23,349.36 |
| County | 2,947.39 |
| Municipal | 1,685.85 |
| Non-profit & Authorities | 1,162.1 |

- Passaic County contains a variety of public and privately held lakes and waterbodies, of which just over 6,900 acres are in lakes greater than 10 acres. In addition to lakes that host residential lake communities, Passaic County has several large reservoirs, including Wanaque, Monksville, and Clinton Reservoirs. *ERI Figure 19* depicts Passaic County's Lake Management Areas, where water quality protection and restoration are deemed critical in the RMP.




*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

- Passaic County's Preservation Area is located within 18 different HUC14 subwatersheds, of which 13 are calculated to be at a net water deficit.
- *ERI Figure 21* depicts Passaic County's 23,150 acres of Prime Groundwater Recharge Areas.




*Source: Highlands Environmental Resource Inventory for Passaic County, May 2011*

## Little Falls Green Infrastructure Feasibility Study

Passaic County Sewerage Commission and Rutgers Cooperative Extension Water Resource Program

As part of its ongoing efforts to help municipalities manage floods, the Passaic Valley Sewerage Commission's (PVSC) partnered with Rutgers to produce the *Little Falls Green Infrastructure Feasibility Study* (the Study), which is a nontechnical guide for Little Falls to implement green infrastructure (GI) practices and provide public education and awareness about the benefits of GI.

The Study provides a primer on common stormwater management and GI terminology. It also includes an easy to understand guide for where different GI techniques can be employed *(Figure 1)*.

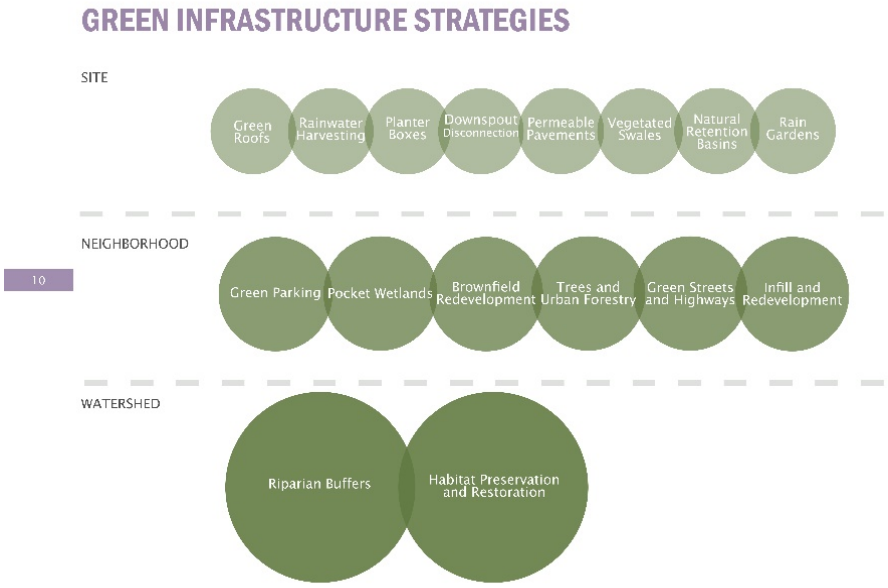



*Figure 1. Source: Little Falls Green Infrastructure Feasibility Study*

The Study provides general descriptions of GI system types, including vegetated systems (rain garden); rainwater harvesting (cisterns); and storage, quantity, and infiltration systems (permeable pavers, asphalt, concrete). Potential locations for GI projects are identified, including discussion about the suitability of a system for each project site, including:

- Little Falls Municipal Building – vegetated system in the form of a rain garden
- Little Falls Recreation Department – rainwater harvesting in the form of rain barrels and porous pavement
- Little Falls Civic Center – Storage, quantity & infiltration in the form of porous pavement and a bioswale

The Study also provides maintenance information for each type of GI practice, including basic tasks for plant care (e.g. watering, weeding, mulching, pruning), and system structural elements (e.g. debris and sediment removal, clearing clogged inlets, winterizing/flow diversion for cisterns, vacuum sweeping for permeable pavements).

The Study also explains FEMA's and Community Rating Systems (CRS), which allows for flood insurance premium reductions where flood damage reduction projects are implemented. The Study goes on to make recommendations for additional GI projects that can help Little Falls improve its CRS, including:

- Little Falls Methodist Church - pervious pavement, bioswales
- Little Falls Public Library – rain gardens, pervious pavement
- Little Falls Public School #1– rain gardens, bioswales
- St. Agnes Church – rain gardens, pervious pavement, bioswales
- Little Falls Dept. of Public Works – buffers, cisterns
- Flood Mitigation Properties (multiple properties, many in the process of being demolished or elevated to withstand flooding – rain gardens, stormwater planters, buffers, pervious pavement, bioswales, depaving

The Study discusses Little Falls ongoing community engagement projects around GI. The first is a rain barrel program that provides hands on training that results in residents constructing and installing their own rain barrel. The second is the "Stormwater in Your Schools" program that provides education and hands on experiences about the natural environment on school grounds.

## Paterson Public School #5 Green Infrastructure Information Sheet

Passaic Valley Sewerage Commission, 2015

The information sheet provides before and after photographic depictions of a green infrastructure cistern project implemented at Paterson Public School #5, which connects and provides water to a nearby community garden *(see Figure 2).*

*Figure 2: PS5 Cistern; Source: Paterson Public School #5 Green Infrastructure Information Sheet, 2015*

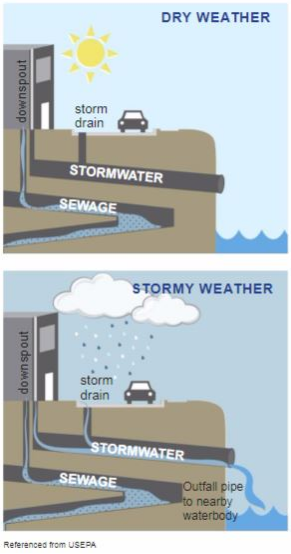
## Green Infrastructure Guidance Manual for NJ

Rutgers Cooperative Extension Water Resource Program, March 2016

The *Green Infrastructure Guidance Manual for New Jersey* (the Manual) was created to provide guidance for identifying locations and implementing green infrastructure (GI) projects throughout NJ. The target audience includes planning and design professionals, municipal engineers and officials, community groups, and residents interested in GI retrofits for existing development.

The Manual provides information about the fundamental function and benefits of select GI practices, as well as technical design standards. It describes the design process for GI practices, and guides the user through the process from site identification to implementation. The intention is that design and planning professionals using the manual will understand the process of planning and implementing GI from start to finish.

Another goal of the Manual is to provide direction for actively engaging the public in the long-term control planning (LTCP) process and associated permit regulations of combined sewer systems (CSS) and municipal separated sewer systems (MS4) systems. The manual explains the urban water cycle, CSSs, MS4s, and the need for green infrastructure *(Figure 3)*.




The Manual provides diagrams, engineering details and specifications, lists of benefits, and examples of GI implementation. All information provided is based on the experience of the Rutgers Cooperative Extension Water Resources Program (RCEWRP) in planning, designing, and implementing green infrastructure throughout New Jersey, in combination with the program's research on green infrastructure initiatives nationwide. GI practices that have been proven to be successful in New Jersey are presented, and each practice is described in terms of its key GI functions, e.g., bioretention and rain gardens for infiltration and storage, bioswales for conveyance and infiltration, and permeable pavements for storage and infiltration. (*See Figure 4 for an example*)

*Figure 3: CSS Example Education Material; Source: Green Infrastructure Guidance Manual for NJ, March 2016*

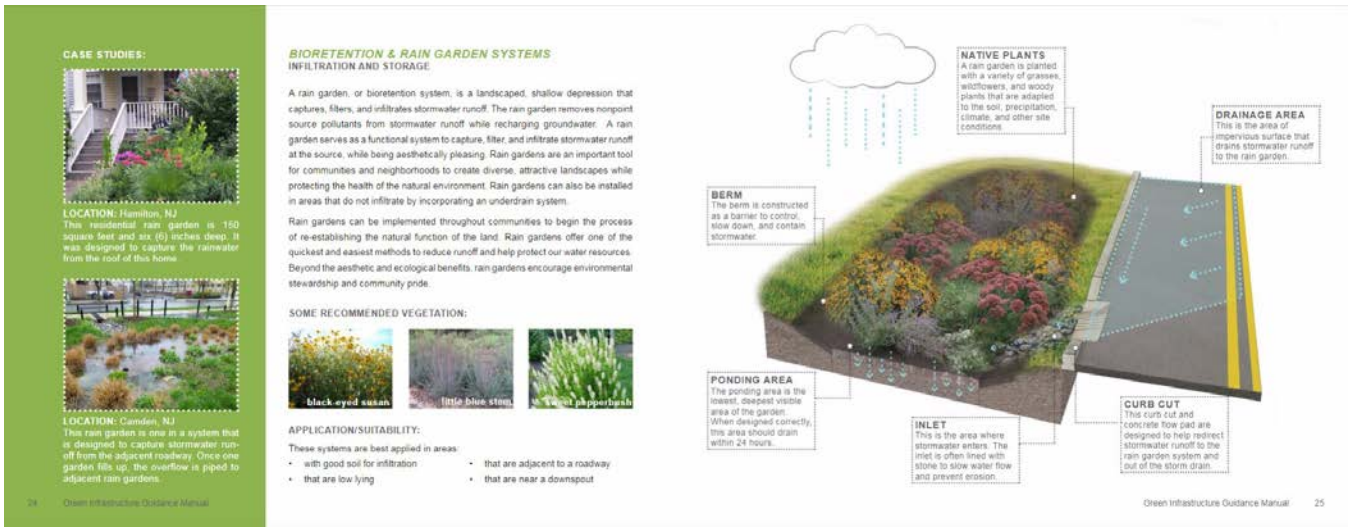



*Figure 4: GI Description Example; Source: Green Infrastructure Guidance Manual for NJ, March 2016*

The Manual breaks the GI design process down into four steps:

1. Assess existing stormwater issues.
2. Identify site opportunities for eliminating, reducing, and disconnecting directly connected impervious surfaces.
3. Evaluate GI feasibility for each site.
4. Design the GI practice (this section provides guidance on the steps involved in designing specific GI practices, including determining drainage area, runoff volume, infiltration rate, and storage capacity).

The Manual includes a graphic representing a decision flow path to guide the ultimate selection of specific GI for a given site *(Figure 5)*.

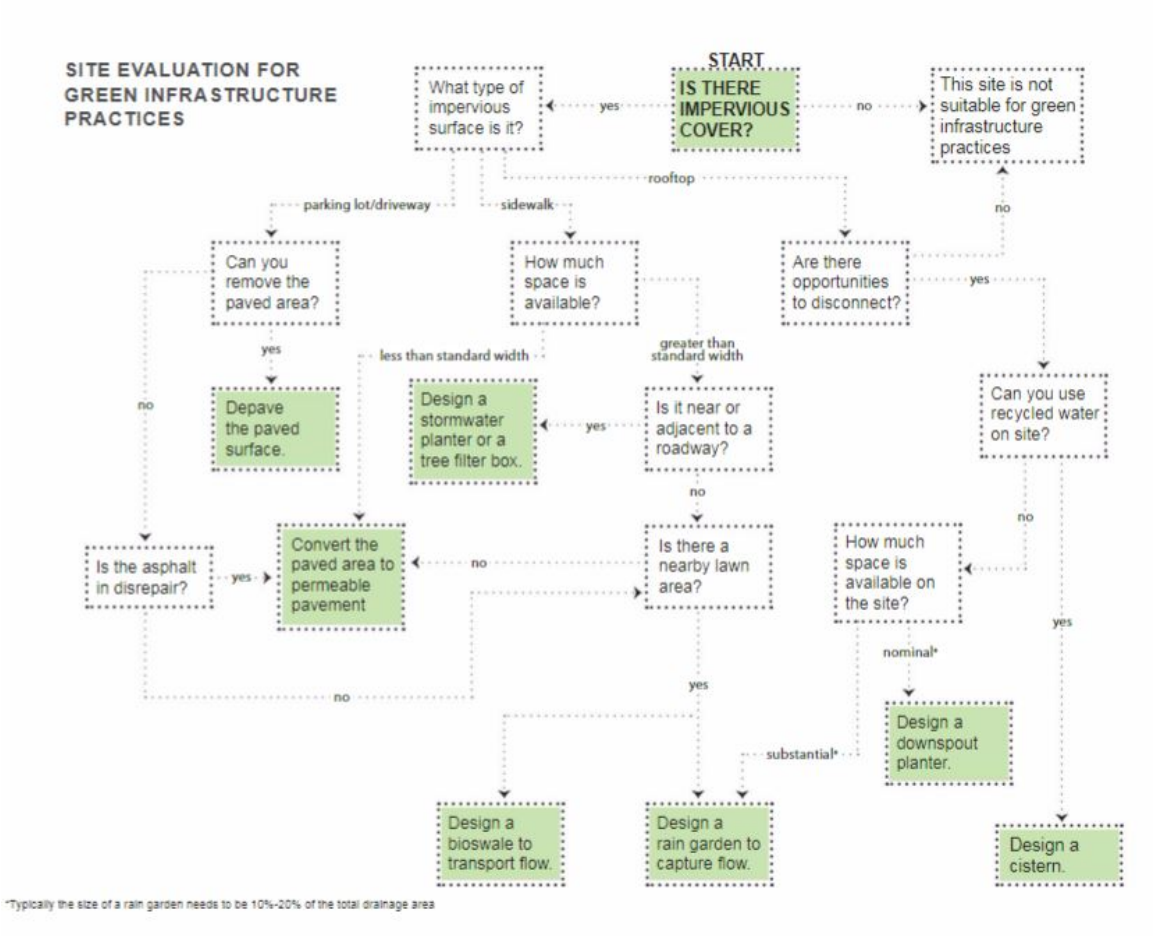



*Figure 5: GI Design Flow Path; Source: Green Infrastructure Guidance Manual for NJ, March 2016*

The Manual encourages communities to begin planning a GI program by preparing a feasibility study. The feasibility study should summarize GI opportunities and provide recommendations for appropriate action. The feasibility study provides an opportunity for community engagement and allows the community to prioritize GI selection and implementation.

Various approaches to community engagement are recommended in the manual. A municipal action team can be established to bring together local government, utility authorities, and community organizations. Community action teams made up of local residents can help to install and maintain certain neighborhood GI practices. Educational programming and workshops (e.g., Build a Rain Barrel) can train residents to take an active role in GI. The Stormwater Management in Your Schoolyard program provides educational lectures, hands-on activities, and outreach for students on water quality issues and stormwater management practices.

The Manual provides engineering details and specifications for representative GI practices, but does not address operations and long-term maintenance, which would be helpful guidance for feasibility analysis and budgeting.

## New Jersey Developers' Green Infrastructure Guide

NJ Future and NJ Builders Association, April 2017

The *New Jersey Developers' Green Infrastructure Guide* (the Guide) was created by the NJ Developers' Green Infrastructure Task Force convened by the NJ Future and NJ Builders Association to address basic questions about green stormwater infrastructure for the New Jersey real estate development community, and to help inform decisions about where and how green stormwater infrastructure (GSI) would be most useful on a project.

The Guide serves is a simple primer on urban hydrology (impervious cover and stormwater runoff) and the most widely used GSI practices. It is not intended as a design manual, and thus, does not provide engineering details, calculations, or specifications. It is also not a guide to planning, or to conducting feasibility assessments. The implicit expectation is that users will seek out detailed technical guidance from other sources.

GSI practices that are described include both landscape (i.e., vegetation based) systems and non-landscape practices. The landscape practices are grouped as either small scale (e.g. bioretention basin, rain garden, curb bumpout, vegetative filter strip, grass swale, downspout planter, and tree trench/tree box) or large scale (e.g. naturalized detention basin, constructed wetland/subsurface gravel wetland, surface infiltration basin, and wet pond with naturalized edge and water re-use). Small-scale landscape practices are most suitable for confined, highly developed urban sites, whereas large-scale landscape practices have large footprints and would be more appropriate in suburban/rural settings. Non-landscape practices include pervious pavement, dry well, cistern/rain barrel, green roof/blue roof, and subsurface infiltration basin. These GSI practices vary in size depending on the specific site.

Each GSI type is presented through a typical photograph and illustrative diagram of the structure and function of the practice, accompanied by a brief narrative of key characteristics *(see Figure 6, for example)*. A series of icons are used to call out the specific financial, community, and regulatory benefits of a given GSI system. These benefits are discussed in detail later in the document. Where applicable, GSI practices are keyed to nonstructural stormwater strategies in the NJ Stormwater Best Management Practices to show how they satisfy NJ Department of Environmental Protection (NJDEP) Best Practice Manual (BMP) requirements. Also, because GSI can be used to meet NJDEP regulatory requirements for the reduction of Total Suspended Solids (TSS) in stormwater, the assumed TSS reduction capacity assigned to each green infrastructure practice by the NJ BMP Manual is shown using an icon.

Image Credit: AKRF, Inc.

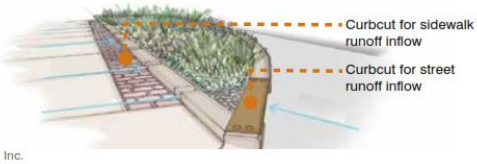



Image Credit: AKRF, Inc.

**Curb Bumpout**

A curb bumpout is an extension of the curb along a sidewalk that extends into the roadway, creating a small area that accepts stormwater runoff from the sidewalk and street, and manages the stormwater as a rain garden would. Because a curb bumpout works much like a rain garden, it may provide the same nonstructural strategies and TSS removal objectives as a rain garden. However, curb bumpout does not currently appear in the NJ BMP manual. When located at intersections, bump-outs can improve the appearance of your development project by creating a highly-visible, attractive looking streetscape. When located at intersections, bump-outs can help slow traffic and improve pedestrian safety by reducing the street crossing distance and by providing a barrier for pedestrians waiting at cross walks.

*Figure 6: GI Type Example; Source: NJ Developers' Green Infrastructure Guide, April 2017*

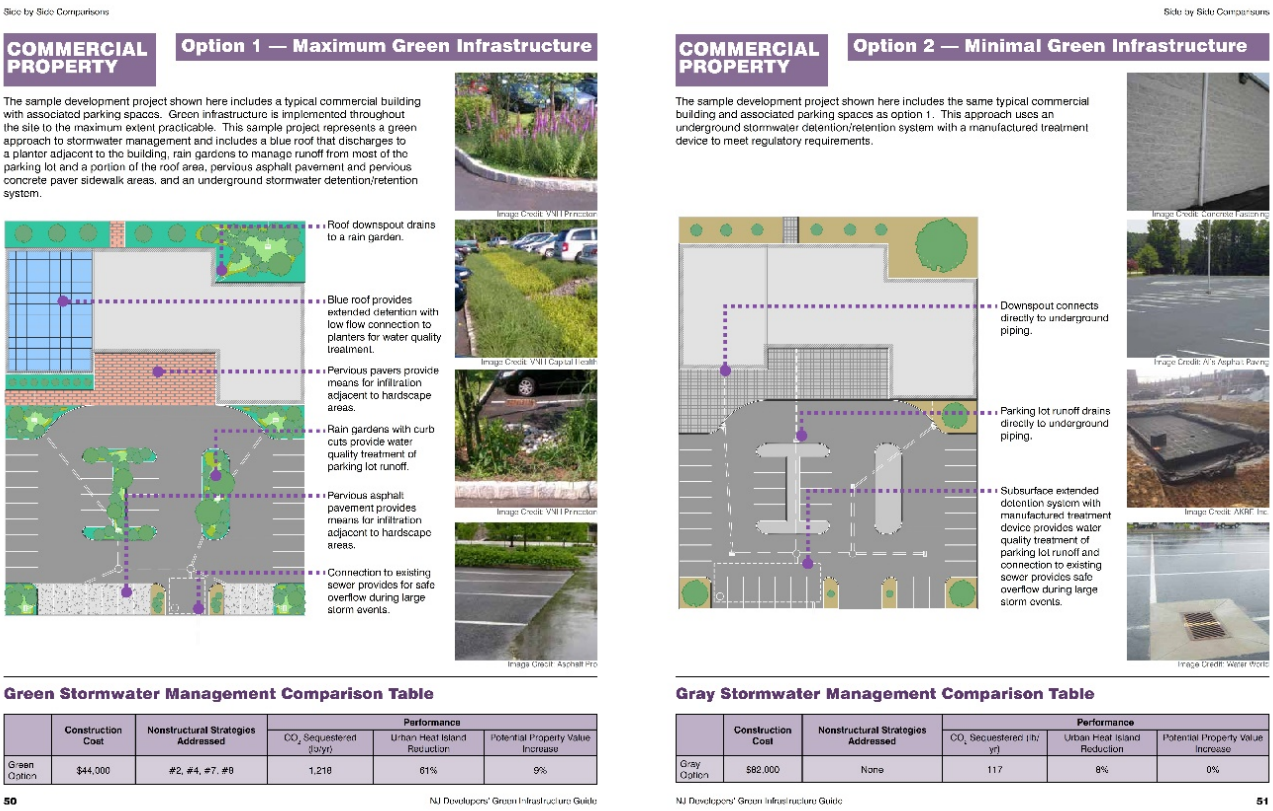
The Guide summarizes the financial, regulatory, and community benefits of green infrastructure and shows developers how to incorporate these benefits into their projects. The GSI practices described earlier in the Guide are linked to these benefits, which include:

- energy cost savings,
- landscape maintenance cost savings,
- increased property values (green amenities),
- marketing opportunities,
- potential for decreased review periods and fewer design revisions for projects requiring NJ DEP permits, and
- community benefits (e.g., public greening, green job opportunities) that generate community stakeholder support for the development project.

The Guide also discusses two tools available to support decision making through cost–benefit analysis *(language from Guide).*

- *The Green Infrastructure Co-Benefits Calculator was designed to estimate costs and benefits based on user-input project details. The calculator is intended to be used as a tool to calculate and compare the social, economic, and environmental benefits of green infrastructure against the costs. The calculator is available for use online at http://www.nycgicobenefits.net/.*
- *The National Green Values Calculator is a stormwater management calculator developed by the Center for Neighborhood Technology as a tool for quickly comparing the performance, costs, and benefits of green infrastructure or low impact development to conventional green infrastructure practices. The tool is intended for a nontechnical audience to evaluate the environmental improvement that can be achieved with green infrastructure. In addition, the calculator provides users with planning-level cost estimates. It is available at http://greenvalues.cnt.org/national/calculator.php.*

The Side-by-Side Comparisons section of the Guide provides a comparative cost–benefit analysis of GSI and gray infrastructure in hypothetical development scenarios, including commercial, residential, and urban infill development project scenarios. A summary table is provided for each scenario that compares cost and other performance metrics. *Figure 7* is an example of the commercial comparative scenario.



Side by Side Comparisons

**COMMERCIAL PROPERTY** — **Option 1 — Maximum Green Infrastructure**

The sample development project shown here includes a typical commercial building with associated parking spaces. Green infrastructure is implemented throughout the site to the maximum extent practicable. This sample project represents a green approach to stormwater management and includes a blue roof that discharges to a planter adjacent to the building, rain gardens to manage runoff from most of the parking lot and a portion of the roof area, pervious asphalt pavement and pervious concrete paver sidewalk areas, and an underground stormwater detention/retention system.



Image Credit: VNH Princeton
Image Credit: VNH Capital Health
Image Credit: VNH Princeton
Image Credit: Asphalt Pro

**Green Stormwater Management Comparison Table**

| | Construction Cost | Nonstructural Strategies Addressed | Performance | | |
|---|---|---|---|---|---|
| | | | $CO_2$ Sequestered (lb/yr) | Urban Heat Island Reduction | Potential Property Value Increase |
| Green Option | $44,000 | #2, #4, #7, #8 | 1,218 | 61% | 9% |

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Side by Side Comparisons

**COMMERCIAL PROPERTY** — **Option 2 — Minimal Green Infrastructure**

The sample development project shown here includes the same typical commercial building and associated parking spaces as option 1. This approach uses an underground stormwater detention/retention system with a manufactured treatment device to meet regulatory requirements.



Image Credit: Concrete Fastening
Image Credit: A's Asphalt Paving
Image Credit: AKRF Inc.
Image Credit: Water Works

**Gray Stormwater Management Comparison Table**

| | Construction Cost | Nonstructural Strategies Addressed | Performance | | |
|---|---|---|---|---|---|
| | | | $CO_2$ Sequestered (lb/yr) | Urban Heat Island Reduction | Potential Property Value Increase |
| Gray Option | $82,000 | None | 117 | 8% | 0% |

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*Figure 7: Comparative Scenario Example; Source: NJ Developers' Green Infrastructure Guide, April 2017*

## Case Studies

The Guide presents three detailed case studies of development projects that incorporated GSI. Each case study provides a project overview, a design summary that describes the GSI elements in the project, a decision-making summary that explains how the project team matched GSI selection to project goals, a discussion of the project challenges (e.g. permitting, construction) and keys to success, and a maintenance overview for the GSI practices (e.g. responsible party, maintenance requirements).

The three case studies include the following:

- Paseo Verde "a mixed use/mixed income development on an urban infill site in the ethnically diverse, low-income neighborhood of North Philadelphia, Pennsylvania". The project includes blue roofs, green roofs, rain gardens, subsurface infiltration basins, and porous pavement.
- Princeton Theological Seminary's redevelopment of a corporate complex with three garden style apartment buildings. The project includes surface infiltration basins and porous asphalt paving.
- Virtua Voorhees Hospital "a 120-acre healthcare campus development on a greenfield site along NJ State Highway Route 73 in Voorhees Township, Camden County, NJ". The project includes surface and subsurface infiltration basins, extended detention basins, wet ponds, constructed stormwater wetlands, vegetated swales, rain gardens, and green roofs.

The Guide also has an FAQ section to address common concerns and misperceptions about GSI.

## Tier A MS4 NJPDES Permit Presentations

NJ Department of Environmental Protection, March 2016

All municipalities with a Municipal Separate Storm Sewer System (MS4) must comply with state and federal rules regarding discharge. The current Tier A MS4 NJPDES master general permit that was issued and became effective in 2009 expired on February 28, 2014 (all Passaic County municipalities are Tier A). Accordingly, Tier A MS4s must update their Stormwater Management Program (SMP) to renew their permit. The NJ Department of Environmental Protection (NJDEP) conducted a series of presentations to municipal officials explaining their responsibilities under the New Jersey Pollutant Discharge Elimination System (NJPDES) rules. A summary of these presentations follows.

Each MS4 SMP must include six Statewide Basic Requirements (SBRs):

- Public Education
- Public Involvement/Participation
- Detection and Elimination of Illicit Discharges
- MS4 Outfall Pipe Mapping
- Post-Construction Stormwater Management for New Development and Redevelopment
- Pollution Prevention for Municipal Operators

Of particular relevance to green infrastructure (GI) and low impact development (LID) goals are NJDEP's regulations related to post-construction stormwater management. Municipalities must enforce NJDEP's minimum standards for stormwater runoff quantity, water quality, and groundwater recharge. Moreover, the NJPDES design and performance standards are enforced through municipal ordinances. Because GI/LIP best practices conform to NJDEP standards; they can be incorporated into the municipal land development review process.

## Hudson County Land Development Review Regulations for Smart Growth & Sustainable Development

Hudson County Planning Board, June 2016

The Hudson County Land Development Regulations (LDR) establish standards for site plan and subdivision reviews for which the County has jurisdiction. This most recent edition of the LDR includes Green Stormwater Infrastructure (GSI) regulations that reflect and incorporate post-Sandy regulatory changes, as well as the County's continued efforts in support of resiliency.

The LDR Circulation and Road Design Standards include a series of typologies that speak to function and characteristics of the County's major roadways and includes a typical roadway section. With the exception of a few of references in the Street Design Element encouraging or allowing green stormwater infrastructure with relation to sidewalks and planting strips, the Circulation and Road Design Standards are largely silent regarding GSI and low impact development (LID).

The Stormwater Management Design Standards include standard language in conformance with New Jersey Pollutant Discharge Elimination System (NJPDES) rules related to design of stormwater control measures, including structural management practices. The GSI standards require the use of green infrastructure and nonstructural best management practices in addition to the regular standards "to the maximum extent possible." Specifically, developments with 5,000 square feet of disturbance or less are required to include one GSI practice, and those with 5,000 square feet of disturbance or more must include two GSI practices. The GSI practice must, at a minimum, handle runoff for 50% of the total disturbance. The LDR requires that the stormwater plan depict the GSI and demonstrate that the design is appropriately sized, placed, and designed to meet the GSI requirement. The standards also require a maintenance plan and assurance. The LDR does allow for a waiver of the requirement because of site size restrictions, unsuitable soil conditions, and constraints due to contamination.

The GSI standards include a list of suggested green stormwater management practices, including basic siting and design guidelines, as well as maintenance requirements. *Figure 8* presents an example green stormwater management practices listing. The GSI standards also include a "Quick Reference Guide" to demonstrate where the green stormwater management practices are most suitable *(Figure 9)*.

# Flow-Through Planters

Flow-through Planters; Portland, Oregon (Right); Columbus Square, Philadelphia, Pennsylvania (Left)

## Practice Description

Flow-through Planters are a sunken, contained, landscaped areas created using curbing designed to collect and temporarily store stormwater runoff. The stored stormwater is then allowed to infiltrate through soil providing water quality treatment, volume reduction and/or attenuation.

## Quick Facts

- Collects stormwater runoff through cuts in planter wall or roof disconnections
- Footprint is generally smaller than a swale due to elimination of grading
- Planter material can be simple concrete or more decorative

## Siting Guidelines

- Minimum of 10' offset from subsurface structures (i.e. basements) for infiltrating practices, unless a liner is included
- Can be placed in wider sidewalks to provide aesthetic benefits and a separation from vehicular traffic
- Where there is parking, systems should be spaced to allow for pedestrians to pass between individual planters
- Where there is parking, systems should be set back from the curb line to allow for car doors to open

## Design Guidelines

- Where practices are unable to infiltrate, a flow regulating underdrain can be installed under the soil layer
- Taller, woodier plants should be combined with other plants to fill the planter during all seasons
- Runoff can be captured trench drains, curb cuts, and rain water conduit disconnections
- Overflow is generally managed through a domed riser or outflow through a receiving curb cut when the system reaches capacity

## Maintenance Requirements

- Quarterly inspection of structures, piping, and storage areas for trash and sediment accumulation
- Quarterly performance of general landscaping maintenance
- Monthly removal of litter and debris
- Removal of leaf debris as needed to keep inlets clear, especially in the Fall

*Figure 8. Example Best Management Practice Listing; Source: Hudson County LDR, 2016*

## Green Stormwater Infrastructure Siting Quick Reference Guide

| | Site | | | | Parking Lots | | | Roadways* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Open Areas | Gateway Entrances | Walkways | Full Buildout | Parking Stalls | Medians | Landscape Buffer | >3.5' Amenity Zones | On-Street Parking | Other Roads |
| **Rain Gardens** | X | X | | | | X | X | | | |
| **Swales** | X | | X | | | X | X | | | |
| **Flow-Through Planters** | | X | X | | | X | X | X | X | |
| **Subsurface Infiltration Trenches** | X | X | X | | X | X | X | X | X | X |
| **Permeable Pavements** | | | | | X | X | | X | | X |
| **Stormwater Curb Extensions** | | | | | | | | | X | X |
| **Green Roofs** | | | | X | | | | | | |
| **Rain Water Harvesting** | | | | X | | | | | | |

*For Street Design guidance, refer to Section VII: Circulation and Roadway Design Standards

*Figure 9. GSI Quick Reference Guide; Source: Hudson County LDR, 2016*

## Newark Greenstreets Initiative: Planning & Implementing Green Stormwater Infrastructure

Together North Jersey, March 2015

As part of Together North Jersey (TNJ), the City of Newark studied opportunities to incorporate green stormwater infrastructure (GSI) into the streetscape and on City-owned land. The resulting report — *Newark Greenstreets Initiative: Planning & Implementing Green Stormwater Infrastructure* — includes best management practices, implementation recommendations, and an appendix of technical specifications. The Report provides guidance to Newark staff through a review of the City's existing GSI specifications; identification of potential pilot locations; concept-level designs with stormwater diversion estimates, cost estimates, and contracting recommendations; and preparation of a horticulture manual.

The City of Newark is already participating in GSI initiatives with neighboring jurisdictions and the Passaic Valley Sewerage Commission (PVSC) in order to comply with its Long Term Control Plan (LTCP) for the combined sewer overflow (CSO) system. There is also a community initiative, Newark DIG (Doing Infrastructure Green!), which has committed to implementing community level pilot projects.

Key findings of the report include the following:

- Streets and City-owned properties provide abundant implementation opportunities.
- Pilot selection should overlap with community priorities, be deemed feasible based on physical suitability, should be linked to outfalls with a history of CSO incidences, and consider cost reasonableness. Furthermore, they should contribute to the implementation of the LTCP.
- A cross-departmental team should be established to implement the pilot projects, including the Water/Sewer Department, Planning, Sustainability, Engineering, and Neighborhood and Recreational Services
- Recommendations that the City establish a systematic approach to identify and implement public GSI projects in every Ward, and to encourage GSI on private property.

The Newark Sustainability Action Plan identified GSI as a major strategy for the City to manage stormwater and included the following actions *(language from the Report):*

- *Double Newark's tree canopy and establish a stable source of revenue for tree maintenance.*
- *Implement a new Newark Stormwater Ordinance and promote GSI policies.*
- *Develop a stormwater infrastructure bank and explore options for funding stormwater improvements through fees on runoff from impermeable surfaces.*
- *Integrate GSI standards into street maintenance and other city capital projects.*
- *Identify and implement new GSI pilot projects.*
- *Support neighborhood - based rain capture projects.*

The Introduction section of the report includes a rationale for the need to implement GSI in Newark based on the fact that the City is 70% impervious cover and has an aging CSO system. It then includes an explanation of GSI and its benefits, including GSI examples. The report also includes a section providing examples from

| Land Ownership | |
|---|---|
| Y | N |
| ☐ | ☐ | Is the proposed GSI site public land or private land? Does ownership affect design? |
| ☐ | ☐ | Are owners of vacant parcels / other open space willing to be a partner? |
| ☐ | ☐ | Are there on-site or adjacent site landowner conflicts? |
| **Infiltration or Storage** | |
| Y | N | |
| ☐ | ☐ | Are soil conditions suitable for infiltration of stormwater? (optimum situation) |
| ☐ | ☐ | Is groundwater at a depth sufficient to facilitate infiltration? |
| ☐ | ☐ | Is depth to bedrock sufficient for infiltration? |
| **Site Topography** | |
| Y | N | |
| ☐ | ☐ | Are there steep slopes >12% that would limit GSI capture/function? |
| ☐ | ☐ | Are street slopes less than 4%, to reduce drainage pipe depth? |
| ☐ | ☐ | Are slopes >5% that would limit the ability to implement porous pavement? |
| **Utility Conflicts** | |
| Y | N | |
| ☐ | ☐ | Are pipes needed to move stormwater from impervious surfaces to the proposed GSI site? |
| ☐ | ☐ | Are water, sewer, energy, communications, or other utilities present in/near proposed GSI locations that will constrain implementation / construction? Include in this review service laterals from the street to homes/businesses. Assess presence of hydrant and fire connections. |
| ☐ | ☐ | Can such utilities be relocated economically to allow implementation? If not, can they be encased or otherwise protected in place to allow implementation of GSI? |
| **Drainage Analysis** | |
| Y | N | |
| ☐ | ☐ | Is street slope suitable, and/or are stormwater inlets present to convey runoff to GSI? Where street slope is suitable, can curb cuts be implemented to allow street runoff to drain to GSI facilities? |
| **Existing Environment** | |
| Y | N | |
| ☐ | ☐ | Are there existing trees that are to remain and that are constraints to locating GSI? |
| ☐ | ☐ | Are there environmental conditions such as contaminated soil, monitoring wells, and groundwater wells that are near the proposed strategies? |
| ☐ | ☐ | Is this an area of localized flooding? |
| ☐ | ☐ | Has this area been identified to have flood reduction potential achievable using GSI, or do flood volumes exceed capacity of GSI? |
| ☐ | ☐ | Is there the potential for excessive sediment load (i.e., from adjacent landscaping)? |

| Vegetation & Landscaping | |
|---|---|
| Y | N | |
| ☐ | ☐ | Is there opportunity for trees to be planted in the project location using GSI designs (tree pits, tree planters)? |
| ☐ | ☐ | Are new trees needed along the street for succession planning? Are additional trees needed along the street for streetscaping design? |
| **CSO LTCP Consistency** | |
| Y | N | |
| ☐ | ☐ | Does the proposed GSI reduce runoff to a regulated CSO outfall? |
| ☐ | ☐ | Is it possible to monitor, model, and measure the runoff volume reduction and water quality improvement of the combined effect of GSI in the CSO subshed? |
| **GSI Best Management Practice Selection** | |
| Y | N | |
| ☐ | ☐ | Tree pits / Tree planters: Does the streetscape have the horizontal and vertical (e.g., underground utility) clearances needed to accommodate GSI installation? |
| ☐ | ☐ | Can stormwater runoff from the road and sidewalk be directed to the proposed tree trench location by surface flow, subsurface flow through a stone media, or piped flow? |
| ☐ | ☐ | Bioretention: Can flow be routed to swale/bioretention GSI (e.g. overland or via pipes)? |
| ☐ | ☐ | Can the GSI location be depressed, or are there mature trees or other features that cannot support reducing the bioretention GSI below existing grade? |
| ☐ | ☐ | Off-street / Open Space GSI: Is there sufficient elevation difference to direct water from the street to the open space? |
| ☐ | ☐ | Porous Pavement: Can subsurface soils accommodate infiltration? |
| **Traffic & Pedestrian Safety** | |
| Y | N | |
| ☐ | ☐ | Is there parking along the road and is a curbside walking path needed for car passengers to safely exit their vehicle without stepping into the GSI facility? |
| ☐ | ☐ | Is a bus stop present at the site or is bus traffic known to travel in parking lane? |

*Figure 10: GSI Implementation Considerations Form; Source: Newark Greenstreets Initiative Report, March 2015*

leading GSI programs from around the country, including best practices for on-street and off-street applications. The report includes a sample form to guide evaluation of property for feasibility of GSI practices *(Figure 10)*.

The GIS Concept Development section provides information about selection of GSI pilot projects based on existing challenges. Considerations included elevation, publicly owned vacant properties, opportunities for clustering GSI, public visibility/public amenity advantages, existing plans and projects, and avoidance of major flooding locations. This section also contains a table describing typical costs and values, lifespan, and gallons of stormwater runoff capture by source *(Figure 11)*.

| SOURCE CONTROL | INCREMENTAL CAPITAL COST (PER SQ. FT. OR UNIT) | NET PRESENT VALUE (PER SQ. FT. OR UNIT) | LIFESPAN (YEARS) | COST PER YEAR | GALLONS* (PER SQ. FT. OR UNIT) | COST TO CAPTURE GALLON | ANNUAL COST PER GALLON |
|---|---|---|---|---|---|---|---|
| Blue Roof (2-inch detention) | $4.00 | $4.00 | 20 | $0.20 | 1.25 | $3.21 | $0.16 |
| Rain Barrel (55-gallon tank) | $200 | $200 | 20 | $10.00 | 55 | $3.64 | $0.18 |
| Sidewalk Biofiltration | $36.81 | $39.68 | 20 | $1.98 | 8.60 | $4.61 | $0.23 |
| Porous Asphalt Parking Lane | $8.13 | $10.33 | 20 | $0.52 | 2.18 | $4.74 | $0.24 |
| Porous Concrete Sidewalk | $6.83 | $8.67 | 20 | $0.43 | 1.82 | $4.77 | $0.24 |
| Swale | $18.73 | $22.50 | 40 | $0.56 | 1.82 | $12.39 | $0.31 |
| Blue Roof (1-inch detention) | $4.00 | $4.00 | 20 | $0.20 | 0.62 | $6.42 | $0.32 |
| Cistern (500-gallon tank) | $3,700.00 | $3,700.00 | 20 | $185.00 | 500 | $7.40 | $0.37 |
| Greenstreet | $42.67 | $82.79 | 30 | $2.07 | 5.24 | $15.81 | $0.53 |
| Sidewalk Reservoir | $98.48 | $110.41 | 20 | $5.52 | 3.74 | $29.52 | $1.48 |
| Green Roof | $24.45 | $62.39 | 40 | $1.56 | 0.47 | $133.37 | $3.33 |
| **REFERENCE CASES** | **INCREMENTAL CAPITAL COST (PER SQ. FT. OR UNIT)** | **NET PRESENT VALUE (PER SQ. FT. OR UNIT)** | **LIFESPAN** | **COST PER YEAR** | **CSO GALLONS (PER SQ. FT. OR UNIT)** | **COST TO CAPTURE GALLON** | **ANNUAL COST PER GALLON** |
| Newtown Creek Tunnel | $1,299,000,000 | $1,300,000,000 | 50 | $26,000,000 | 40,000,000 | $32.50 | $0.65 |
| Flushing Bay Tunnel | $1,038,000,000 | $1,039,000,000 | 50 | $20,800,000 | 25,000,000 | $41.56 | $0.83 |

Note: **Gallons refers to the gallons of stormwater runoff that can be retained or detained by the source control technology.

Source: Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure; USEPA; August 2010; EPA-841-F-10-004

*Figure 11: Typical GSI Costs; Source: Newark Greenstreets Initiative, March 2015*

Ultimately, 10 pilot locations in three neighborhoods were recommended. The Report includes an overview of the neighborhoods and pilot projects, including a discussion about drainage area impacts, potential costs, and design concepts.

The GSI program recommendations section details specific planning considerations and processes used to implement a GSI program. *Figure 12* shows a flow chart of GSI program considerations, including the planning, design, and construction/maintenance processes involved.

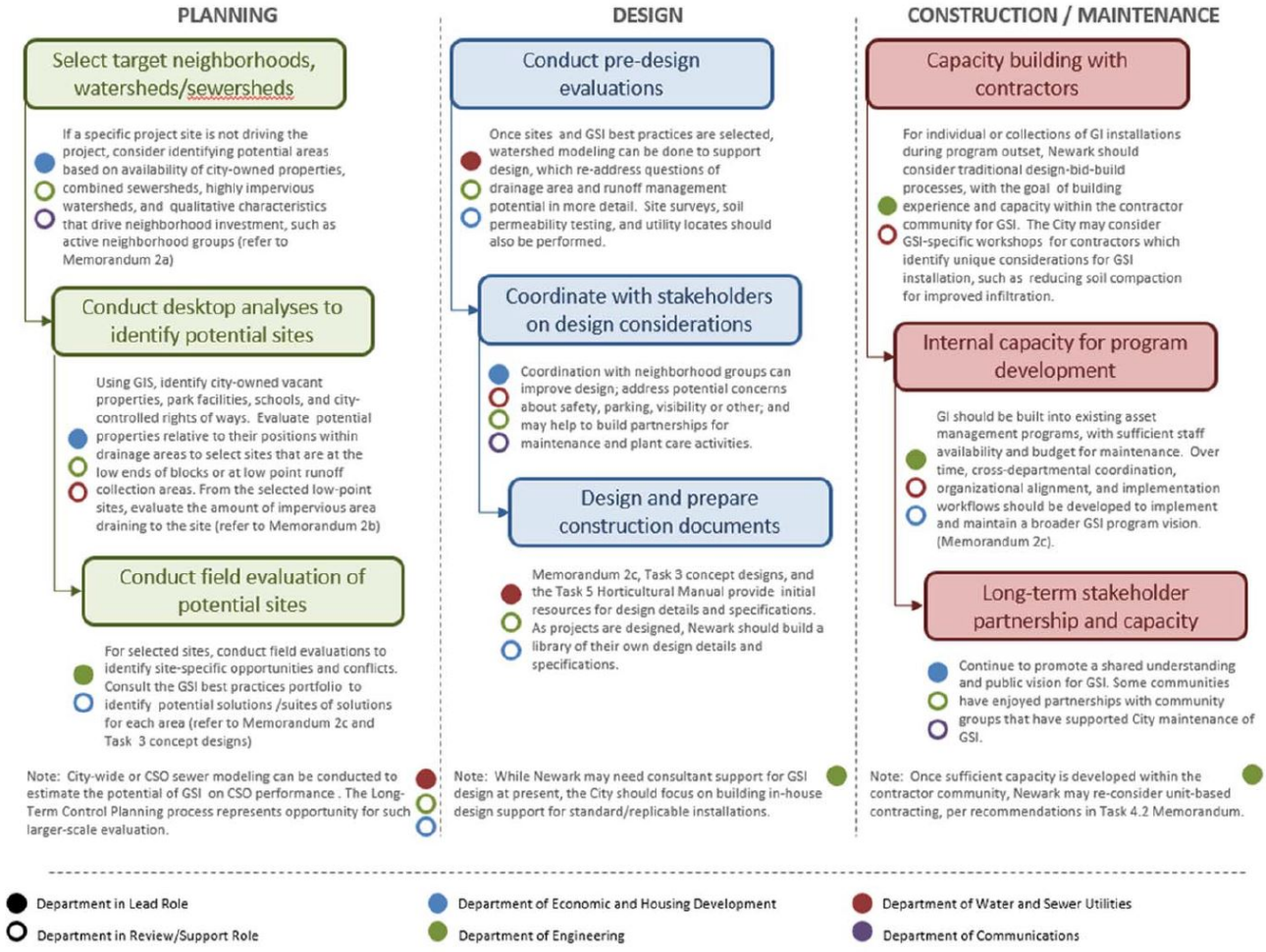


*Figure 12: GSI Program Considerations; Source: Newark Greenstreets Initiative, March 2015*

The remainder of the section outlines funding and financial resources, policy, and institutional recommendations. In general, the sewer fee is inadequate to address the City's GSI needs, and until clarification is provided by the NJ legislature, it is unlikely that the City will establish a stormwater utility capable of charging a fee for stormwater management. In the interim before clarification is obtained, the report makes a recommendation to collect in lieu payments from developers that cannot develop sufficient stormwater management on site. The Report also recommends that additional study be conducted to determine the overall impact potential of GSI in relation to the necessary reductions required in the LTCP. Finally, the Report recommends sufficient public engagement to ensure community support for GSI efforts.

## Appendix B: Greenstreet Specifications

Appendix B includes examples of regulations and design specifications from example communities throughout the US, as well as draft regulation and design specifications for the City of Newark to adopt.

## Appendix C: Task 5 Horticulture Manual

The Horticultural Manual provides guidelines to identify appropriate vegetation and soil characteristics suitable for GSI techniques within the City, as well as advice related to installation and maintenance.

## Hoboken Green Infrastructure Strategic Plan

Together North Jersey, October 2013

As part of the Together North Jersey Local Demonstration Project program, the City of Hoboken developed the *Green Infrastructure Strategic Plan* (the Plan) to address the impacts of more intense and frequent severe weather and flood events on the City's stormwater infrastructure system.

The Plan includes a sewershed level analysis that organized the City into three zones based on the carrying capacity of the underlying land. The three zones include: 1) the Gray Zone, where aboveground Best Management Practices (BMPs) are most appropriate due to poor infiltration; 2) the Green Zone, where infiltration is more feasible, and thus infiltration BMPs are acceptable; and 3) the Blue Zone, where detention is most feasible because of the low elevations. Based on the sewershed analysis and zone classification, the Plan identifies the most cost-effective places for green infrastructure.

The Plan recommends a number of BMPs that could be effectively used in the City, including constructed wetlands, permeable pavements, stormwater street trees, vegetated swales, rainwater harvest and reuse, basins or ponds, rain gardens, stormwater infiltration planters, subsurface storage, and green roofs. The Plan includes an analysis of both capital and maintenance costs for each BMP *(Figure 1)*. While the Plan does not include design guidelines for each BMP, it does provide insights into site suitability costs for each one *(see Figure 2 for an example BMP)*.

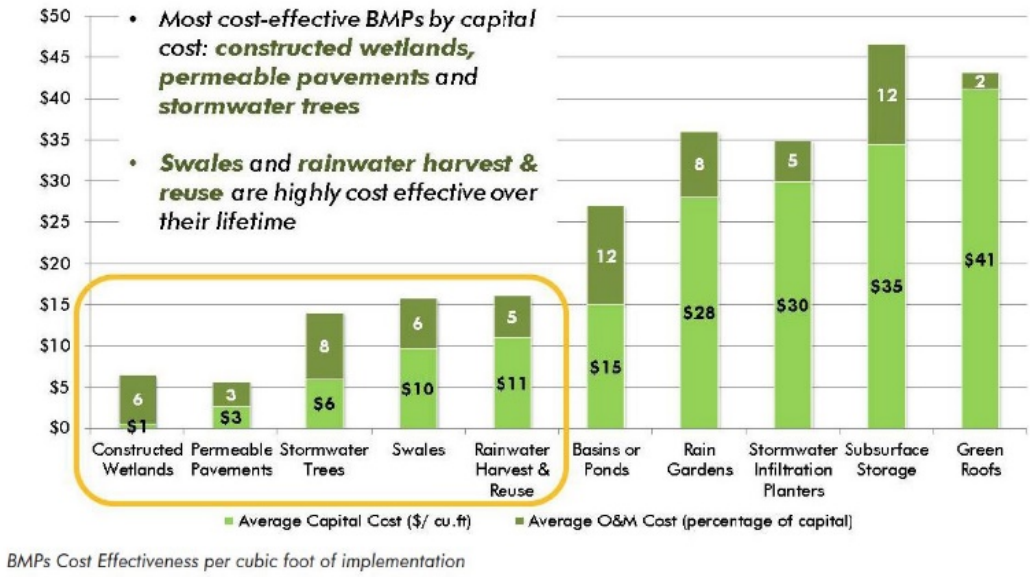


*Figure 13. BMP Cost Effectiveness; Source: Hoboken Green Infrastructure Strategic Plan, 2013*

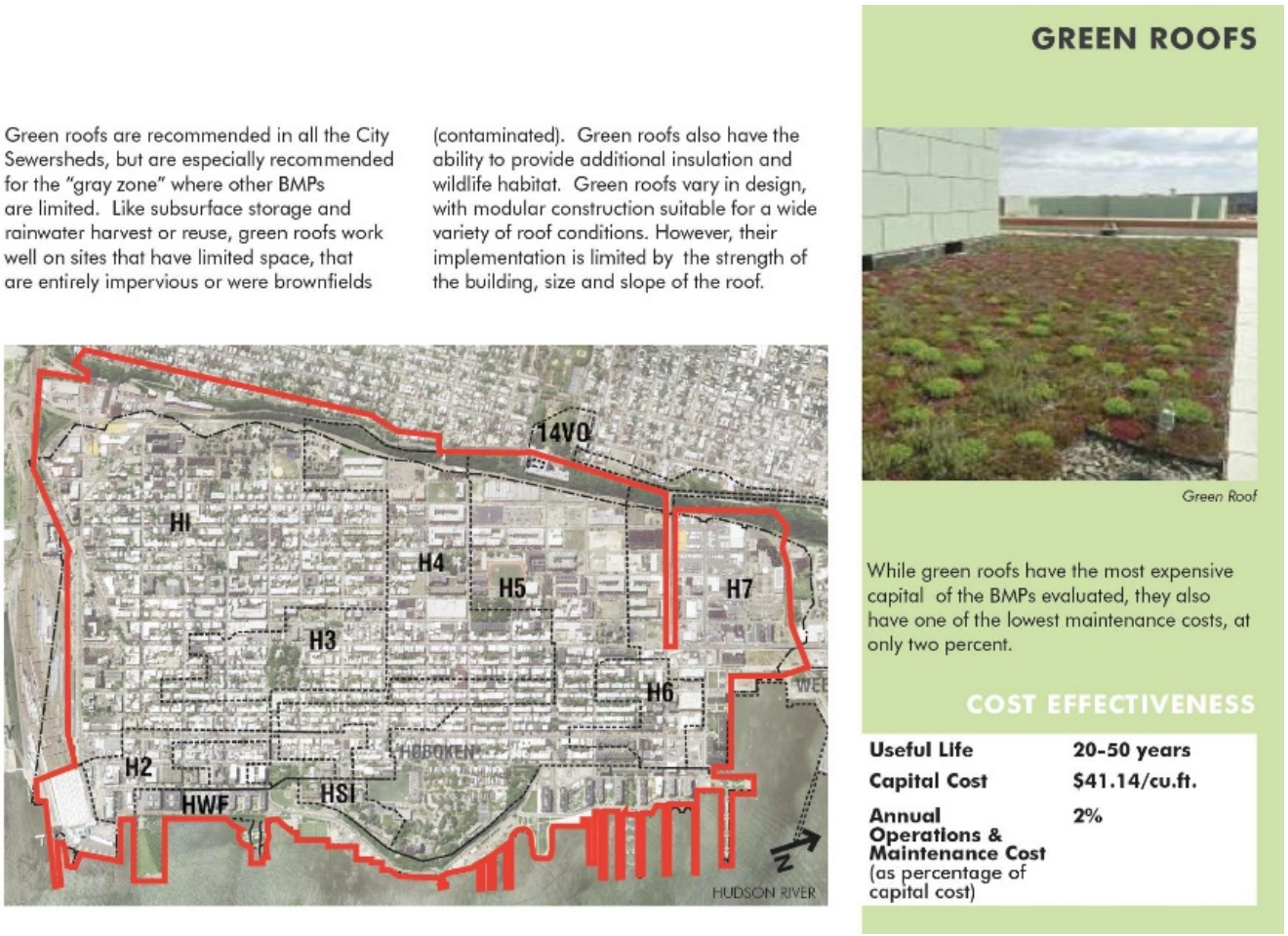


*Figure 14. Example BMP; Source: Hoboken Green Infrastructure Strategic Plan, 2013*

The Plan includes the following recommendations for innovative implementation strategies to help the City achieve its green infrastructure (GI) goals:

- Incorporate performance based standards that include minimum standards for stormwater management without prescriptive language about how the standard is attained, thus allowing for flexibility of design. It further recommends incentive zoning that gives bonuses to encourage retention greater than the minimum standard.
- Establish a Stormwater Trust Fund to collect funds from individual development projects where specific site conditions limit the ability to incorporate GI. Instead of forcing ineffective GI applications, the City can collect funds to construct more effective solutions offsite.
- Conduct a further study to determine the feasibility of other financial incentive programs such as a Stormwater Management Tax Credit, rebates, and installation financing.

## City of Philadelphia Stormwater Management Guidance Manual, Version 3.0

Philadelphia Water, July 2015

Philadelphia Water (PWD) Stormwater Regulations require onsite stormwater management for development projects that cause 15,000 square feet (5,000 in certain watersheds) or more of earth disturbance. Other types of construction activities may also trigger portions of the Stormwater Regulations, including demolition and voluntary stormwater retrofit projects. The *Philadelphia Stormwater Management Guidance Manual, v. 3.0* (the Manual) is a comprehensive resource to help the real estate development community navigate the Stormwater Plan Review process and demonstrate compliance with Stormwater Regulations.

The Manual provides detailed guidance for an applicant on how to comply with the Stormwater Regulations for development and other construction projects. Using the Manual, the applicant will be able to *(language from Manual)*:

- *determine if a project is regulated under the Stormwater Regulations and, if so, what specific requirements need to be met;*
- *learn about new ways to incorporate green approaches to stormwater management that provide benefits for development projects and expedite the stormwater approval process;*
- *design specific stormwater management practices (SMPs) to meet PWD's standards;*
- *prepare and submit application materials;*
- *learn how to ensure proper installation and protection of SMPs during construction activity; and*
- *obtain information on post-construction and operations and maintenance (O&M) requirements.*

The Manual is organized into an Introduction, Chapters, and Appendices. Each chapter provides guidance on how to use the content in that chapter. Chapters also contain tables and flow charts, diagrams, and detailed illustrative renderings for clarification of important concepts. Because design, submittal, and review processes are closely related, there is extensive cross-referencing with hyperlinks throughout the Manual. Chapter descriptions follow *(language from the Manual)*:

- *Chapter 1 - Regulatory Requirements provides an overview of the Stormwater Regulations and allows the applicant to determine if a project is regulated, and if so, which requirements apply to a particular project based on the project's characteristics.*
    - Regulatory requirements differ based on the watershed in which development is being proposed; for example, peak runoff rates differ, and location also determines the level of channel protection required.
    - The extent of earth disturbance is the other primary determination of stormwater regulation applicability.
- *Chapter 2 - Submission, Review, and Approval Procedures outlines the steps required to obtain PWD Stormwater Plan Review approvals.*
    - Of note within this chapter is the discussion about stormwater retrofits that are being voluntarily pursued as a means to reduce the monthly stormwater bill, and/or implement a project under a stormwater grant. Some retrofits are eligible for technical assistance, or financial assistance through the City's Stormwater Management Incentive Program (SMIP) and Greened Acre Retrofit Program (GARP) grant program.
    - To encourage GI, PWD also offers expedited review for projects that are able to disconnect 95%

of their stormwater through installation of GI.

- *Chapter 3 - Site Design and Stormwater Management Integration guides the designer in successfully incorporating stormwater management into development site designs, while meeting PWD Stormwater Regulations. The site design procedure is based on Pennsylvania Department of Environmental Protection recommendations, with minor modifications adapted to conditions in Philadelphia.*
    - This chapter emphasizes the PWD's desire for GI to be integrated into the stormwater management system and provides specific guidance on "highest-preference" stormwater management practices (SMPs). *(See Table 3.2-4)*

**Table 3.2-4:** SMP Hierarchy

| SMP / SMPs in Series | Section |
|---|---|
| **HIGHEST PREFERENCE** | |
| Bioinfiltration | 4.1 |
| Bioretention | 4.1 |
| Porous Pavement | 4.2 |
| Green Roofs | 4.3 |
| **MEDIUM PREFERENCE** | |
| Subsurface Infiltration | 4.4 |
| Cisterns | 4.5 |
| Blue Roofs | 4.6 |
| Ponds and Wet Basins | 4.7 |
| **LOWEST PREFERENCE** | |
| Subsurface Detention with Vegetated Media Filters | 4.8 / 4.9 |
| Subsurface Detention with Roof Runoff Isolation | 4.8 / 3.2.4 |
| Subsurface Detention with Media Filters | 4.8 / 4.9 |
| Vegetated Media Filters | 4.9 |
| Media Filters | 4.9 |

*Source: City of Philadelphia Stormwater Management Guidance Manual Version 3.0, July 2015*

    - The chapter includes narrative encouraging applicants to view stormwater as a resource to be used, rather than looked at as "waste."
    - Of note, as part of the site assessment, the applicant must conduct a review of flood issues on site and on adjacent properties and their relation to stormwater runoff to inform SMP selection. Existing physical features must also be assessed "to identify opportunities to use existing natural areas and drainage patterns for stormwater management." The site assessment must also determine if there are contaminants present that would preclude infiltration.
    - The Manual provides guidance to assist the designer with regard to siting and selecting SMPs, including
        - assessment of space constraints,
        - creating amenities,
        - maximizing infiltration,
        - prioritizing low-lying areas,
        - minimizing conveyance requirements,
        - avoiding utilities,
        - avoiding sensitive features,

        - providing maintenance access,
        - avoiding contamination,
        - avoiding unstable fill,
        - maintaining sight lines,
        - ensuring safety,and
        - appropriateness for vegetated SMPs.
    - Where site conditions deem necessary, the Manual does provide for stormwater management "trading."

- *Chapter 4 - Stormwater Management Practice Guidance provides detailed guidance to the designer regarding stormwater management practices (SMPs), as well as pretreatment, inlet control, and outlet control systems that support SMP functions. Each SMP includes a 1-page quick reference sheet, followed by detailed narrative and design specifications. (See Figure 15 for an example reference sheet.)*


*Figure 15: Example SMP Reference Sheet; Source: City of Philadelphia Stormwater Management Guidance Manual Version 3.0, July 2015*

- *Chapter 5 - Construction Guidance provides guidance for developers, engineers, and contractors on construction-related topics, including construction inspections, commonly encountered construction issues, and construction documentation.*

- *Chapter 6 - Post-Construction and Operations and Maintenance Guidance provides guidance for the property owner on Operations and Maintenance (O&M) requirements and on post-construction SMP inspection. Chapter 6 also provides information on stormwater credits, for which property owners may be eligible following SMP construction. Further information on the Stormwater Credits Program is also found in this chapter.*
- *The Appendices contain additional resources, including watershed and Flood Management District mapping, submission checklists, worksheets, a sample Record Drawing, and landscape guidance.*

PWD encourages the use of a comment form provided on the website to suggest changes, corrections, and other feedback that will assist in improving the Manual in future versions.

## City of Philadelphia Green Streets Design Manual

Philadelphia Water and Philadelphia Streets Department, 2014

Philadelphia Water (PWD) and Philadelphia Streets Department (PSD) worked collaboratively to produce the *Green Streets Design Manual* (the Manual), which provides guidance for designing, constructing, and maintaining green stormwater infrastructure (GSI) in the City right-of-way (i.e., "green streets"). The effort ties in with the requirements of the City's stormwater management system and the goal to manage more than one-third of the City's impervious cover in combined sewer overflow (CSO) areas through GSI measures.

The Manual includes an introduction to stormwater management and GSI, as well as an explanation of the green streets link to the City's CSO management plan. The City's GSI goals will be met through stand-alone PWD capital projects, and PWD partner projects with other agencies, like PSD, as well as through private investments during development and redevelopment. Philadelphia streets represent 30% of the City's impervious cover; therefore, it is seen as a prime opportunity to incorporate GSI. The Manual supplements other City documents related to stormwater management practices (SMPs) and GSI, but provides specific guidance about green streets strategies. The Manual also complements the Philadelphia Complete Streets Design Handbook (2012).

Chapter 2 discusses GSI SMPs appropriate for right-of-way application. There are a number of SMPs already implemented within the City right-of-way, including stormwater trees, stormwater tree trenches, stormwater planters, permeable pavement, and stormwater bumpouts. In addition, the Manual deems additional GSI SMPs suitable, even though they have not yet been implemented within the City, including green gutters and stormwater drainage wells. The Manual further encourages investigation of other innovative GSI practices, not mentioned in the Manual, during the design phase where appropriate. The Manual includes a series of fact sheets about the referenced GSI SMPs, each including an overview of the SMP, and discussion about the SMP benefits, constraints, bike/pedestrian considerations, urban design context, and maintenance, and includes examples of the SMP within the City *(see Figure 16 for an example fact sheet).* Appendix 6.1 of the Manual includes complete design details of the GIS SMPs referenced.

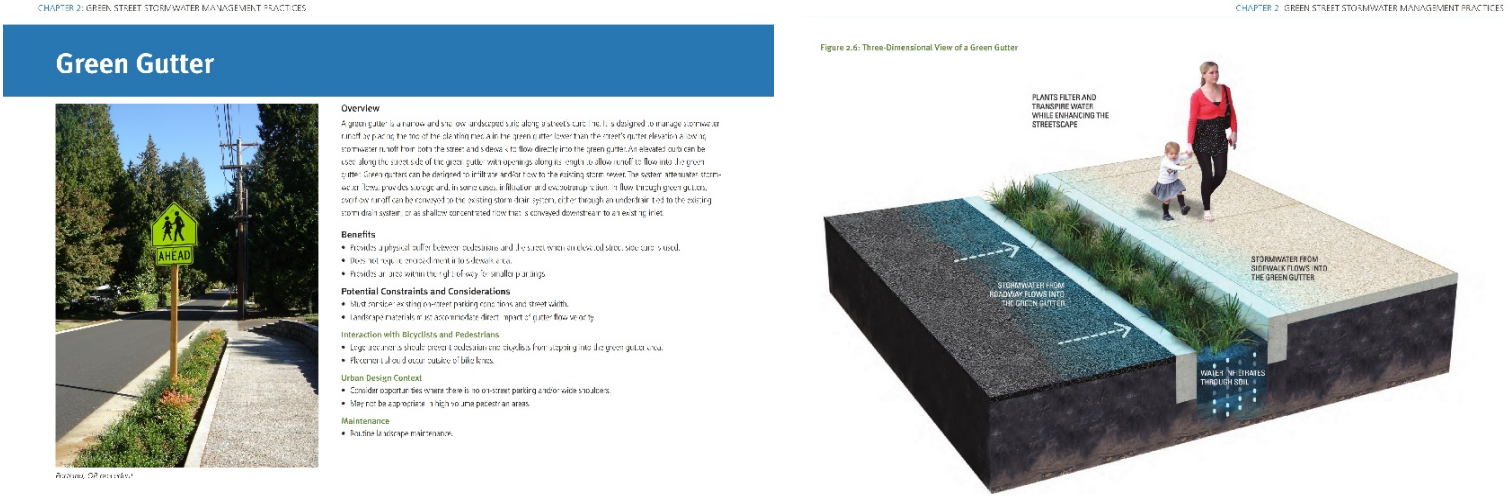


*Figure 16: Example Fact Sheet; Source: City of Philadelphia Green Streets Design Manual, 2014*

Chapter 3 summarizes the street typologies found in the *Philadelphia Bicycle and Pedestrian Plan* and the *Philadelphia Complete Streets Design Handbook* to assign contextually suitable GSI SMPs. *Figure 3.1* provides a matrix of GSI suitability by street type.

Figure 3.1: SMP Suitability Matrix

| | High-Volume Pedestrian | Civic / Ceremonial | Walkable Commercial Corridor | Urban Arterial | Auto-Oriented Commercial / Industrial | Park Road | Scenic Drive | City Neighborhood Street | Low Density Residential | Shared Narrow | Local |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stormwater Bump-out** | | | | | | | | | | | |
| **Midblock** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Corner** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Stormwater Tree Trench** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Stormwater Tree** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Planter** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Permeable Pavement** | ● | ●* | ●* | ●* | ●* | ● | ● | ● | ● | ● | ● |
| **Green Gutter** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Stormwater Drainage Well** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

*Treatment is appropriate for use within pedestrian, bicycle, parking, and shoulder areas only

● Recommended

● Possible, but there is probably a better choice

● Not recommended

Note: For installations along State Routes, coordinate with PennDOT to identify appropriate recommended treatments.

Note: The criteria by which an SMP is determined to be recommended, possible, or not recommended for a given street are explored further in Chapter 4.

*Source: City of Philadelphia Green Streets Design Manual, 2014*

Chapter 4 discusses the appropriate location of GSI within the right-of-way of the City's street types. It includes a step-by-step procedure for evaluating and selecting GSI SMPs as follows:

1. Identify potential streets where GSI is appropriate based on existing conditions, including grade and slope, drainage area, potential conflicts, and size requirements of the SMP.
2. Determine the street type, then reference the Complete Streets Design Handbook for guidance related to pedestrian and bicycle accommodations, furnishings, curbside treatments, and cartway.
3. Use the Suitability Matrix *(Figure 3.1 above)* to determine potential GSI SMPs.
4. Use the Manual for selection and technical guidance for implementing the most appropriate GSI SMP.

The Manual includes a series of illustrative two-page GSI siting scenarios for five different street types *(see Figure 15, for example)*.

*Figure 17: Example Siting Scenario; Source: City of Philadelphia Green Streets Design Manual, 2014*

Chapter 5 prescribes design requirements for GSI SMPs and SMP systems (i.e., a series of connected SMPs), including the following:

- Soil Suitability — the City requires stormwater infiltration, unless deemed infeasible due to poor infiltration rates, contamination, or geotechnical concerns. As such, the soil is to be tested to determine suitability. Where there are soil infiltration concerns, mitigation should be considered.
- Sizing — The SMP size should be based on the area and volume of stormwater to be managed. The Manual recommends a 10:1 loading ratio for infiltration and provides the following equation to determine storage volume:

$$V = A \times P/12$$

*Where, V = required storage volume (cu. ft.)*
*A = impervious drainage area (sq. ft.)*
*P = precipitation = 1 in. or more*

- System Drainage — GSI systems "must completely drain within 72 hours; drain down within 24 hours is recommended."
- Adjacency — there must be sufficient distance between the SMP and adjacent structures to avoid damage and/or flooding.
- Detention/Slow Release — GSI SMP/system maximum release rate "is 0.05 cubic feet per second (cfs) per acre of impervious drainage area managed. The minimum orifice control diameter that may be used in a GSI SMP or system designed for detention is 0.5 inches."
- Inlet Selection and Placement — "[S]tormwater entrances should be located directly upstream of existing stormwater inlets to maximize runoff capture from the right of way and minimize the length of flow for stormwater runoff bypass. Inlets must be sized to convey the one-year storm peak runoff rate to the GSI SMP or system[.]"
- Erosion and Sediment Controls — must comply with PA Code 102 requirements.

Chapter 6 of the Manual provides an overview of Green Streets SMP design for the City's right-of-way, with

more detailed design guidance provided in Appendix 6.2. The Manual groups the components of Green Streets SMPs into the following 12 functional systems *(language from Manual)*:

- *FS-1 Area Protection (AP)*
- *FS-2 Energy Dissipation (ED)*
- *FS-3 Stormwater Entrance (SE)*
- *FS-4 Storage Media (SM)*
- *FS-5 Media Separation (MS)*
- *FS-6 Planting Media (PM)*
- *FS-7 Landscaping (L)*
- *FS-8 Impermeable Barriers (IB)*
- *FS-9 Piping (P)*
- *FS-10 Pretreatment (PR)*
- *FS-11 Subsurface Stabilization (SS)*
- *FS-12 Identification and Education (IE)*

Within each functional system area series of design components, not all have specifications. Accordingly, the Manual provides a key within the component listing to determine whether the City has a particular design specification included in Appendix 6.2 *(see Figure 15, for example)*.


*Figure 18: Functional System/Design Component Example; Source: City of Philadelphia Green Streets Design Manual, 2014*

Chapter 7, explains the five phases of review and approval process for GSI within the City right-of-way as follows *(language from the Manual)*:

- *Phase One: Proposal and Location Approval* — PWD reviews and provides comment.
- *Phase Two: Concept Design & Approval* — both PWD and PSD reviews and provides comment. PennDOT must review applications on State roads.
- *Phase Three: Preliminary Design (Optional)* — An optional meeting is held with both PWD and PSD.
- *Phase Four: Final Design* — PWD and PSD provide final approvals, but the tree planting plan must be approved by Philadelphia Parks & Recreation (PPR).
- *Phase Five: Permitting Process* — the project must apply for an obtain all other applicable necessary pre-construction permits.

Once approvals are obtained, the applicant must have a preconstruction meeting with PWD and submit to construction phase and final inspections. PWD assumes ownership and maintenance of "standard" GSI assets with a warranty from the applicant for a predetermined period of time according to a maintenance agreement, but it can refuse the same if the applicant does not meet the terms of the agreement. GSI SMPs that include features not standard to PWD guidelines must be maintained by the property owner and will be subject to a Memorandum of Understanding between PWD and the property owner.

The Manual highlights collaborative funding opportunities whereby PWD may be able to provide partial funding to non-municipal organizations for GSI design and/or implementation. The Manual outlines all possible sources of funding, including many that Passaic County could potentially pursue *(Table 7.1)*.

Table 7.1 Potential Green Street Funding Programs

| FEDERAL GRANT PROGRAMS | | | | |
|---|---|---|---|---|
| **Grant Name** | **Sponsoring Agency** | **Link to Further Information** | **Description** | **Eligibility Requirements or Funding Restrictions** |
| Targeted Watersheds Grant Program | EPA: Office of Water | http://water.epa.gov/grants_funding/twg/initiative_index.cfm | The targeted watersheds grant program through EPA encourages successfully community based approaches to protect and restore the nation's waterways. Grant funds can be used to support activities relating to the prevention, reduction, and elimination of water pollution. Projects cannot be activities required or regulated under the Clean Water Act. | None |
| Community Development Block Grants | Funding provided by U.S. Department of Housing & Urban Development (HUD); administered by the Philadelphia Office of Housing & Community Development (OHCD) | http://www.phila.gov/ohcd/hud.htm | GSI elements for green streets could be eligible for Transportation Enhancement (TE) funds. One of the categories eligible for these funds includes "mitigation of water pollution due to highway runoff." DVRPC solicits, reviews, and approves TE projects in the Philadelphia region | Municipality, county, state agency, or not-for-profit agency. |
| Highway Safety Improvement Program | Funding provided by USDOT, Federal Highway Administration; administered by PennDOT | http://safety.fhwa.dot.gov/hsip/ | Types of projects funded include the rehabilitation and new development of parks and recreation facilities; acquisition of land for active or passive park and conservation purposes; and planning for feasibility studies, trails studies, conservation plans, site development planning, and comprehensive recreation, greenway and open space. | Municipalities and authorized non-profit organizations. |
| EPA Urban Waters Small Grants | EPA's Urban Waters Program | http://www.epa.gov/urbanwaters/funding/index.html | Eligible projects are those which involve the acquisition of land, easements or rights-of-way and the construction, improvement, expansion, extension, repair or rehabilitation of either a system for the supply, treatment, storage or distribution of water not used solely for residential purposes, or a system for the collection, treatment or disposal of wastewater (including industrial waste and the separation of sanitary sewers and storm sewers) not used solely for residential purposes. Grants are provided at a $5 million maximum or 75% of total eligible project costs, whichever is less. Loans are also available at a $5 million maximum per project with a 2% interest rate and repayment terms up to 20 years. | Municipalities; Industrial Development Corporations; Municipal Authorities; Investor-owned water or wastewater enterprise |

| Grant Name | Sponsoring Agency | Link to Further Information | Description | Eligibility Requirements or Funding Restrictions |
|---|---|---|---|---|
| TIGER Grants | United States Department of Transportation | http://www.dot.gov/tiger | Funds work designed to transform systems so that environmental problems are not created in the first place; supports efforts to reduce the damage currently being done by unsustainable practices; looks for programs and initiatives that help repair the damage caused by unsustainable practices; looks for places where capital investment are not available to correct an environmental problem. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |
| Clean Water State Revolving Fund (CWSRF) | Funding provided by EPA; administered by PADEP | http://www.portal.state.pa.us/portal/server.pt/community/pennvest/9242 | Project must be within one of the five issue areas: global health, climate & environment, basic survival safeguards, urbanization, and social & economic security; for climate & environment it needs to be related to sustainable growth and resilience to climate change. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |
| **NATIONAL PRIVATE FOUNDATION GRANT PROGRAMS** | | | | |
| The Heinz Endowments | Howard Heinz Endowment | http://www.heinz.org/grants_apply.aspx | Funds work designed to transform systems so that environmental problems are not created in the first place; supports efforts to reduce the damage currently being done by unsustainable practices; looks for programs and initiatives that help repair the damage caused by unsustainable practices; looks for places where capital investment are not available to correct an environmental problem. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |
| Rockefeller Foundation Funding | The Rockefeller Foundation | http://www.rockefellerfoundation.org/grants | Project must be within one of the five issue areas: global health, climate & environment, basic survival safeguards, urbanization, and social & economic security; for climate & environment it needs to be related to sustainable growth and resilience to climate change. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |
| **Grant Name** | **Sponsoring Agency** | **Link to Further Information** | **Description** | **Eligibility Requirements or Funding Restrictions** |
| Surdna Foundation Grant | Surdna Foundation | http://www.surdna.org/grants/grants-overview.html | Projects qualifying for grants under Surdna's Sustainable Environments program include those focused on improving transportation systems and encouraging smart growth. One of their funding priorities in this area is "supporting state and city leaders in the development and implementation of innovative solutions and the transfer of best practices that create environmental, economic and social benefits. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |
| Environmental & Cultural Preservation Grants | The Tiffany & Co. Foundation | http://www.tiffanyandcofoundation.org/apply.aspx | To improve the urban parks experience by supporting infrastructure improvements and beautification efforts in existing parks and by supporting the creation of additional green spaces. **They were a major funder for the High Line Park project in NYC, which includes sustainable stormwater management features. | Must be a 501(c)(3) non-profit organization to qualify. Individuals and for-profit organizations are not eligible. |

*Source: City of Philadelphia Green Streets Design Manual, 2014*

## Appendix 6.2 - Design Details

The Appendix includes a series of illustrative design detail sheets that can be adapted for use by public and private entities in designing site-specific GSI SMPs. The first two pages of the Appendix include a key for understanding the design detail sheets, as well as general rules for GSI location and design. The illustrative design sheets include the following:

- SP-01 Stormwater Planter Placement Diagram
- SP-02 Stormwater Planter
- TT-01 Stormwater Tree Trench

- ST-01 Stormwater Tree
- SB-01 Stormwater Bump-out Placement Diagram
- SB-02 Stormwater Bump-out (Mid-Block)
- SB-03 Stormwater Bump-out (Corner)
- SB-04 Stormwater Bump-out (Bus Stop)
- PP-01 Permeable Pavement
- GG-01 Green Gutter
- DW-01 Stormwater Drainage Well

## A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds

Philadelphia Water Department, August 2009

*A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds* (the Report) was prepared for Philadelphia Water (PWD) Office of Watersheds (OOW) by Stratus Consulting of Boulder, Colorado. Engineering cost information was provided by Camp, Dresser and McKee. The purpose of the Report was to provide PWD with a more complete understanding of the "implications of the green and traditional infrastructure approaches in terms of their respective ability to provide environmental, social, public health, and other values." A triple-bottom line (TBL) approach recognizes that there are external benefits to society not captured in a cash flow financial analysis.

The Report compares the benefits and external costs of low impact development/green infrastructure (LID/GI) and traditional stormwater approaches to manage combined sewer overflow (CSO). The PWD prepared a separate study to look at the performance and engineering design costs/benefits.

As described in the Introduction, the Report provides the following information *(language from the Report)*:

1. *a brief overview of the four PWD watershed areas addressed by the policy options, as well as abbreviated descriptions of the 16 CSO control options being considered for each area.*
2. *a general description of the data and methods used to conduct the TBL-oriented benefit-cost assessment of the alternatives.*
3. *more detailed descriptions of the estimated levels of benefits (and external costs) for each major benefit-cost category. An overview of the methods, data, and limitations associated with these estimates is also provided.*
4. *summaries of the benefit estimates for two of the prominent CSO control options under consideration, aggregated across the four watershed areas. These summaries provide a city-wide overview of the physical and economic magnitude of benefits (and external costs) for two highlighted CSO control alternatives. The two highlighted CSO control options are the LID-50% option (reflecting a green infrastructure approach), and the 30' Tunnel option (reflecting a more traditional infrastructure approach).*
5. *detailed tables that indicate watershed-specific estimates for each benefit and external cost category, for each CSO control option evaluated.*
6. *Discussion of the key uncertainties inherent in this type of TBL-oriented benefit-cost analysis, and the results of several sensitivity analyses are provided to provide insights as to the level of stability of the estimates to alternative input values and assumptions.*
7. *detailed technical appendices — one for each benefit or external cost category assessed. These appendices describe the methods, data, findings, and caveats relevant to each endpoint, and also contain relevant reference citations.*

Philadelphia's CSO area encompasses about 40,500 acres, and is managed on a watershed-basis. For each watershed, PWD has developed a suite of CSO control options based on LID and traditional approaches, as described below *(language from the Report)*.

### *LID/GI Approaches*

*For each watershed, PWD has developed a range of LID CSO control options (e.g. 25, 50, 75, and 100% of runoff from impervious surfaces managed through green infrastructure), representing different levels of implementation. The LID approach focuses on restoring a more natural balance between stormwater runoff and infiltration, reducing pollutant loads, and controlling runoff rates at levels that minimize stream bank*

*erosion. Controls incorporated into the different LID options include disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, and tree canopy. Land-based measures are a key part of this approach because they provide benefits to the community beyond water quality improvement (e.g. recreational opportunities, improved aesthetics, and increased home values).*

*The LID options also include a variety of water-based approaches to CSO control, including bed and bank stabilization and reconstruction, aquatic habitat creation, plunge pool removal, improvement of fish passage, and floodplain reconnection. The ultimate goal of this component of the LID program is to restore designated uses and ultimately remove CSO streams from the state's list of impaired waters. Similar to the land-based approaches described above, stream restoration will provide a number of benefits beyond water quality improvement.*

#### *Traditional Infrastructure-Based Management Measures*

Traditional control measures include tunneling; transmission, plant expansion and treatment; and transmission and satellite treatment to provide traditional storage, conveyance, and treatment measures within the collection and treatment system.

According to the Report, compared with LID approaches, *traditional control measures do not provide environmental, social, and public health benefits to the community beyond water quality improvement. Also, traditional infrastructure-based measures may not address the root causes of impairment in Philadelphia's urban streams, where the primary causes of impairment are modified flow patterns and habitat degradation. Infrastructure-based measures are typically focused on removing loads of specific pollutants rather than restoring natural flow conditions and habitat.*

### Methodology and Assumptions

External costs & benefits includes costs and benefits beyond traditional engineering estimates, including energy and air quality implications (e.g. fuel spent in construction related traffic, air quality improvements due to added greenery).

Methods for quantifying/valuing impacts. The Report used standard industry practices, many originated by relevant government agencies, including the US Environmental Protection Agency (EPA), and US Forest Service (USFS).

Time-horizon of analysis. The Report analyzes annual costs and benefits over a 40-year period (2010-2049) based on estimated construction and maintenance schedules, factoring in such aspects as tree/plant growth.

Value is based on 2009 dollars considering 4% inflation and a 4.875% discount rate.

Additivity and double-counting. Particularly related to property value, there are quantitative aspects that have duplicative impacts; therefore, property value additive is represented at 50% to avoid double-counting.

Omissions, biases, and uncertainties. The appendices include detailed descriptions about the assumptions and their impact on the analysis, as well as a sensitivity analysis of changing key assumptions.

### Key Findings

Key findings are described below *(language from the Report)*.

*Recreation. Under the LID-based options, streamside recreational opportunities will be increased as a result of stream restoration and riparian buffer improvements. Recreation will also improve in non-creekside parts of the*

*City due to the general increase in vegetated and treed acreage in the City. These recreational benefits are not anticipated under the traditional infrastructure approaches.*

*Increased Community Aesthetics, Reflected in Higher Property Values.* *Trees and plants improve urban aesthetics and community livability and studies show that property values are higher when trees and other vegetation are present.*

*Heat Stress Reduction.* *Green infrastructure (trees, green roofs, and bio-retention areas) creates shade, reduces the amount of heat absorbing materials and emits water vapor — all of which cool hot air. This cooling effect will be sufficient to reduce heat stress-related fatalities in the City during extreme heat wave events.*

*Water Quality and Aquatic Ecosystem Improvements.* *The traditional infrastructure options (e.g. plant expansions, tunnels) are aimed at reducing the number of overflow episodes, but do little to directly improve the physical riparian area environment (i.e., riparian and aquatic ecosystems and habitat areas) or otherwise enhance living resources in many of the City's watershed environments. In contrast, the LID options, in conjunction with the related watershed restoration efforts, are expected to generate important improvements to these living natural resources.*

*Wetland Creation and Enhancement.* *The watershed restoration and related efforts, as associated with the LID options, are expected to create or enhance over 190 acres of wetlands in the relevant watersheds. These added and enhanced wetland acres will provide a range of services in the urban area watersheds.*

*Poverty Reduction from Local Green Jobs.* *Specialized labor is required for construction of conventional stormwater management solutions (e.g. boring, tunneling). Such skilled laborers might typically be already employed in the construction field. Green infrastructure creates the opportunity to hire local unskilled — and otherwise unemployed — laborers for landscaping and restoration activities. Thus the benefits of providing these local green jobs include the avoided costs of social services that the City would otherwise provide on behalf of the same people if they remained unemployed.*

*Energy Savings and Carbon Footprint Reduction.* *Green space helps lower ambient temperatures and, when incorporated on and around buildings, helps shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. In addition, diverting stormwater from wastewater collection, conveyance, and treatment systems reduces the amount of energy needed to pump and treat the water. Reduced energy demands in buildings, and increased carbon sequestration by added vegetation, result in a lower carbon footprint (reduced CO2 emissions).*

*Air Quality Improvement.* *Trees and vegetation also improve air quality by filtering some airborne pollutants (e.g. particulate matter and ozone). Likewise, reduced energy consumption results in decreased emissions (e.g. SO2 and NOx) from power generation facilities. These air quality improvements can reduce the incidence and severity of respiratory illness.*

*Construction- and Maintenance-Related Disruption.* *All of the CSO options will result in some level of disruption due to construction and/or program activities. Social costs of disruption can include traffic delays, limited access to places of business, increased noise and pollution, and other inconveniences. Under all of the CSO alternatives, construction activities will likely result in occasional delays and increased travel times for passenger and commercial vehicle travelers in Philadelphia; however the level of disruption will be considerably less for the LID options than many of the traditional infrastructure alternatives.*

*Table S.2* summarizes the benefits and costs of a 50% LID option versus a traditional approach using a tunnel to pipe away stormwater runoff.

*Table S.2. City-wide present value benefits of key CSO options: Cumulative through 2049 (2009 million USD); Source: A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds, 2009*

| **Benefit categories** | **50% LID option** | **30' Tunnel option**[a] |
|---|---|---|
| Increased recreational opportunities | $524.5 | |
| Improved aesthetics/property value (50%) | $574.7 | |
| Reduction in heat stress mortality | $1,057.6 | |
| Water quality/aquatic habitat enhancement | $336.4 | $189.0 |
| Wetland services | $1.6 | |
| Social costs avoided by green collar jobs | $124.9 | |
| Air quality improvements from trees | $131.0 | |
| Energy savings/usage | $33.7 | $(2.5) |
| Reduced (increased) damage from $SO_2$ and $NO_X$ emissions | $46.3 | $(45.2) |
| Reduced (increased) damage from $CO_2$ emissions | $21.2 | $(5.9) |
| Disruption costs from construction and maintenance | $(5.6) | $(13.4) |
| **Total** | **$2,846.4** | **$122.0** |

*a. 28' Tunnel option in Delaware River Watershed.*

## NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways

NYC Department of Environmental Protection, September 2010

Following adoption of *PlaNYC: A Comprehensive Sustainability Plan for New York City*, New York City developed the *NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterway*s (the Plan) to apply alternative "green" approaches to improving water quality, particularly by reducing flows into the City's combined sewer overflow (CSO). The Plan includes specific attainment goals, including:

- reducing CSO volume by an additional 3.8 billion gallons per year (bgy);
- capturing rainfall from 10% of impervious surfaces in CSO areas over 20 years; and
- providing substantial and quantifiable sustainability benefits, including cooling the city, reducing energy use, increasing property values, and cleaning the air.

The Plan includes a chart of private and public green infrastructure (GI) opportunities to meet their goals *(Table 1)*.

**Table 1: Green Infrastructure Opportunities, Strategies, and Technologies (citywide)**

| Land Use | % of Combined Sewer Watershed | Potential Strategies and Technologies |
|---|---|---|
| New development and redevelopment | 5.0% | Stormwater performance standard for new and expanded development |
| | | Rooftop detention; green roofs; subsurface detention and infiltration |
| Streets and sidewalks | 26.6% | Integrate stormwater management into capital program in partnership with DOT, DDC, and DPR |
| | | Enlist Business Improvement Districts and other community partners |
| | | Create performance standard for sidewalk reconstruction |
| | | Swales; street trees; Greenstreets; permeable pavement |
| Multi-family residential complexes | 3.4% | Integrate stormwater management into capital program in partnership with NYCHA and HPD |
| | | Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement |
| Parking lots | 0.5% | Sewer charge for stormwater |
| | | DCP zoning amendments |
| | | Continue demonstration projects in partnership with MTA and DOT |
| | | Swales; permeable pavement; engineered wetlands |
| Parks | 11.6% | Partner with DPR to integrate green infrastructure into capital program |
| | | Continue demonstration projects in partnership with DPR |
| | | Swales; permeable pavement; engineered wetlands |
| Schools | 1.9% | Integrate stormwater management into capital program in partnership with DOE |
| | | Rooftop detention; green roofs; subsurface detention and infiltration |
| Vacant lots | 1.9% | Grant programs |
| | | Potential sewer charge for stormwater |
| | | Rain gardens; green gardens |
| Other public properties | 1.1% | Integrate stormwater management into capital programs |
| | | Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels; permeable pavement |
| Other existing development | 48.0% | Green roof tax credit |
| | | Sewer charges for stormwater |
| | | Continue demonstration projects and data collection |
| | | Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement |

*Source: NYC Green Infrastructure Plan, 2010*

The Plan also includes analysis of predicted performance and cost effectiveness of green and gray strategies; and concluded that the GI strategy would reduce CSO volume by 2 bgy more than a gray strategy, and that the green strategy to capture 10% of impervious cover would cost approximately $1.5 billion in public funds compared to $3.9 billion for the equivalent amount of runoff capture with gray strategies. The Plan also

estimates that the green strategies would result in $139 to $418 million in additional benefits to residents and property owners through reduction in energy use, increased property value, and health benefits. The Plan further emphasizes that gray strategies serve only one function and are activated only in overflow situations; whereas, green infrastructure functions in every storm event, thus achieving more day-to-day value. Finally, the Plan discusses the construction and operating related emissions of many gray strategies, compared to more passive green solutions.

The Plan recommends increased stormwater runoff performance standards for new development, which can be met by rooftop or subsurface solutions. It also identifies opportunities to capture additional runoff from green roofs, blue roofs, and rain barrels, as well as retrofits with porous pavement in existing developments. The Plan also includes an evaluation of the potential cost of the proposed increased stormwater runoff performance standards on various development scenarios *(Table 12)*.

**Table 12: Costs for Proposed Stormwater Performance Standard***

| | Scenario 1 | | Scenario 2 | | Scenario 3 | | Scenario 4 | |
|---|---|---|---|---|---|---|---|---|
| Building Type | Low-Density Residential | | Office Building Medium-Density Residential | | Office Building Medium-Density Residential | | Big Box Retail | |
| Lot Size | 5000 | | 10,000 | | 20,000 | | 43,560 | |
| Zoning | R4 | | R6A/C4-2A | | R6A/C4-2A | | C8-1 | |
| FAR | 0.9 | | 3 | | 3 | | 1 | |
| Building Footprint, sq ft | 1,500 | | 6,000 | | 12,000 | | 21,780 | |
| Development Size, sq ft | 4,500 | | 30,000 | | 60,000 | | 43,560 | |
| Runoff Coefficient | 0.7 | 0.9 | 0.7 | 0.9 | 0.7 | 0.9 | 0.7 | 0.9 |
| Proposed Rule Compliance Cost | $20,000-26,000 | $23,000-27,000 | $35,000-37,000 | $43,000-47,000 | $59,000-80,000 | $71,000-97,000 | $98,000-127,000 | $106,000-167,000 |
| Increment of Proposed Rule | $3,000-9,000 | $4,000-9,000 | $15,000-17,000 | $15,000-19,000 | $32,000-53,000 | $32,000-58,000 | $44,000-73,000 | $31,000-93,000 |
| Proposed Rule ÷ Total Development Cost* (%) | 1.1-1.4% | 1.3-1.5% | 0.3% | 0.4% | 0.3% | 0.3-0.4% | 0.6-0.7% | 0.6-1.0% |

* Total development cost is based on $400 per square foot. Does not include design and construction management costs; costs based on tanks, gravel beds, and combination tank and blue roof systems.

*Source: NYC Green Infrastructure Plan, 2010*

The Plan recommends implementation of a sewer charge for stormwater to provide a dedicated funding source for green infrastructure projects. It suggests that NYC DEP launch a pilot program first, which would charge stand-alone parking lots for its stormwater runoff. The NYC DEP established a stormwater grant program for community groups to build and monitor GI projects.

The right-of-way was identified as another opportunity to capture stormwater runoff through infiltration swales and enhanced street tree pits. Moreover, the Plan calls for the continuation of the existing City program to convert paved traffic islands and medians into green spaces. The Plan also calls for bioswales, rain gardens, and other green infrastructure strategies to be incorporated into parks.

The Plan includes an estimate of opportunities, performance, and cost at the watershed level, and provides a strategy to monitor the rate and effectiveness of implementation over the coming years.