CITY OF ROCHESTER & MONROE COUNTY

GREEN INFRASTRUCTURE RETROFIT MANUAL

Project Funded By
The National Oceanic and
Atmospheric Administration and
New York Sea Grant

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City of Rochester, NY
Lovely A. Warren, Mayor
Rochester City Council

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ACKNOWLEDGMENTS

The creation of the City of Rochester and Monroe County Green Infrastructure Retrofit Manual was a collaborative process. Individuals from many organizations came together to identify and prioritize the information necessary to plan, design, implement and maintain GI retrofit projects within the City and County.

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Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of Stony Brook University or New York Sea Grant.

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The project collaboration included a full day Work Session on Green Infrastructure Design Standards for Retrofit and Redevelopment. The workshop was held on July 12, 2016 in Henrietta, NY. We would like to thank all of the organizations that participated.

Association of State Floodplain Managers
City of Rochester
City of Rochester Bureau of Architecture and Engineering
City of Rochester Bureau of Planning and Zoning
City of Rochester Division of Environmental Quality
Genesee Transportation Council
Monroe County
Monroe County Department of Planning and Development
Monroe County Department of Environmental Services
Monroe County Department of Transportation
Monroe County Soil & Water Conservation District
National Oceanic and Atmospheric Administration (NOAA)
NOAA Office for Coastal Management
NOAA National Weather Service
Northeast Regional Climate Center
NYS Department of Environmental Conservation
NYS Department of State
NY Sea Grant
PUSH Buffalo
State University of New York College of Environmental Science and Forestry
Rochester Institute of Technology
Town of Brighton
Town of Greece
Town of Henrietta
Town of Webster

Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.

Environmental Protection Agency

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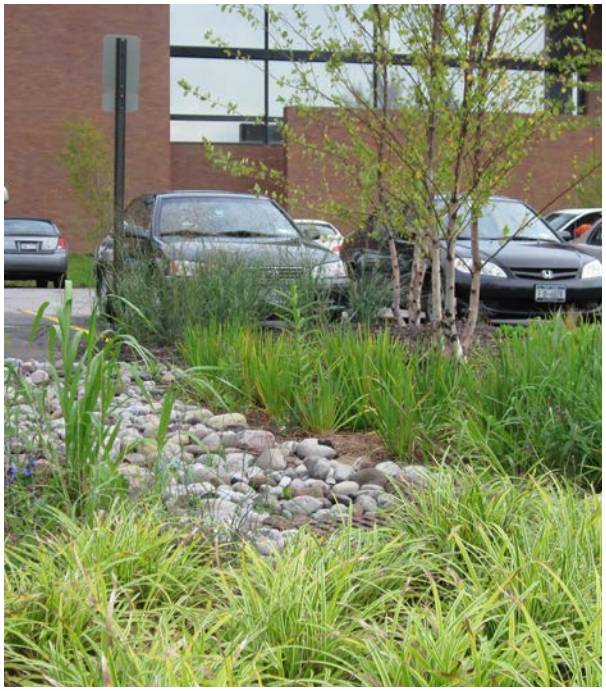
Rain Garden, Henrietta NY

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any Best Management Practice (BMP), or is inadequately treated by an existing BMP.

NYS Stormwater Management Design Manual



Bioretention, Henrietta NY

The Environmental Protection Agency Recognizes Green Infrastructure Benefits as Including: Water Quality & Quantity Benefits, Air Quality Benefits, Climate Resiliency, Habitat & Wildlife Benefits and Community Benefits.

https://www.epa.gov/green-infrastructure/benefits-green-infrastructure

Larry the H2O Hero

Monroe County Stormwater Coalition

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1.0 INTRODUCTION

1.1 PURPOSE OF THE MANUAL

Green infrastructure (GI) is a design strategy that applies a natural systems approach to managing stormwater and creating healthier, more sustainable environments.

With increasing frequency, the City of Rochester and Monroe County are utilizing GI technology for public stormwater management redevelopment projects across their respective jurisdictions. Similarly, there is an emerging interest from the private sector and surrounding communities in the use of GI for stormwater management and flood risk reduction. While GI is not a panacea for flood risk reduction, it can help tremendously with urban drainage related flooding and small stream flash flooding, particularly in urban and suburban areas.

At the regulatory level, the New York State Department of Environmental Conservation (NYSDEC) Stormwater Management Design Manual (NYS SMDM) requires elements of GI to be included in projects requiring coverage under the State Pollution Discharge Elimination System (SPDES) construction permit. As these trends gain momentum, it is important to pro-actively develop best management practices to guide the planning, design, implementation and maintenance of GI installations.

Monroe County, the City of Rochester and the Monroe County Stormwater Coalition have established a partnership to develop the GI Retrofit Manual. The Manual will be utilized to encourage and guide the proper use and installation of GI technologies. Because State stormwater design standards are primarily focused on new construction, this Manual focuses on opportunities for including GI practices in retrofits and redevelopment projects.

> ***"Single-purpose gray stormwater infrastructure is largely designed to move urban stormwater away from the built environment, while green infrastructure reduces and treats stormwater at its source while delivering other environmental, social, and economic benefits. Introducing green infrastructure to supplement the existing gray infrastructure can promote urban livability and add to communities' bottom line".***
>
> *Environmental Protection Agency*

Bioretention, Rochester NY

GI retrofit and redevelopment projects are part of a larger system of stormwater management. Where there are existing natural systems, such as forests, grasslands and wetlands, the cheapest and most effective solution is to preserve these systems through conservation practices.

While conservation and low impact development protect existing natural systems, reduce cost and improve effectiveness of stormwater management in undeveloped areas, GI retrofit projects address existing issues in developed areas. GI practices also create connections between undeveloped areas providing safer access to additional natural resources by birds, pollinators, and other wildlife.

The goal of the Manual is to improve the ability to successfully incorporate GI into stormwater management within the City of Rochester and Monroe County. The Manual is intended for a wide audience, including design professionals, private developers, and municipal staff.

With a focus on local conditions, the Manual presents current best practices for integrating GI into redevelopment projects. Implementation of the design recommendations, guidelines and maintenance protocols in the Manual will support the following positive outcomes:

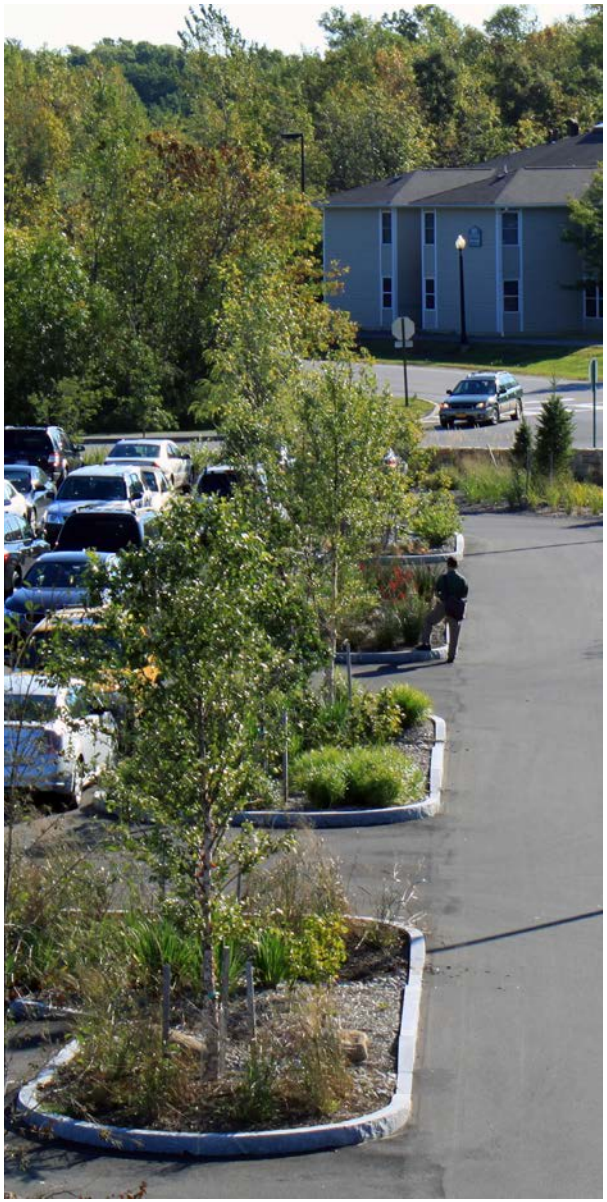
- Increased community resiliency;
- Reduction in nuisance flooding;
- Reduction of expensive end-of-pipe water treatment;
- Water quality improvements to impaired waterbodies;
- Improved quality of life;
- Elevated property values;
- Enhanced streetscape appearance and better community design; and
- Opportunities for interaction with natural systems in urban settings.

Rain Garden, Henrietta NY

The Manual is designed so it can be easily replicated by other communities, expanding the potential for positive environmental impacts and improved water quality. The format of the Manual allows for modifications in response to new field data and evolving climate conditions, insuring the long term performance of GI installations while concurrently improving both community resiliency and water quality.

The project sponsors include the New York Sea Grant (funding source), the National Oceanic and Atmospheric Administration (funding source), the Association of State Floodplain Managers, Inc. (funding source), Monroe County, the City of Rochester and the Monroe County Stormwater Coalition.

Review and input for the Manual was also provided by Don Lake Jr., P.E., CPESC, members of the Monroe County Stormwater Coalition and attendees at the Work Session on Green Infrastructure Design Standards for Retrofit and Redevelopment, July 12, 2016.



Bioretention, Henrietta NY

1.2 HOW TO USE THE MANUAL

This Manual is divided into Sections on Planning, Design, Construction, and Operation, Maintenance & Monitoring. These stages are equally important and interdependent.

- ***Planning*** is necessary to see projects within a larger context and locate projects where they will be most effective. Manual users can use the planning section of this document as a resource for site selection, mapping, identifying concerns, advocating for GI and planning for maintenance.

- ***Design*** is where the form of GI practices is created. This section includes eleven standard GI practices, identified by NYSDEC. Each practice includes recommendations specific to Monroe County, and a list of reference materials with further information on the practice. In addition, each section includes illustrations of the practice, a case study example of where this practice has been used locally, and lessons learned by design professionals during the construction and implementation of the case study.

  In addition, this section includes hybrid and emerging technologies related to GI. It also includes additional retrofit practices included in the NYS SMDM that are not considered to be GI practices.

- ***Construction*** is where GI is implemented. This section informs Manual users of considerations for the construction of GI projects in Monroe County. Several low impact development construction techniques are part of this section including stockpiling topsoil and soil restoration. In addition, this section includes a list of critical times for construction inspection.
- ***Operation and Maintenance Practices*** ensure that the investment put into GI continues to be beneficial for years to come. This section includes a visual maintenance guide for GI practices, recommendations for maintenance and inspection of GI practices, information on warranties and performance monitoring.

The Manual also includes appendices with additional information.

A NOTE ON MONITORING:

Monitoring provides evidence of the impact of GI that can be used to seek further funding, and to do cost benefit analyses for GI projects. Monitoring also helps to refine standards for GI; ensuring the next generation of GI practices will be even more effective. In addition, working with universities increases student awareness of GI which will influence future designers, builders, and policy makers.

Monitoring is not necessary for all projects, however, Monroe County boasts exceptional educational institutions which are leaders in technical innovation. Where appropriate, working with universities and citizen science organizations to arrange monitoring of GI projects can be very beneficial.

Vegetated Swale, Henrietta NY

1.3 RELATION OF THE MANUAL TO OTHER DOCUMENTS

There are many existing documents and references for GI practices. In New York State, the NYS SMDM has regulatory authority on the design requirements for stormwater practices. It is necessary to meet the minimum construction requirements specified by the NYS SMDM in order to have a project covered under the State Pollution Discharge Elimination System (SPDES) construction permit program.

The additional documents listed here provide guidelines for the planning, design, construction and maintenance of GI practices.

REFERENCE DOCUMENTS

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual
Department of Environmental Conservation.
<http://www.dec.ny.gov/chemical/29072.html>

All text in this font is quoted directly from the New York State Stormwater Management Design Manual.

EPA Green Infrastructure Municipal Handbook
Environmental Protection Agency.
<https://www.epa.gov/green-infrastructure/green-infrastructure-municipal-handbook>

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates
Environmental Protection Agency.
<https://vermont4evolution.files.wordpress.com/2011/12/ulm-elc_coldclimates.pdf>

UNH Stormwater Center
University of New Hampshire
<http://www.unh.edu/unhsc/>

PLANT SELECTION FACTORS

USDA Hardiness Zone Map
United States Department of Agriculture
<http://planthardiness.ars.usda.gov/PHZMWeb>
Also refer to **Appendix 8**.

REFERENCE DOCUMENTS (CONTINUED)

MAINTENANCE CONSIDERATIONS

Certifications for Green Infrastructure Professionals. Harvard Law School.
<http://environment.law.harvard.edu/wp-content/uploads/2015/08/certifications-green-infrastructure-professionals.pdf>

Maintenance Guidance for Stormwater Management Practices
Department of Environmental Conservation.
<http://www.dec.ny.gov/docs/water_pdf/smpmaintguiddraft.pdf>

Save the Rain Program Green Infrastructure Maintenance Manual
Save the Rain, Onondaga County, New York.
<http://savetherain.us/wp-content/uploads/2012/03/MaintenanceBinder_Rev-april2013.pdf>

The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure. Environmental Protection Agency
<https://www.epa.gov/sites/production/files/2015-04/documents/green_infrastructure-om_report.pdf>

Green infrastructure is still new technology, and many new guidelines are being created as new innovations impact best practices. For an up to date list of documents please see the EPA list of Design Manuals:

https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation

REFERENCE DOCUMENTS (CONTINUED)

This Manual is intended as an overview of information relevant to green infrastructure retrofit practices within Monroe County. It references other documents where they are applicable and suggests additional sources for more information within each section.

The NYS Stormwater Management Design Manual (NYS SMDM) is quoted throughout as the regulatory standard for green infrastructure practices in New York State.

In addition, this Manual draws from documents created by other communities which have established green infrastructure programs.

ADDITIONAL RETROFIT CONSIDERATIONS

Low Impact Development - Retrofit Guidance

Credit Valley Conservation. ***<http://www.creditvalleyca.ca/low-impact-development/low-impact-development-support/stormwater-management-lid-guidance-documents>***

Stormwater Retrofit Guidance Manual

Philadelphia Water

<http://www.phila.gov/water/PDF/SWRetroManual.pdf>

Stormwater Retrofit Project Design Manual.

East of Hudson Watershed Corporation.

<http://eohwc.org/wp-content/uploads/2013/05/EOHWC-SRPDesignManual-rev1.pdf>

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

<http://www.staunton.va.us/directory/departments-h-z/planning-inspections/images%20and%20files/Urban%20retro-fit%20storm%20water.pdf>

REFERENCE DOCUMENTS (CONTINUED)

ADDITIONAL PLANTING GUIDANCE RESOURCES

Also see **Appendix 8**.

Cornell Woody Plants Database. Cornell University
<http://woodyplants.cals.cornell.edu/home>

New York State Native Plant Database. Ladybird Johnson National Wildflower Center
<http://www.wildflower.org/collections/>

Plantfinder. Chicago Botanic Garden
<http://www.chicagobotanic.org/plantcollections#plantfinder>

Tree Planting, Syracuse NY

ADDITIONAL REFERENCE GUIDES FROM OTHER COMMUNITIES

Green Infrastructure Planning Design Guidelines. Genesee/Finger Lakes Regional Planning Council.
<http://www.gflrpc.org/uploads/5/0/4/0/50406319/giplanningdesignguidelines.pdf>

Chesapeake Stormwater Network. ***<http://chesapeakestormwater.net/category/publications>***

City of Philadelphia Green Streets Design Manual. Mayor's Office of Transportation and Utilities.
<http://www.phillywatersheds.org/img/GSDM/GSDM_FINAL_20140211.pdf>

City of Portland OR. Green Streets Program. ***<http://www.portlandoregon.gov/bes/34602>***

City of Newburgh Green Infrastructure Guide.
<http://www.law.pace.edu/sites/default/files/LULC/CAC%20Green%20Infrastructure%20Guide.pdf>

REFERENCE DOCUMENTS (CONTINUED)

Permeable Pavement and Tree Installation, Syracuse NY

Green Infrastructure Maintenance Manual Development Process Plan. City of Philadelphia. ***<http://phillywatersheds.org/ltcpu/Green%20Infrastructure%20Maintenance%20Manual%20Development%20Process%20Plan.pdf>***

NYC Sustainable Urban Site Design Manual. ***<http://www.nyc.gov/html/ddc/downloads/pdf/ddc_sd-sitedesignmanual.pdf>***

San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook. ***<http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/03/San-Mateo-Green-Streets.pdf>***

The Chicago Green Alley Handbook. Chicago DOT. ***<http://www.cityofchicago.org/content/dam/city/depts/cdot/Green_Alley_Handbook_2010.pdf>***

University of New Hampshire Stormwater Maintenance Documents. ***<http://www.unh.edu/unhsc>***

REFERENCE DOCUMENTS (CONTINUED)

ADDITIONAL REFERENCES CITED IN SECTION 1

Greening CSO Plans. Environmental Protection Agency
<https://www.epa.gov/sites/production/files/2015-10/documents/greening_cso_plans_0.pdf>

I-Tree. US Forest Service
<http://www.itreetools.org/>

Immerse Yourself in a Forest for Better Health. Department of Environmental Conservation
<http://www.dec.ny.gov/lands/90720.html>

The Economic Benefits of Green Infrastructure, Environmental Protection Agency
<https://www.epa.gov/green-infrastructure/economic-benefits-green-infrastructure-case-study-lancaster-pa>

"Redevelopment of previously developed sites is encouraged from a watershed protection standpoint because it often provides an opportunity to conserve natural resources in less impacted areas by targeting development to areas with existing services and infrastructure. At the same time, redevelopment provides an opportunity to correct existing problems and reduce pollutant discharges from older developed areas that were constructed without effective stormwater pollution controls".

NYS Stormwater Management Design Manual

2.0 - PLANNING

2.1 LAND USE CONSIDERATIONS & CONTEXT: URBAN, SUBURBAN, RURAL

GI is scalable, with a wide variety of practices available, along with a growing number of new practices and refinements. Every retrofit or redevelopment opportunity provides a chance to include GI practices.

Though every retrofit presents opportunities for GI, the types of opportunities will vary throughout Monroe County. Existing land use and density of development will help to determine which GI practices are best suited to each retrofit and redevelopment project. In addition, the best options for GI will vary based on physical constraints of the site, including area, soil conditions, and slope.

Urban areas often have limited green space and , therefore, relatively small GI investments such as tree planting can have a positive impact.

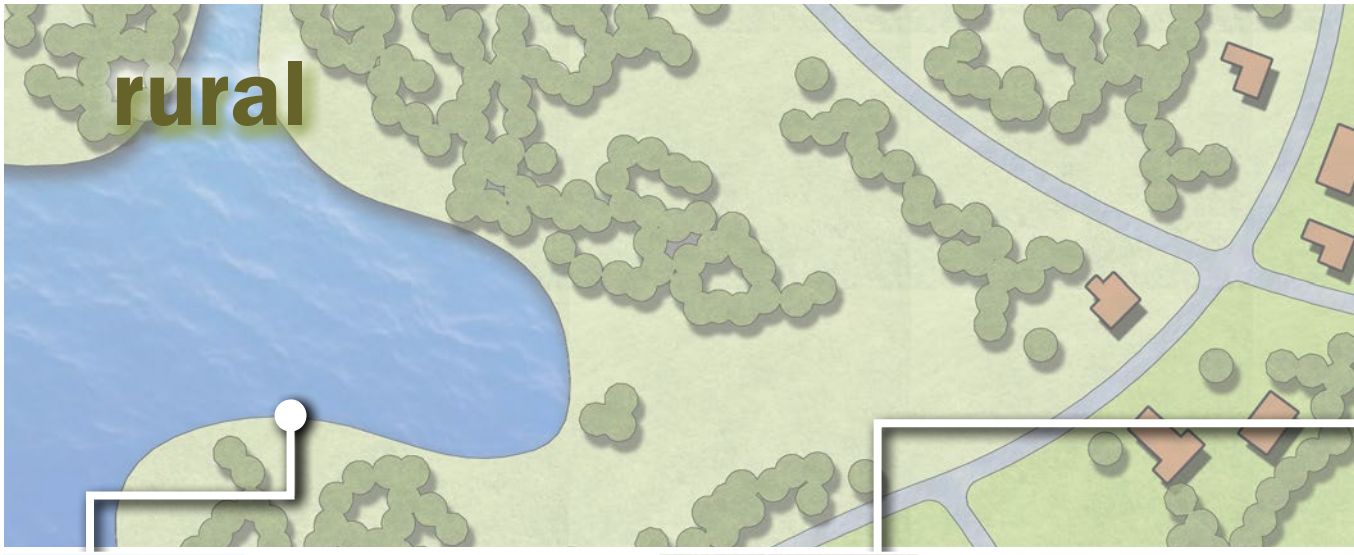
Land uses that require dedicated parking provide an opportunity to redefine the standard parking lot, by incorporating bioretention, tree planting, or permeable paving to create a more aesthetically appealing pedestrian friendly lot while addressing stormwater issues. These may include commercial districts, industrial districts, and high density residential areas.

Some project types such as green roofs or stormwater planters may make the most sense in dense urban areas with a large percentage of impermeable surface. These are more heavily constructed practices that are designed to make big impacts where space is limited.

Other projects such as stream buffer restoration may be more feasible in rural settings. Where natural systems are already in place it is cheapest and most effective to preserve these systems through conservation practices.

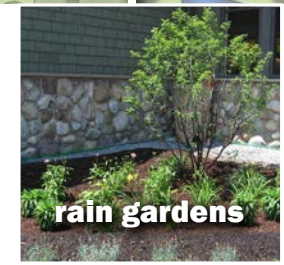
While individual green infrastructure projects can have far reaching impacts, GI is most effective when planning occurs at a watershed scale. The Genesee/Finger Lakes Green Infrastructure Planning Design Guidelines are a regional tool for organizing GI planning efforts.

<http://www.gflrpc.org/uploads/5/0/4/0/50406319/giplanningdesignguidelines.pdf>



When managed properly, existing or newly created wetlands filter stormwater and allow beneficial wildlife and plants to flourish.

Natural stream channel restoration and daylighting of previously piped streams improve system stormwater management and ecology.



Manage and treat runoff using a conditioned soil bed and planting materials within a shallow depression.

In addition to providing recreation and fresh air opportunities, parks and green spaces are ideal for integrating GI.

Small landscaped treatment devices can be designed as infiltration or filtering practices in almost any setting.

2.2 WATER QUALITY & QUANTITY

Monroe County receives approximately 34" of rain and melted snow per year, including 99" of snow (US Climate Data).

99" of snow is equivalent to approximately 10" of rain, though this varies depending on the water content of the snow (USGS).

On average, a third of the precipitation in Monroe County accumulates over the winter. This can create significant flooding and strain green infrastructure practices when snow melts.

http://water.usgs.gov/edu/earthrain.html
http://www.usclimatedata.com/climate/rochester/new-york/united-states/usny1232

Utilization of GI stormwater practices can have a significant positive impact upon water quantity and quality. Large impervious areas, often associated with urban environments, can create an increased frequency of localized flooding. Impervious areas create additional demand on sewer systems which can lead to an increased frequency of combined sewer overflows. Utilization of GI can lessen the demand on traditional piped storm sewers though infiltration and reuse of stormwater at the source. Any decreases in stormwater volume through infiltration or reuse will lessen the frequency of localized flooding and instances of combined sewer overflows.

According to the Environmental Protection Agency (EPA), "heavy downpours have increased in frequency and intensity worldwide in the last 50 years. They are expected to become more frequent and intense as global temperatures continue to rise. As a result, the risk of flooding is likely to increase dramatically in the United States." Annual damages from flooding are predicted to increase by $750 million by 2100. The EPA recommends GI practices in order to "reduce the volume of stormwater that flows into streams and rivers, protect the natural function of floodplains, and reduce the damage to infrastructure and property" (Manage Flood Risk).

The Environmental Protection Agency completed a study of the flood risk reduction potential of GI over a twenty year period (2020-2040). The study incorporated twenty Hydrologic Unit Code 8 (HUC8) sample watersheds which were selected to be representative of climate and development conditions throughout the United States. The study predicted savings of between $0.4 billion and $1 billion dollars between 2020 and 2040, with a prediction that benefits would continue to increase after 2040 (Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management).

The National Oceanic and Atmospheric Administration (NOAA) published "A Guide for Assessing Green Infrastructure Costs and Benefits for Flood Reduction. This guide identifies a six step planning process for assessing GI for flood risk management:

- Defining the flooding problem, including area, type of flooding, and assessing risk,
- Assessing flooding scenarios without GI, including modeling current and future flooding and quantifying damages,
- Identifying how a reduction target can be met with green infrastructure, including selecting GI options, identifying potential sites for GI, and determining the storage capacity of GI projects,
- Assessing flooding scenarios with green infrastructure, including modeling current and future flooding including GI and quantifying damages,
- Estimating benefits and costs, and
- Identifying and communicating a GI strategy.

This guide is a useful resource for planners and municipalities to inform planning-scale assessments of GI practices (A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction).

Green infrastructure practices can have a significant impact on flood mitigation. For example, a GI practice that captures rainfall from an acre of impervious surface would reduce runoff by:
1" storm event - 27,154 gallons
2" storm event - 54,309 gallons
3" storm event - 81,463 gallons

In addition to the impact of impervious surfaces on water quality, they are also a source of pollutants including:

- Contaminants from atmospheric deposition;
- Oil, grease and heavy metals from vehicles;
- Bacteria from pet waste;
- Litter; and
- Sediment from unstabilized soil areas.

Rain and snowmelt events wash these pollutants from our urban and impervious areas and convey them to receiving waterbodies. These pollutants can have significant detrimental impacts upon our waterbodies. The NYSDEC maintains an inventory of impaired waters known as the 303 (d) list. Discharges

to these waters from construction activities can require additional permit and design considerations.

As outlined in the current NYS SPDES Construction Permit (GP-0-15-002), the following Monroe County waterbodies are impaired from pollutants associated with stormwater discharges:

- Lake Ontario Shoreline, Western
- Mill Creek/Blue Pond Outlet and tributaries
- Rochester Embayment - East
- Rochester Embayment - West
- Unnamed tributary to Honeoye Creek
- Genesee River, Lower, Main Stem
- Genesee River, Middle, Main Stem
- Black Creek, Lower, and minor tributaries
- Buck Pond
- Long Pond
- Cranberry Pond
- Mill Creek and tributaries
- Shipbuilders Creek and tributaries
- Minor tributaries to Irondequoit Bay

Why is the Beach Closed?

Monroe County conducts extensive water quality monitoring of the Ontario Beach swimming area.

The following five parameters typically determine if the beach will be safe for swimming:

1. Bacteria: Studies have shown a definite relationship between the amount of indicator bacteria in coastal and Great Lakes waters and the incidence of swimming-associated illnesses. Indicator bacteria include total and fecal coliform, enterococcus and E. coli. They are called indicator bacteria because although they may not be directly harmful to humans, they are relatively easy to test for and are typically found in the presence of harmful viruses and bacteria.

2. Local rainfall: Local rainfall causes closures because it washes contaminants to the Beach or into local streams which impact the Beach.

3. Water Clarity: Particulate matter results in poor water clarity and provides substrate for bacterial growth. It also reduces ultraviolet ray penetration that would kill bacteria.

4. Organic Debris: Organic debris in the form of decaying plant matter causes closures because it is a substrate for bacteria and sustains the bacteria by shielding ultraviolet light. Excessive algae also impair physical water quality.

5. Genesee River Flow: The Genesee River is laden with particulate matter and stormwater runoff. The proximity of the River to the Beach and the volume of the River, relates closely to water quality at the Beach during certain conditions. Typically, the easterly lake current pushes the river water east, away from the beach.

https://www2.monroecounty.gov/eh-poolsbeaches.php

- Thomas Creek/White Brook and tributaries

The NYS SMDM indicates the following common pollutants found in urban stormwater runoff:

- ***Sediment (Suspended Solids)*** Sources include erosion from construction sites and stream-banks. The NYS SMDM Manual indicates that stream-bank erosion may account for up to 70% of the sediment load in urban watersheds.
- ***Nutrients*** Main sources include phosphorus and nitrogen from fertilizers, atmospheric deposition, animal waste and stream bank erosion. Nutrient loading to waterbodies can lead to eutrophication that causes excessive growth of algae and other aquatic plants.
- ***Organic Carbon*** Main sources include sediment from stream-bank and construction site erosion, and as a byproduct of algal growth. Organic matter can deplete oxygen in waterbodies that can impact aquatic life.
- ***Bacteria*** Main sources include pet waste, combined sewer overflows, wastewater and illicit connections to the storm sewer system. Bacteria are a prime contributor to beach closures.
- ***Hydrocarbons*** The main source is from automobiles and other gasoline powered equipment.

- ***Trace Metals*** Elements including cadmium, copper, lead and zinc.
- ***Pesticides*** Insecticides and herbicides are routinely detected in urban stormwater at concentrations that approach or exceed toxicity thresholds for aquatic life.
- ***Chlorides*** The primary source is deicing in winter months which can impact aquatic species and lead to incomplete mixing of waterbodies.
- ***Thermal Impacts*** Runoff from impervious surfaces can increase the temperature in receiving waters that can impact aquatic species, especially species of trout that require cool temperatures.
- ***Trash and Debris*** The primary source is litter that can introduce toxins and organic matter, along with diminished aesthetic beauty of our water resources.
- ***Snowmelt Concentrations*** Snow can store nearly all of the contaminants outlined above and can be a significant source of pollutant loading during snow melt events.

Ontario Beach Park

Retrofits to our existing stormwater collection and conveyance system, particularly those that involve the implementation of GI, can reduce the overall volume of stormwater leading to less frequent instances of localized flooding and can improve the quality of the stormwater that discharges to our surface water resources. See **Appendix 1, Pollutant Removal Efficiencies of Green Infrastructure Practices**.

2.3 MAXIMIZING COMMUNITY BENEFITS OF GI SYSTEMS

While GI is often valued exclusively for its water management benefits, well designed GI practices can provide many more services to communities. The benefits provided by plant life and working ecological systems are often called ecosystem services. The following is a list of some of the ecosystem services provided by GI.

> ***"Ecosystem goods and services are the many life-sustaining benefits we receive from nature—clean air and water, fertile soil for crop production, pollination, and flood control. These ecosystem services are important to environmental and human health and well-being, yet they are limited and often taken for granted".***
>
> *Environmental Protection Agency*

1. ***Biodiversity*** - By incorporating a wide variety of species, GI practices can have a positive impact on local biodiversity. Biodiverse ecosystems are more resilient - more able to adapt to change (Town and Country Planning Association).
2. ***Urban Ecology*** - We tend to build cities in ecological hot-spots where multiple types of habitats meet, such as at the edge of rivers, lakes, or forests. These areas are critical for many other species. By improving the ecological functioning of cities we can have a huge positive impact on the many other species that rely on the places we call home (Cities and Biodiversity).
3. ***Pollinator Benefits*** - Pollinator species are crucial for fertilizing our crops and sustaining the plant populations around us. GI projects with a wide variety of plants can help sustain our pollinators by supplying consistent sources of food throughout the year. (Center for Neighborhood Technology).
4. ***Air Quality*** - Plants purify the air, removing pollutants such as carbon monoxide, ozone, dust and soot (US Forest Service).

5. ***Carbon Sequestration*** - Trees sequester carbon which can reduce greenhouse gas emissions (US Forest Service).
6. ***Heat Island Mitigation*** - Plants provide cooling benefits including transpiration and shade (Environmental Protection Agency).
7. ***Pedestrian Environments*** - GI practices can be integrated into traffic calming to help create pedestrian scale environments which encourage people to spend time outside (Environmental Protection Agency).
8. ***Health & Wellness*** - High quality pedestrian environments which encourage people to spend time outside also encourage physical activity. This can have many positive impacts including reducing stress levels and decreasing incidence of diabetes and heart disease (Environmental Protection Agency).
9. ***Property Value***s - Incorporating GI into developments can increase vegetation and tree cover which has a positive impact on property values (Environmental Protection Agency).

Green infrastructure (GI) is an approach to design that uses natural processes such as soils and vegetation to manage stormwater and create healthier environments. GI is an environmentally friendly alternative for treatment of water quality and quantity. GI begins with a strong understanding of how planning, design, and the creation of multi-functional green spaces and environmental features work together to achieve sustainability.

A USDA Forest Service program called ITree is useful for estimating the ecosystem services provided by trees and calculating the value of these benefits. According to the US Forest Service, based on land use data, Monroe County is receiving these benefits from our tree canopy.

The ITree service does not calculate the benefits we receive from plants other than trees, and it does not yet include benefits such as pollinator habitat or human health benefits. As a result, this $31 Million is just a fraction of the ecosystem services Monroe County receives each year.

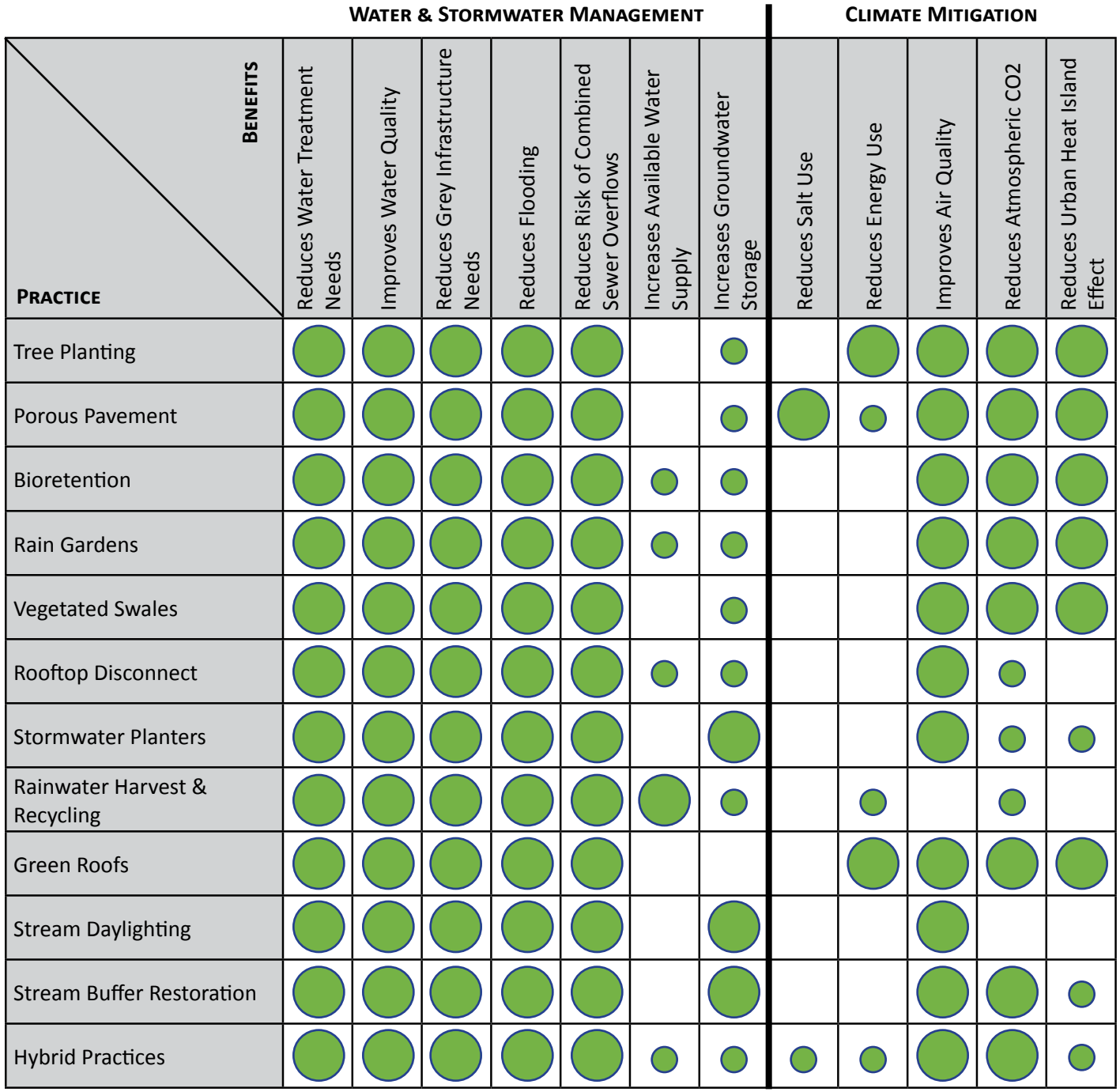
Monroe County is 1,367 square miles and has approximately 17% tree cover.

For more information on the ITree ecosystem benefit calculations see the following website.

US Forest Service

https://landscape.itreetools.org/maps/benefits/

BENEFIT FROM MONROE COUNTY TREE CANOPY	***AMOUNT***	***SAVINGS***
Total Carbon Storage	12.3 Million Tons	$1.7 Billion
Carbon Sequestered Each Year	190 Thousand Tons	$26.4 Million
Carbon Monoxide CO2 Removed Each Year	284 Thousand Pounds	$3.4 Thousand
Nitrogen Dioxide NO2 Removed Each Year	1.2 Million Pounds	$15.6 Thousand
Ozone O2 Removed Each Year	10.4 Million Pounds	$905 Thousand
Particulate Matter PM2.5 & PM10 Removed Each Year (such as dust and smog)	3 Million Pounds	$1.9 Million
Sulfur Dioxide SO2 Removed Each Year	801 Thousand Pounds	$2.7 Thousand
Transpiration Per Year	30.7 Thousand Tons	
Rainfall Interception Per Year	23.7 Thousand Tons	
Avoided Runoff Per Year	256 Tons	$2.1 Million
TOTAL YEARLY SAVINGS		***$31 MILLION EACH YEAR***



MATRIX OF GREEN INFRASTRUCTURE RETROFIT PRACTICES & BENEFITS

SIGNIFICANT

POTENTIAL

Table modified from "The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental, and Social Benefits," Center for Neighborhood Technology and American Rivers, 2010 and "Green Infrastructure Practices and Benefits", National Oceanic and Atmospheric Administration, 2014"

	Community Benefits								Ecological Benefits		
Practice / Benefits	Improves Aesthetics	Increases Recreational Opportunities	Reduces Noise Pollution	Improves Community Cohesion	Increases Property Values	Human Health Benefits	Traffic Calming and Bike/ Pedestrian Safety	Cultivates Public Educational Opportunities	Provides Pollinator Habitat	Increases Biodiversity	Increases Habitat Connectivity
Tree Planting	●	●	●	●	●	●	●	●	●	●	●
Porous Pavement			●					●			
Bioretention	●	●	◉	◉	◉	●	●	●	●	●	●
Rain Gardens	●	●	◉	◉	◉	●	●	●	●	●	●
Vegetated Swales	◉	◉	◉	◉	◉	●	●	●	●	●	●
Rooftop Disconnect	◉		◉	◉	◉	●	◉	●	◉		
Stormwater Planters	●	●	◉	◉	◉	●	●	●	●	●	●
Rainwater Harvest & Recycling		◉	◉	◉	◉		◉	●			
Green Roofs	●	●	◉	◉	◉	●		●	●	●	●
Stream Daylighting	●	●	◉	◉	◉	●	◉	●	●	●	●
Stream Buffer Restoration	●	●	●	◉	●	●	◉	●	●	●	●
Hybrid Practices	◉	◉	◉	◉	◉	●	◉	●	◉	◉	◉

MATRIX OF GREEN INFRASTRUCTURE RETROFIT PRACTICES & BENEFITS

● **SIGNIFICANT**

◉ **POTENTIAL**

Table modified from "The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental, and Social Benefits," Center for Neighborhood Technology and American Rivers, 2010 and "Green Infrastructure Practices and Benefits", National Oceanic and Atmospheric Administration, 2014"

2.4 INCORPORATING MAINTENANCE INTO PLANNING

Many GI practices can provide valuable services with relatively little maintenance. The key to low maintenance GI is considering maintenance during the planning and design phases. This can increase the effectiveness of GI maintenance, cut down on costs, and increase the lifespan of GI practices. GI systems can include pervious pavements, bioretention areas, and infrastructure for water harvesting/recycling. All project elements, living and constructed, will require adequate maintenance over the long term.

PLANNING

Communities that are planning for GI implementation are encouraged to identify the potential GI strategies, the associated maintenance requirements, confirm the responsibilities for maintenance, and take action to fund a maintenance plan, so that long term GI benefits are realized.

- ***Incorporating a maintenance plan into design*** - This plan should detail which staff will be responsible for maintenance, what maintenance tasks need to be performed, and at what frequency. In addition, the cost for replacement of components of a GI practice should be included in the plan. A maintenance plan cuts down on surprises and reduces inefficiencies in project maintenance. See **Appendix 6, Sample Maintenance Agreement**.

- ***Planning for a second planting*** - As part of the communities long term GI maintenance plan, long term care for the plantings needs to be considered. Three to five years after construction, when plants are established, there is an opportunity to do a second infill planting. This can fill in any open spaces, decreasing the need for weeding and improving the appearance of GI. A second planting will generally be much smaller in scale than the initial planting, and plants can be selected based on which plants are already thriving.

"Without a plan to ensure necessary maintenance is conducted with sufficient frequency, the project may fail to achieve desired objectives. Failure to properly maintain green infrastructure can lead to excessive sedimentation, clogged inlets and outlets, loss of vegetative plantings, soil compaction, and failure to properly infiltrate stormwater. This can lead to additional overflows, and have a harmful effect on water quality, thus negating the original intent of the project. Because projects such as rain gardens, pervious pavements, and green roofs constitute a relatively new approach to stormwater management... projects in disrepair can erode confidence in the viability of green infrastructure".

Environmental Protection Agency
The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure

The American Recovery and Reinvestment Act Green Project Reserve Operation and Maintenance Study found the top three keys to successful green infrastructure practices were:

Have a dedicated revenue source to pay for operation and maintenance activities.

Provide training and/or educational materials on how to maintain green infrastructure.

Have an operation and maintenance plan, manual, or similar guide in place.

Environmental Protection Agency
The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure

- ***Staying organized - keeping track of GI projects - GIS services*** - Keeping track of all the GI practices in a community and managing them together can reduce redundancies, making project maintenance more efficient. Using Geographic Information Systems (GIS) software is one way to track the location, health, and maintenance of GI practices. Additionally, a GIS or map record of GI projects can serve as a planning document and a demonstration of a community's commitment to GI and meeting stewardship goals. Monroe County has already developed a record of existing and potential GI locations. Continuing or expanding these efforts could have many benefits for the future of GI in Monroe County.

- ***Training maintenance staff*** - Planning for GI should also consider the training of staff to maintain the GI practices. Without this, GI would be maintained by municipal staff with little or no training in GI care. Providing information about the purpose of GI, how it functions, and how to care for it, can increase staff buy-in and improve the effectiveness of maintenance (The Need for National Green Infrastructure Training and Certification).

- ***Training construction staff*** - Many of the techniques for installing GI are different than typical construction best practices for non GI projects. Training construction staff about GI best practices can seriously improve the quality of GI which can make projects easier to care for and maintain over time. There are certification programs for GI practices - hiring GI certified staff or certifying municipal staff is one way to increase the impact of GI and potentially decrease long term costs. The National Ready Mixed Concrete Association is one of the many groups that provide GI certification programs. See 'The Need for National Green Infrastructure Training and Certification' and 'Certifications for Green Infrastructure Professionals' for more information.

- ***Referencing Local and Regional Planning Documents*** - Individual GI practices are a part of a larger, systems based approach to stormwater management. Referencing municipal plans, county wide initiatives, and regional goals helps to coordinate efforts and build momentum for GI projects.

2.5 PROGRAMS AND POLICIES FOR SUPPORTING GREEN INFRASTRUCTURE

Stormwater Management Fees and Drainage Districts:

Funding maintenance is necessary to ensure effective and attractive GI practices. Because of limitations to conventional funding sources, such as the NYS Tax Cap, municipalities may benefit from considering alternative means of funding GI projects.

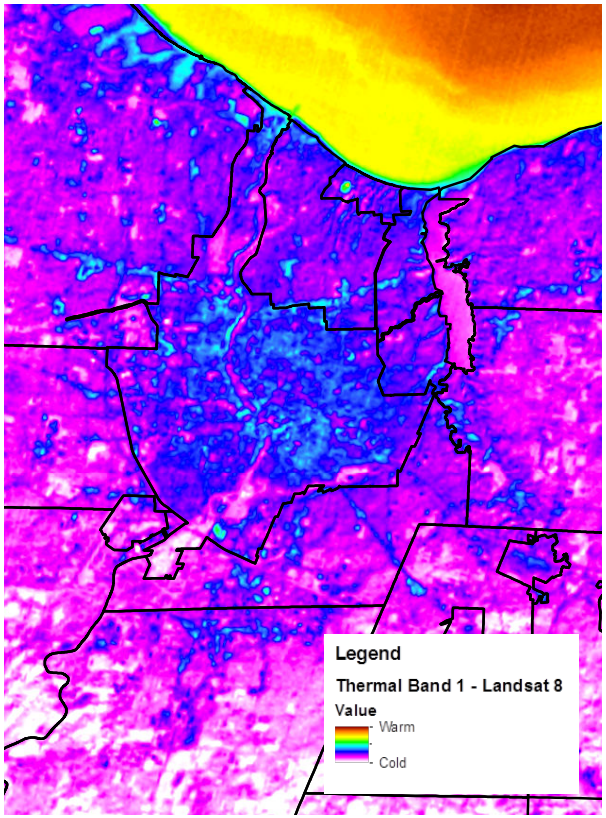
Drainage districts allow municipalities to obtain funds through additional fee(s) paid by property owners located within the district boundaries. With these funds, the drainage district initiates specific programs to maintain the improvements proposed for the area.

Any stormwater fees applied to property owners must be an equitable, fair, low-cost, and effective. In addition, any revenue should be specifically designated for GI improvements, maintenance repairs, and enhancements that would benefit all properties within the district.

There are several funding strategies that can be used for the basis of district formation. Three options include a dedicated property tax, an increase in sanitary / sewer fees annually, or an impervious area-based stormwater management fee.

An impervious area based fee provides an additional incentive for property owners to implement green strategies or reduce the amount of stormwater runoff through more sustainable site measures. Impervious surfaces would include hard pavement surfaces, rooftops, driveways, sidewalks, concrete porches, patios, etc. that keep rainfall and runoff from infiltrating on-site.

Bioretention, Henrietta NY



Heat Map, Monroe County NY January 2015

> ***"A geographic information system (GIS) lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends."***
>
> *http://www.esri.com/what-is-gis*

2.6 UTILIZING GIS FOR PLANNING

"A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships" (National Geographic).

GIS FOR DECISION MAKING

GIS is expanding and redefining planning, allowing planners to process and visualize data in novel ways. In Monroe County, GIS is being used to understand where GI practices will have the most benefit. These decisions are based on overlaying and assessing many sources of information, including the following:

National Hydrography Dataset (NHD). The National Hydrography Dataset is a nationwide map of all watersheds using a 12 digit Hydrography Unit Code (HUC). HUC 12 brings the watershed mapping to the sub watershed level. This data allows a user to plan projects in areas where they will have the greatest impact. The NHD is also a good source for information on all waterbodies in the country, providing information on surface water types and conductivity ***<http://nhd.usgs.gov/>.***

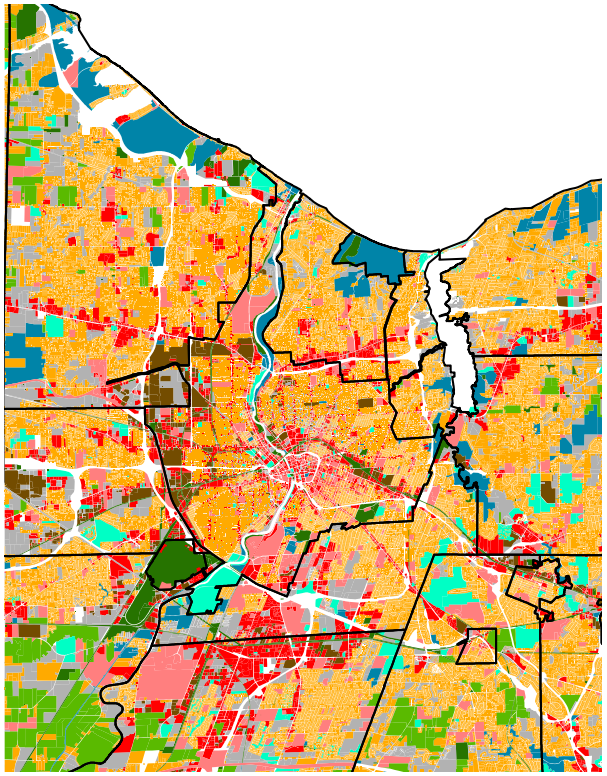
New York State Priority Waterbodies List (PWL). In New York State, the NHD is combined with water quality data to create the Priority Waterbodies List. The data is updated every 5 years and provides the impairment status for every water body in the State ***<http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1117>.***

303(d) Status. The New York State Priority Waterbodies List includes the 303(d) status of a water body. 303(d) status is an EPA and NYSDEC status for impaired waterbodies. These waterbodies may have a Total Maximum Daily Load (TMDL) for specific pollutants, or other restrictions to restore and protect impaired waters. ***<http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1117>.***

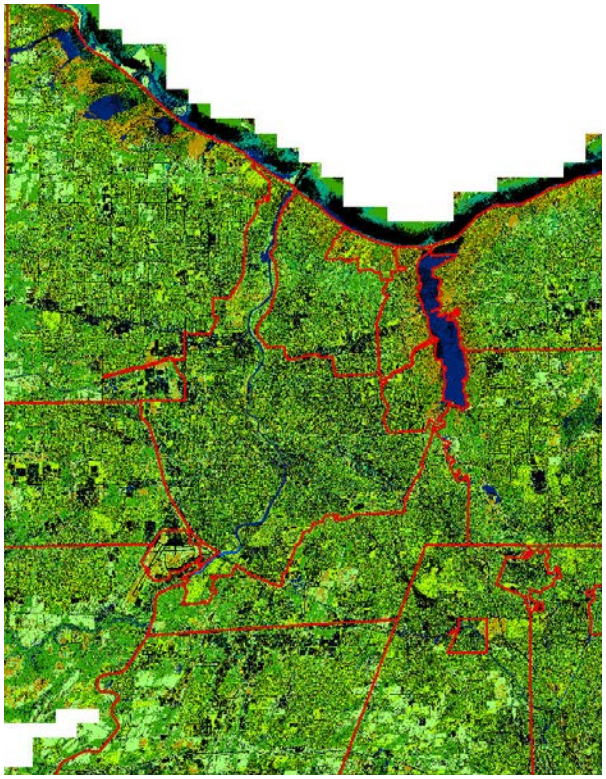
Soil Survey Geographic Database (SSURGO). SSURGO is a useful resource for all soil data. It is a very robust database which combines the traditional soil survey books with spatial data. The data is in an access database where users can identify the soil types in a specific location and generate reports for any soil type. These reports include engineering characteristics useful for the design of GI ***<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627>.***

Combined Sewer Overflow (CSO) Data. Combined sewers receive stormwater, domestic sewage and industrial wastewater in a single system. These systems can be overwhelmed during storm events, so that untreated water is released into waterbodies. GI is being successfully used by many municipalities to reduce the amount of stormwater entering sewers during rain events and minimize overflows. The only combined sewers in Monroe County are in the City of Rochester. Other municipalities within Monroe County maintain their sewers separately. Areas which are linked to a combined sewer system may be priorities for GI projects ***<http://www.dec.ny.gov/chemical/48595.html>.***

Parcel data. Within parcel data there are many fields that can be helpful for GI projects. One such field is the water status of the parcel. This field records which parcels are served by a municipal water service area and which are served by individual wells. Another relevant field is sewer service, which records which parcels are served by municipal sewers and which are on septic systems. Land use can be determined using the parcel land classification code. Having previous versions of the parcel data can help planners understand how land use has changed over time.



Land Use by Parcel, Monroe County NY



Land Cover Map, Monroe County NY

Monroe County has two land cover models for estimating impervious surface coverage. Both were created using aerial imagery and supervised classification techniques. These tools provide useful information about land use patterns.

NYSDEC maintains a database of all water withdrawals in New York having the capacity to withdraw 100,000 or more gallons a day ***<http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1265>***. There is also a database of water wells, with limited attributes ***<http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1203>.*** This data can help planners identify where potential contaminants could have a significant impact on groundwater supply wells.

GIS FOR ORGANIZATION AND RECORD KEEPING

Monroe County has mapped various existing GI projects. This data is managed by the Department of Environmental Services. The data includes basic information on each project, including who created the project and what funding was used. For more information on using GIS for record keeping see **Section 2.4**.

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Vegetated Swale, Irondequoit NY

Permeable Concrete, Brighton NY

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3.0 - DESIGN

Section 3.1 provides information on eleven GI practices listed in the NYS SMDM, including:

- A Description of the Practice;
- Recommended Applications;
- Standard Design Requirements;
- Retrofit Considerations;
- Local Climate and Environmental Conditions; and
- A Case Study.

Each practice also includes pictures of how the practice has been incorporated into retrofit projects regionally, and where appropriate, construction drawings and sample planting lists to give users a better understanding of the practice. These drawings and planting lists are intended as samples only. All GI projects should be tailored to site conditions.

Because the NYS SMDM sets regulatory standards for GI in New York State this document is quoted frequently in the design section of this Manual.

In addition to these GI practices, Chapter 3 includes six structural stormwater management practices described in the NYS SMDM. These are also alternatives to conventional gray infrastructure systems. They are included in **Section 3.2.**

Section 3.3 includes a discussion of the NYS SMDM guidelines for retrofit projects.

Permeable Concrete, Brighton NY

Because retrofit projects sometimes have a variety of constraints, such as limited space available for GI, they may be particularly good candidates for testing out hybrid practices that incorporate both green and gray infrastructure on-site. These hybrid practices can maximize the effectiveness of limited GI. There are also a number of other emerging technologies for GI that may be well suited to the individual conditions at specific sites. These are included in **Section 3.4.**

Which GI practices are applicable to a particular site is determined by site conditions. These include:

- How much space is available;
- Site programming and aesthetics;
- Additional underground considerations including utilities, existing foundations, and hotspots or pollutant levels;
- Amount of impervious surface;
- Proximity to sensitive ecological communities;
- Site opportunities such as on-site resources and potential collaborations or educational opportunities;
- Soil conditions including drainage characteristics, compaction level, and existing soil biology; and
- Cost.

Rain Garden Planting, Monroe County NY

Despite the fact that Low-Impact Development (LID) technologies have been promoted and studied since the early 1990s, for many stormwater managers and developers, LID is still a new and emerging technology. As with most new technologies, installation and other costs of LID are highest during the early phases of development and adoption. Over time, as practitioners learn more about the technology, as the number of suppliers of inputs expands, and as regulations adapt to the new technology, costs will likely decline.

The Economics of Low-Impact Development: A Literature Review

http://www.econw.com/media/ap_files/ECONorthwest-Economics-of-LID-Literature-Review_2007.pdf

Funds for GI practices are often limited. Considering project economy during the design phase allows designers to maximize project value. A careful consideration of cost saving factors can lead to a better overall project. Some of these factors are listed below.

Using Locally Sourced or Reclaimed Materials

- Locally sourced materials not only cut down on transportation costs, they also make projects more site specific and give them a regional character.
- Reusing materials that have been discarded from nearby sites is both ecologically responsible and economically intelligent. These materials may be provided at low or no cost.

Amending Topsoils on Site

- Amending topsoil on site instead of bringing in new topsoil cuts down on transportation costs. See **Appendix 3** for topsoil amendment recommendations.

Selecting Small Caliper or Bare Root Trees

- Smaller trees recover more quickly from transplanting. Though these trees may not be as impressive at installation, they establish more quickly and will likely outgrow larger trees.
- Bare root trees are significantly less expensive, and easier to plant correctly. In addition, bare root trees actually retain more of their roots during transplanting, which makes establishment easier.
- Some species of trees transplant easily bare root, while others do not. Please see the Cornell University Woody Plants Database to identify trees that are compatible with bare root planting. Trees should be 1.5-2” caliper.

- Bare root trees need to be transplanted quickly and to have their roots protected from drying out. An innovative slurry called hydrogel can be used to prevent root dessication.
- For more information on bare root planting see 'The Bare Root Method' Urban Horticulture Institute. Cornell University ***<http://www.hort.cornell.edu/uhi/outreach/pdfs/bareroot.pdf>***.

Selecting Smaller Plants

- Using rooted plugs instead of containerized plants. These are inexpensive, and especially effective for establishing grasses.
- Using seed mixes for large scale projects, or a mix of rooted plugs and seed mixes. Though seed mixes have low germination rates, they are cheap, light weight, and easy to store. They can also be used to supplement other plantings (University of Washington).

See **Appendix 9** for Funding Opportunities.

Most sites will be compatible with some incorporation of GI practices. There may be some extreme conditions, such as brownfield sites with highly contaminated soil or groundwater, in which infiltration is not desirable. Even these sites can potentially benefit from stormwater planters or other practices that address stormwater through evapotranspiration without allowing water to infiltrate.

Before choosing a GI practice, it is important to quantify rainfall and existing drainage patterns, and to test existing soil conditions. Instructions for these essential preliminary steps is available in the NYS SMDM, and in **Appendix 2, Infiltration Testing Protocol**, and **Appendix 3, Soil Testing and Amendment**.

Rain Garden Planting, Monroe County NY

3.1.1 - TREE PLANTING

DESCRIPTION

Plant or conserve trees to reduce stormwater runoff, increase nutrient uptake, and provide bank stabilization. Trees can be used for applications such as landscaping, stormwater management practice areas, conservation areas and erosion and sediment control.

RECOMMENDED APPLICATIONS

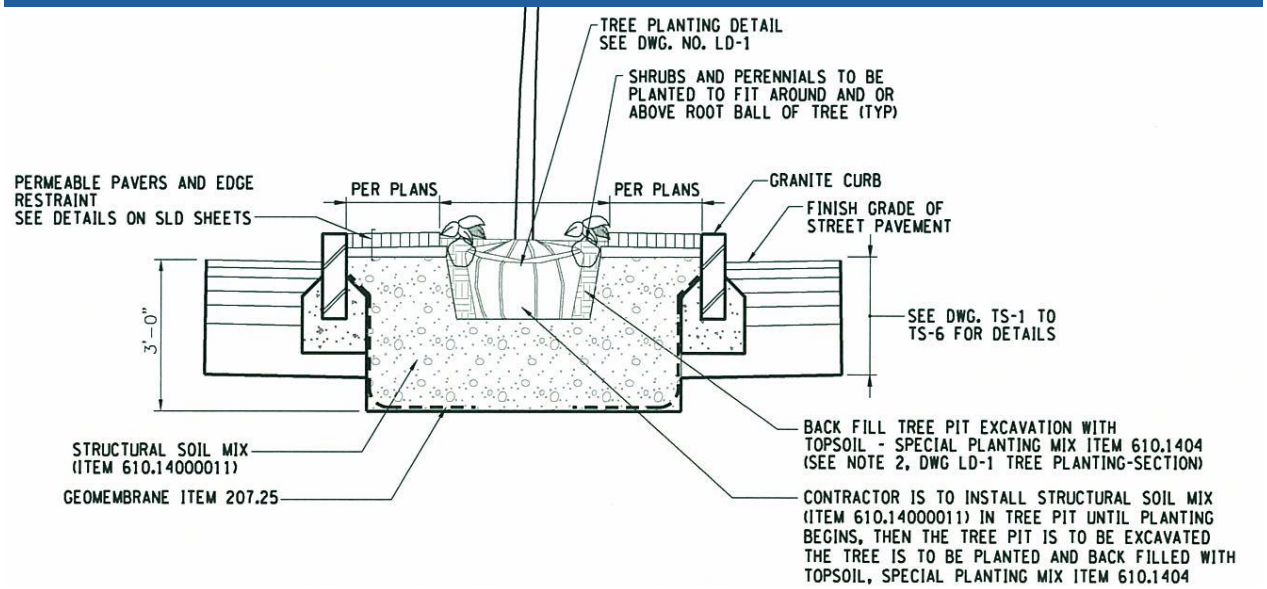
- *Conservation of existing trees is recommended where stands of existing trees are non-invasive, healthy and likely to continue to flourish in the proposed site conditions.*
- *Planting of new trees is recommended for areas that will remain or become pervious in the proposed condition and are large enough to sustain multiple trees.*
- *Planting of trees in tree pits is recommended in street rights-of-way or other small-scale pervious areas in highly impervious redevelopment sites that can support limited tree development.*

Street Trees, Rochester NY

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

Street Trees, Rochester NY

STANDARD DESIGN REQUIREMENTS



Raised Median Tree Planting Detail

- *While tree planting can enhance stormwater management goals, it is not a "stand alone" treatment or management practice.*
- *The area considered for runoff reduction is limited to the pervious area in which trees are planted. In an urban setting where trees are contained by impervious structures such as curbs and sidewalks, the area is calculated as follows: For up to a 16-foot diameter canopy of a mature tree, the area considered for reduction shall be ½ the area of the tree canopy. For larger trees, the area credited is 100 SF per tree. This can be considered the drainage area into the below grade tree pit.*
- *An alternative sizing for runoff reduction in urban setting may follow the bioretention or stormwater planters (with infiltration) design and sizing. In this case sizing of the practice relies on storage capacity of the soil voids in the cavity created for the root ball of the tree and the ponding area. The infiltration rate of the in-situ soil must be a minimum of 2 inches per hour.*

Street Trees, Brockport NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- The tree species must be appropriate for site conditions. See Cornell Urban Street Tree List and **Appendix 8, Recommended Plants for GI Practices.**
- *New trees planted must be planted within 10 feet of ground-level, directly connected impervious areas.*
- *Recommend minimum 1,000 cubic feet soil media available per tree.*
- *For new trees, the average slope for the contributing area, including the area under the canopy must not be greater than 5%. The maximum slope can be increased where existing trees are being preserved. Slope specifications for filter strips and buffers should be followed as guidelines. The maximum reduction permitted, for both new and existing trees, is 25% of directly connected ground level impervious area.*
- *Trees should be selected for diversity and to promote native, non-invasive species.*
- *During the first three years, mulching, watering and protection of young trees may be necessary and should be included in the inspection list.*
- *Inspections should be performed every three months and within one week of ice storms, within one week of high wind events that reach speeds of 20 mph until trees have reached maturity, and according to established tree inspection requirements as identified within this document.*
- *As a minimum, the following items should be included in the regular inspection list:*
  - *Assess tree health.*
  - *Determine survival rate; replace any dead trees.*
  - *1) Inspect tree for evidence of insect and disease damage; treat as necessary.*
  - *2) Inspect tree for damages or dead limbs; prune as necessary.*

RETROFIT CONSIDERATIONS

- *Soil quality and volume may be poor. Soil amendments and decompaction may be required prior to planting. Heavy equipment traffic should be limited in the vicinity of both existing and proposed tree planting areas.*
- Test the existing soil in the proposed tree planting area. Soils compaction is especially likely to be a problem on retrofit sites. Determine whether soil immediately around trees should be amended or replaced.
- Avoid underground utilities wherever possible.
- Maximize the soil volume around trees to increase tree resilience and water storage capacity while decreasing maintenance costs.
- Tree planting can be combined with additional practices such as permeable paving combined with structural soil for increased water storage and soil capacity in tight spaces.

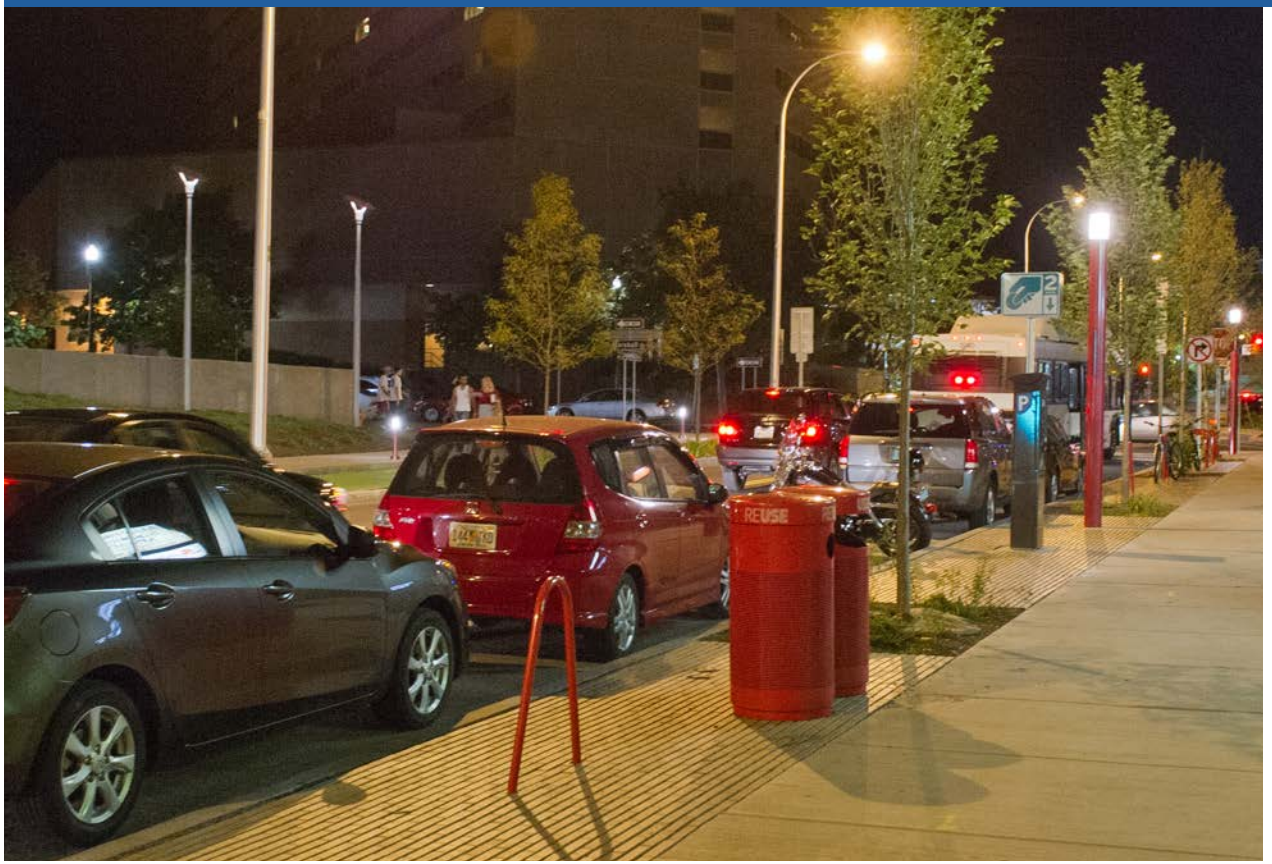
LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- In addition to selecting trees that are cold and salt tolerant, some species are prone to damage from snow load. These species should be avoided. See **Appendix 8, Recommended Plants for GI Practices**, for more information.

Street Trees, Rochester NY

The Rochester Forestry Division maintains approximately 70,000 public trees. This includes tree pest management, pruning, planting, removal, inspection and responding to public requests.

TREE PLANTING CASE STUDY



Tree Planting, Syracuse NY

PROJECT DATA

Connective Corridor
East Genesee St. from Forman Ave. to
State St. and West Fayette St. from
Townsend St. to West St. and University Avenue
Syracuse NY 13210

Catchment area: 949,000 sq. ft.
Run-off Reduction: 16,717,000 gallons/year
Total Trees Planted: 159
Project Cost: $155,000

PROJECT DESCRIPTION

The City of Syracuse, in partnership with Syracuse University, has created a true bicycle, pedestrian and transit corridor to connect major portions of downtown Syracuse and University Hill while revitalizing the areas in between. This project has a significant GI focus including tree planting, permeable paving, stormwater planters and rain gardens.

SAMPLE TREE PLANTING LIST (CONNECTIVE CORRIDOR PHASES 2-3)

A variety of species should be selected to strengthen landscape resilience through increasing biodiversity. One potential outcome of this would be a reduction in pests and diseases.

ABBREVIATIONS:
QUANT - Quantity
B&B - Balled and burlapped
CONT - Container
O.C. - On Center

DECIDUOUS TREES - MAJOR

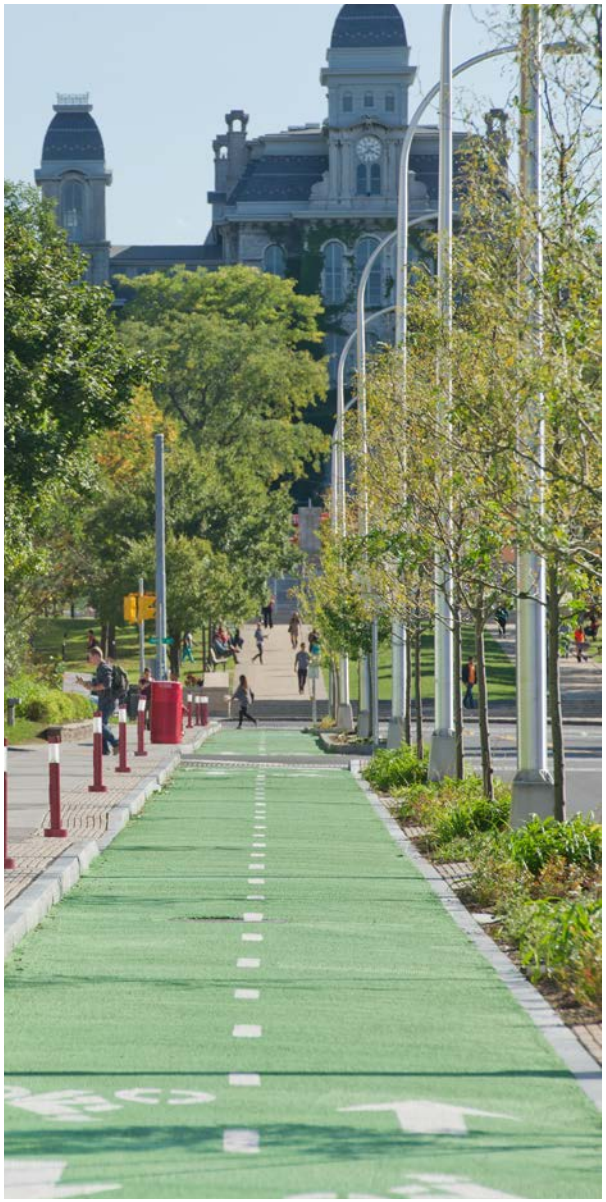
QUANT	KEY	LATIN NAME	COMMON NAME	CALIPER	ROOTS	HEIGHT	REMARKS
10	ACF	Acer freemanii 'Autumn Blaze'	Autumn Blaze Maple	2"	B&B	10'	
6	CEO	Celtis occidentalis 'Magnifica'	Hackberry 'Magnifica'	2"	B&B	10'	
11	GDE	Gymnocladus dioicus 'Espresso'	Espresso Kentucky Coffeetree	2"	B&B	10'	Seedless
3	NYS	Nyssa sylvatica	Blackgum	2"	B&B	9'	
6	PLO	Platanus occidentalis	American Sycamore	2"	B&B	10'	
2	QUB	Quercus bicolor	Swamp White Oak	2"	B&B	10'	
9	QMU	Quercus muehlenbergii	Chinkapin Oak	2"	B&B	10'	

DECIDUOUS TREES - MINOR

QUANT	KEY	LATIN NAME	COMMON NAME	CALIPER	ROOTS	HEIGHT	REMARKS
2	CAC	Carpinus caroliniana	Musclewood	1 1/2"	B&B	8'	
3	CEC	Cercis canadensis	Eastern Redbud	1 1/2"	B&B	8'	

DECIDUOUS SHRUBS - 18" HEIGHT / SPREAD

QUANT	KEY	LATIN NAME	COMMON NAME	CALIPER	ROOTS	HEIGHT	REMARKS
10	ILV	Ilex verticillata 'Red Sprite'	Red Sprite Winterberry		#3 CONT	18"	3'O.C.
2	ILJ	Ilex verticillata 'Jim Dandy'	Jim Dandy Winterberry		#3 CONT	18"	3'O.C.
67	ITV	Itea virginica 'Sprich'	Little Henry Virginia Sweetspire		#3 CONT	18"	3'O.C.
33	RHA	Rhus aromatica 'low grow'	Low Grow Fragrant Sumac		#3 CONT	18"	3'O.C.



Tree Planting, Syracuse NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

Recommended Urban Trees

Cornell University

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

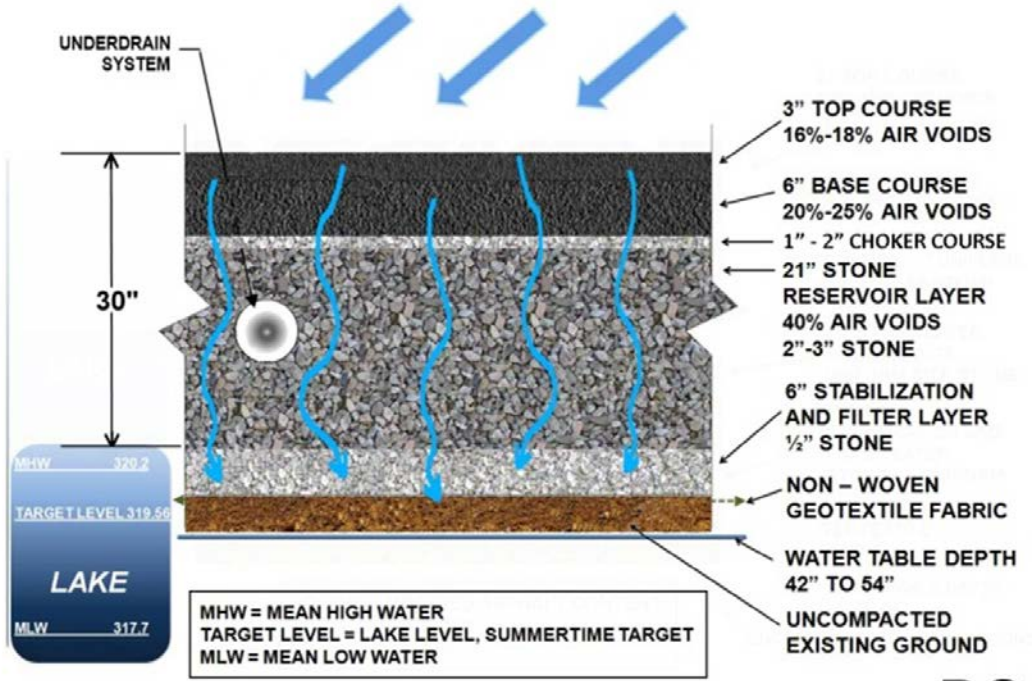
3.1.2 - POROUS PAVEMENT

DESCRIPTION

Pervious types of pavements that provide an alternative to conventional paved surfaces, designed to infiltrate rainfall through the surface, thereby reducing stormwater runoff from a site and providing some pollutant uptake in the underlying soils.

Permeable paving has three main design components: surface, storage, and outflow. The surface types of paving can be broken into two basic design variations: porous pavement and permeable pavers.

Porous pavement is a permeable asphalt or concrete surface that allows stormwater to quickly infiltrate to an underlying reservoir. Porous pavement looks similar to conventional pavement, but is formulated with larger aggregate and less fine particles, which leaves void spaces for infiltration. Permeable pavers include reinforced turf, interlocking concrete modules, and brick pavers.



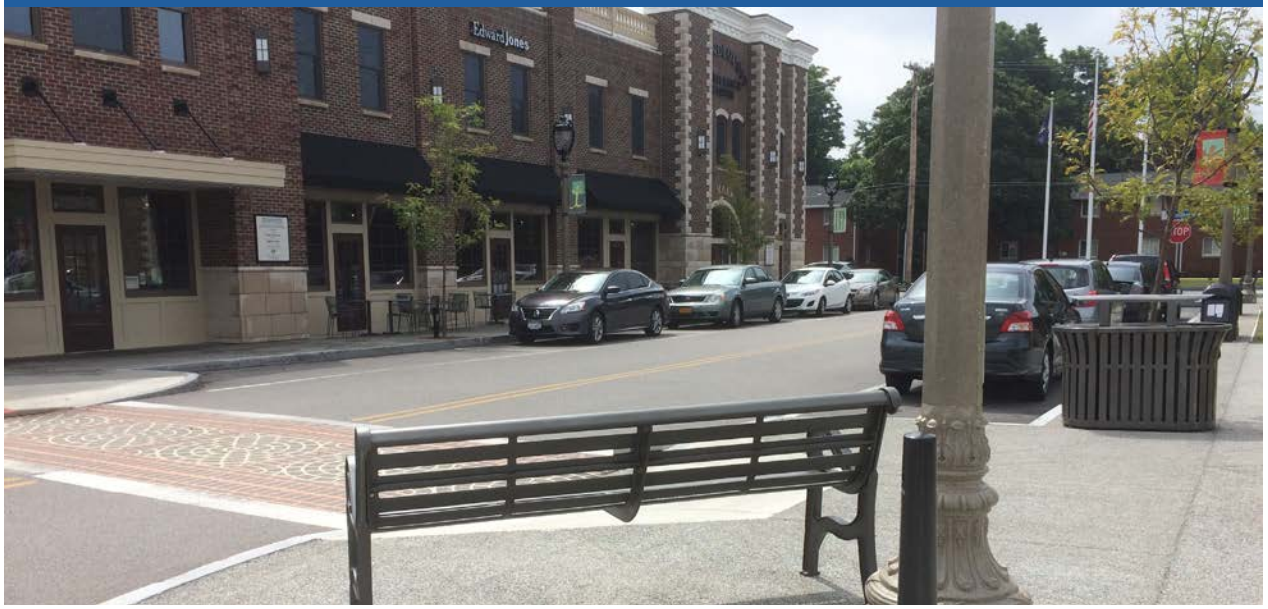
Porous concrete section, Lake George NY

In addition to these materials, new porous surfaces are being utilized including Flexi-pave, a material made from recycled tires which is being used in several projects throughout Monroe County, including Rochester tree pits and the bus stations of the Monroe Avenue Green Infrastructure Grant Program project. As GI becomes more common, a new generation of porous surfaces will provide additional opportunities for GI.

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

Porous concrete, Brighton NY

STANDARD DESIGN REQUIREMENTS



Porous concrete, Irondequoit New York

RECOMMENDED APPLICATIONS

- *Permeable paving provides the structural support of conventional pavement, while reducing stormwater runoff by draining directly into the underlying base and soils. It can be used to treat low traffic roads (i.e., a few houses or a small cul-de-sac), single-family residential driveways, overflow parking areas, sidewalks, plazas, tennis or basketball courts, and courtyard areas. Good opportunities can be found in larger parking lots, spillover parking areas, schools, municipal facilities, and urban hardscapes. Permeable paving is intended to capture, infiltrate and/or manage small frequent rainfall events (i.e. channel protection). The practice can be applied in both redevelopment and new development scenarios. The area proposed for a porous pavement system must be fully evaluated, addressing all the factors including but not limited to infiltration, geotechnical, hotspot conditions, topography, and setbacks.*

Permeable Pavers, Syracuse NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Runoff shall flow through and exit permeable pavements in a safe and non-erosive manner.*
- Permeable pavements should be designed to maximize infiltration. Placing an underdrain at the bottom of the practice can reduce total infiltration and decrease the effectiveness of this practice. However, in some conditions, particularly when soils are not well draining, an underdrain can be used in the middle of the stone course to allow infiltration but prevent back-flow in large storm events.
- *The contributing drainage area should be limited to small adjacent impervious areas (i.e. non-traffic sidewalk and rooftops).*
- *When designing porous pavement systems for treatment of adjacent areas, the subbase storage must be designed with extra capacity by adding to the filter course. Adjacent impervious surfaces can also be graded so that the runoff from the impervious area sheet flows over the porous pavement or may be connected to the underlying storage bed. Pretreatment of impervious areas connected directly to the bed is required to prevent particulate materials clogging the subbase of the porous pavement system.*
- *As a back-up measure in case of clogging, permeable paving practices can be designed with a perimeter trench to provide some overflow treatment should the surface clog. Pavement systems should include an alternate mode, such as a trench for runoff to enter the subbase reservoir. In curbless designs, this could consist of a 2-foot wide stone edge drain. Raised inlets may be required in curbed applications (from MD Manual).*
- *Runoff should sheetflow across permeable pavement. Slopes across the surface and bottom of the stone reservoir should not exceed 5 percent to prevent ponding of water on the surface and within the subbase. Ideally it should be completely flat so that the infiltrated runoff will be able to infiltrate through the entire surface. A terraced system may be used on slopes. Perforated pipes may be used to distribute runoff through the reservoir evenly.*

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *All permeable pavement shall be capable of bearing the anticipated vehicle and traffic loads. Pavement systems conforming to the specifications found in this Manual should be structurally stable for typical (e.g. light duty) applications. (MD Design Manual)*

- *Subbase aggregates shall be clean and free of fines. All aggregates within infiltration storage beds shall meet the following criteria:*

  Maximum wash loss of 0.5%
  Minimum Durability Index of 35
  Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions
  Wash loss - percentage of material by weight lost during washing according to AASHTO ND T 11 test procedure.
  Durability index - a measurement of a material's tendency to degrade, producing fine clay like particles.
  Abrasion - scraping or wearing away

- *Depth of the stone base can be adjusted depending on the management objectives, total drainage area, traffic load, and in-situ soil characteristics.*

- *Installation procedures are vital to the success of pervious pavement projects, particularly pervious asphalt and concrete pavement mixes. The subgrade cannot be overly compacted with the inclusion of fine particulates or the void ratio critical to providing storage for large storm events will be lost. Weather conditions at the time of installation can affect the final product. Extremely high or low temperatures should be avoided during construction of pervious asphalt and concrete pavements.*

- *Areas for porous pavement systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.*

Porous asphalt, Lake George NY

"A 75% average reduction in annual salt use was observed for porous asphalt based on low amounts of snow and ice cover and high skid resistance. 'Black-ice' did not form on pervious concrete, eliminating the need for salt during thawing-refreezing conditions."

University of New Hampshire Stormwater Center

Porous asphalt cross section, Lake George NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Pervious pavement and other infiltration practices should be installed toward the end of the construction period. Upstream construction shall be completed and stabilized before connection to porous pavement system. A dense and vigorous vegetative cover shall be established over any contributing pervious drainage areas before runoff can be accepted into the facility.*
- *Stringent sediment controls are required during the construction stage, and all adjacent land areas should be stabilized prior to installing permeable paving practices. Where feasible, a grass filter strip is recommended to pre-treat adjacent land areas that drain to porous pavement areas.*
- *Subsurface area should be excavated to proposed depth. Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.*
- *The bottom of the infiltration bed shall be at a level grade.*
- *Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.*
- *Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated.*
- *As the site is fully stabilized, excess geotextile can be cut back to the edge of the bed.*

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Install aggregate course in lifts of 6-8 inches. Keep equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings. The engineer is responsible for developing detailed specifications and Quality Assurance/Quality Control measures for individual design projects.*

- *The type of permeable paving and the location of the site dictate the required maintenance level and failure rate. Concrete grid pavers and plastic modular blocks require less maintenance because they are not clogged by sediment as easily as porous asphalt and concrete. Areas that receive high volumes of sediment will require frequent maintenance activities, and areas that experience high volumes of vehicular traffic will clog more readily due to soil compaction.*

- *Permeable paver (e.g., interlocking block, concrete grid pavers, etc.) areas that do not have a storage reservoir are most effective when designed to accommodate small rainfall depths (e.g., less than 1 inch) that fall directly on the paver areas. They are less effective and more prone to clogging when used to also receive runoff from other areas. Unless underlying soils are extremely permeable, larger storms will either sheet flow off the site, or if not graded properly, will pond on the site. To address these concerns, the following restrictions are placed on the use of permeable pavers installed without an underlying storage reservoir:*
  - *The area of application is not subject to traffic (allowed for patios, walkways, small driveways)*
  - *The area of application must overlay highly permeable soils (A or B).*
  - *No additional area drains onto the paver area.*

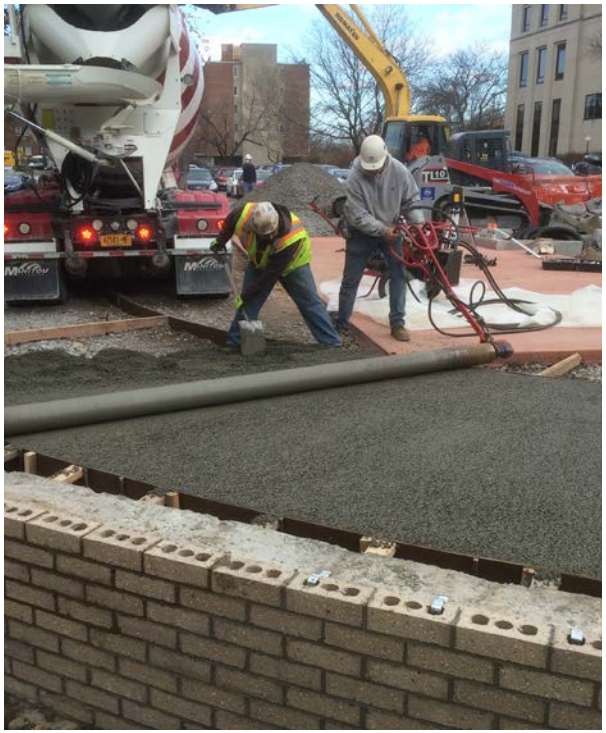
- *Permeable pavements are highly susceptible to clogging and subject to owner neglect. Individual owners need to be educated to ensure that proper maintenance and winter operation activities will allow the system to function properly.*

Flexi-pave path, Rochester NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *When maintenance of permeable paving areas is required, the cause of the maintenance should be understood prior to commencing repairs so unnecessary difficulties and recurring costs can be avoided (Ferguson, 2005). Generally, routine vacuum sweeping and high-pressure washing (with proper disposal of removed material and wash-water) can maintain infiltration rates when clogged or crusted material is removed. Signs can also be posted visibly within a permeable paving area to prevent such activities as resurfacing, the use of abrasives, and to restrict truck parking.*

- Permeable paving should be installed by contractors with permeable paving experience. Permeable paving certification programs are available for contractors. Seeking contractors who are certified, or certifying municipal employees, is recommended. See **Section 4.6** for Porous Pavement Construction considerations.



Pervious Concrete Installation, Rochester NY

RETROFIT CONSIDERATIONS

- *It is important to confirm that local soils are permeable and can support adequate infiltration, since past grading, filling, disturbance, and compaction can greatly alter the original infiltration qualities. Sandy and silty soils are critical to successful application of permeable pavements.*

- *The underlying parent soils should have a minimum infiltration rate of 0.5 inches per hour. To maintain effective pollutant removal in the underlying soils, organic matter content in the subsoils is important.*

- Determine the location of underground utility lines and avoid conflicts.

- Provide the appropriate load bearing capacity for volume and traffic loads.

- For project sites with high traffic loads, permeable paving can be used selectively for sidewalks, parking spaces, or other lower use areas.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- *Care should be taken when applying salt to permeable pavement, since chlorides can easily migrate into the groundwater.*
- Studies at the University of New Hampshire Stormwater Center have shown that it is possible to reduce salt use by as much as 75% on porous pavements, while maintaining the same level of skid resistance. This is because the rougher surface of porous pavements is more skid resistant than conventional asphalt paving, and because during freeze thaw conditions melt water quickly passes through the pavement so that 'black ice' does not form. Salt applied to porous pavement also stays in place longer, cutting down on the need for reapplications (UNH Stormwater Center).
- Sand applications on porous pavement should be limited because they will increase the need for vacuuming (UNH Stormwater Center)
- Plowing after every storm, with a slightly raised blade, is recommended, see **Appendix 5, Operation and Maintenance Inspection Forms**, and **Chapter 5, Operations, Maintenance and Monitoring**, for more information (UNH Stormwater Center).
- *Systems shall be designed to ensure that the water surface elevations for the 10-year, 24-hour design storm do not rise into the pavement to prevent freeze/thaw damage. Depending on the intended use of the system, a perforated pipe system (set at an elevation above the design storm that is intended for infiltration) can convey water from the storage bed to an outflow structure. The storage bed and outflow structure can be designed to control the Channel Protection and/or Flood Control requirement. Inlets can be used to provide positive overflow for impervious areas that are connected to the underlying storage bed, if additional rate control is not necessary.*

Flexi-pave Tree Surrounds, Rochester NY

POROUS PAVEMENT CASE STUDY

Porous concrete, Brighton NY

PROJECT DESCRIPTION

The Monroe Avenue Green Street project was constructed along a one mile segment of NYS Route 31 in the Town of Brighton, NY. Goals for the project went above and beyond stormwater management, incorporating urban ecology, transportation improvements and active design into a plan for a truly "complete" urban corridor environment. The Monroe Avenue Green Street Project incorporated porous asphalt in parking areas, porous concrete for sidewalks, and Flexi-Pave, a proprietary porous pavement made from recycled rubber and local stone, at the bus shelters.

The project incorporated a heavy duty porous asphalt that was developed by NYSDOT and engineers from Barton & Loguidice. The specification calls for a polymer modified binder with higher asphalt content than older porous mixes to better resist against shear failure and pavement raveling. The specification also calls for mineral fibers which minimizes drain down and improves adherence of the liquid asphalt to the stone aggregate.

PROJECT DATA

Monroe Avenue Green Street
Monroe Avenue, Brighton New York

Total Project Cost: 1.5 Million

LESSONS LEARNED

For this project, the Town of Brighton received grant money to get their staff certified in porous pavement installation - which led to an exceptionally smooth and professional installation. See **Section 2.4** for GI staff education recommendations.

During maintenance operations commissioned by a private owner, a small section of pervious asphalt was inadvertently sealed. This type of setback will become less common as GI practices become more well known. Increasing local knowledge about GI practices through outreach and education is recommended. For information on avoiding GI setbacks see **Section 5.8**.

Porous concrete, Irondequoit New York

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

UNH Stormwater Center

University of New Hampshire

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.3 - BIORETENTION

DESCRIPTION

Shallow stormwater basin or landscaped area which utilizes engineered soils and vegetation to capture and treat runoff.

- Pore space in soil and gravel layers retains water and sandy soil provides filtration to remove pollutants from water.
- Water is able to infiltrate through the practice and return to groundwater.
- Plants release water into the air through evapotranspiration.
- Common pollutants are sequestered or neutralized by plant communities through phytoremediation.

RECOMMENDED APPLICATIONS

- Bioretention is typically used for larger areas than rain gardens (>1,000 sq ft) because it includes an overflow.
- An underdrain can be utilized to tie in to an existing drainage system to address overflow.
- Most easily installed in relatively flat areas.

Bioretention Practice, Rochester NY

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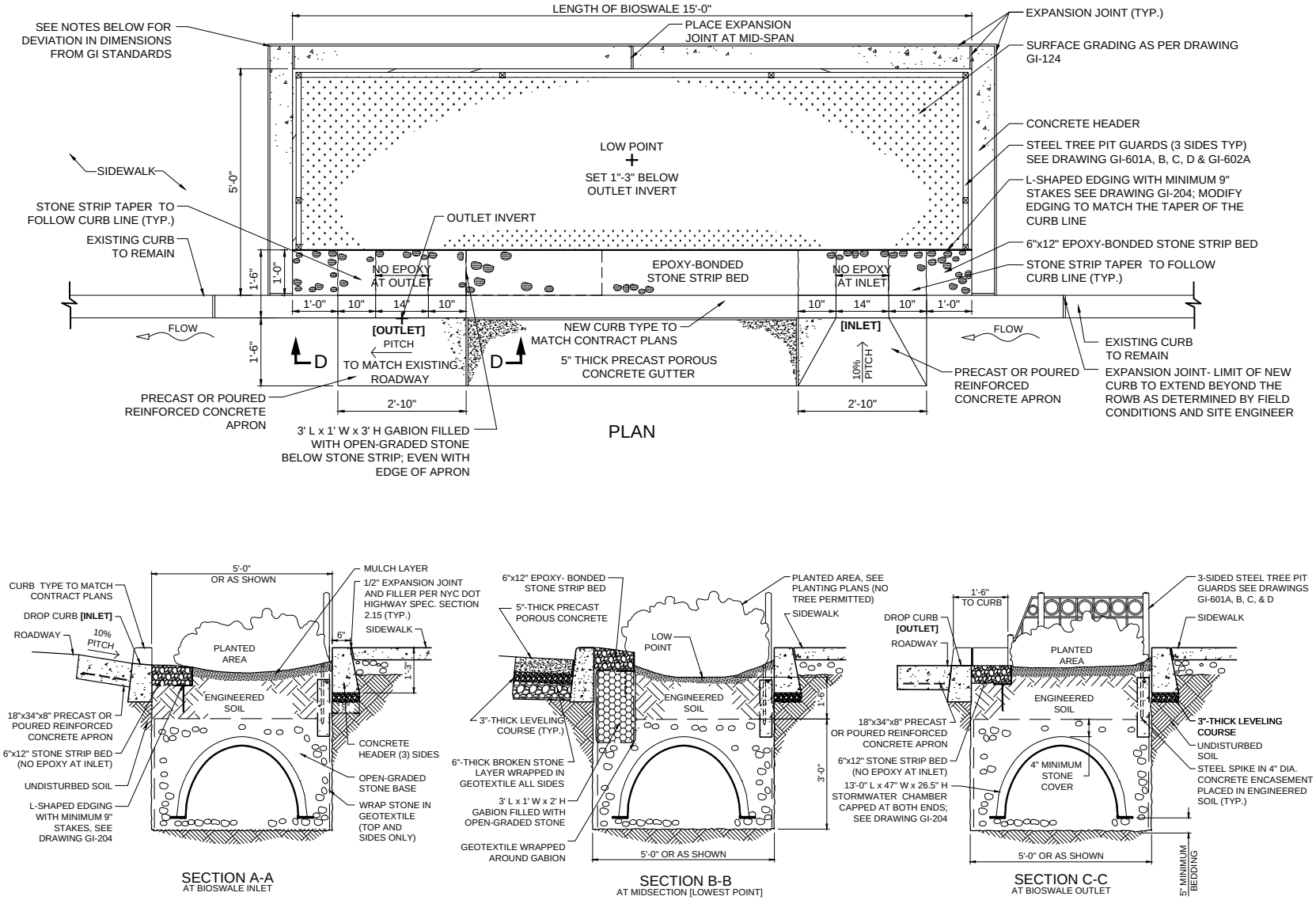
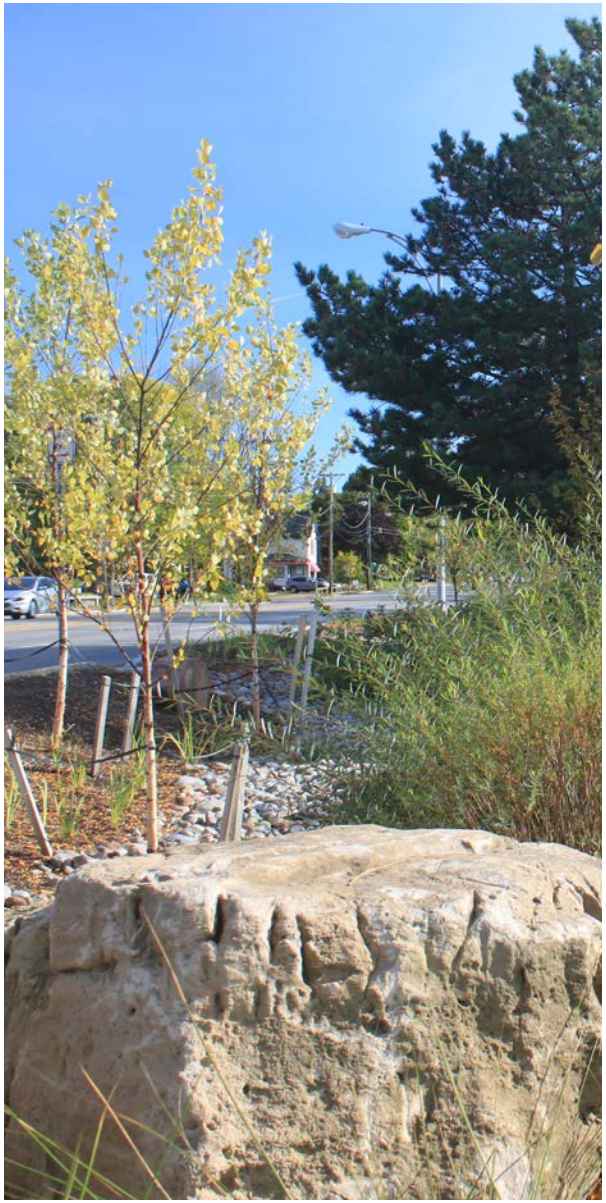


Sections of Bioretention - NYC Department of Environmental Protection



Bioretention, Brighton NY

STANDARD DESIGN REQUIREMENTS

- The recommended maximum contributing area to an individual bioretention practice is typically under 10 acres.
- Though individual calculations are necessary for each bioretention practice, generally, approximately 1/4 to 1/5 of the impermeable surface is a good initial estimate for a bioretention area.
- The practice shall include an overflow.
- *A flow regulator (or flow splitter diversion structure) shall be supplied to divert the WQv to the bioretention practice, and allow larger flows to bypass the practice.*
- Bioretention practices should include a perforated pipe underdrain in a gravel layer. A permeable filter fabric shall be placed between the gravel layer and the filter media.
- *Require a minimum 2' separation between the filter bottom and groundwater.*
- *The entire treatment system (including pretreatment) shall be sized to temporarily hold at least 75% of the WQv prior to filtration.*
- Recommended soil media (University of New Hampshire Stormwater Center Specifications. See **Appendix 3** for more information).
  - 0% Material > 4.76 mm
  - <5% Very Coarse Sand/Gravel (2.0-4.76mm)
  - 60-85% Sand (0.42-2.0 mm)
  - <20% Silt (0.074-0.42 mm)
  - <5% Clay (<0.074mm)
- Dense vegetative cover shall be established before bioretention facility is utilized. Bioretention practices are typically planted with containerized plants. If bioretention practice is seeded, diversion measures should be utilized until vegetation is established.

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas.* (See **Appendix 8, Recommended Plants for GI Practices**).

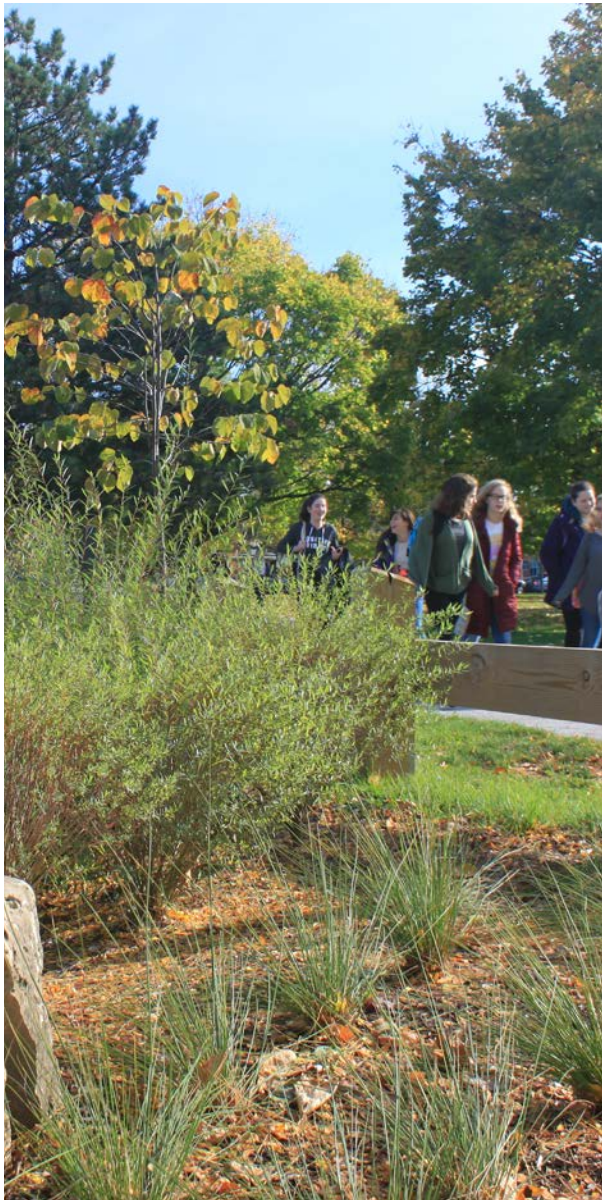
- *Planting recommendations for bioretention facilities:*
  Vegetation should be selected based on a specified zone of hydric tolerance. (**See Appendix 8**).
  A selection of trees with an understory of shrubs and herbaceous materials should be provided.
  Woody vegetation should not be specified at inflow locations.
  Trees should be planted primarily along the perimeter of the facility.

- Native vegetation should be specified where possible. See **Appendix 8** for Plant Selection Information.

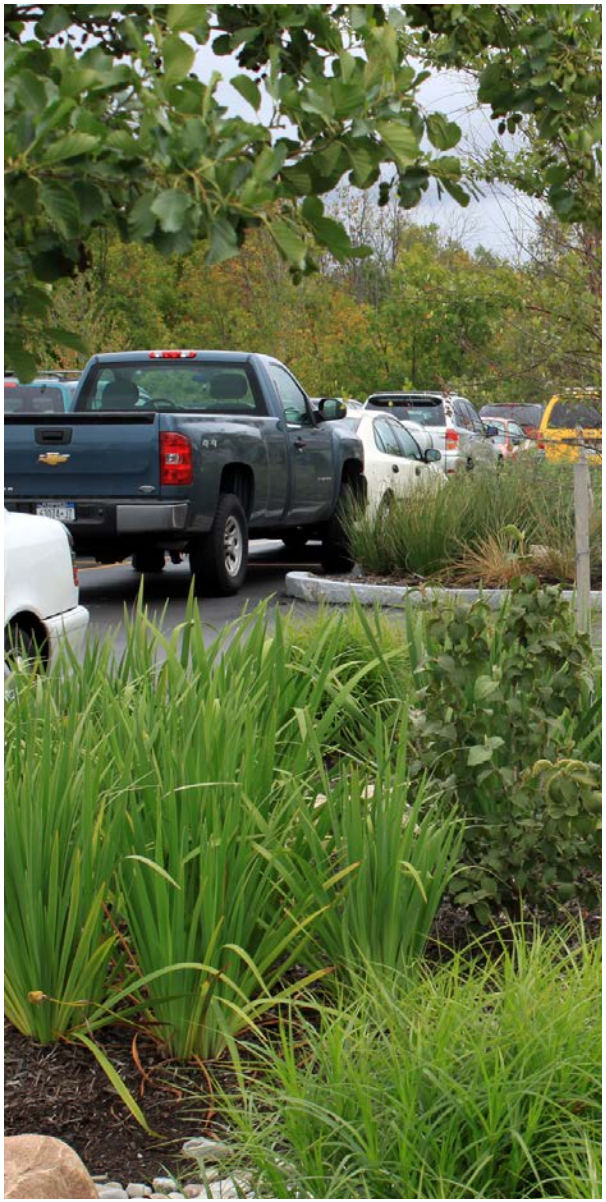
- The following quantities of specific plant types are suggested per 100 square feet of bioretention area:
  1 large tree;
  2-4 small trees;
  6 ferns or grass-like plants;
  Groundcover plantings and wildflower plugs 12" on center placed in a triangular pattern;
  A native grass or wildflower seed mix can be used as an alternative to groundcover plantings;
  Seed mix shall be free of weed seeds.

- *A legally binding and enforceable maintenance agreement shall be executed between the facility owner and the local review authority.*

- *A stone drop of at least six inches shall be provided at the inlet of bioretention facilities.*



Bioretention, Brighton NY



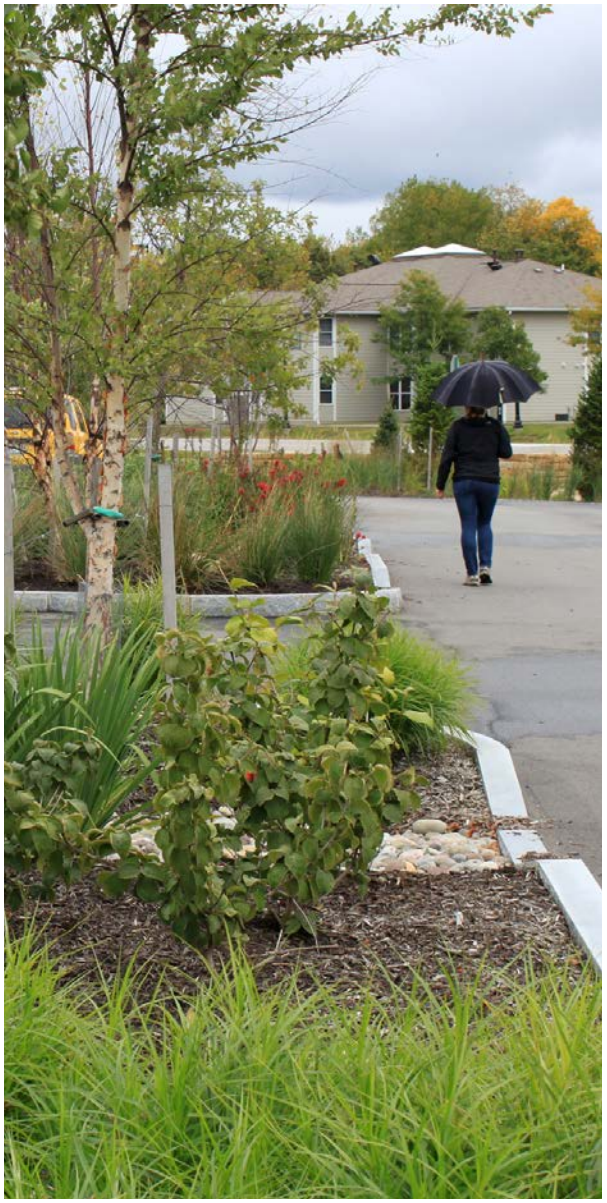
Bioretention, Henrietta NY

RETROFIT CONSIDERATIONS

- Test soil and groundwater conditions at the proposed location. (See **Appendix 2, Infiltration Testing Protocol** and **Appendix 3, Soil Media, Testing and Amendment**).
- Locate bioretention at least 10 feet from building foundations where possible. If unfeasible, provide impermeable liner to protect building foundations.
- Locate the bioretention system as close as possible to the source of runoff.
- Avoid placing bioretention systems over underground utilities wherever possible.
- Bioretention retrofit opportunities may include:
  - Installation around perimeter of parking lots or on parking lot islands;
  - Installation in the bottom of a dry pond;
  - Incorporation in streetscapes, tree pits, cul-de-sacs or traffic calming measures;
  - Incorporation into pedestrian buffer between sidewalks and roadways.
  - Splitting flows from smaller pipes to a large bioretention area;
  - Using bioretention as a landscape feature.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- Because bioretention practices are less effective when the ground is frozen, where possible, bioretention should be combined with a second GI practice to provide additional treatment during winter months.
- *Use a minimum 8" diameter underdrain in a 1' gravel bed. Increasing the diameter of the underdrain makes freezing less likely, and provides a greater capacity to drain standing water from the filter. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media.*
- *Replace standpipes with weirs, which can be "frost free."*
- When bioretention is used to treat runoff from a roadway or parking lot that is sanded during snow events, the sand can accumulate and clog the bioretention system. A 25'+ grass buffer should convey flow into the bioretention practice.



Bioretention, Henrietta NY

Bioretention, Brighton NY

PROJECT DESCRIPTION

The Monroe Avenue Green Street project was constructed along a one mile segment of NYS Route 31 in the Town of Brighton, NY. Goals for the project went above and beyond isolated transportation issues to integrate stormwater management, urban ecology and Active Design into a plan for a truly "Complete" urban corridor environment.

PROJECT DATA

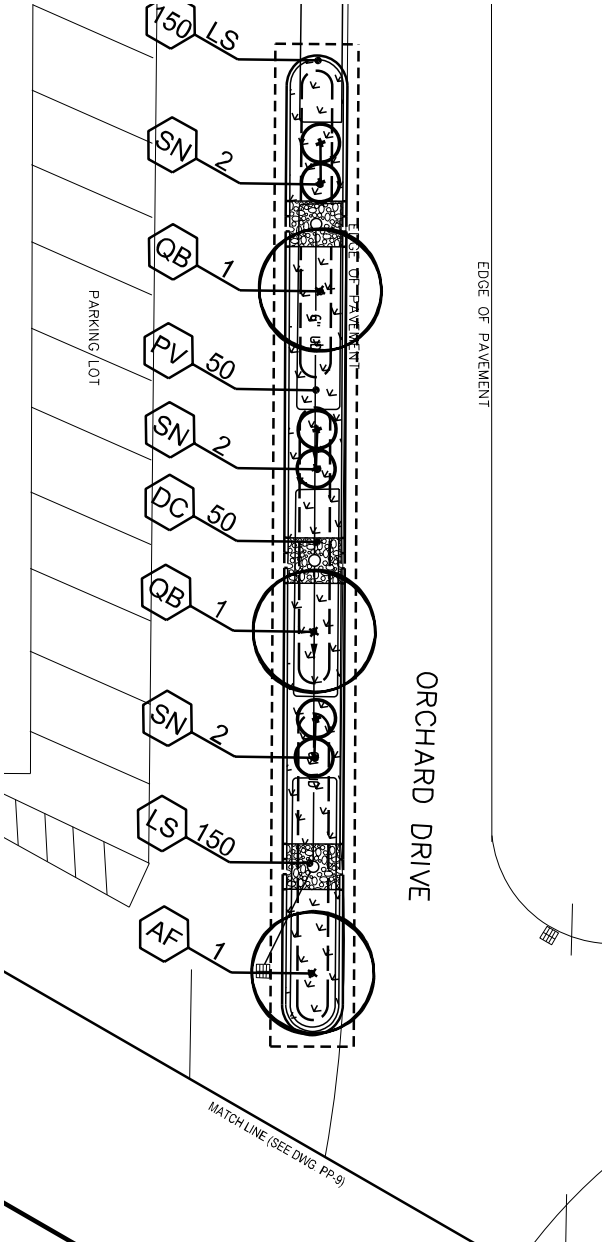
Monroe Avenue Green Street Project
Monroe Avenue, Brighton, NY

Catchment area: 22.3 Acres
249,878 cubic feet of runoff reduction from bioretention practices
1,026,022 cubic feet of total runoff reduction including bioretention, rain gardens, and permeable paving.
Total Project Cost: $1.5 Million

LESSONS LEARNED

The Monroe Avenue Green Street Project used the New York State Green Infrastructure Grant Program to fund a comprehensive project that not only manages stormwater sustainably, but also improves site aesthetics and makes Brighton a more walkable community.

This shows that ecologically healthy communities also benefit community members in far reaching ways.



BIORETENTION RIGHT-OF-WAY SAMPLE PLANTING PLAN

PLANT LIST

QTY	KEY	BOTANICAL NAME	COMMON NAME	SIZE	ROOT	COMMENTS
	DECIDUOUS TREES - MAJOR					
10	AF	ACER FREEMANII 'JEFFER'S RED'	AUTUMN BLAZE MAPLE	2" CAL	BALL & BURLAP	
14	BN	BETULA NIGRA 'CULLY'	HERITAGE RIVER BIRCH	2" CAL	BALL & BURLAP	SINGLE STEM
3	GB	GINGKO BILOBA 'HALKA'	SARATOGA GINGKO'	2" CAL.	BALL & BURLAP	MALE ONLY
7	GT	GLEDITSIA TRIACANTHOS 'SKYLINE'	SKYLINE HONEYLOCUST	2" CAL	BALL & BURLAP	
4	LQ	LIQUIDAMBAR STYRACIFLUA 'HAPPY DAYS'	HAPPY DAYS SWEETGUM	2" CAL	BALL & BURLAP	FRUITLESS
13	QB	QUERCUS BICOLOR	SWAMP WHITE OAK	2" CAL	BALL & BURLAP	
	DECIDUOUS TREES - MINOR					
8	CC	CERCIS CANADENSIS	EASTERN REDBUD	1 ¾" CAL	BALL & BURLAP	SINGLE STEM
16	CI	CRATAEGUS CRUS-GALLI 'INERMIS'	THORNLESS COCKSPUR HAWTHORN	1 ¾" CAL	BALL & BURLAP	SINGLE STEM
2	NS	NYSSA SYLVACTICA	BLACKGUM	1 ¾" CAL	BALL & BURLAP	
2	OV	OSTRAYA VIRGINIANA	AMERICAN HOPHORNBEAM	1 ¾" CAL	BALL & BURLAP	FALL PLANTING
	SHRUBS					
QTY	KEY	BOTANICAL NAME	COMMON NAME	SIZE	ROOT	COMMENTS
63	CS	CORNUS SERICEA 'BAILEY'	BAILEY REDTWIG DOGWOOD	3 GAL.	CONT.	
74	SN	SALIX PURPUREA 'NANA'	DWARF ARCTIC WILLOW	3 GAL.	CONT.	
	PERENNIALS AND ORNAMENTAL GRASSES					
QTY	KEY	BOTANICAL NAME	COMMON NAME	SIZE	ROOT	COMMENTS
1123	CL	CAREX LURIDA	LURID SEDGE	QUART	CONT.	18" O.C.
2174	DC	DESCHAMPSIA CESPITOSA	TUFTED HAIR GRASS	1 GAL.	CONT.	18" O.C.
2175	IV	IRIS VERSICOLOR	BLUE FLAG IRIS	QUART	CONT.	18" O.C.
979	JE	JUNCUS EFFUSUS	SOFT RUSH	QUART	CONT.	18" O.C.
1718	PV	PANICUM VIRGATUM	SWITCH GRASS	1 GAL.	CONT.	18" O.C.
449	HE	HEMEROCALLIS	DAYLILY	1 GAL.	CONT.	18" O.C.
2773	LS	LIRIOPE SPICATA	LILY TURF	1 GAL.	CONT.	18" O.C.

Bioretention Planting Plan and Plant List, Brighton NY

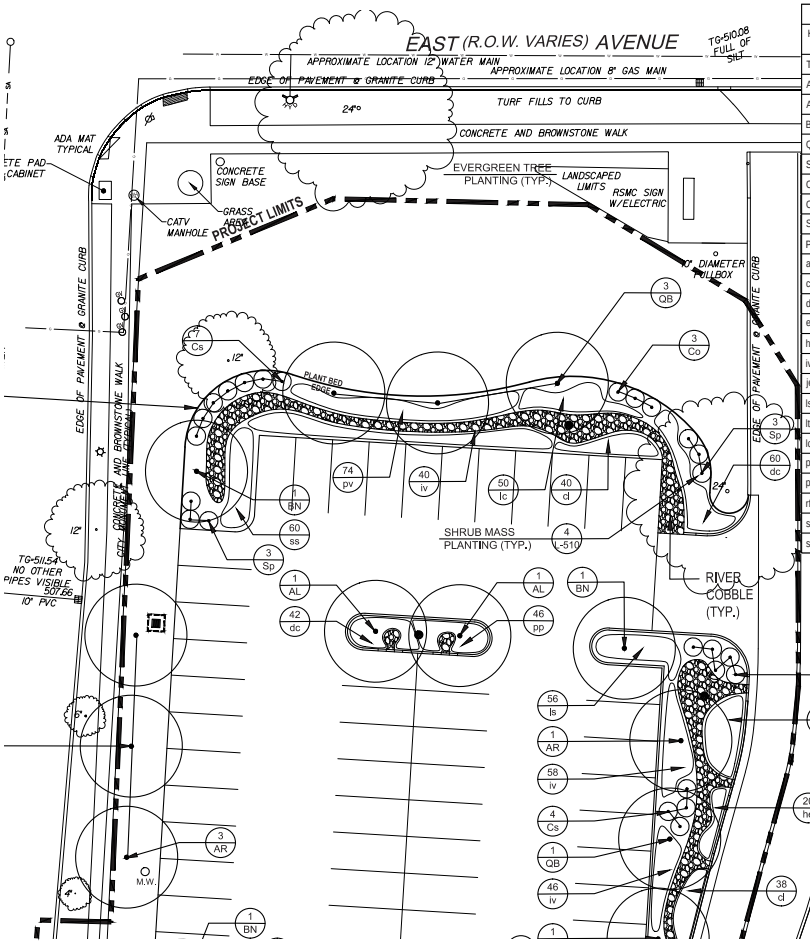
LEGEND:

PROPOSED STONE COBBLE

PROPOSED BIORETENTION PLANTINGS

PROPOSED RAIN GARDEN PLANTINGS

BIORETENTION PARKING LOT SAMPLE PLANTING PLAN



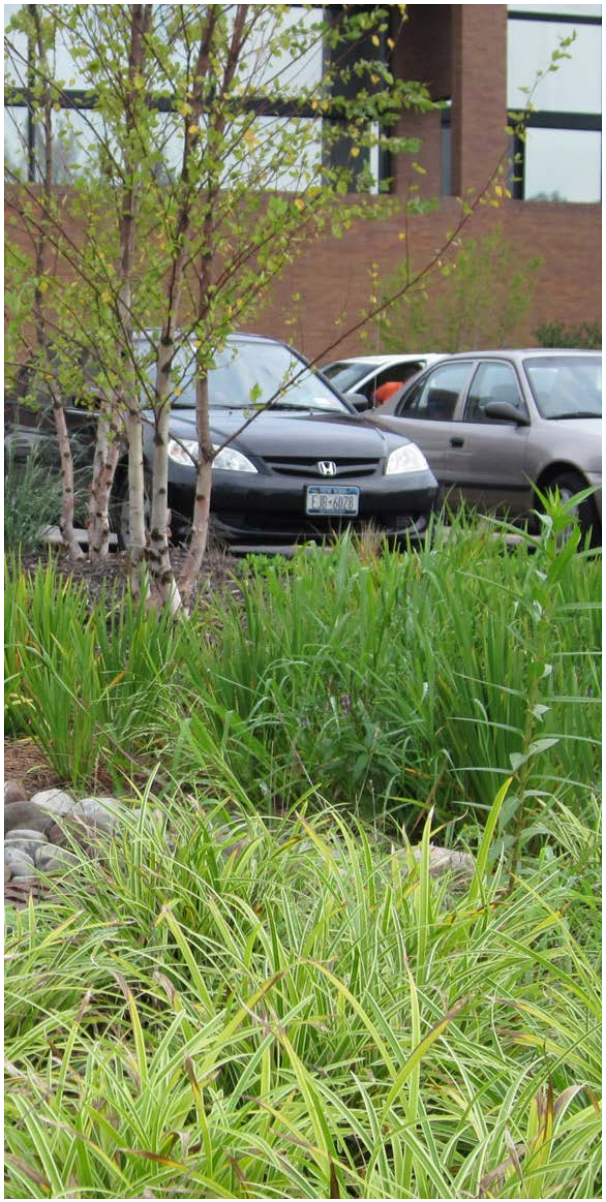
PLANT SCHEDULE L-401

KEY	COMMON	BOTANICAL	SIZE	ROOT	CONDITION	QTY.
TREES						
AR	RED MAPLE	ACER RUBRUM	2" CAL.	BALL & BURLAP	SINGLE-STEM	5
AL	ALLEGHENY SERVICEBERRY	AMELANCHIER LAEVIS 'PRINCE CHARLES'	2" CAL.	BALL & BURLAP	MULTI-STEM(3-4)	4
BN	RIVER BIRCH	BETULA NIGRA	2" CAL.	BALL & BURLAP	MULTI-STEM (3-4)	5
QB	SWAMP WHITE OAK	QUERCUS BICOLOR	2" CAL.	BALL & BURLAP	SINGLE-STEM	4
SHRUBS						
Co	BUTTONBUSH	CEPHALANTHUS OCCIDENTALIS	3 GAL.	CONT.		3
Cs	BAILEY REDSTEM DOGWOOD	CORNUS SERICEA 'BAILEY'	3 GAL.	CONT.		11
Sp	DWARF ARCTIC WILLOW	SALIX PURPUREA 'NANA'	3 GAL.	CONT.		11
PERENNIALS AND GRASSES						
an	NEW ENGLAND ASTER	ASTER NOVAE-ANGLIAE	1 GAL.	CONT.		
cl	LURID SEDGE	CAREX LURIDA	1 GAL.	CONT.		138
dc	TUFTED HAIR GRASS	DESCHAMPSIA CESPITOSA	1 GAL.	CONT.		186
ep	PURPLE CONE FLOWER	ECHINACEA PURPUREA	1 GAL.	CONT.		
he	DAYLILY	HEMEROCALIS	1 GAL.	CONT.		20
iv	IRIS	IRIS VERSICOLOR	1 GAL.	CONT.		200
je	SOFT RUSH	JUNCUS EFFUSUS	1 GAL.	CONT.		
ls	SHASTA DAISY	LEUCANTHEMUM X SUPERBUM	1 GAL.	CONT.		56
lt	BLAZING STAR	LIATRIS SPICATA	1 GAL.	CONT.		78
lc	CARDINAL FLOWER	LOBELIA CARDINALIS	1 GAL.	CONT.		50
pv	SWITCHGRASS	PANICUM VIRGATUM	1 GAL.	CONT.		74
pp	SUMMER PHLOX	PHLOX PANICULATA	1 GAL.	CONT.		92
rf	BLACK EYED SUSAN	RUDBECKIA FULGIDA	1 GAL.	CONT.		
ss	LITTLE BLUESTEM	SCHIZACHYRIUM SCOPARIUM	1 GAL.	CONT.		60
st	UPLAND WHITE ASTER	SOLIDAGO PTARMICOIDES	1 GAL.	CONT.		

SITE LEGEND

- IMPERVIOUS ASPHALT PAVEMENT
- POROUS ASPHALT PAVEMENT
- PERVIOUS PAVERS
- PERVIOUS CONCRETE PAVEMENT
- IMPERVIOUS CONCRETE PAVEMENT
- IMPERVIOUS CONCRETE PAVEMENT: INTEGRALLY COLORED
- STONE COBBLE
- 510.00 MAJOR CONTOUR
- 510.50 MINOR CONTOUR
- 513.15 SPOT ELEVATION
- C.O. 12" PREFABRICATED COMPOSITE EDGE DRAIN WITH FLAT PIPE ADAPTER AND CLEANOUT
- ST ST SICPP STORM LINE
- 4" SAMPLING UNDERDRAIN
- DRAINAGE STRUCTURE, 18" RISER
- DRAINAGE STRUCTURE, INLET CHASE
- CITY OF ROCHESTER TYPE C CATCH BASIN WITH SEWER TRAP
- W CURB STOP, WATER LINE, WATER CONNECTION
- UNDERGROUND ELECTRIC CONNECTION
- M.W. MONITORING WELL
- M.R. MONITORING WEIR (PROVIDED BY OTHERS, INSTALLED BY CONTRACTOR)
- SIGN / INTERPRETIVE PANEL EXHIBIT PEDESTAL
- SALVAGED, REFURBISHED AND RELOCATED LIGHT POLE
- TREE
- SHRUB
- PERENNIAL MASSING
- PROJECT LIMITS
- CATCH BASIN INLET PROTECTION

Bioretention Planting Plan and Plant List, Rochester NY



Bioretention, Henrietta NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

UNH Stormwater Center

University of New Hampshire

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.4 - RAIN GARDENS

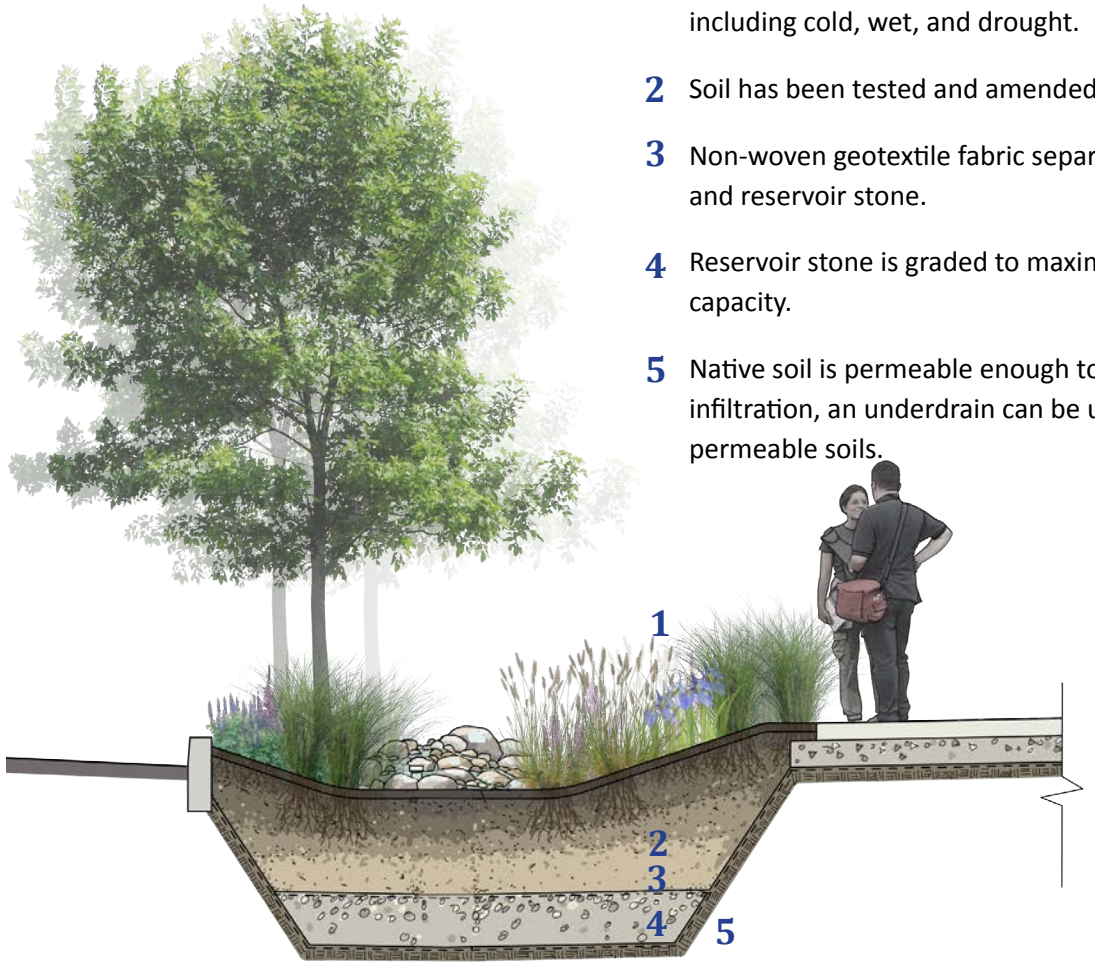
DESCRIPTION

Manage and treat small volumes of stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression.

The system consists of an inflow component, a shallow ponding area over a planted soil bed, mulch layer, gravel filter chamber, attractive shrubs, grasses and flowers, and an overflow mechanism to convey larger rain events to the storm drain system or receiving waters.

RECOMMENDED APPLICATIONS

- Appropriate for small volumes of water from sources such as rooftops, driveways and sidewalks.
- Most easily installed in relatively flat areas.
- Requires a well draining sub soil.
- Water that does not infiltrate should be conveyed to an overflow drain or directed to safely sheet flow.



Section Elevation of Rain Garden

1. Plants are tolerant of diverse conditions including cold, wet, and drought.
2. Soil has been tested and amended.
3. Non-woven geotextile fabric separates the soil and reservoir stone.
4. Reservoir stone is graded to maximize storage capacity.
5. Native soil is permeable enough to allow infiltration, an underdrain can be utilized in less permeable soils.

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

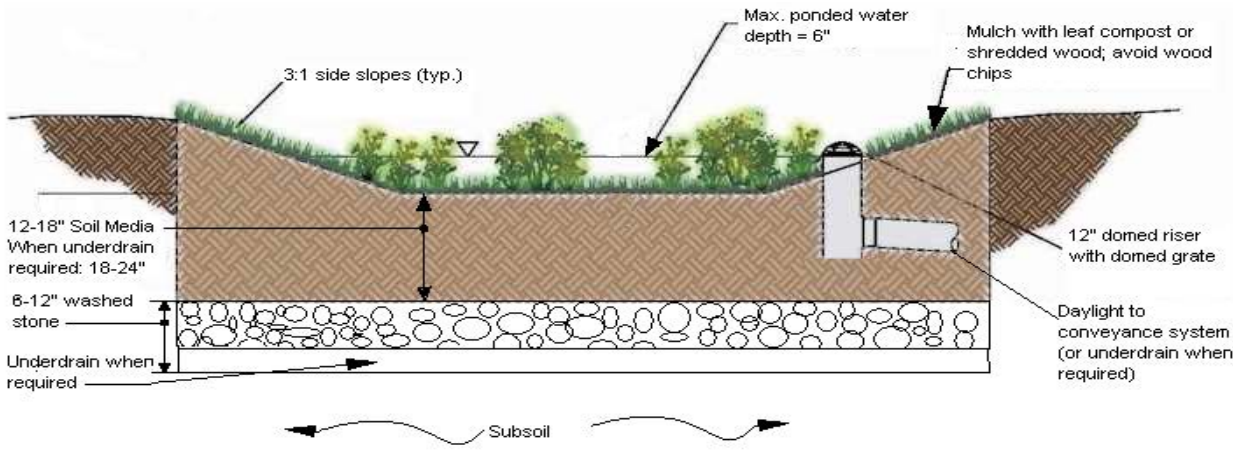
Rain Garden or Bioretention?

The NYS SMDM defines a rain garden as a small practice, targeting less than 1,000 square feet of impervious surface, and describes larger practices as bioretention. However, the Environmental Protection Agency and the Environmental Facilities Corporation do not distinguish between these two terms. Rain Garden and Bioretention are commonly used interchangeably, and many practices that are bioretention according to the NYS SMDM may frequently be referred to as rain gardens.

NYS Environmental Facilities Corporation
https://www.efc.ny.gov/Default.aspx?tabid=453

Environmental Protection Agency
https://www.epa.gov/green-infrastructure/what-green-infrastructure#raingardens

STANDARD DESIGN REQUIREMENTS



Section of Rain Garden - NYS SMDM

- *A single rain garden system should be designed to receive sheet flow runoff or shallow concentrated flow from an impervious area or from a roof drain downspout with a total contributing drainage area equal to or less than 1,000 square feet. Treatment of larger drainage areas should incorporate the design elements of bioretention practices.*
- *Rain gardens should be dug out to a 24" depth.*
- *Rain gardens should be located within approximately 30 feet of the downspout or impervious area treated. Runoff from driveways and other paved surfaces should be directed to the rain garden at a non-erosive rate through shallow swales, or allowed to sheet flow across short distances.*
- *Surface area is dependent upon storage volume requirements but should not exceed a loading ratio of 5: 1 (drainage area to infiltration area).*

Rain Garden, Courtesy of Monroe County Department of Environmental Services

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- Recommended soil media (University of New Hampshire Stormwater Center Specifications. See **Appendix 3** for more information).
  - 0% Material > 4.76 mm
  - <5% Very Coarse Sand/Gravel (2.0-4.76mm)
  - 60-85% Sand (0.42-2.0 mm)
  - <20% Silt (0.074-0.42 mm)
  - <5% Clay (<0.074mm)
- *The depth of the amended soil should be approximately 4 inches below the bottom of the deepest root ball.*
- *Rain gardens should be treated as a component of the landscaping, with routine maintenance specified through a legally binding maintenance agreement.*
- *Shredded hardwood mulch should be applied up to 2" to help keep soil in place.*
- *Weeding and watering are essential the first year, and can be minimized with the use of a weed free mulch layer.*
- *Once the rain garden has matured, the garden area should be free of bare areas except where stepping stones are located.*

RETROFIT CONSIDERATIONS

- Rain gardens require 1”/hour drainage in subsoils to work properly. In many retrofit sites, subsoils are heavily compacted. Soil restoration may be necessary for heavily compacted soils.
- Soil tests are recommended to identify an appropriate soil amendment package. See **Appendix 3, Soil Media, Testing and Amendment**
- If soil infiltration is inadequate, a bioretention area or other infiltration practice with an under drain may be necessary.
- Locate bioretention at least 10 feet from building foundations where possible. If unfeasible, provide impermeable liner to protect building foundations.
- Avoid placement over underground utilities if possible.
- Confirm that existing runoff can be intercepted by the rain garden.
- *Rain gardens should only be installed when surrounding landscapes are stabilized and not subject to erosion.*
- *Rain gardens require relatively flat slopes to be able to accommodate runoff filtering through the system. Some design modifications can address this constraint through the use of berms and timber or block retaining walls on moderate slopes.*
- Rain garden retrofit opportunities may include:
  Installation within parking lot islands or around perimeter;
  Incorporation in streetscapes, tree pits, cul-de-sacs or traffic calming measures;
  Installation to treat rooftop runoff from residential or commercial properties;
  Utilization as a landscape feature.
- Maximize stormwater management by capturing the largest contributing drainage area possible.

Rain Garden, Henrietta NY

Rain Garden, Henrietta NY

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- Rain gardens are typically sized to the local 90% rainfall event, 0.9" in Monroe County. The NYS SMDM uses this number to calculate water quality volume (WQv) for an individual practice.
- The Manual specifies *the storage volume in the rain garden must be equal to or greater than the water quality volume (WQv).* This minimum may not be adequate to account for runoff from snow melt. In some cases, consider designing for a 5 or 10 year storm event.
- Plants should be cold hardy to USDA Zone 5 and tolerant of both wet and dry conditions.
- Plants that are salt tolerant should be used on sites that will receive runoff from roads or parking lots.
- Woody plants can be damaged by snow piling and should only be used where snow will not be stored.
- Rain gardens without woody plants can be used to provide snow storage during the winter.
- Rain gardens may be less effective during the winter because of frozen ground.

RAIN GARDEN CASE STUDY

Rain Garden, Rochester NY

PROJECT DESCRIPTION

The City of Rochester has completed a three-part GI improvement project that involved the installation of a green roof, green pervious parking lot, and rain gardens. The project demonstrates the City's commitment to green innovation and sustainability, by reducing the amount of runoff from wet weather into the City's combined storm/sewer system, and into the region's rivers, streams and lakes.

The project provides for other public and private building owners a demonstration of green construction and the potential system benefits.

PROJECT DATA

Rochester City Hall Rain Garden
30 Church St, Rochester, NY 14614

Square footage: 345 sq ft
Catchment area: 6,440 sq ft
Approximate construction cost: $27,300

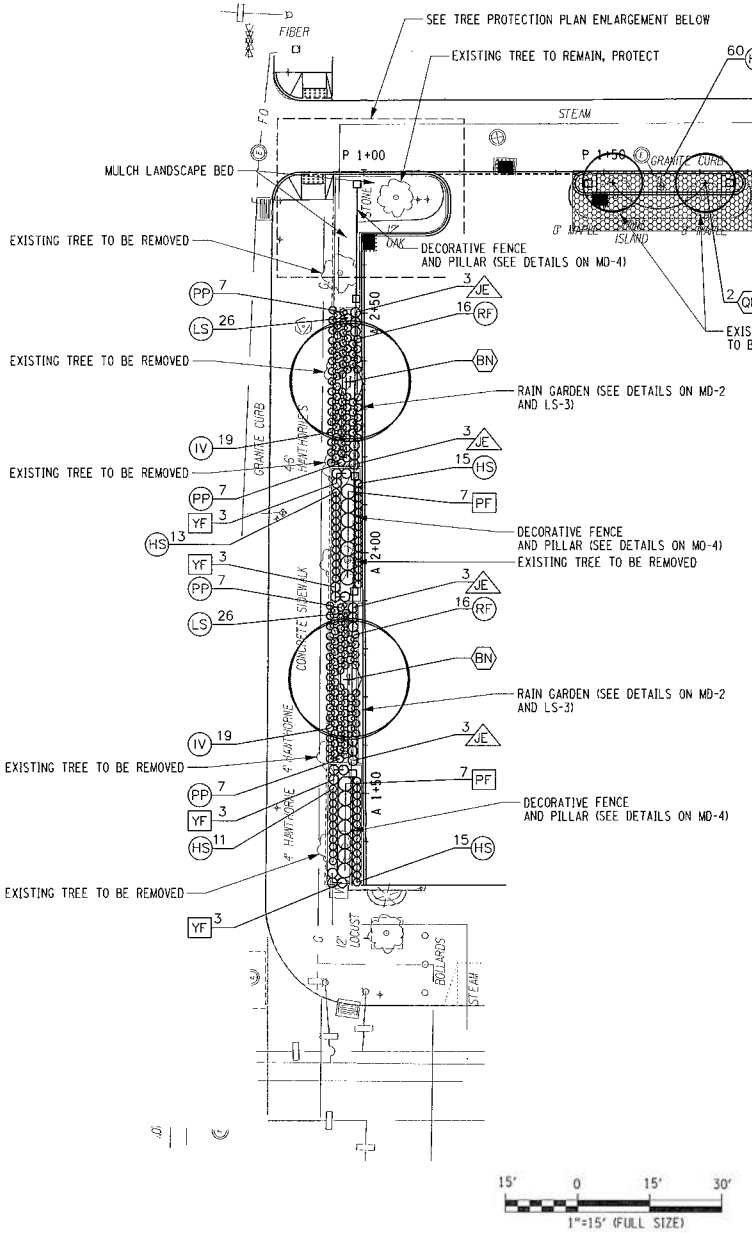
LESSONS LEARNED

The plant list for this project provides outstanding continuous three season aesthetic value and has been a great success with pollinators. Something is always blooming. Considering a wide variety of plant qualities including bloom time can have lasting impacts for GI projects. See sample planting plan on the following page.

The City of Rochester has been maintaining the rain garden through seasonal weeding, watering, and mulching. Sound design, sound construction, and sound maintenance are all required elements to make a project a success.

RAIN GARDEN SAMPLE PLANTING PLAN

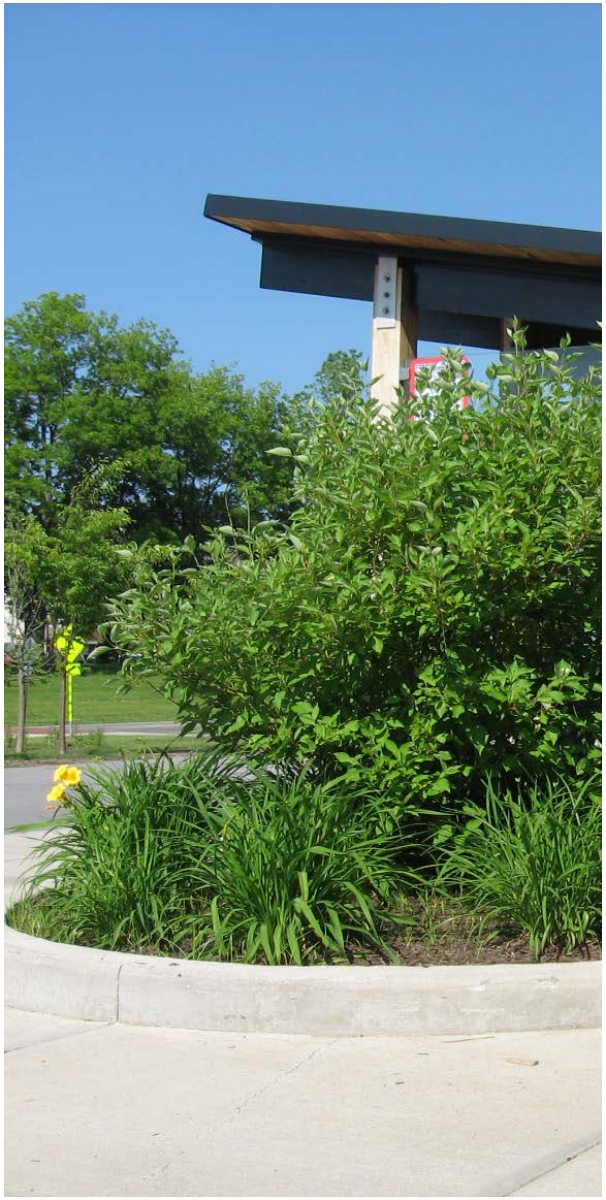
Plant species need to be selected that are adaptable to the wet/dry conditions that will be present. The goal of planting the rain garden is to establish an attractive planting bed with a mix of upland and wetland native shrubs, grasses and herbaceous plant material arranged in a natural configuration starting from the more upland species at the outermost zone of the system to more wetland species at the inner most zone.



PLANT LIST

SYM	QTY	SCIENTIFIC NAME	COMMON NAME	SIZE	ROOTS	REMARKS
DECIDUOUS TREES – MAJOR (ITEM 611.0151)						
BN	2	BETULA NIGRA	RIVER BIRCH	2" CAL	B&B	TREE FORM
QP	6	QUERCUS PALUSTRIS 'GREEN PILLAR'	GREEN PILLAR PIN OAK	2" CAL	B&B	
SHRUBS (ITEM 611.0422)						
PF	14	POTENTILLA FRUTICOSA 'GOLDFINGER'	GOLDFINGER POTENTILLA	15" HT.	#3 CONT.	3' O.C.
YF	12	YUCCA FILAMENTOSA 'HOFER'S BLUE'	HOFER'S BLUE YUCCA	15" HT.	#3 CONT.	2' O.C.
PERENNIALS (ITEM 611.0651)						
HS	234	HEMEROCALLIS STELLA D'ORO	STELLA D'ORO DAYLILY	16" HT	#1 CONT.	18" O.C.
IV	38	IRIS VERSICOLOR	BLUE FLAG IRIS	16" HT	#1 CONT.	18" O.C.
LS	52	LIATRIS SPICATA	BLAZING STAR	16" HT	#1 CONT.	18" O.C.
PP	28	PHLOX PANICULATA	SUMMER PHLOX	16" HT	#1 CONT.	18" O.C.
RF	32	RUDBECKIA FULGIDA 'GOLDSTRUM'	BLACK EYED SUSAN	16" HT	#1 CONT.	18" O.C.
GRASSES (ITEM 611.0651)						
JE	12	JUNCUS EFFUSUS	SOFT RUSH	16" HT	#1 CONT.	2' O.C.

Rain Garden Planting Plan and Plant List, Rochester NY



Rain Garden, Henrietta NY

REFERENCES

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STANDARD DESIGN AND SIZING REQUIREMENTS

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Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

UNH Stormwater Center

University of New Hampshire

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.5 - VEGETATED SWALES

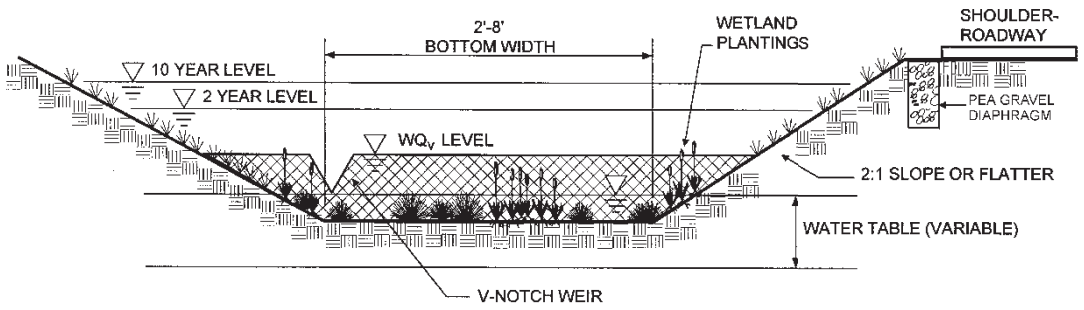
DESCRIPTION

Natural drainage paths, or properly designed vegetated channels, can be used instead of constructing underground storm sewers or concrete open channels to increase time of concentration, reduce the peak discharge, and provide infiltration.

RECOMMENDED APPLICATIONS

- *A vegetated swale can be used where the contributing DA is less than 5 acres, and when the WQv peak flow (QWQV) is less than 3cfs.*
- Used as a lined open channel along roads within the right of way; as an alternative to underground storm sewers.
- Used along the edges of small parking lots.
- Used to capture runoff directed from small impervious areas.

Vegetated Swale, Henrietta NY



Wet Swale Detail, NYS SMDM

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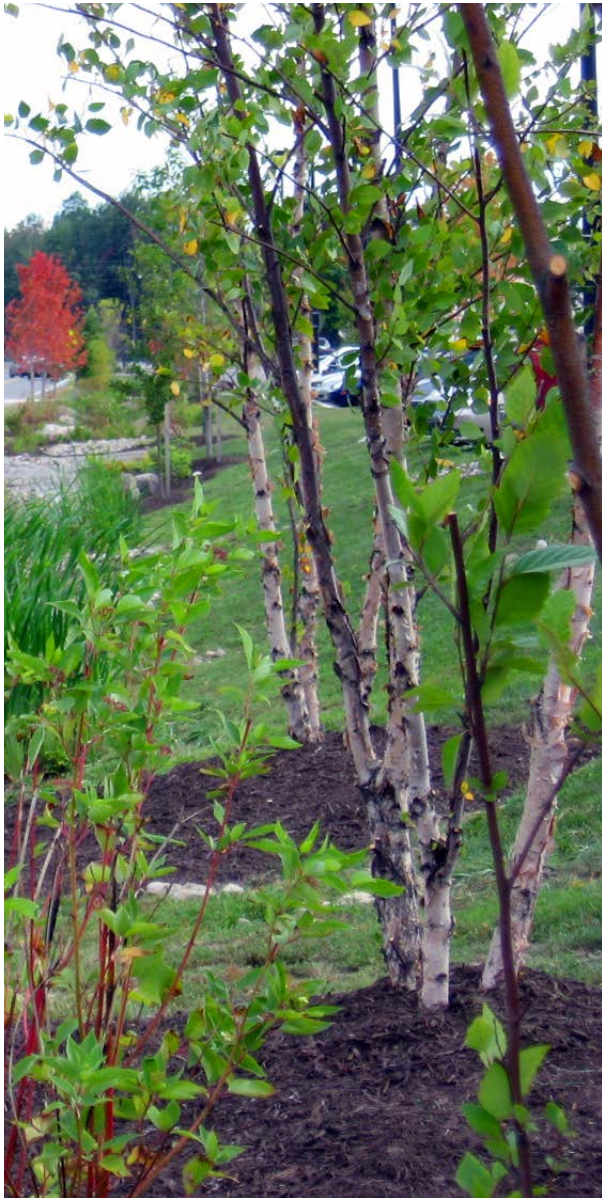


Vegetated Swale, Henrietta NY

STANDARD DESIGN REQUIREMENTS

- *Provide sufficient length (minimum 100 ft) to retain the computed treatment volume for 10 minutes in a swale that receives runoff as a point discharge at the inlet, or an average of 5 minutes of retention time for a swale receiving sheet drainage or multiple point discharges along its length.*
- *Convey the peak discharge...*
  - *a. at a velocity of < 1.0 fps, and*
  - *b. at a flow depth of 4 inches or less.*
- *Check Dam may be required to achieve the above criteria.*
- *Have a trapezoidal or parabolic shape, with a bottom width minimum of 2' and no greater than 6'.*
- *Have side slopes no steeper than 3 horizontal:1 vertical.*
- *Have a slope between 0.5% and 4% (between 1.5- 2.5 percent recommended).*
- *Convey the 10-year storm with 6 inches of freeboard at a velocity < 5 fps.*
- *Strip vegetation, soil and debris from swale by hand where possible.*
- *Amend soil as needed with fertilizer and lime during construction.*
- Use phosphorus free fertilizer unless soil tests indicate need for phosphorus.
- *Provide 4 inches of topsoil.*
- *Remove all stones and debris that may hinder flow and maintenance.*
- *Apply recommended seed mixes (or sod).*
- *Fertilize and lime as needed to maintain dense vegetation.*

Vegetated Swale, Henrietta NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Mow as required during the growing season to maintain grass heights at 4 inches to 6 inches.*
- *Remove any sediment or debris buildup by hand if possible in the bottom of the channel when the depth reaches 2 inches.*
- *Inspect for pools of standing water. Regrade to restore design grade and revegetate.*
- *Repair rills in channel bottom with compacted topsoil, anchored with mesh or filter fabric. Seed and mulch.*
- *Use of heavy equipment for mowing and removing plants/debris should be avoided to minimize soil compaction. Disturbed areas should be stabilized with seed and mulch, or revetment, as necessary.*

RETROFIT CONSIDERATIONS

- Consider the site's natural topography when siting the swale. If possible, locate the swale along contours and natural drainage pathways with slopes of 2-3%.
- Determine the location of underground utility lines and avoid conflicts.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- Vegetated swales are one of the practices that do not require inlets, outlets, or underdrains. Because frozen pipes may crack, this makes vegetated swales particularly adaptable to cold climates without having to consider damage to pipes.
- Vegetated swales rely on infiltration, which is sometimes limited during winter by frozen soil.
- Vegetated swales can store a great deal of snow during winter months and hold water from snow melt before it is able to infiltrate.

VEGETATED SWALE CASE STUDY

Vegetated Swale, Henrietta NY

PROJECT DESCRIPTION

Perkins Green is a project at the Rochester Institute of Technology that integrates GI with active transportation planning. The project includes an extensive vegetated swale, a bus shelter with rain gardens, and a new bike and pedestrian concourse.

PROJECT DATA

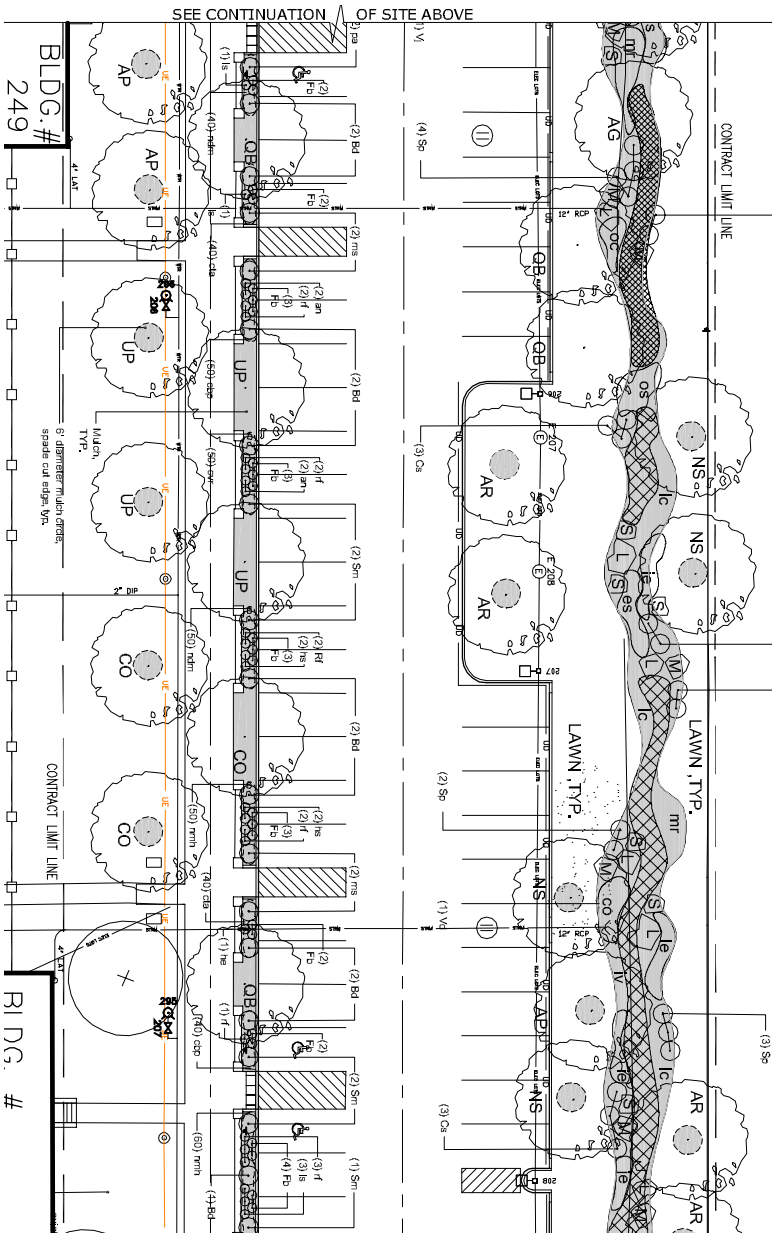
Rochester Institute of Technology
Perkins Green
Henrietta, NY 14623

Length: 800 feet
Approximate Construction Cost: $120,000

LESSONS LEARNED

During construction, boulders were collected from the spoils pile of a local golf course expansion, less than 10 miles from the project site. Being aware of these local opportunities can cut project costs and promote sustainability.

Emulating natural systems can increase both the beauty and functionality of GI practices. The Perkins Green project accomplished this in several ways. Various sizes of gravel and cobbles were combined to suggest natural processes of erosion and deposition in stream channels on the ground plane, and to enhance trapping of particulates. Design of the plantings within the swale was based on observation of established ecological communities in the woodlots and wetlands that surround Perkins Green.



VEGETATED SWALE SAMPLE PLANTING PLAN

TREES

Label	Botanical Name	Common Name	Size (cal.)	Notes
AG	Alnus glutinosa	Black alder	3"	B&B
AP	Acer griseum	Paperbark maple	14'	B&B
AR	Acer rubrum 'Red Sunset'	Red maple	4"	B&B
BN	Betula nigra 'Heritage'	'Heritage' River birch	14'	B&B
CO	Celtis occidentalis	Hackberry	4"	B&B
NS	Nyssa sylvatica	Black tupelo	4"	B&B
QB	Quercus bicolor	Swamp white oak	4"	B&B
UP	Ulmus parvifolia	Lacebark Elm	4"	B&B

SHRUBS

Label	Botanical Name	Common Name	Size	Notes
Cs	Cornus sericea	Red-osier Dogwood	18-24"	B&B or Cont
Fb	Forsythia virid. 'Bronxensis"	Dwarf Forsythia	18-24"	B&B or Cont
Hv	Hamamelis virginiana	Witch hazel	18-24"	B&B or Cont
Ra	Rhus aromatica	Grow-Lo Sumac	18-24"	B&B or Cont
Sm	Syringa meyeri	Meyer Lilac	18-24"	B&B or Cont
Sp	Sambucus pubens	Scarlet elder	18-24"	B&B or Cont
Vj	Viburnum x. juddii	David viburnum	18-24"	B&B or Cont
Vd	Viburnum davidii	Judd viburnum	18-24"	B&B or Cont

PERENNIALS & GROUND COVERS - SPACING: 18" O.C. TYP.

Label	Botanical Name	Common Name	Size	Notes
an	Aster novae-angliae	New England Aster	#1	Container
bd	Buddleia davidii 'Pink Delight'	Butterfly Bush	#1	Container
co	Carex obnupta	Slough Sedge	#1	Container
em	Eupatorium maculatum	Joe Pye Weed	#1	Container
es	Equisetum scorpoides	Dwarf Horsetail	#1	Container
hc	Hypericum calycinum	Saint John's Wort	#1	Container
hs	Hemerocallis 'Stella de Oro'	Day Lilly	#1	Container
iv	Iris versicolor	Blue Flag Iris	#1	Container
ie	Iris ensata 'Variegata'	Variegated Iris	#1	Container
je	Juncus effusus	Soft Rush	#1	Container
lc	Lobelia cardinalis	Cardinal Flower	#1	Container
ls	Leucanthemum superbum 'No. Lights'	Shasta daisy	#1	Container
mr	Mimulus ringens	Monkey flower	#1	Container
ms	Miscanthus sinensis 'Morning Light'	Maiden grass	#1	Container
oc	Osmunda cinnamonea	Cinnamon Fern	#1	Container
os	Onoclea sensibilis	Sensitive fern	#1	Container
pa	Polystichum acrostichoides	Christmas Fern	#1	Container
pe	Pennisetum alopecuroides	Fountain grass	#1	Container
pf	Athyrium n. 'Pictum'	Japanese Painted Fern	#1	Container
rf	Rudbeckia fulgida 'Goldsturm'	Black-eyed susan	#1	Container
tm	Typha minima	Dwarf Cattail	#1	Container

BULBS - SPACING: 12" O.C. TYP.

cta	Crocus tommasinianus 'Albus'	Wild Crocus	each	bulb
cbp	Crocus tommasinianus 'Barr's Purple'	Wild Crocus	each	bulb
cvr	Crocus vernus 'Remembrance'	Dutch Crocus	each	bulb
ndm	Narcissus 'Dutch Master'	Daffodil (yellow)	each	bulb
nmh	Narcissus 'Mount Hood'	Daffodil (white)	each	bulb

Vegetated Swale Planting Plan and Plant List, Henrietta NY

REFERENCES

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COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

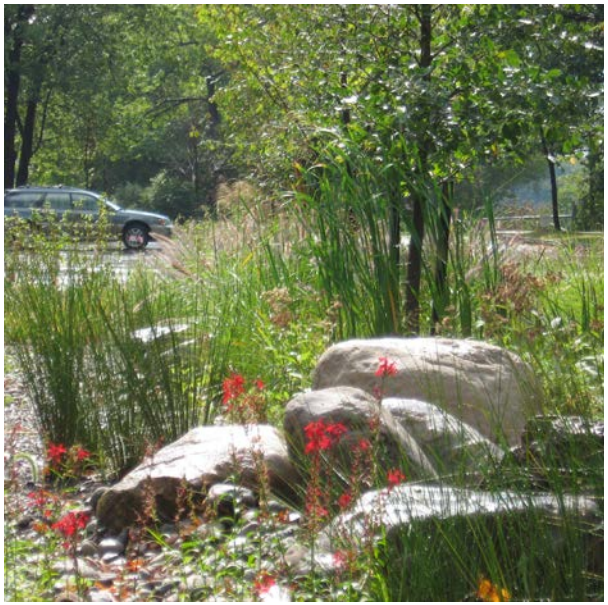
ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water



Vegetated Swale, Irondequoit NY

3.1.6 - ROOFTOP DISCONNECT

DESCRIPTION

Direct runoff from residential rooftop areas and upland overland runoff flow to designated pervious areas to reduce runoff volumes and rates.

RECOMMENDED APPLICATIONS

- Rooftop repairs are excellent opportunities to consider disconnecting from the stormwater sewer system.
- There are many strategies for rooftop disconnects. This section focuses on rain barrels as a rooftop disconnect practice. Several other options are portrayed in the following sections, including:

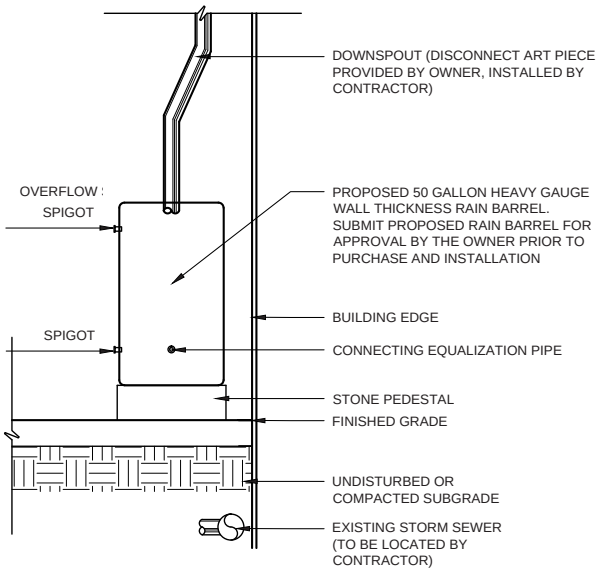
  Rain water harvest and recycling - cisterns **(Section 3.1.7);**

  Directing water to stormwater planters **(Section 3.1.8);**

  Green roof retrofit projects **(Section 3.1.9).**

Rooftop Disconnect, Rochester NY

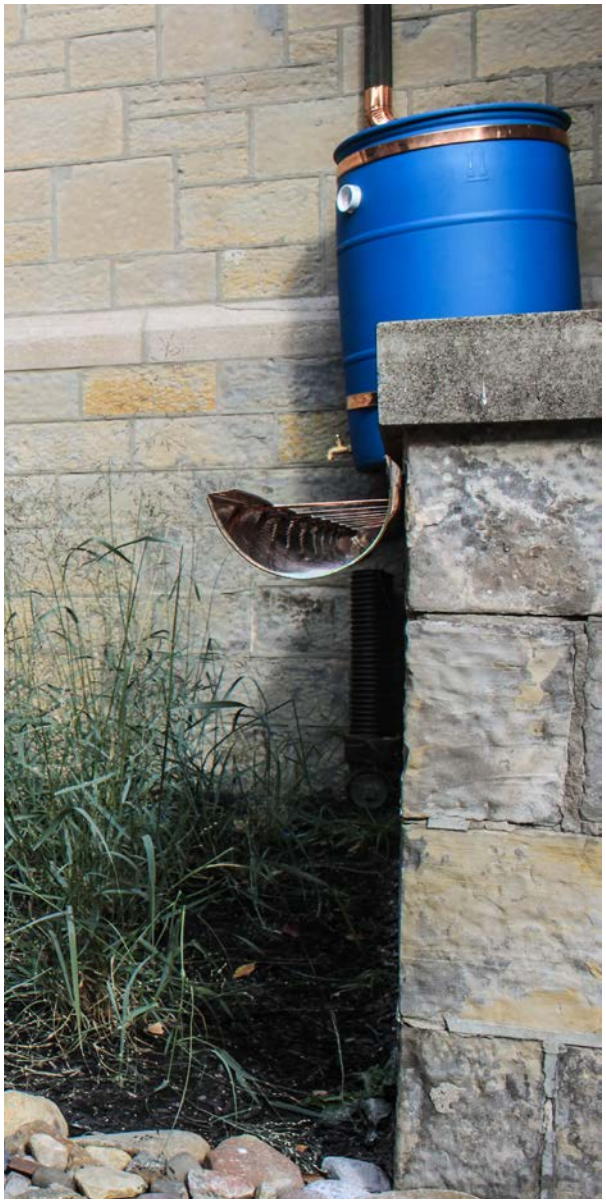
All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.



Rooftop Disconnect Detail

STANDARD DESIGN REQUIREMENTS

- *Runoff from disconnected rooftop must be directed to a designated area that is appropriately graded for storage and infiltration of the runoff, re-vegetated and protected from other uses, and designed for conveyance in a non-erosive manner within the site boundary. Use splash pads or flow spreaders (See the NY Standards and Specifications for Erosion and Sediment Control for the design of flow spreaders) as required to distribute runoff to designated areas with infiltration capacity.*
- *Disconnections are encouraged on permeable soils (HSGs A and B).*
- *In less permeable soils (HSGs C and D), permeability as well as water table depth shall be evaluated by a certified/licensed professional to determine if a soil enhancement and spreading device is needed to provide sheet flow over grass surfaces. In some cases, soil restoration by deep tilling, decompaction,or compost amendment is needed to compensate for a poor infiltration capability.*
- *Runoff shall not come from a designated hotspot.*
- *The maximum contributing flow path length from impervious areas shall be 75 feet.*
- *Downspouts shall be at least 10 feet away from the nearest impervious surface to discourage "re-connections".*
- *The contributing area of rooftop to each disconnected discharge shall be 500 square feet or less; larger roof areas up to 2,000 square feet may be acceptable with a suitable flow dispersion technique such as a flow spreader.*



Rooftop Disconnect, Rochester NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *The disconnected, contributing impervious area shall drain through a vegetated channel, swale, or filter strip (filtration/infiltration areas) for a distance equal to or greater than the disconnected, contributing impervious area length.*
- *The entire vegetative filtration/infiltration area shall have an average slope of less than five (5) percent.*
- *Siting and sizing of this practice should address WQv and runoff reduction requirements and cannot not result in overflow to undesignated areas.*

RETROFIT CONSIDERATIONS

- Where possible, locate cisterns and rain barrels at a higher elevation than the intended reuse practice in order to promote gravity flow.
- Make certain that overflow can safely sheet flow or be directed to a conventional stormwater sewer system.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- *In cold climates specific design or maintenance strategies will need to be considered to prevent freezing such as providing insulation or disconnecting the system during the winter months.*

- *Climate is an important consideration and capture/reuse systems should be designed to account for the potential for freezing. In cold climates where cisterns are designed for use throughout the year, they will need to be protected from freezing. These systems may need to be located indoors or underground below the frost line if freezing conditions are expected. Cisterns placed on the ground require extra insulation on the exposed surfaces (Stensrod, et all., 1989). For cisterns placed on rock, the bottom surface will also need to be insulated. For underground systems it may be cost-prohibitive to place the cistern below the freezing depth, so alternatively, insulation may be placed below the surface and above the underground cistern to prevent freezing. Other methods to prevent freezing include lining the intake pipe and cistern with heat tape and closing the overflow valve (Stensrod, et all, 1989). Water levels in the cistern must be lowered at the beginning of winter to prevent possible winter ice damage and provide the needed storage in the cistern for capturing rooftop runoff from the spring snow melt.*

- *The year round use of rain barrels in cold climates is not recommended since these containers may burst due to ice formation and freezing temperatures (Metropolitan Council, 2001). It is recommended that the rain barrels be disconnected from the roof gutters and placed indoors during the winter months. Downspout piping must be reconnected and directed to a grassy area away from the structure to prevent winter snowmelt from damaging building foundations.*

Rooftop Disconnect, Pattersonville NY

ROOFTOP DISCONNECT CASE STUDY

Rooftop Disconnect, Rochester NY

PROJECT DESCRIPTION

The Interactive Downspout Garden is located at the Rochester Museum and Science Center's Gannett Building, which is home to the RMSC preschool and adjacent to the Genesee Community Charter School. Two existing downspouts were disconnected and diverted into four linked rain barrels, which were hand-painted by Charter School students. A treadle pump provides a human-powered, off grid irrigation system that recycles water from the rain barrels to a spray fixture in the rain garden. The GI practices at the Downspout Garden provide a playful legibility to the water cycle and the importance of stormwater management.

PROJECT DATA

Rochester Museum and Science Center
Regional Green Infrastructure Showcase
657 East Avenue, Rochester, NY 14607

5 Rain Barrels
250 Gallons
Project Cost: Not Available

LESSONS LEARNED

Genesee Community Charter School students helped to design and paint the barrels for the Interactive Downspout Garden. Involving local community organizations increases project buy-in and makes projects more unique and personalized.

Note student in the picture manually operating a treadle pump to irrigate a rain garden from rain water stored in a rain barrel that was collected from rooftop disconnection.

Rooftop Disconnect, Rochester NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.7 - RAIN WATER HARVEST & RECYCLING

DESCRIPTION

Capture and store stormwater runoff to be used for irrigation systems or filtered and reused for non-contact activities.

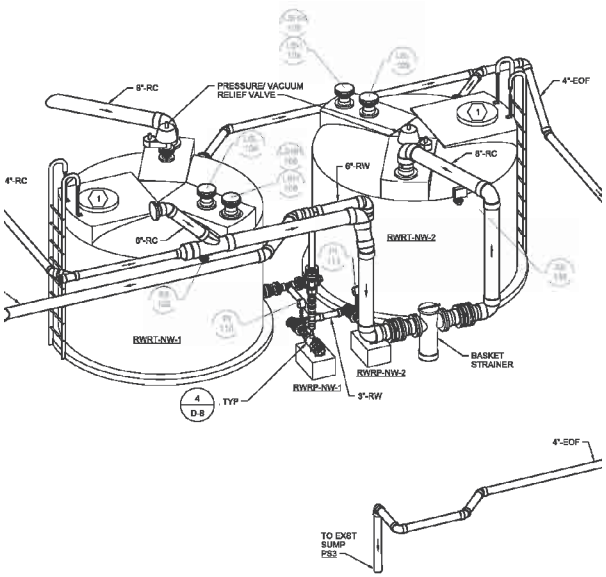
Rain barrels are rooftop catchment storage systems typically utilized in residential settings while cisterns are large-scale rain barrels used in commercial and industrial settings. The basic components of a rain barrel and cistern include: a watertight storage container, secure cover, a debris/mosquito screen, a coarse inlet filter with clean-out valve, an overflow pipe, a manhole or access hatch, a drain for cleaning, an extraction system (tap or pump).

OnCenter War Memorial Arena Rainwater Reuse System, Syracuse NY
Utilized to capture stormwater for ice creation and maintenance
for Syracuse's professional hockey team
http://savetherain.us/str_project/war-memorial/

RECOMMENDED APPLICATIONS

Cisterns can be interior or exterior, above or below ground. Rain water harvest can also include small scale practices such as rain barrels. See **Section 3.1.6** Rooftop Disconnect for more information on rain barrels.

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.



1 NORTHWEST RAINWATER RECEIVER SYSTEM ISOMETRIC
3/8"=1'-0"
D-2

Rain Water Harvesting, Syracuse NY

http://savetherain.us/str_project/war-memorial/

STANDARD DESIGN REQUIREMENTS

- The cistern/rain barrel sizing is based on the water demand for the intended use. The amount of water available for reuse is a function of the impervious area that drains to the device. Runoff reduction credit is applied if the water demand and system sizing is equal to or greater than the WQv.
- A rain barrel may be located beneath a single downspout or multiple rain barrels may be located such that they collect stormwater from several rooftop sources. Due to the size of rooftops and the amount of contributing impervious area, increased runoff volume and peak discharge rates for commercial and industrial sites may require large capacity cisterns. Rain barrels and Cisterns designed to capture small, frequent storm events must be either actively or passively drained to provide storage for subsequent storm events or located in an area where overflow runoff can be conveyed to a suitable area such as a buffer, open yard, grass swale or a rain garden.

RETROFIT CONSIDERATIONS

- Where possible, locate cisterns and rain barrels at a higher elevation than the intended reuse practice in order to promote gravity flow.
- Make certain that overflow can safely sheet flow or be directed to a conventional stormwater sewer system.

Rain Water Harvesting, Rochester NY

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- *In cold climates specific design or maintenance strategies will need to be considered to prevent freezing such as providing insulation or disconnecting the system during the winter months.*
- *Climate is an important consideration and capture/reuse systems should be designed to account for the potential for freezing. In cold climates where cisterns are designed for use throughout the year, they will need to be protected from freezing. These systems may need to be located indoors or underground below the frost line if freezing conditions are expected. Cisterns placed on the ground require extra insulation on the exposed surfaces (Stensrod, et all., 1989). For cisterns placed on rock, the bottom surface will also need to be insulated. For underground systems it may be cost-prohibitive to place the cistern below the freezing depth, so alternatively, insulation may be placed below the surface and above the underground cistern to prevent freezing. Other methods to prevent freezing include lining the intake pipe and cistern with heat tape and closing the overflow valve (Stensrod, et all., 1989). Water levels in the cistern must be lowered at the beginning of winter to prevent possible winter ice damage and provide the needed storage in the cistern for capturing rooftop runoff from the spring snow melt.*
- *The year round use of rain barrels in cold climates is not recommended since these containers may burst due to ice formation and freezing temperatures (Metropolitan Council, 2001). It is recommended that the rain barrels be disconnected from the roof gutters and placed indoors during the winter months. Downspout piping must be reconnected and directed to a grassy area away from the structure to prevent winter snowmelt from damaging building foundations.*

RAIN WATER HARVEST & RECYCLING CASE STUDY

Rain Water Harvesting, Rochester NY

PROJECT DATA

Monroe County Crime Lab
85 W Broad St, Rochester, NY 14614

1500 square foot storage tank
Total project runoff reduction:
34,882 gallons during a 2 year storm
Project Cost: Not Available

PROJECT DESCRIPTION

A 1500 gallon storage tank is used to collect water from roof of the crime lab building, which will be used to supply water closets and several exterior hose bibs. The tank is sized based on the anticipated catchment area of rainwater from the National Weather Service, and building water usage. The Monroe County Crime Lab is a LEED Platinum building.

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

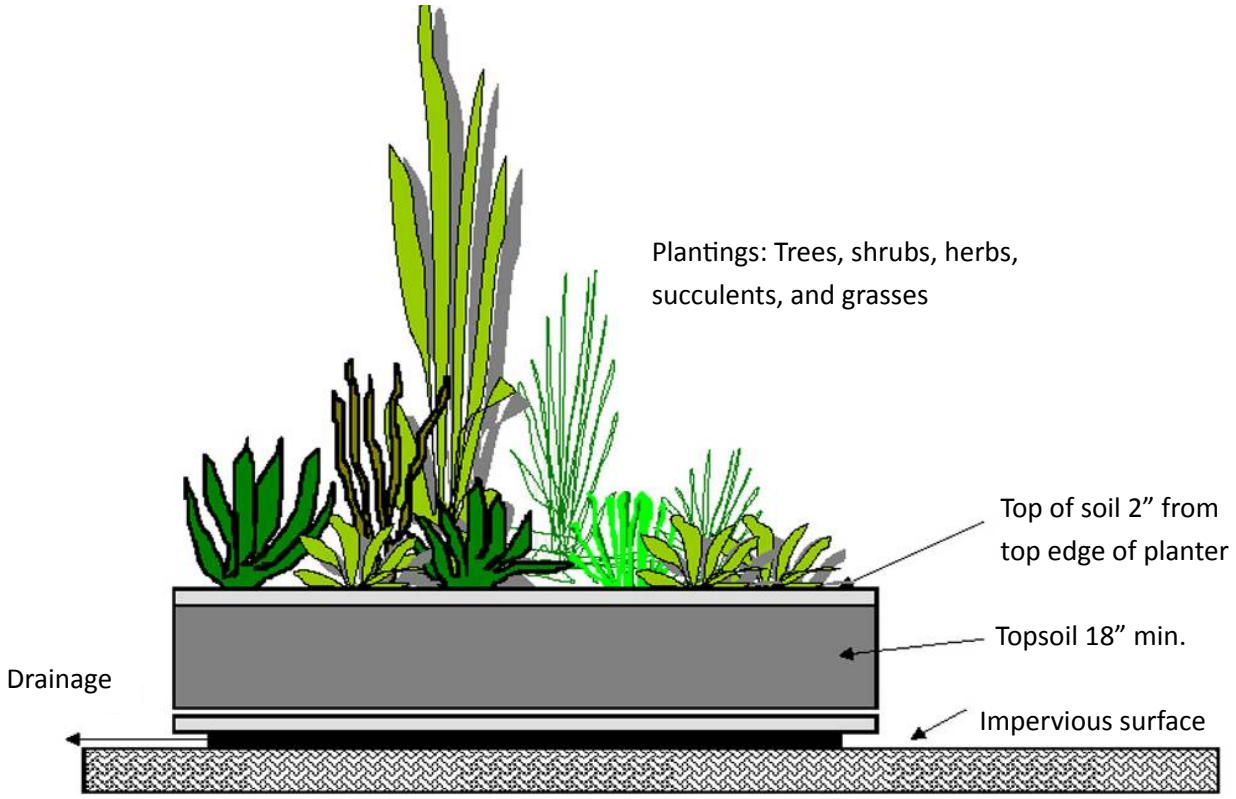
3.1.8 - STORMWATER PLANTERS

DESCRIPTION

Small landscaped stormwater treatment devices that can be designed as infiltration or filtering practices. Stormwater planters use soil infiltration and biogeochemical processes to decrease stormwater quantity and improve water quality.

RECOMMENDED APPLICATIONS

The versatility of stormwater planters makes them uniquely suited for urban redevelopment sites. Depending on the type, they can be placed adjacent to buildings, on terraces or rooftops. Building downspouts can be placed directly into infiltration or flow-through planters; whereas contained planters are designed to capture rainwater, essentially decreasing the site impervious area. The infiltration and adsorption properties of stormwater planters make them well suited to treat common pollutants found in rooftop runoff, such as nutrients, sediment and dust, and bacteria found in bird feces. Stormwater planters are most effective at treating small storm events because of their comparatively small individual treatment capacity.

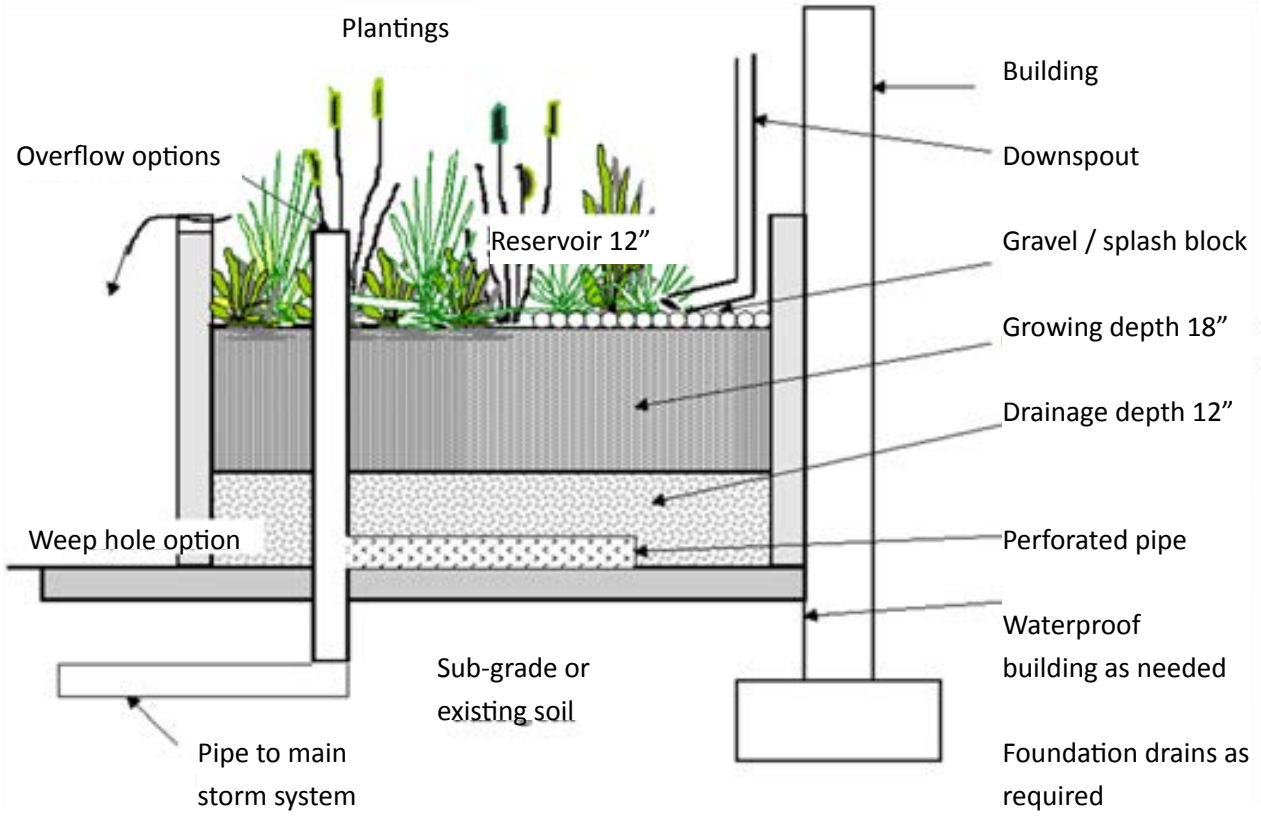


Section of Stormwater Planter from NYS SMDM

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

Stormwater Planter, Henrietta NY

STANDARD DESIGN REQUIREMENTS



Section of Infiltration Stormwater Planter from NYS SMDM

Stormwater Planter, Henrietta NY

STANDARD DESIGN REQUIREMENTS

- *Flow-through and infiltration stormwater planters should not receive drainage from impervious areas greater than 15,000 square feet.*
- *Infiltration planters should be located a minimum distance of ten feet from structures.*
- *To prevent erosion, splash rocks should be placed below downspouts or where stormwater enters the planter.*
- *Stormwater planters should be designed to pond water for less than 12 hours, with a maximum ponding depth of 12 inches.*
- *An overflow control should redirect high flows to the storm drain system or an alternative treatment facility.*
- *Generally, flow-though and infiltration planters should have a minimum width of 1.5 and 2.5 feet, respectively.*
- *Soil specifications for the stormwater planter growing medium should allow an infiltration rate of 2 inches per hour, and 5 inches an hour for the drainage layer.*
- *Soil compaction must be no greater than 85% in the planter.*
- *The growing medium depth for all three stormwater planter types should be at least 18 inches.*
- *Growing media should be a uniform mixture of 70% sand and 30% topsoil with an average of 5% organic material, such as compost or peat, free of stones, roots and woody debris and animal waste.*
- *For infiltration and flow-through planters the drainage layer should have a minimum depth of 12 inches. Drainage layer should be clean sand with 100% passing the 1-inch sieve and 5% passing the No. 200 sieve.*

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *The infiltration rate of the native soil should be a minimum of 2 inches per hour.*
- *A minimum infiltration depth of 3 feet should be provided between the bottom of the infiltration practice and any impermeable boundaries, such as the seasonal high groundwater level or rock.*
- *Infiltration planters should also be designed and constructed with no longitudinal or lateral slope.*
- *Materials suitable for planter wall construction include stone, concrete, brick, clay, plastic, wood, or other durable material.*
- *Treated wood may leach toxic chemicals and contaminate stormwater, and should not be used.*
- *Flow-through planter walls can be incorporated into a building foundation, with detailed specifications for planter waterproofing.*

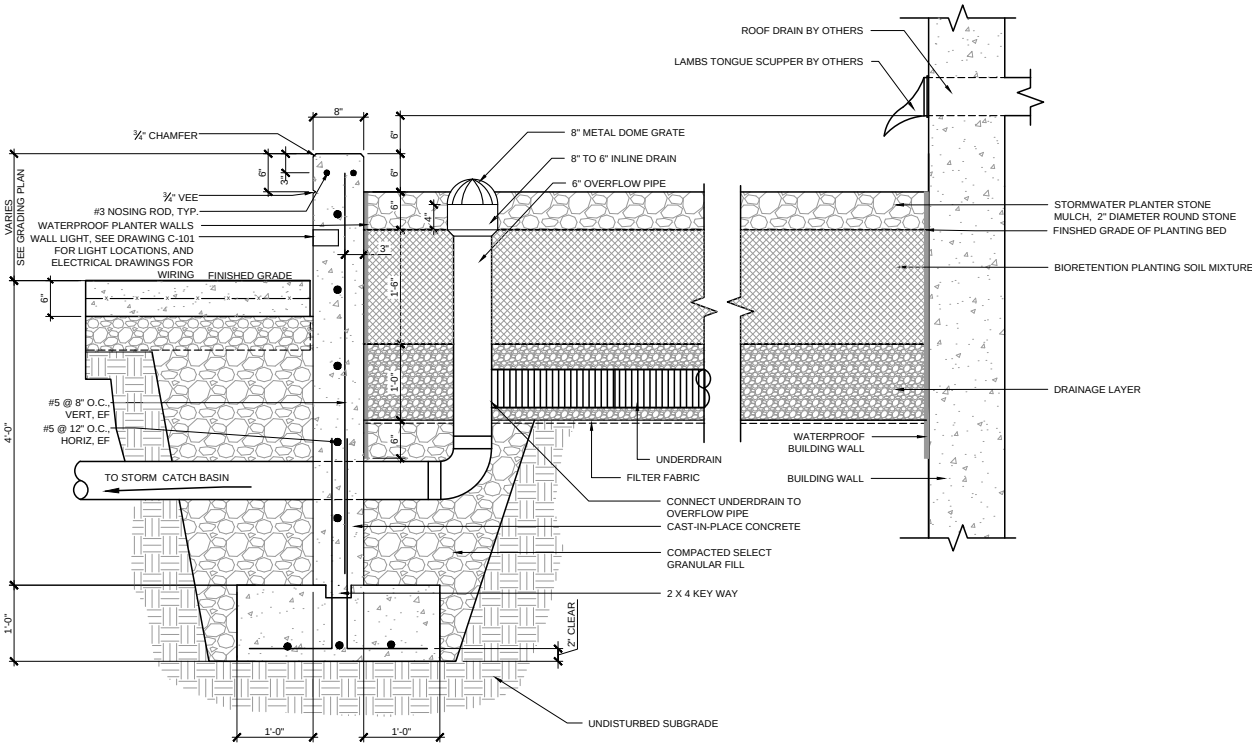
RETROFIT CONSIDERATIONS

- Make certain to protect building structures adjacent to planters with waterproofing.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- There are many different options for stormwater planters, some of which may be more susceptible to damage from freeze-thaw cycles. Consider how different types of planters could be impacted by winter weather before selecting a GI practice.

STORMWATER PLANTER CASE STUDY



12 C-604 STORMWATER PLANTER
Scale: 1" = 1'-0"

PROJECT DESCRIPTION

The 135,000 SF LEED Gold certified facility provides 4000+ seats, and is home to the RIT Men and Women's Division 1 hockey teams. The site design for the Gene Polisseni Center (GPC) integrates GI with active transportation and low-impact development strategies. Stormwater planters have been provided to capture and treat roof run-off. Site design of the GPC reflects the innovation goals of RIT and enhances the overall sustainability, quality, and visual character of the campus.

PROJECT DATA

Rochester Institute of Technology
Gene Polisseni Center
51 Lomb Memorial Dr, Rochester, NY 14623

Total Project Cost: Not Available

LESSONS LEARNED

Numerous disciplines collaborated on this project from beginning to end. Architects incorporated roof runoff into the design – and landscape architects designed a stormwater planter to capture/harvest rainwater. Early collaboration can present additional opportunities for creative stormwater management.

Tufted Hair Grass

Blue Oat Grass

Dwarf Fountain Grass

STORMWATER PLANTER SAMPLE PLANTING PLAN

BOTANICAL NAME	*COMMON NAME*	*SIZE*	*ROOT*	*COMMENTS*
DESCHAMPSIA CESPITOSA	TUFTED HAIR GRASS	1 GAL.	CONT.	18” O.C.
HELICTOTRICHON SEMPERVIRENS	BLUE OAT GRASS	1 GAL.	CONT.	18” O.C.
PENNISETUM ALOPECUROIDES ‘HAMELN’	DWARF FOUNTAIN GRASS	1 GAL.	CONT.	18” O.C.

ABBREVIATIONS:
GAL - Gallon
CONT - Container
O.C. - On center

Stormwater Planter, Henrietta NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.9 - GREEN ROOFS

DESCRIPTION

Capture runoff by a layer of vegetation and soil installed on top of a conventional flat or sloped roof. The rooftop vegetation allows evaporation and evapotranspiration processes to reduce volume and discharge rate of runoff.

Green roofs are divided into intensive and extensive systems. **Extensive green roofs** have shallower soil and support a smaller range of plants - generally a combination of sedums and perennials. Extensive green roof soil depths range from 3-6 inches.

Intensive green roofs, sometimes called **rooftop gardens,** have deeper soil and, depending on soil depth, may support a large range of plant types including trees. Intensive green roof soil depths range from 6-24 inches. Intensive green roofs are sometimes accessible to visitors for recreation.

Extensive Green Roof, Rochester NY

RECOMMENDED APPLICATIONS

- Green roofs are most effective in areas with a large percentage of rooftop coverage such as commercial, industrial, and multi-family housing.
- *Green roofs can be installed on flat roofs or on roofs with slopes up to 30% provided special strapping and erosion control devices are used. Generally, extensive green roofs can be built on flat or sloped roofs; whereas intensive systems are built on flat or tiered roofs.*

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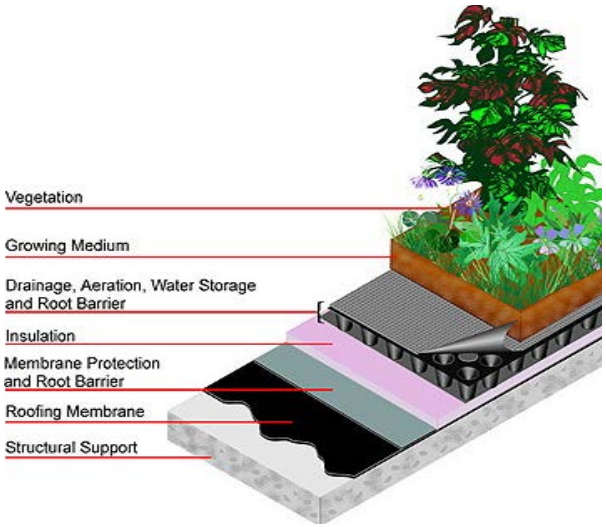


http://www.uwm.edu/Dept/GLWI/ecoli/Green roof/images/greenroofcom.jpg

from NYS SMDM

STANDARD DESIGN REQUIREMENTS

A green roof has five components: a roof structure, waterproofing, a drainage system, soil, and plant material.

- *Green roofs weighing more than 17 pounds per square foot (saturated) require consultation with a structural engineer.*
- *For fire safety non-vegetative materials should be installed around all rooftop openings and at the base of all walls that contain openings.*
- *The first layer above the roof surface is a waterproofing membrane. Two common materials for waterproofing are monolithic and thermoplastic sheet membranes.*
- *The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media.*
- *Soils are generally lighter than standard soil mixtures, and consist of 75% mineral and 25% organic material, without clay size particles. The porosity of the soil layer should be greater than or equal to 15%.*
- Plants suitable to use on green roofs are limited by high winds, drought, and low winter temperatures.
- *A qualified botanist or landscape architect should be consulted when choosing plant material.*
- Native plants may be selected for low maintenance and benefits for local wildlife.
- Alpine species may be selected for tolerance of more extreme conditions including limited soil depth, high temperature variation and drought tolerance.
- *Both a structural engineer and an experienced installer are required for the design and installation of intensive green roof systems.*

Green Roof, Rochester NY

"A green roof can have up to twice the lifespan of a conventional roof, making the long-term cost of the two comparable."

EPA Green Infrastructure Municipal Handbook

Retrofit Policy Guidelines

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *Once the waterproofing has been installed, it should be tested fully prior to the construction of a drainage system.*
- Green roof maintenance may include watering, fertilizing, and weeding, and is typically greatest in the first two years as plants become established.
- For successful establishment, watering of plants should begin during the construction phase.
- *After establishment maintenance consists of two visits per year for weeding of invasive species, and safety and membrane inspections.*

RETROFIT CONSIDERATIONS

- Extensive green roofs may be better candidates for retrofits because the increase in weight load (16-50 pounds per square foot) is more likely to be compatible with an existing structure than an intensive green roof (up to 200 pounds per square foot).
- When calculating the additional weight load of the green roof, it is important to assume full soil saturation.
- Buildings with shallow or flat roofs are better candidates for green roof retrofits, though green roofs with a slope of up to 30% have been successfully created. Roofs with some slope may provide a larger number of niches and add to the potential biodiversity of the site.
- Rooftops that need replacement and sites with a large percentage of impervious cover are especially good candidates for retrofit.

RETROFIT CONSIDERATIONS (CONTINUED)

- Ensure sufficient accessibility and safety measures are in place as required for maintenance teams, and installation.
- Confirm that adequate drainage is in place to safely convey larger rainfall events.
- Before using an existing waterproofing membrane, it is important to confirm that the manufacturer is willing to warrant use of the membrane with a green roof.

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- Plants in the ground are insulated from temperature extremes. Plants used on a green roof must be especially tolerant of temperature fluctuations. See **Appendix 8 Recommended Plants for GI Practices,** for more information.

Green Roof, Rochester NY

GREEN ROOF CASE STUDY

Green Roof, Rochester NY

PROJECT DATA

Rochester City Hall Green Roof
30 Church St, Rochester, NY 14614

8,700 Square feet
Project Cost: $246,868

- Consists of specially manufactured growing medium and sedum plants installed over an existing rooftop waterproofing system.
- The installation reused materials on the existing roof.
- A filter fabric remains in place as part of the drainage layer.
- The gravel ballast, the layer of gravel used to keep the roof material down in the wind, now supports the perimeter of the growing media.

PROJECT DESCRIPTION

This green roof consists of manufactured layers of waterproofing, drainage, soil or growing media, and then vegetation. Of the various types of green roofs being designed today, the City of Rochester's green roof is an "extensive" green roof, meaning it requires minimal maintenance, using plants selected for their self-sustaining capabilities. While this particular roof is not meant for visiting except to perform limited maintenance, it is still a spectacular sight from the sky and a model of sustainability to be replicated by other owners of large vacant roof spaces.

LESSONS LEARNED

The thick carpet of sedum on the City's green roof reduces stormwater up to 90%, minimizing the impact on the combined sewer system and reducing system overflows during "peak flow" rainfall into the watershed and reducing the amount of pollutants that flow into the region's streams, rivers and lakes.

Green Roof, Syracuse NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.10 - STREAM DAYLIGHTING

DESCRIPTION

Stream daylighting involves uncovering a stream or a section of a stream that had been artificially enclosed in the past to accommodate development. The original enclosure of rivers and streams often took place in urbanized areas through the use of large culvert operations that often integrated the storm sewer system and combined sanitary sewers. The daylighting operation, therefore, often must include overhaul or updating of storm-drain systems and re-establishing stream banks where culverts once existed. Stream daylighting converts what once was a linear pipe of heavily polluted water to a open-air stream channel with a vegetated riparian buffer, functional (albeit usually limited) floodplain, and quality in-stream habitat. Stream daylighting provides dramatic improvements to a range of functions and values associated with a stable stream resource, including flood mitigation, aesthetics, habitats and water quality. When restored to a natural stream system, stream daylighting can often lead to increased property value.

Stream Daylighting, Columbia County NY

RECOMMENDED APPLICATIONS

- *Consider daylighting when a culvert replacement is scheduled.*
- *Restore historic drainage patterns by removing closed drainage systems and constructing stabilized, vegetated streams.*
- *Carefully examine flooding potential, utility impacts and/or prior contaminated sites.*
- *Consider runoff pretreatment and erosion potential of restored streams/rivers.*
- Consider stream daylighting in association with open-space / aesthetic improvements in public settings such as parks.

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

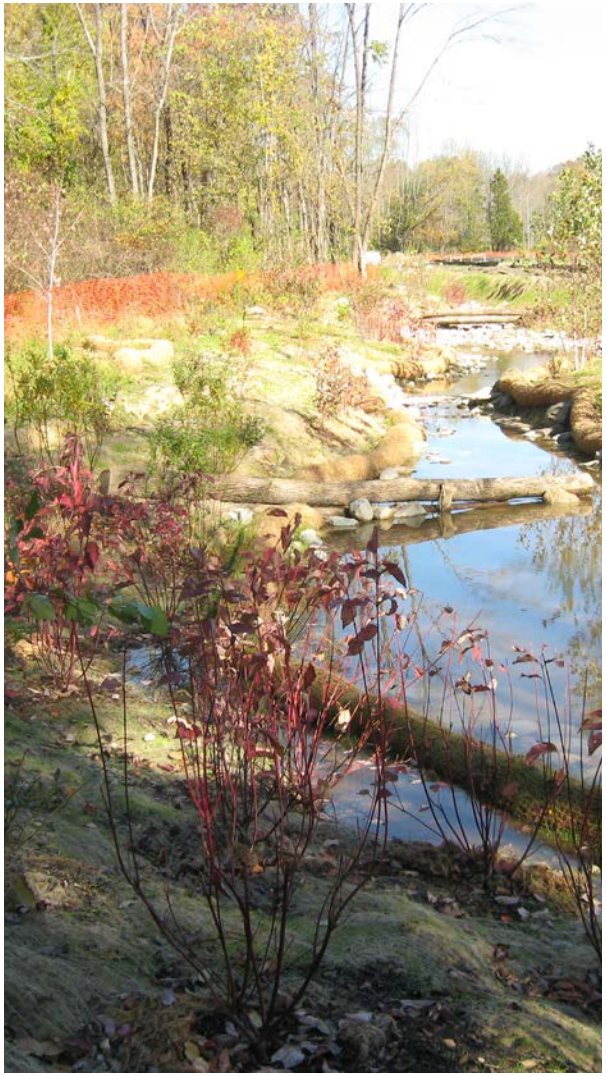
Stream Daylighting, Westchester County NY

RECOMMENDED APPLICATIONS (CONTINUED)

- Stream daylighting can be utilized in unison with natural channel design-based stream restoration to stabilize stream-banks. This helps to reduce discharges of pollutant-laden sediments to the receiving stream system.
- Culverts often represent physical barriers to the movement of fish and other aquatic organisms through the stream system. Stream daylighting can be used to reconnect fragmented segments of stream habitat to promote aquatic organism passage.
- Undersized culverts typically restrict conveyance of water, elevating flood hazards associated with both upstream backwater and downstream velocity increases. Daylighting a culvert to restore appropriate channel cross-section (including over-bank floodplain) can reduce flood velocity and floodwater elevations, as well as promote groundwater infiltration / recharge.

STANDARD DESIGN REQUIREMENTS

- *The sizing of the stream channel must, at minimum, equal or exceed the existing drainage capacity of the piped drainage system.*
- The stable physical form of a stream channel is directly dependent upon a variety of influencing factors within the contributing watershed. Where adequate open space exists to accommodate the approach, natural channel design methodology should be utilized to ensure adequate sizing of the restored stream channel and its floodplain. This methodology also ensures that stable geomorphic parameters (planform, cross-section, slope, profile, frequency and spacing of riffle and pools, etc. consistent with the stream setting are included in the design.



Stream Daylighting, Dutchess County NY

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- Where sufficient open space exists, adequate floodplain should be incorporated into the daylighting design. Establishment of native-vegetated riparian buffers within the floodplain (and beyond, if achievable) enhances the water quality, habitat, and aesthetic benefits of the project.
- *Where combined sewer overflow (CSO) separation and other upgrades to storm-sewer systems are part of a daylighting project, significant water-quality improvements can be expected during wet-weather events.*
- *Because ultraviolet radiation is one of the most effective ways to eliminate pathogens in water, exposing daylighted streams to sunlight could significantly decrease pathogen counts in the surface water.*

RETROFIT CONSIDERATIONS

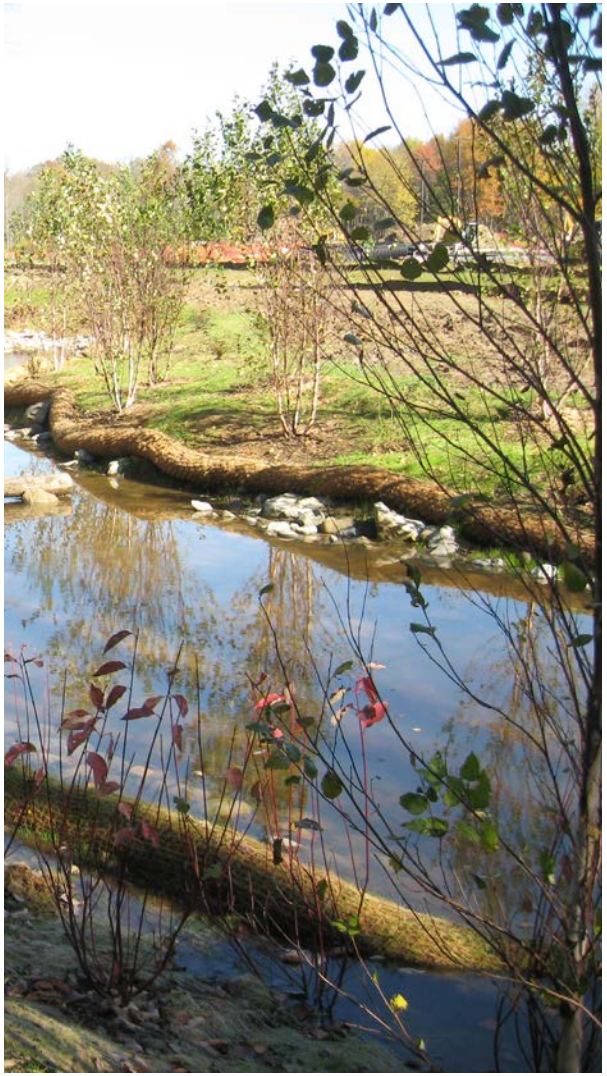
- *Stream daylighting is generally applied most successfully to sites with considerable open or otherwise vacant space. If the site is too small to accommodate a properly-sized and aligned stream channel and floodplain, the benefits of the approach are significantly diminished, and may not justify the project cost.*
- In developed (i.e. urban / suburban) settings, adequate grade control measures should be incorporated into the stream daylighting design in order to reduce the risk of stream-bed scour and channel incision / entrenchment.
- In developed settings, replacement of the restored stream channel back into its historic location may no longer be the most stable configuration. Again, the natural channel design methodology should be utilized to determine stable geomorphic parameters for the restored channel.

RETROFIT CONSIDERATIONS (CONTINUED)

- In settings where stream-flow is primarily a function of stormwater discharge from a piped (closed) drainage system, considering supplemental stormwater controls to reduce the rate and intensity of runoff to the stream will reduce 'flashiness' of the channel and provide additional benefits to habitat and water quality.
- Stream daylighting and the associated restoration of a functional stream channel segment require short-term monitoring and maintenance to maximize long-term success of the project. Stream daylighting plans should include a post-construction monitoring and maintenance plan.

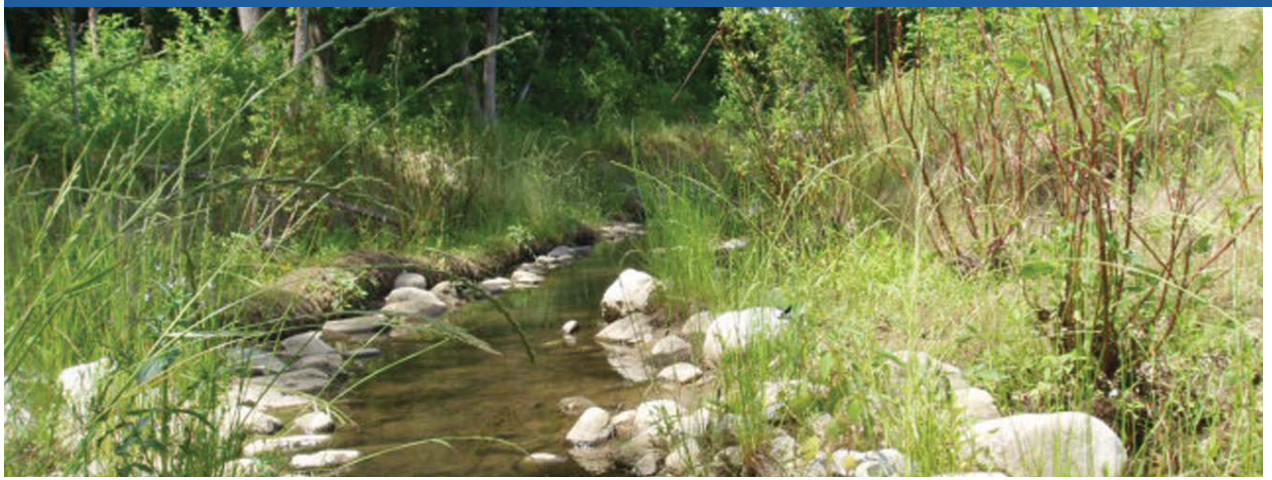
LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- When considering a stream daylighting project, subsurface soil conditions should be assessed to determine feasibility of reconnecting the stream channel with the adjacent groundwater table, and to ascertain the potential for reestablishment of native vegetation along the restored stream-banks and floodplain. Soil amendments may be necessary.
- When developing a floodplain planting plan to accompany the stream daylighting, only locally-native plant species should be utilized. A number of vendors are available that can supply plant species native to the greater Monroe County region.



Stream Daylighting, Dutchess County NY

STREAM DAYLIGHTING CASE STUDY



Stream Daylighting, Dutchess County NY

PROJECT DESCRIPTION

The multi-faceted stormwater management plan implemented during redevelopment of the Taconic Regional Headquarters of NYS Office of Parks, Recreation, and Historic Preservation located in Staatsburg, New York included daylighting and restoration of approximately 600 linear feet of an unnamed tributary to Indian Kill Creek previously passing through an underground culvert.

The daylighted stream segment was stabilized by integrating natural channel design methodology to ensure long-term stable function, creation of reconnected floodplains to provide adequate conveyance of over-bank flows, and reestablishment of high-quality in-stream and riparian habitats.

By supporting the stream daylighting project with additional stormwater controls, excessive flooding events farther downstream have been mitigated, stability and performance of the recreated stream channel have been greatly enhanced, and aesthetic and ecological values associated with the stream and adjacent floodplains and riparian corridor are vastly improved. This project is registered with the U.S. Green Building Council (USGBC) and earned a LEED Platinum certification.

PROJECT DATA

Stream Daylighting and Stormwater Management, Taconic Regional Headquarters Renovation

NYS Office of Parks, Recreation and Historic Preservation's Taconic Regional Headquarters in Staatsburg, New York

Approximate construction cost: $190,000

LESSONS LEARNED

- The most critical aspect of the construction phase of a stream daylighting project is restoration of the stream channel following culvert removal. Installation of a natural channel design project is not a standardized construction practice. Having a qualified contractor who is familiar with the concepts of natural channel design greatly improves the chances of building a successful stream restoration project.
- On-site inspection should be provided by a professional experienced in natural channel design and familiar with the specific design being implemented.

Stream Daylighting, Westchester County NY

REFERENCES

All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

See end of Chapter 3 for a full list of references and website addresses.

STANDARD DESIGN AND SIZING REQUIREMENTS

New York State Stormwater Management Design Manual

Department of Environmental Conservation.

COLD CLIMATE CONSIDERATIONS

Stormwater BMP Design Supplement for Cold Climates

Environmental Protection Agency.

PLANT SELECTION FACTORS

USDA Hardiness Zone Map

United States Department of Agriculture

MAINTENANCE CONSIDERATIONS

Maintenance Guidance for Stormwater Management Practices

Department of Environmental Conservation.

ADDITIONAL RETROFIT CONSIDERATIONS

Urban Stormwater Retrofit Practices

Center for Watershed Protection.

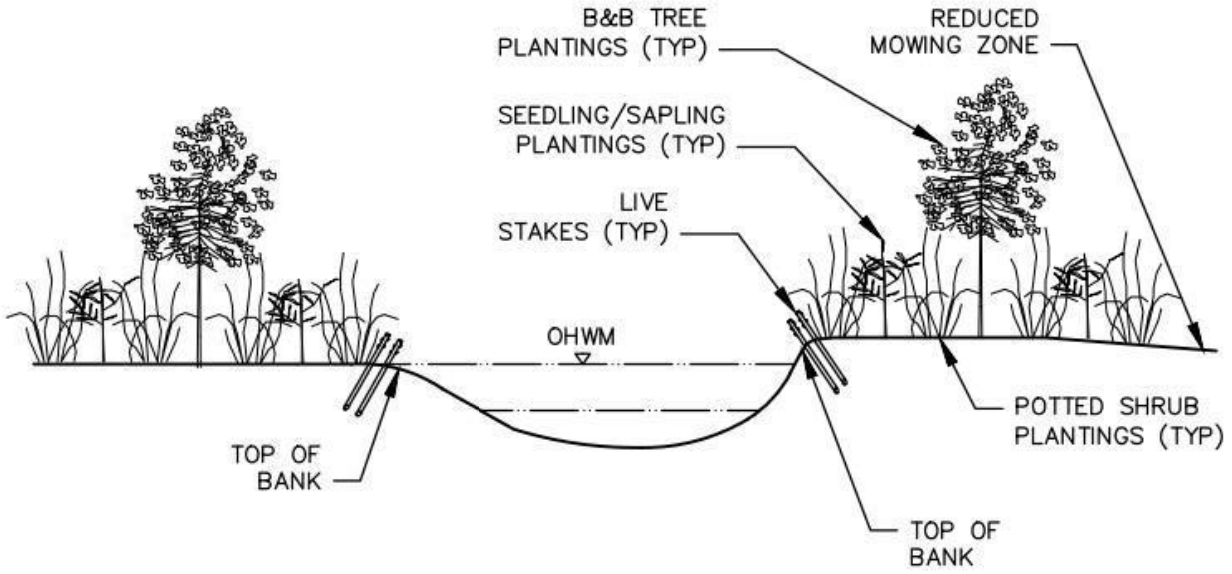
Stormwater Retrofit Guidance Manual

Philadelphia Water

3.1.11 - STREAM BUFFER RESTORATION

DESCRIPTION

Riparian buffers are naturally-vegetated areas which serve as the transition zone between terrestrial (land) and aquatic (water) habitats. If sufficiently structured, protected, and maintained, riparian buffers serve to mitigate the volume and intensity of stormwater runoff entering the adjacent waterbody, and can act to mitigate the discharge of pollutants to the waterway often associated with stormwater runoff. Healthy riparian buffers provide a range of benefits in addition to water quality, including reduced flood hazards, improved stream-bank stability, enhancement of in stream and stream-side habitats, aesthetics, and opportunities for recreation and environmental education, outreach and stewardship.



Riparian Buffer Section

RECOMMENDED APPLICATIONS

- *Delineate and preserve naturally-vegetated riparian buffers where they already exist*
- Utilize grading and siting/disturbance plans that minimize proximity of disturbance and development to adjacent water resources.

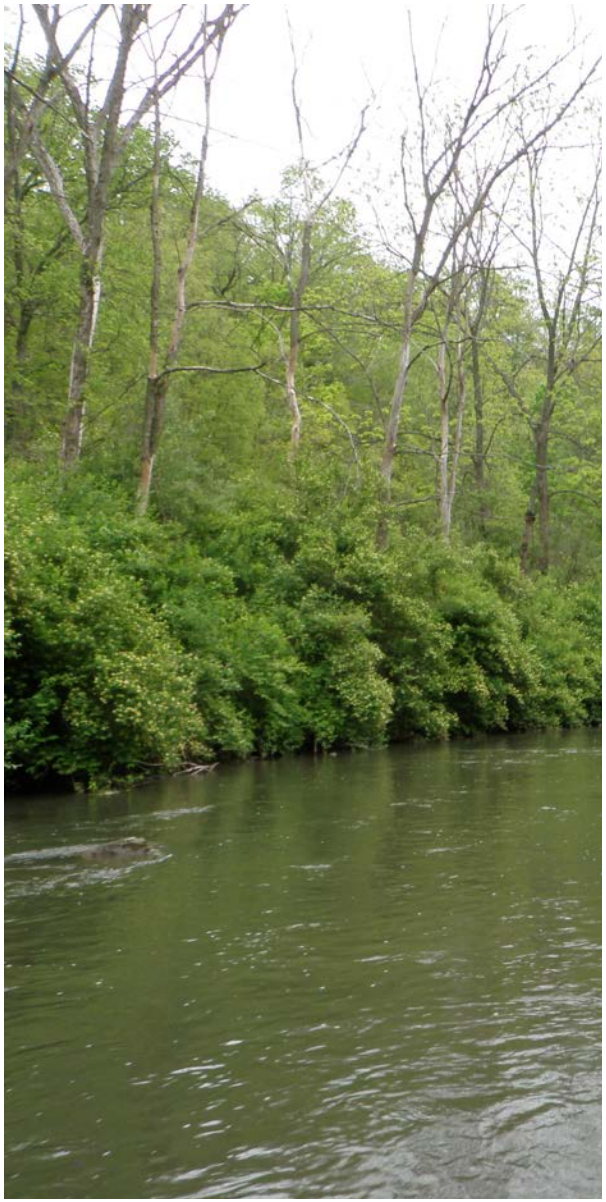
All text in this font style and color is quoted from the NYS Stormwater Management Design Manual.

RECOMMENDED APPLICATIONS CONTINUED

- *Define the buffer width, identify target vegetation, and designate methods to preserve the buffer indefinitely* (incorporate riparian buffer preservation/establishment components into site development plan requirements).
- *Ensure buffers and native vegetation are protected throughout planning, design, construction and occupancy* (promote conservation easements or deed restrictions to protect buffers post-development).
- *Consult local planning authorities for wetland and stream regulations or guidelines for more stringent buffer widths. The buffer width needed to perform properly will depend on stream size and surrounding conditions.*
- Maximize riparian buffer width and structure in areas containing or adjacent to high-quality or unique habitats, or offering prime educational outreach potential (projects near schools, public properties, parks, etc.).
- Promote continuity of riparian buffers along waterways across multiple development sites, establishing robust corridors for wildlife passage and reducing the risk of habitat fragmentation.

STANDARD DESIGN REQUIREMENTS

- Healthy riparian buffers should be comprised of regionally-native plant species. Management plans developed for riparian buffers should include measures for the delineation and removal of invasive, noxious, and non-native species, and should include considerations for long-term monitoring and maintenance to address reestablishment of these species.
- *The riparian buffer should be comprised of a range of native plant species and age classes to occupy the herbaceous (ground cover), understory (young trees and shrubs), and over-story (mature trees) strata, or forest plant layers.*
- *A riparian buffer can be of fixed or variable width but should be continuous and not interrupted by impervious or disturbed areas. Where possible, riparian buffers should occupy, at minimum, the width of the 100-year floodplain.*
- *Riparian buffers should incorporate three zones: Stream-side Zone, Middle Zone, and Outer Zone.*
- *The Stream-side Zone should be a minimum of 25 feet wide, measured outward from the edge of the stream. The width of this Zone should be maximized where possible, incorporating any wetlands or unique habitats present. Total appropriate width of the Stream-side Zone is determined by the size of the adjacent water body and other influencing local conditions.*
- Because of its location within the high velocity flood zone, the Stream-side Zone should be dominated by herbaceous plants, forbs, shrub and tree species that are tolerant of frequent inundation and capable of surviving in frequently-moist soil conditions.
- *The Middle Zone serves as the core of the riparian buffer, and should be comprised of mature forest, providing for maximized filtration and retention of stormwater runoff between the developed site and the adjacent waterbody.*
- *The width of the Middle Zone should be a minimum of 25 feet, but should be maximized where possible.*



Healthy Stream Buffer

STANDARD DESIGN REQUIREMENTS (CONTINUED)

- *The Middle Zone can be utilized for light recreation activities, including hiking / biking trails.*
- With the addition of interpretive signage, trail networks can provide opportunities for education and outreach.
- The Middle Zone should be actively managed to maintain the desired age structure and species composition.
- The Outer Zone serves as a transition between the developed site and the functional portions of the riparian buffer.
- *At a minimum, the Outer Zone should provide a 25-foot offset to the disturbed / developed area, but this offset should be maximized where possible.*
- Preferred cover types in the Outer Zone include herbaceous forbs and grasses (i.e. a "no-mow" area) or shrubs and young trees (i.e. early successional forest habitat). *However, in many settings this Zone is occupied by residential lawns, stormwater control measures (BMPs), gardens, etc.*
- *Development within the riparian buffer should be limited only to those structures and facilities that are absolutely necessary. Such limited development should be specifically identified in any codes or ordinances enabling the buffers.*

RETROFIT CONSIDERATIONS

- The presence of native vegetation in close proximity to a waterbody provides a range of benefits. When retrofitting, buffers should be established where possible even if the minimum recommended zone or overall buffer widths cannot be achieved.

RETROFIT CONSIDERATIONS (CONTINUED)

- Soil conditions should be evaluated prior to installing riparian buffer plantings. Soil amendments may be necessary in order to bolster the establishment and vigor of planted materials. Ensure that no fertilizers or other amendments that may negatively affect water quality are utilized in areas where they are at risk of entering the adjacent waterway.
- In settings where potential riparian buffer width is limited, buffer establishment / enhancement should be coupled with other GI and stormwater management measures to maximize effectiveness.
- Riparian buffers not only provide water quality improvements, they also serve as habitats for desirable wildlife species (such as birds). When developing a riparian planting plan, include native species that offer additional value by way of wildlife cover and/or food (such as soft mast or berry-producing native trees and shrubs).
- The root depth and density of riparian plants adjacent to the stream (Stream-side Zone) play a significant role in maintaining stream-bank stability and resisting stream-bank erosion. Water quality benefits associated with riparian buffers are enhanced by a reduction in stream-bank erosion and corresponding inputs of sediment to the stream. When developing a riparian buffer planting plan, include native species that provide robust root depth and density in order to maximize this benefit.
- In urbanized settings, riparian buffers offer opportunities to manage stormwater, improve water quality, enhance aesthetics, establish habitat for wildlife, and provide environmental education, even at a small, localized scale. Elements such as utilities, access, traffic lines-of-sight, etc. must be considered when planning and installing riparian buffers in urbanized settings.
- All the benefits of riparian buffers are maximized when the buffer exists and functions in a “natural” state. This “unkempt” condition may generally not appeal to the public in some instances. Including an element of public outreach and education as part of the riparian buffer retrofit plan, particularly in areas that are more heavily developed, urbanized, or are actively maintained may be beneficial.

Healthy Stream Buffer

Healthy Stream Buffer

LOCAL CLIMATE AND ENVIRONMENTAL CONSIDERATIONS

- When developing a riparian planting plan, only locally-native plant species should be utilized. A number of vendors are available that can supply plant species native to the greater Monroe County region.
- The moisture preference / tolerance of the plant materials to be utilized must be considered when developing the planting plan. For example, plant species more suited to moist conditions can be prescribed within an active floodplain, whereas those that prosper in drier soil conditions can be assigned a more upland setting.
- As a general rule, seeding and planting is most effectively done in the early spring or in the fall, as both allow for vigorous plant establishment prior to the rigors of summer weather conditions.
- Seeding and planting riparian buffers in late spring may be preferential in areas routinely subjected to high flows and ice scour associated with spring snowmelt / runoff. Plant materials installed just prior to such an event are prone to damage or washout.
- In settings where heavy browsing of recently-planted materials by deer, livestock or other mammals is a potential risk, consider including requirements for protective measures such as tree tubes or fencing.
- Depending on the project setting, it may be necessary to limit or restrict access to newly-planted areas until native riparian vegetation becomes established.

STREAM BUFFER CASE STUDY

Black Creek Stream Mitigation Conceptual Rendering

PROJECT DESCRIPTION

The intent of the riparian buffer enhancement plan was to increase the width and composition of the existing riparian buffer, remove invasive species and replace with a more diverse suite of native vegetation types, establish three functional buffer zones, and prescribe measures to ensure long-term establishment and maintenance of a healthy, robust and functional riparian buffer. Being located within a County Park, the riparian buffer enhancement plan was developed in a manner to provide education and interpretive values while limiting conflicts with other popular Park uses. Aspects of the buffer enhancement were specifically-prescribed to address stormwater runoff entering the waterway from a residential neighborhood located just north of the Park / mitigation site.

PROJECT DATA

Stream Mitigation / Buffer Enhancement – UNT Black Creek
Village of Churchville, NY
Approximate construction cost: $125,000

LESSONS LEARNED

- Riparian buffers function most effectively when allowed to exist in a 'natural' state. Depending on the project setting, the public may strongly prefer a more maintained or 'manicured' aesthetic. Public education and outreach is a valuable tool at the outset of a proposed riparian buffer project to help bridge this gap.
- Establishing a functional riparian buffer in areas previously dominated by invasive plant species requires long-range planning. Planning for multiple removal efforts over several growing seasons at the outset of the project, along with routine monitoring and maintenance of the planted native buffer vegetation is key to success.

Healthy Stream Buffer

REFERENCES

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Center for Watershed Protection.

Stormwater Retrofit Guidance Manual

Philadelphia Water

3.2 - ADDITIONAL RETROFIT OPPORTUNITIES

Stormwater Wetland, Penfield NY

STRUCTURAL STORMWATER MANAGEMENT PRACTICES

The NYS SMDM describes the practices listed in Section 3.1 above as Green Infrastructure Practices. The Manual also provides guidelines for the following practices, which it describes as structural stormwater management practices.

These practices can provide many of the same benefits as the GI practices listed above because they are additional tools for addressing stormwater issues on a site by site basis. This can reduce the strain on large scale gray infrastructure, replenish local water tables, and address water quality issues.

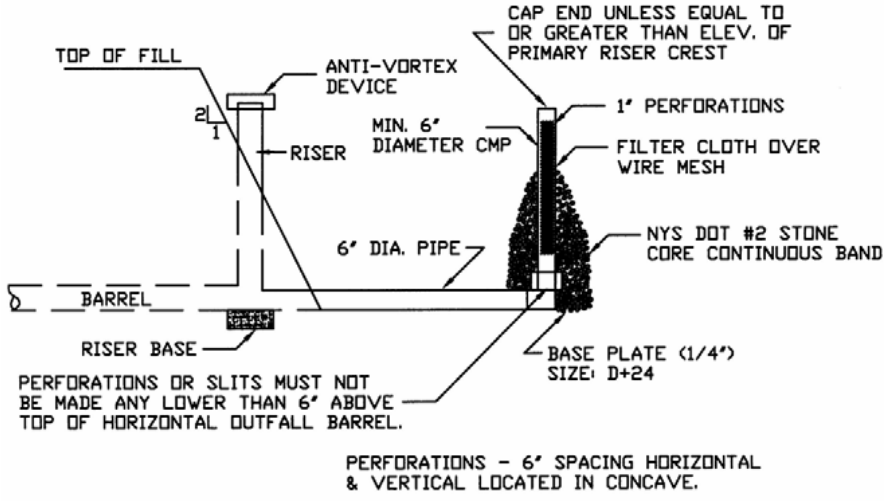
STORMWATER WETLANDS

Stormwater wetlands (a.k.a. constructed wetlands) are structural practices that incorporate wetland plants into the design to both store and treat runoff. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice (NYS SMDM). Wetlands can provide water quantity benefits including runoff reduction and channel protection. Wetlands also provide water quality benefits through plant nutrient uptake, along with providing habitat for wildlife.

STORMWATER PONDS

Stormwater ponds provide temporary storage of runoff to attenuate peak stormwater runoff rates. This attenuation can decrease localized flooding and instances of combined sewer overflows. Stormwater ponds can also provide a water quality benefit through deposition and nutrient removal from aquatic plant species.

Many existing stormwater ponds were only installed for flood control, so retrofit opportunities may exist to provide additional water quality treatment. Retrofit opportunities may include increasing detention time through outlet modifications, reconfigurations to the outlet structure including utilization of a skimmer dewatering device, revised grading, and adding vegetation (Philadelphia Stormwater Retrofit Guidance Manual).



Outlet Modification Dewatering Device
NYS Standards & Specifications for Erosion and Sediment Control

Stormwater Pond, Penfield NY

STORMWATER INFILTRATION

Infiltration is at the core of most GI practices. Standard practices included in the NYS SMDM include infiltration trenches and basins. Infiltration practices provide ideal retrofit opportunities assuming geotechnical and subsurface soil requirements are met. Typically infiltration practices are equipped with pretreatment to provide additional water quality benefits.

Subsurface Infiltration

STORMWATER FILTRATION

Stormwater filters are utilized primarily as a water quality treatment practice from small impervious areas that may be hotspots for water quality contaminants. They are a good retrofit option for areas that have limited space, where they can be used off-line (i.e. not part of the larger stormwater conveyance system). The NYS SMDM includes several variations including Surface Sand Filters, Underground Sand Filters, Perimeter Sand Filters and Organic Filters.

OPEN CHANNELS

Open channels include vegetated systems that are designed and constructed to capture and treat stormwater runoff within dry or wet channels. Dry swales are similar to linear bioretention cells and wet swales function as linear wetlands. Retrofit opportunities include modifications to existing channels including widening, deepening, and reducing the gradient. Typical retrofit situations include treatment from residential streets and parking lots.

UNDERGROUND STORAGE

Underground storage systems serve as subsurface detention basins primarily for water quantity (attenuation) control. They are most applicable for retrofit opportunities within high-density urban areas where develop-able footprint space is at a premium. They can consist of arched structures, chambers, vaults or large diameter pipes. They can also provide infiltration benefits in areas where permeable subsoils are present.

3.3 - NYS STORMWATER MANAGEMENT DESIGN MANUAL REDEVELOPMENT ACTIVITIES

Because the NYS SMDM requirements were "primarily intended for new development projects", there are different requirements for redevelopment projects. These are listed in Chapter 9 of the NYS SMDM.

There are four options for water quality improvements for redevelopment projects within the NYS SMDM.

1. Reduction of existing impervious cover by a minimum of 25% of the total disturbed impervious area.

This option allows developers to manage stormwater by increasing the amount of pervious area on site. Site grading should direct water toward pervious areas.

2. 25% of water quality volume (WQv) from the disturbed, impervious area is captured and treated by the implementation of standards SMPs or reduced by the application of GI techniques.

This option allows developers to use standard SMPs (such as stormwater wetlands and open channels, see Section 3.2 Additional Retrofit Practices) and GI (see Section 3.1) to manage stormwater. The 25% requirement is less than a typical non-retrofit project.

3. 75% of WQv from the disturbed, impervious area captured and treated using alternative SMPs.

This option allows for new and innovative practices in retrofit settings. This is an opportunity to test new methods of managing stormwater. See Section 3.4, Hybrid Practices and Emerging Technologies, for more information.

4. A combination of the practices above.

Redevelopment activities can range from large-scale redevelopment (e.g. reconstruction of a box store, mall, etc.), to much smaller building, parking lot or road reconstruction project. The proposed density of the large-scale projects can be high, resulting in space constraints to implement on-site stormwater controls. Added to this basic space constraint is the need to tie in to the existing drainage infrastructure, which may be at an elevation that does not provide enough head for certain stormwater management practices (SMPs). Other problems encountered in redevelopment include the presence of underground utilities, incompatible surrounding land uses, highly compacted soils that are not suitable for infiltration, and contaminated soils that require mitigation and can drive up project costs.

3.4 - HYBRID PRACTICES AND EMERGING TECHNOLOGIES

GREEN INFRASTRUCTURE IS STILL DEVELOPING

New technologies are changing how we design and construct GI practices. These developments vary in scale. Some are small refinements of existing products, such as incorporating mineral fibers or recycled materials into porous pavements. Over time, these small refinements could lead to GI practices that are more durable, more effective, and easier to install and maintain. In addition, there are also brand new GI systems being explored, such as floating wetlands. As GI technologies evolve, Monroe County has the chance to test and compare these and other potential improvements to GI systems, in order to develop a distinct approach to stormwater management based on local conditions. Following are a few of the many new developments occurring in GI today.

STORMWATER PRETREATMENT TECHNOLOGIES

Where space is at a premium using GI to treat stormwater can be challenging. Systems such as bioretention and stormwater planters have a limited capacity to treat stormwater based on their scale. Additional volumes of water beyond the design storm are generally directed back into the gray infrastructure network without treatment.

Several companies have developed modular pretreatment systems, to be used together with GI practices to further improve water quality and to increase the water cleaning and storage capacity of limited spaces. Many of these technologies trap debris and sediment before it enters planted GI systems, significantly reducing the need for maintenance and improving the appearance of GI projects. In addition, these hybrid practices remove pollutants from stormwater before it enters the GI practice, increasing the overall effectiveness of the practice.

Manufactured treatment systems are often attractive during redevelopment activities because they tend to take up little space, often installed underground, and can usually be retrofitted to existing infrastructure.

ALTERNATIVE PHOSPHORUS TREATMENTS

Because phosphorus is often the limiting nutrient in water bodies, controlling phosphorus levels can have an enormous impact on water quality. Though there is no total maximum daily load for phosphorus in the Genesee Watershed, Lake Ontario has elevated phosphorus levels. In addition, the Genesee River is the primary contributor to phosphorus levels within Lake Ontario.

As a result, Monroe County has a unique opportunity to have a tremendous impact on the water quality of Lake Ontario.

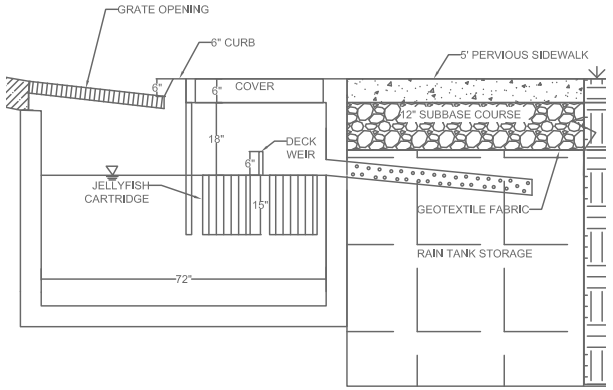
Many of the GI practices listed within this retrofit manual can reduce total phosphorus loads, but not all. Some practices such as green roofs and bioretention type practices, could actually contribute phosphorus to Stormwater runoff. The dissolved portion of Total Phosphorus, which accounts for roughly half of the phosphorus load in stormwater, is more difficult to reduce. Biological techniques are sometimes used to remove phosphorus from stormwater, but these techniques can be less effective during winter months. See **Appendix 1, Pollutant Removal Efficiencies of Green Infrastructure Practices**, for more information.

Alternative treatments which adsorb dissolved phosphorus can be incorporated into other GI practices, such as permeable pavements or tree planting projects. These treatments include proprietary technologies such as Sorbtive Media , which is an "activated" filter matrix that chemically extracts phosphorus and thus enhances pollutant removal.

Because of increasing standards for water quality and phosphorus reduction, and Monroe County's critical position as a steward of Lake Ontario, opportunities to incorporate alternative phosphorus treatments into GI practices should be considered.

Advances in phosphorus treatment technologies have recently become available and better understood, providing the ability to capture high levels of both particulate-bound and dissolved phosphorus. Amending both conventional BMPs and LID applications with engineered solutions offers increased ability to achieve existing and future phosphorus based TMDLs.

Urban Stormwater Runoff Phosphorus Loading and BMP Treatment Capabilities



Hybrid Filter Detail

KEY:

① 6" CURB LINE
② CURB OPENING
③ ACCESS COVER
④ BACK WASH WEIR
⑤ CARTRIDGE
⑥ OPEN BACK INLET TO ALLOW FLOW TO BIORETENTION
⑦ OBSERVATION WELL
⑧ RIP RAP, PLACED COBBLES, AND OR TURF REINFORCEMENT
⑨ PERFORATED PVC
⑩ WASHED STONE
⑪ UNDISTURBED SOIL
⑫ PLANTING MEDIA

VEGETATION AND TREE BENEFITS:

- VOLUME REDUCTION BY EVAPOTRANSPIRATION
- VOLUME REDUCTION BY INFILATRATION
- STORMWATER INTERCEPTION
- PHYTOREMEDIATION OF CONTAMINATED SOIL AND WATER
- REDUCTION IN ATMOSPHERIC CARBON
- AIR QUALITY BENEFITS
- ENHANCED ECOSYSTEM SERVICES
- INCREASED CANOPY COVER, REDUCTION OF HEAT ISLAND EFFECT
- IMPROVED AESTHETIC AND PROPERTY VALUES

BIORETENTION SYSTEM WITH PRETREATMENT CHAMBER

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Hybrid GI System

Bioretention, Brighton NY

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Permeable Pavement, Brighton NY

4.0 CONSTRUCTION

Gallons of Stormwater Managed / $1,000 Invested

Stormwater Control	*Gallons Managed / $1,000 Invested*
Conventional Storage Tanks	2,400
Green-street	14,800
Street Trees	13,170
Green roof	810
Rain Barrel	9,000

The Economics of Low Impact Development: A Literature Review

See **Appendix 7**, Construction and Maintenance Costs, for more information.

4.1 PROTECTION OF EXISTING CONDITIONS/FEATURES

- Care should be taken not to create pathways for water migration to adjacent infrastructure.
- Minimum setback from buildings is 13’ for infiltration practices.
- Impermeable liners can be used to protect adjacent infrastructure when setbacks are encroached upon.
- In retrofit applications, older foundations and infrastructure may require greater attention due to greater susceptibility to water penetration from increased subsurface hydrology.

4.2 PERIMETER CONTROLS

“Perimeter controls are one component to a multi-barrier approach that includes settling and filtration controls. These controls protect off-site areas, natural resource features and BMPs from disturbances that generate sediment laden runoff and compaction from vehicle traffic. Drip lines of trees, soil stockpile sites and infiltration practices are a few of the key features that must be protected by perimeter controls to prevent sedimentation and soil compaction throughout the construction time frame” (Credit Valley Conservation Authority Low Impact Development Construction Guide).

4.3 SETBACKS FROM STRUCTURES AND UTILITIES

- Gas Lines – 1 foot
- Water Mains – 18” vertically, 5 feet horizontally
- Front steps of buildings – 1.5 feet
- Right-of-way lines/private property; utility structures, vents, sewer laterals, major electric lines, etc. – 3 feet
- Utility poles (telephone, street lights, etc.) – 5 feet
- Between existing structures (buildings, walls, etc.) and GI – 10 feet; 5 feet if structure has no basement

GI Construction, Rochester NY

4.4 TREE PROTECTION BEST MANAGEMENT PRACTICES

Tree Protection, Rochester NY

Excavation should be avoided within the drip lines of existing trees unless trees are to be removed. Existing trees are to be preserved wherever possible.

Tree protection should include:

- Accurate measurement and canopy area/width dimensions on base plans
- During construction, install adequate tree protection fencing around the tree protection zones to protect vegetation from construction damage. Maintain temporary fence and remove when construction is complete.
- Do not store construction materials, debris, or excavated material inside tree protection zones.
- Do not permit vehicles or foot traffic within tree protection zones; prevent soil compaction over root systems.

If surface pavement removal is required within a tree's drip line, the following steps are advised:

- Construction drawings must indicate where surface pavement removal will be occurring within a tree's drip line, along with detailed notes on the construction drawings that reference correct procedures for this type of task. The construction drawings should include all relevant details (i.e. "Tree Protection When Working within Drip line"). Notes should include statements that indicate if damage occurs to trees during construction, trees will be replaced at the Contractor's expense.
- Prior to any pavement replacement fibrous roots should be relocated away from the undersides of pavement, curbing, etc., by air spading/pneumatic excavation or hand digging to prevent ripping or tearing. Roots can be moved aside and then replaced before paving if they are kept moist. Where possible, avoid cutting roots.
- If root systems are extensive under pavement and/or along curbs, and roots cannot be moved away, roots may need to be pruned to prevent excessive damage to roots. Try to avoid pruning roots that are more than 1 inch in diameter.
- If root systems must be pruned, watering in the current growing season is essential to minimize stress on the tree. The tree canopy should only be pruned in the next growing season to remove die-back.
- Be sure to prune roots using clean cuts that allow for the fastest callusing of necessary wounds and healthy re-growth of lost root systems.

Construction and maintenance activities are accessible to entry-level personnel, provided they receive appropriate training and can demonstrate a base level of applicable knowledge and skill. The entry-level, accessible nature of green infrastructure construction and maintenance jobs offers an opportunity to support job creation and long-term employment opportunities in communities where green infrastructure is being implemented.

The Need for National Green Infrastructure Training and Certification

4.5 SOIL STOCKPILING

- “Excavated materials are often stockpiled on site, requiring additional erosion control measures.
- Excavated topsoil, if suitable for reuse in final landscaping, should be separated from sub- soils. Protect stockpile sites with perimeter control and keep stockpiles away from practices.
- A project stockpile site should be provided for the development. All excess materials not needed for backfill should be immediately taken away during excavation.
- Stabilize stockpile locations with vegetation and/or silt fence. Stockpiles must not be adjacent to excavation area.
- Erosion Sediment Control (ESC) measures should be established around all non-aggregate stockpiles (even if it will be used for backfill) on the day the pile is created.
- All stockpiles will be placed no closer than 10 feet from the curb and maintained on-site.
- Stockpiles should be seeded and mulched if the pile will not be moved within 7 days for slopes that are 3:1 or greater and 14 days for slopes that are 3:1 and flatter.
- Never stockpile soil, mulch or other materials on pavement”(Credit Valley Conservation Authority Low Impact Development Construction Guide).

4.6 POROUS PAVEMENT CONSTRUCTION RECOMMENDATIONS

Porous pavements, including porous asphalt and porous concrete, should be installed by a contractor with porous pavement construction experience or a contractor who has completed a porous pavement construction certification. See **Section 2.4** for more information on certification programs.

If possible, porous pavements should be constructed after the rest of construction is completed.

"If this is not feasible, a plan needs to be put in place to keep construction equipment and traffic off the pavement.

The typical construction sequence for permeable pavement is as follows:

1. Stabilize all tributary areas. If the permeable pavement is immediately adjacent to traditional pavement, the traditional pavement should be installed to at least the base course prior to porous pavement construction".
2. Excavate porous pavement area to subgrade elevation. Using a toothed backhoe for excavation will help to scarify the subgrade soil and promote infiltration".
3. Install geotextile fabric to envelope the entire stone courses and prevent mixing of the stone courses with the soil below. A geotextile fabric must be used on the sidewalls of the feature to prevent soil mixing and protect the adjacent area from sloughing into the infiltration bed. If soils are poor and an underdrain system will be used, then a geotextile fabric should also be used on the bottom of the feature".
4. Leave the geotextile fabric roughly 18" long on all sides for cutting flush after the pavement is installed.
5. Install infiltration bed and choker course (1"-2" max), compacting in lifts per specifications and creating a smooth surface to place pavement.
6. Fold the extra geotextile fabric over the top of the infiltration bed/choker course to serve as a backup sediment protection until permeable pavement is placed.

Pervious Pavement Construction, Rochester NY

Porous Asphalt Construction, Lake George NY

7. Place porous pavement per specifications. For porous asphalt, both base and top courses should be placed before the top course of the surrounding pavement for ease of construction.
8. Establish perimeter controls to protect the pavement from compaction and sedimentation while construction continues on adjacent parts of the site.
9. Vacuum the pavement at least twice a year to remove accumulated sediment. Use of deicing agents and sand application during winter maintenance should be minimized" (Credit Valley Conservation Authority Low Impact Development Construction Guide).

Porous Asphalt Construction Specifications:

- Porous asphalt should be constructed based on NYSDOT specifications for
  NYSDOT 420.10130201 - Top Course Porous Asphalt Pavement with Mineral Fiber F3
  NYSDOT 420.10190201 - Top Course Porous Asphalt Pavement with Mineral Fiber F9
  NYSDOT 420.01190201 - Binder Course Porous Asphalt Pavement F9

Based on recent construction experience some important factors to consider include:

- Do not place porous asphalt top course on a wet surface or when the surface temperature is below 50° F.
- Target paving temperature of the asphalt is 275-295° F. Paving must not be heated to more than 295° F. Minimize drain down to less than 0.15%
- Do not use any type of solvent or kerosene, diesel fuel, gasoline etc. to clean tools.

- Do not use a tack coat.
- Prior to the placement of a top course, the binder coarse (also known as base course) should be cleaned to the satisfaction of the engineer in charge.
- Place each coarse of porous asphalt in one lift. Use a rubber tracked paver to place as much of the mix as possible to minimize the amount of handwork.
- After completion of each pavement course, allow the pavement to cure for a minimum of 24 hours before placing the next course or allowing traffic of any kind on pavement surface.
- A 10-13 ton double drum asphalt roller with a minimum drum width of 54” is required. The roller must be operated in static mode at all times. Do not stop the roller on the freshly placed mix.
- The roller must move at the slowest pace possible or the layers can develop ripples.
- Do not attempt to roll the top course until the surface temperature is below 250° F. Roll it at least once before the surface temperature reaches 200° F.
- Each course must be rolled at least once while the surface temperature is 100-150° F to achieve design density. The asphalt is not compactible under 100° F. Multiple passes at this temperature range are permissible.

Porous Asphalt, Warrensburg, NY

Porous Asphalt Construction, Lake George NY

Porous Concrete Construction Specifications:

- Porous concrete should be constructed based on NYSDOT specifications for NYSDOT 502.01010010.

Based on recent construction experience some important factors to consider include:

- Porous concrete should not be placed when the ambient temperature predicted for the job site is below 40° F or above 90° F within the next seven days.
- Mix time: Truck mixers shall be operated at the speed designated as mixing speed by the manufacturer for 75 to 100 revolutions of the drum.
- Concrete should be used within one hour of the introduction of mix water.
- Prior to placing concrete, the stone shall be thoroughly moistened and in a wet condition. Failure to provide a moist subbase will result in a reduction in strength of the pavement.
- Curing procedures shall begin within 15 minutes after placement. The pavement surface shall be covered with a minimum six (6) mil thick polyethylene sheet or other approved covering material. Prior to covering, a fog or light mist shall be sprayed above the surface. The cover shall overlap all exposed edges and shall be fully secured throughout the curing period (without using dirt) to prevent dislocation due to winds or adjacent traffic conditions.
- No traffic shall be allowed on concrete for at least 7 days.

The use of porous pavements is encouraged for many hardscape applications; however, porous pavements are not appropriate for all applications.

- Fixed edge restraints (flush concrete or granite curb, etc.) are required for where porous pavers abut flexible pavement (i.e., asphalt); edge restraints (e.g., PermEdge) are also recommended for where porous pavers abut vegetated areas (e.g., planters, tree pits, etc.). Ensure that metal edge restraints are installed as per manufacturer's recommendations and that the top of the metal edge restraint is installed at least ¼-inch to ½-inch below the finished grade (surface) of the paver. Under no circumstances shall the edge restraint be visible or protrude from the surface.

- It is recommended that porous pavements be designed with edge treatments designed to accept runoff in the event that the porous pavement is ever seal-coated or becomes clogged through time. Choice of edge treatment will depend on the site use and aesthetic but all edge treatments should be installed with a connection to the subsurface storage/infiltration bed underlying the porous pavement. Potential edge treatments include river-stone or pre-cast porous concrete; however, pre-cast porous concrete is discouraged where there is a high potential for surface clogging. Catch basins/ curb cuts connected to the subsurface storage/infiltration bed may be used in lieu of edge treatments provided that surface grading of the porous pavement is such that runoff generated by the pavement will drain to the catch basin/curb cut.

- Edge treatments for the purpose of preventing vehicular traffic damage to adjacent areas may include curbs, guard rails or bollards and will be dependent on site use, aesthetics and owner preferences.

- Consideration should be given to the typical dimensions of porous pavers when laying them out on a plan (to avoid having to excessively cut pavers in the field to meet atypical dimensions). A field mockup by the Contractor should be required during construction.

- To avoid settlement of pavers, the sub-base under porous pavements shall be compacted in 8” lifts, even when the sub-grade is uncompacted to allow for infiltration. The sub-base shall be rolled or compacted with a plate compactor. Triaxial geogrid should also be used to provide additional stability and when used shall be placed 6 inches below the top of the sub-base stone.

- Plant-mixed and field-poured porous concrete should be avoided due to concerns with proper mix design and placement.

4.7 SOIL RESTORATION AND SOIL MIXTURES

Soil Restoration is a required practice applied across areas of a development site where soils have been disturbed and will be vegetated in order to recover the original properties and porosity of the soil. Healthy soil is vital to a sustainable environment and landscape. A deep, well drained soil, rich in organic matter, absorbs rainwater, helps prevent flooding and soil erosion, filters out water pollutants, and promotes vigorous plant growth that requires less irrigation, pesticides, and fertilizer.

GI Planting, Rochester NY

Soil Restoration is applied in the cleanup, restoration, and landscaping phase of construction followed by the permanent establishment of an appropriate, deep-rooted groundcover to help maintain the restored soil structure. Soil restoration includes mechanical decompaction, compost amendment, or both.

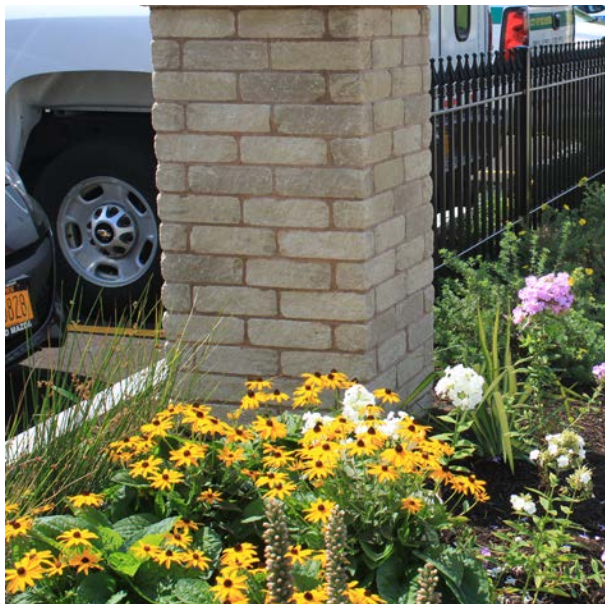
Proper soils and engineered soil mixes are critical to the success of low impact GI installations. Bioretention soil mixes should be pre-mixed prior to arriving on site, and not installed until the site is properly excavated and any settling of subsoils or storage areas has been assessed and alleviated. In addition, all underdrain systems shall be in place and any testing or lab samples should be required prior to placement. On site soils to be used should be tested for classification, porosity, texture, pH, and compost (organic content) prior to specifying a requisite soil mix. The main cause for failure of soil mixes are improper mixing, which often results in an improper ration of fines and clay materials. Soils should be frequently tested throughout the mixing and placement process to ensure the mixes meet the infiltration capacity, vegetative growth rates, and pollutant removal ability necessary.

See **Appendix 2**, Infiltration Testing Protocol and **Appendix 3**, Soil Media, Testing and Amendment

Table 5.3 Soil Restoration Requirements			
Type of Soil Disturbance	**Soil Restoration Requirement**		**Comments/Examples**
No soil disturbance	Restoration not permitted		Preservation of Natural Features
Minimal soil disturbance	Restoration not required		Clearing and grubbing
Areas where topsoil is stripped only - no change in grade	HSG A &B	HSG C&D	Protect area from any ongoing construction activities.
	apply 6 inches of topsoil	Aerate* and apply 6 inches of topsoil	
Areas of cut or fill	HSG A &B	HSG C & D	
	Aerate and apply 6 inches of topsoil	Apply full Soil Restoration **	
Heavy traffic areas on site (especially in a zone 5-25 feet around buildings but not within a 5 foot perimeter around foundation walls)	Apply full Soil Restoration (de-compaction and compost enhancement)		
Areas where Runoff Reduction and/or Infiltration practices are applied	Restoration not required, but may be applied to enhance the reduction specified for appropriate practices.		Keep construction equipment from crossing these areas. To protect newly installed practice from any ongoing construction activities construct a single phase operation fence area
Redevelopment projects	Soil Restoration is required on redevelopment projects in areas where existing impervious area will be converted to pervious area.		

from NYS SMDM

4.8 PLANT MATERIALS



Rain Garden, Rochester NY

After selecting the proper plants species for the retrofit measure, it is critical during construction that the plant materials are healthy and vigorous to encourage successful establishment. Plants shall be as specified in plans, and the root and foliage areas should be inspected as soon as they are on-site, or if possible, inspected and selected by the designer at the supplier. Larger planting (minimum 1 gallon) or seedlings establish much faster than seed or plugs, and are much more tolerant of site conditions and expected inundations of stormwater. Establishing high quality vegetation in areas of frequent ponding or concentrated flows should be prioritized. If planting occurs during any construction operations, elements to protect new plantings should be considered such as protection fence, signage, and equipment limitations. Planting facilities should also be over-planted or installed in masses to assist in the planned function of the vegetative materials. This also makes plantings easier to maintain, discourages unwanted weeds and invasive species in open areas, and is considered more aesthetically pleasing.

4.9 TRANSPLANTING

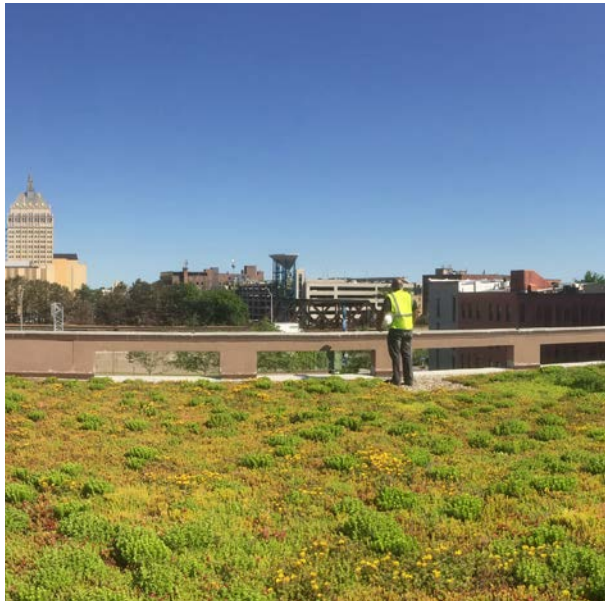
Project areas benefit from maintaining the existing plant material if appropriate and desired for the area. Although transplanting may be considered risky, it may present some well-established planting selections which have already successful adapted to current or adjacent sites. Proper care and handling is necessary when transplanting any planting. Transplanting established plants can often damage feeder roots, which are responsible for the majority of essential nutrients and water. This can be alleviated with proper root pruning techniques to encourage new feeder roots. Once the plant is carefully excavated from the existing conditions, an adequate amount of soil should be retained to reduce the amount of shock the plant experiences. The root ball, or root zone, should be dug out to be at minimum 2-3 times the size (diameter and depth) of the plant size. The American Standard for Nursery Stock (ANSI Z60.1-2004) provides minimum recommendations for transplant sizes and types.

4.10 LESSONS LEARNED

Retrofit projects can present opportunities for salvaging materials and using them in innovative ways. Projects may also be able to benefit from materials salvaged from other nearby projects such as unused boulders or curbing.

Retrofit projects may have unanticipated site conditions. Knowledgeable contractors may have suggestions for design modifications based on below ground conditions discovered during construction. Working with contractors to respond to on site conditions can make the unknowns involved in a retrofit practice less challenging or even beneficial.

Many GI projects are highly specialized. They can be counterintuitive for contractors because they may require deviations from standard construction best practices. GI has a unique set of best practices, and that those best practices are evolving quickly. Additional communication between contractors, municipal staff, and designers can help resolve these differences and build unified project goals.



Green Roof, Rochester NY

Sediment Protection, Rochester NY

4.11 CRITICAL TIMES FOR CONSTRUCTION INSPECTION

Communication throughout the construction process is critical to the success of GI retrofit projects. Traditional construction would often allow a separate and isolated process and inspections or decisions were determined on an as-needed basis. The inspection process allows the designer to gain access to critical information as the process moves through project layout, excavations, utility installation and protection, drainage networks, pavement construction, and final landscaping and site stabilization. Each level of construction requires diligent knowledge and inspection of activities and conditions, and allows both the designer and contractor to embrace the uniqueness of GI retrofit form and function.

Key communication and inspection moments should occur during the following construction activities:

- Erosion and sediment controls - proper installation practices, down gradient perimeter control, checklist conformity, appropriate responses
- Excavation, grading and site preparations – critical staging and phasing of operations, identify infiltration areas, keep water/storage clean and protected, identify stabilization areas, limit compaction as necessary
- Utility installation and protection – identify utilities to remain and protection measures, shared conveyances if possible, may require careful vacuum excavation to limit disturbances, ensure anti-seepage collars are installed where required, coordination with owners of utilities
- Stormwater infrastructure – services kept off line until surface measures in place, proprietary devices functioning and properly installed, elevations are critical of structures and piping inverts

- Pavement installation – inspections to ensure proper compaction, subbase and storage depths; limit debris and sediment; observe construction traffic, compaction, and protection; direct stormwater to temporary stabilized areas if necessary
- Finish grading – attention to detail, proper elevations of pavements, curbs, structures, slopes, low points, etc; communicate proper adjustments if necessary; appropriate soil amendments, tilling, decompaction and permeability testing if needed; installation of rock areas, diaphragms, and outlet/ inlet elements
- Vegetation – proper planting techniques, locations, depths, procedures; ensure adequate water and moisture retention for establishment; inspect for disease, dying or decaying materials; ensure proper placement and type for function of plantings

See **Appendix 4, Construction Inspection Forms**.

Pervious Concrete Construction, Brighton NY

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5.0 OPERATION, MAINTENANCE & MONITORING

5.1 INTRODUCTION

Maintenance is often cited as a potential concern when considering GI projects. However, when GI programs are well coordinated they can require less maintenance than corresponding gray infrastructure systems. According to a recent study, GI is approximately 25% less costly to maintain over the life of a project (EPA). See **Appendix 7, Construction and Maintenance Costs**, for more information.

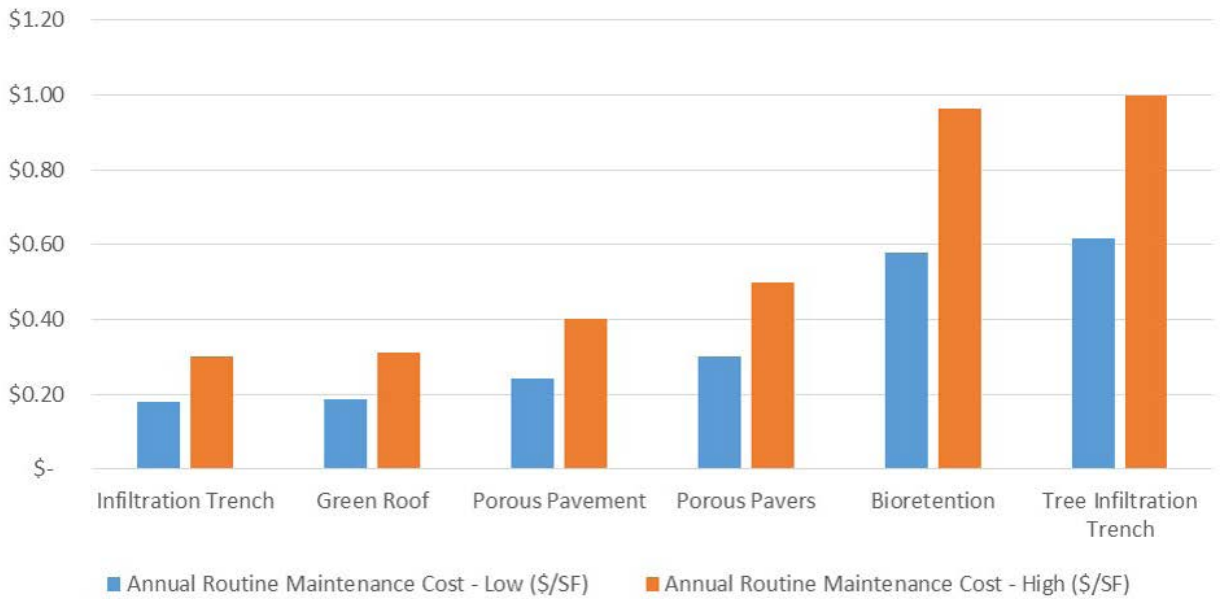
Maintaining GI does not have to be more difficult or more costly, but it does provide new challenges. GI projects are dynamic living systems, which require different care than either conventional gray infrastructure systems or conventional landscapes.

Conventional gray infrastructure systems are frequently more consolidated than green infrastructure. Maintenance activities may be limited to a few sites. GI systems are most effective when they are widely distributed. This means that though there may be less total maintenance, there is a greater need for organization. It addition, because GI systems are living ecologies, they require types of care that stormwater management staff may be unfamiliar with, such as horticultural care.

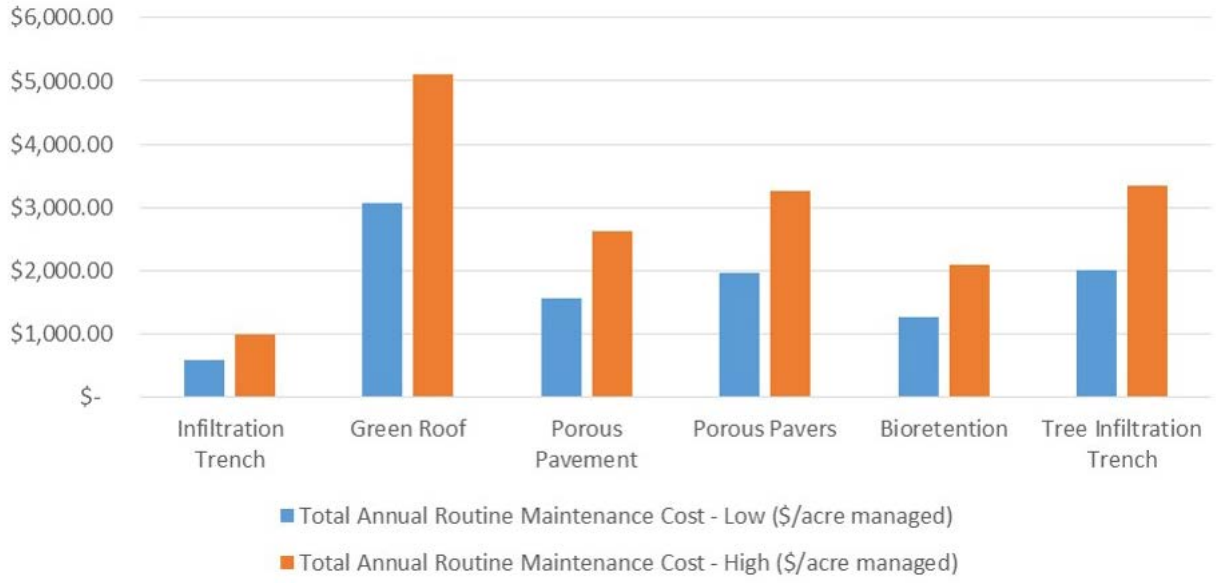
GI systems also differ from the conventional landscapes that are typically cared for by horticulturists and landscapers. GI projects are designed as functional systems. GI projects can be beautiful, but they will generally have a different character than more manicured landscapes. Educational outreach is one way to manage expectations about the appearance of GI projects.

Activities necessary to maintain GI practices are generally divided into two categories: routine maintenance and non-routine maintenance. Details about each of these categories are provided below.

> ***"Recent studies have examined the effectiveness of green infrastructure in managing stormwater, as well as its cost effectiveness when compared to gray infrastructure. One study found that in general, green infrastructure is just as effective at removing pollutants from stormwater, reducing peak flows, and mitigating flooding and sedimentation as gray infrastructure, but on average costs 5-30% less to construct and is approximately 25% less costly to maintain over the life of a project".***
>
> *Environmental Protection Agency*
> *The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure*



Annual Maintenance Cost Range for GI ($/SF of GI area)



Annual Maintenance Cost Range for GI ($/Acre of Impervious Area Managed)

Graphs by CH2M,
Source: Water Environment Federation

Routine Maintenance: Routine maintenance includes preventative maintenance activities that should be conducted regularly. Though routine maintenance varies for different GI practices, examples include weeding and removing trash and sediment from practices. Routine maintenance tasks may vary in frequency, with weekly, monthly, seasonal and yearly tasks being common.

Non-routine Maintenance: Non-routine maintenance is necessary when unexpected issues arise, such as when elements of GI practices are damaged by unusual weather conditions and require replacement. These activities are more difficult to predict, but funding for them should be built into GI maintenance budgets.

"In addition to the tasks necessary to maintain a GI project, a maintenance program should establish frequencies for inspecting the site and performing maintenance activities. The following elements should be considered when establishing maintenance and inspection frequencies:

- GI practice type (i.e., bioretention, porous pavement, rain barrel, etc.);
- Site specific factors (dependent on actual site conditions such as runoff volume, traffic loading, sediment loading, litter/debris loading, etc.);
- Seasonal variations (i.e., fall leaf drop, snow removal, etc.);
- Temporary adjacent site activities (i.e., construction); and
- Irregular weather events" (A Survey of Green Infrastructure Maintenance Programs).

The necessary maintenance frequency for each site could vary throughout the year.
Agreed upon maintenance frequency may be weekly, monthly, seasonally, or a certain number of times per year.

Bioretention, Rochester NY

Tree Planting, Syracuse NY

Planting trees in adequate soil volumes can reduce lifetime maintenance costs for trees by 66%.

Rethinking Maintenance of Urban Trees

5.2 MINIMIZING MAINTENANCE THROUGH PLANTING BEST PRACTICES

- ***Providing adequate soil volume*** - According to a study in the Journal of Arboriculture - 'inadequate soil rooting space can be one of the most important factors in the premature mortality of trees in urban areas'. It should be no surprise then, that trees in inadequate volumes of soil require more maintenance. They are more susceptible to diseases, more likely to suffer in drought conditions, and more likely to require replacement.

- One of the most effective ways to cut down on maintenance for trees is to ensure adequate soil volumes. A minimum soil volume ordinance is one way to accomplish this. A minimum soil volume ordinance specifies a minimum volume of loam soil, to be included in all design plans and on project tree list spreadsheets. According to Dr. Kim Coder from the Warner School of Forestry, University of Georgia, in areas with over 30" of annual rainfall (such as Monroe County) - planting trees in adequate soil volumes can reduce lifetime maintenance costs for trees by 66%.

- As a general rule, a soil volume of 220 cubic feet is adequate for a medium sized tree, or 2 cubic feet per 1 square foot of crown projection (MacDonagh).

- ***Adequate tree spacing*** - In addition to adequate soil and water, trees need space to grow and access to light. Placing trees further apart can also improve tree health and reduce maintenance costs (MacDonagh).

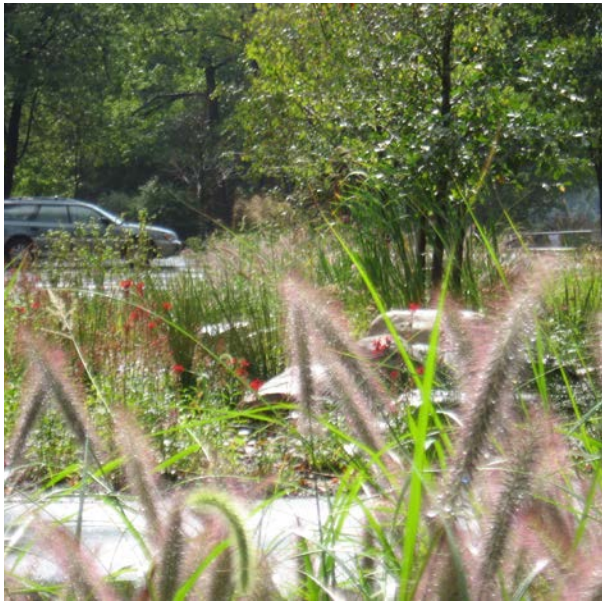
- Large trees - 35' on center
  Medium trees - 30' on center
  Small trees - 20' on center

- ***Adequate mulch*** - Placing 3” of mulch out to the drip-line of plants helps plants retain water, regulates temperatures, and reduces competition from weeds. All of these reduce maintenance needs. Fine textured mulches prevent evaporative water loss better than course textured mulches, and may stay in place better if plantings are flooded. Mulch should not be piled against the bark of plants, and using too much mulch may negatively impact plants and increase maintenance needs.

- ***Planting in masses*** - Biodiversity increases the resiliency of GI practices, creating populations that can adapt over time to thrive in changing environmental conditions. Unfortunately, using a wide range of plants can present problems for maintenance staff who may not have the training to recognize a large number of plants throughout the year. This can lead to problems with weed identification, so that weeds may not be removed, or plants that were included in the design might be removed unintentionally.

- Planting in masses is the practice of grouping relatively large numbers of one plant together. How large these masses are will depend on the scale of the GI practice. This practice can allow for a diverse and resilient GI practice, while making it easier for maintenance staff to identify weeds. In addition, mass plantings have an intentional or garden-like quality that may be better received by residents and visitors who prefer tidy plantings.

- ***Generous groundcover plantings*** - While it can be tempting to start with fewer plants in order to save money during construction, planting ground-covers more densely will enable them to cover the ground more quickly, shortening the establishment phase in which the most weed removal is necessary.



Vegetated Swale, Irondequoit NY

Tree Planting, Rochester NY

- ***Right plant, right place*** - Plants should always be selected based on site conditions including cold tolerance, light levels, water availability, and soil conditions. Plants that are poorly adapted to their environment will require much more maintenance in order to survive. **Appendix 8, Recommended Plants for GI Practices,** includes a general list of recommended plants for GI in Monroe County. However, within Monroe County site conditions can vary significantly. Conditions such as moisture level and light level can vary even within a 1/4 acre site. It may even be necessary to consider plants with different levels of cold tolerance for different Monroe County sites. Planters or green roof plantings are separated from the insulating effects of the ground and may need to be more cold hardy, while plants in a south facing courtyard may need to be more heat tolerant.

- Educational online databases are a great way to look up particular plants or find plants that will be well adapted to specific conditions. Locally, Cornell University's Woody Plant Database is a great resource for trees and shrubs. The Ladybird Johnson Wildflower Center has a database of plants native to New York State. For a more general guide, the Chicago Botanic Garden Plantfinder can be a very useful resource. See Section 1.3.

- Ensuring plants are well adapted to their environments will allow them to establish more quickly, filling in the available space and cutting down on the need to weed projects. Well adapted plants are less likely to require watering after the establishment phase. In addition, well adapted plants are less likely to have disease issues which could impact their appearance or require replacement.

- Salt tolerance should be a key factor in plant selection. Maintenance practices should include strategies for reducing application of deicing materials, to protect both pervious paving and plant species.

5.3 VISUAL MAINTENANCE GUIDE

Appropriate levels of maintenance for GI practices vary depending on a number of factors including the following.

- ***Design Level*** - If the project was designed with a very specific outcome in mind, additional maintenance will help steer the practice toward that outcome.
- ***Desired Aesthetic Character*** - If the project is intended to have a more natural feeling less maintenance may be desirable.
- ***Level of visibility*** - Projects that are prominently placed may be good candidates for higher maintenance levels.
- ***Available maintenance staff*** - Maintenance expectations for each project should be based on a realistic understanding of available resources for project care.

Rain Garden Planting, Monroe County NY

There is a minimum maintenance level necessary for practices to function properly. Additional maintenance beyond this minimum may improve the appearance of GI practices, as well as providing additional ecosystem services. For example, a more maintained practice may be more ecologically diverse and provide more habitat for pollinators and desirable wildlife.

This guide details the following maintenance levels:

- Minimal;
- Low; and
- Moderate.

One of the many advantages of GI is that projects are designed as functioning ecological systems, rather than primarily focused on aesthetics. As a result, GI practices should not require intensive maintenance.

Minimal Maintenance, Henrietta NY

MINIMAL MAINTENANCE - Minimal maintenance is focused primarily on the stormwater management aspects of GI, with less emphasis on aesthetic benefits or additional ecosystem services such as ecological benefits. Minimal maintenance is appropriate for larger GI practices or practices that are not very visible.

Minimal maintenance levels for planted GI practices would include the following:

- Adequate plant cover (60%);
- Weedy plants acceptable;
- Practice is mulched (2-4”) and shows limited signs of erosion, channelization, scouring or compaction;
- Adequate drainage (most water drains within 48 hours); and
- Limited accumulation of sediment and debris.

Requirements for meeting this base level for hardscape include:

- Infrastructure is accessible;
- Less than 50% blockage caused by organic matter, sediment, debris or trash;
- Hardscape elements at least 50% secure; and
- Porous pavement infiltration rate of 3”/hour.

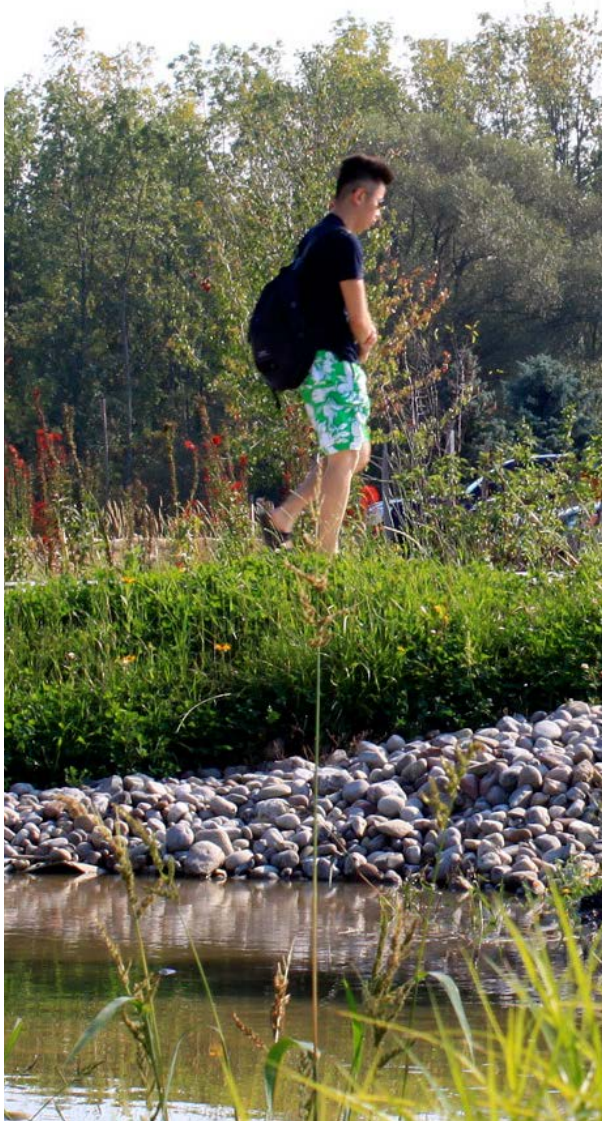
LOW MAINTENANCE - Low maintenance is appropriate for projects where a highly naturalized appearance is acceptable or desirable.

Low maintenance levels for planted GI practices would include the following:

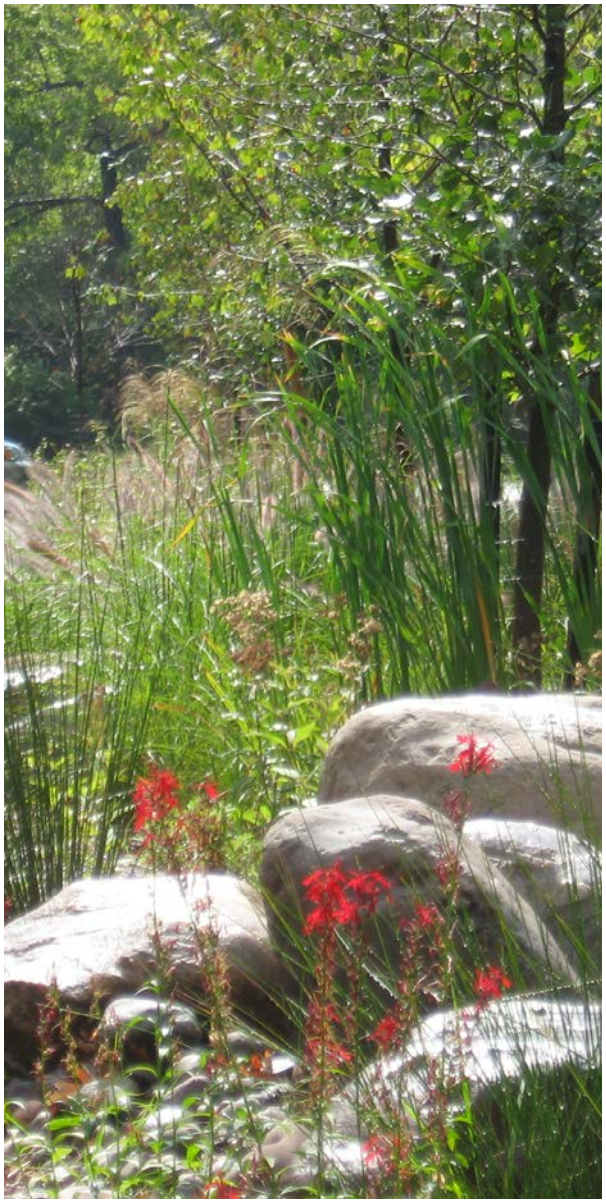
- 60-80% covered with vegetation;
- <40% of vegetation is weeds;
- Practice is mulched (2-4”) and shows limited signs of erosion, channelization, scouring or compaction;
- Adequate drainage (most water drains within 48 hours); and
- Limited accumulation of sediment and debris.

Requirements for meeting this maintenance level for hardscape include the following:

- Infrastructure is accessible;
- Less than 30% blockage caused by organic matter, sediment, debris or trash;
- Minimal erosion;
- Hardscape elements at least 70% secure; and
- Porous pavement infiltration rate of 10”/hour.



Low Maintenance, Henrietta NY



Moderate Maintenance, Irondequoit NY

MODERATE MAINTENANCE - Moderate maintenance is appropriate in sites where a somewhat naturalized appearance is acceptable or desirable.

Moderate maintenance levels for planted GI practices would include the following:

- 80-90% covered with vegetation;
- <20% of vegetation is weeds;
- Adequate drainage (most water drains within 24 hours); and
- Limited accumulation of sediment and debris.

Requirements for meeting this maintenance level for hardscape include the following:

- Infrastructure is accessible;
- Less than 20% blockage caused by organic matter, sediment, debris or trash;
- Minimal erosion;
- Hardscape elements at least 80% secure; and
- Porous pavement infiltration rate of 20”/hour.

5.4 MAINTENANCE / INSPECTION SCHEDULE RECOMMENDATIONS

The NYSDEC Maintenance Guidance for Stormwater Management Practices (MGSMP) is a document that provides guidance on how to inspect and maintain the stormwater management practices in the NYS SMDM. This document details three levels of maintenance.

- Level 1 - Property Owners, Property Managers, Municipal Maintenance Staff
- Level 2- Trained Municipal Staff
- Level 3- Qualified Professionals

This distinction helps to cut costs by allowing less trained individuals do the majority of GI maintenance. The MGSMP recommends that all practices receive at least a level one inspection annually, and more often during the establishment phase of the GI practice.

MGSMP mostly deals with troubleshooting for GI failures rather than routine maintenance.

See **Appendix 5, Operation and Maintenance Inspection Forms**, for more information.

The GI maintenance table below is based on the Onondaga County Save the Rain Program GI maintenance manual.

The Level 1 Inspection should be conducted at least annually for all practices and is often supplemented with additional visits after large storms, winter salting or sanding, or other seasonal changes. In addition, it is recommended that inspections take place more frequently during the first few years after installation of the SMP. Many issues can be identified and corrected during this early period so that they do not lead to larger problems in subsequent years. Plant establishment and health is one of these key issues. Once the SMP is stable and seems to be functioning properly, the inspections can become less frequent.

NYSDEC Maintenance Guidance for Stormwater Management Practices

Maintenance Task	*Recommended Frequency*	*Description*
Porous Pavement Vacuuming	Semi-annually (2x/year) for concrete, asphalt and flexible pavement; annually in spring for pavers	Porous pavement surfaces require vacuuming to remove debris that may clog the permeable layers/voids and prevent infiltration.
Porous Pavement Power Washing	Once every three years (or as necessary)	Power washing restores permeability and should follow porous pavement vacuuming. Porous pavers should not be power washed.
Porous Paver Maintenance (Restoring Aggregate)	As needed when gravel infill is not within 1/2 inch of the paver surface, immediately following vacuuming	This task refers to the refilling of voids between pavers with additional aggregate material to replace any material that has been lost by vacuuming and/or due to natural migration, settlement, and erosion.
Winter Maintenance for Porous Pavements	As necessary during Winter	Porous pavement surfaces require modified plowing and salting practices during the winter months when snow is present.
Stormwater Structure Cleaning	Semi-annually (2x/year)	Stormwater Structure Cleaning refers to removing debris or clogged materials and vacuuming the interior of the structure.
Inlet Filter Insert Cleaning or Filter Insert Pouch Replacement	Clean Quarterly (4x/year) until it is determined a particular inlet requires less frequent cleaning; Replace annually	Filter inserts need to be cleaned with an industrial vacuum to remove debris and prevent clogging.

Maintenance Task	*Recommended Frequency*	*Description*
Green Roof Maintenance	Spring and Fall, after initial 2-3 year establishment period; must adhere to the project specifications/warranty provisions	Remove debris, weed, prune plants, replenish, fertilize if needed. Follow project specific maintenance plan, if prepared and approved.
River-stone Edge Maintenance	Annually in Spring	Remove debris, weed, rake, replenish as needed.
Tree General Maintenance, Weeding, Mulching, Soil Amendment	Year 1 is covered by Contractor's maintenance agreement/warranty; Year weeding occurs 3 times/year; mulching occurs annually in Spring	Tree inspection covers an initial tree health assessment, followed by tree pit weeding and tree pit mulching.
Landscaping Areas General Maintenance, Weeding, Mulching	Inspection: 1x/year; Weeding to occur 3x/year (spring clean-up; Summer maintenance; fall put to bed); Mulching to occur 1x/year in Spring	Landscape inspection covers an initial health assessment of the plantings, followed by trash removal, weeding, and mulching.
Meadow Inspection, Control of Invasive Species	Monitor meadow monthly during growing season for invasive species during first 2 to 3 years	Inspect and monitor the meadow for invasive species.
Tree Watering	Year 1 is covered by Contractor's maintenance agreement/ warranty; Year 2: water weekly in the absence of rain; Years 3+: only as necessary in during extended periods of drought	Tree and landscape watering refers to watering during establishment in Years 1 and 2 and as necessary during extended periods of drought.
Landscape Watering	Year 1 is covered by Contractor's maintenance agreement/warranty; Year 2 and 3: water during the first 4-6 weeks of the growing season, and then only during extended periods of drought	Tree and landscape watering refers to watering during establishment in Years 1 and 2 and as necessary during extended periods of drought.

Maintenance Task	*Recommended Frequency*	*Description*
Tree Pruning	Year 1 is covered by Contractor's maintenance agreement/warranty; One-time per year in Year 3 (Fall or Spring depending on species); One time per year in years 5, 8, 12, 18, 24, 30, 36, 44, 52, 60	Tree and landscape pruning refers to annual pruning to maintain aesthetics and promote tree vigor.
Landscape Pruning	Year 1 is covered by Contractor's maintenance agreement/warranty; 1x/year beginning in Year 2 depending on plant type	Tree and landscape pruning refers to annual pruning to maintain aesthetics and promote tree vigor.
Meadow Mowing	Year 1: once a month from Apr-Nov; Year 2: Once in Fall; Year 3 and beyond: once every 2 years in Spring	Mowing helps prevent/control woody plant and weed establishment, and helps to disperse seeds of desirable species.
Landscape Replacement (excludes Trees)	Spring and Fall, as a corrective maintenance task that should only be performed on an as needed basis	Replace missing, dead, or diseased shrubs and herbaceous plant material.

5.5 WARRANTIES

Maintenance activities begin during construction – especially for planted practices. Adequate early maintenance, including weeding and watering, gives desirable plants an opportunity to establish and outperform weeds. This can cut down on long term maintenance requirements for a GI project.

In many cases there is a warranty period in which the contractor is contractually responsible for maintenance. The length of this warranty period varies, but is typically 1-2 years. There may be a retainage (generally 10%) in the construction contract to ensure that maintenance is performed. The full extent of maintenance activities during the warranty period should be included in the initial contract.

Rain Garden Planting, Monroe County NY

5.6 MAINTENANCE ENTITIES

In many cases there is a warranty period for who performs GI maintenance after the initial warranty period. Each of these options has its own unique considerations. After initial period maintenance on public projects frequently performed by one or more of the following:

- General or landscape contractors
- Municipal agency (frequently parks dept.)
- Non-profits/community groups

Contractors:

- GI maintenance often similar to grounds maintenance
- May include staff that performs sewer inspections/cleanings
- Ideally familiar with both wetland/natural environment and more formal plantings

Municipal Agency (such as Parks Department):

- Familiar with maintaining vegetation,
- Have maintenance protocols in place, and
- Have skilled staff and equipment required to maintain GI practices.

Non-profit/community group:

- Many nonprofits and community groups have mission statements centered on improving neighborhoods, economies, and the environment.
- "Nonprofits offer the ability to develop programs linked to creating a green jobs workforce and developing other synergies (i.e., outreach activities, voluntary clean-up events around GI, etc.)" (A Survey of Green Infrastructure Maintenance Programs).
- May be used to supplement maintenance from contractors or municipal agencies to cut costs.

In all cases, there should be a formal agreement about the following:

- "Specifying protocols for maintenance activities;
- The required frequency of activities;
- The protocol for documenting activities;
- The protocol for responding to work orders; and
- Any other details associated with conducting maintenance" (Survey of Green Infrastructure Maintenance Programs).

See **Appendix 6**, Sample Maintenance Agreement, for more information.

"It is necessary to consider the potential equipment and resources required to perform maintenance. For most vegetated practices, these resources will include the equipment necessary for landscaping maintenance, such as shovels and trash bags" (Survey of Green Infrastructure Maintenance Programs). Some practices may require sewer inspection equipment and jet-vac trucks for maintenance. "Additionally, vacuum trucks for maintaining porous pavement are also necessary" (Survey of Green Infrastructure Maintenance Programs).

"This equipment is costly and should be considered when a program is selecting its maintenance entity. For these reasons, consideration of the materials and resources necessary to perform maintenance may dictate whether or not maintenance can be performed in-house" (Survey of Green Infrastructure Maintenance Programs). For municipalities that choose in-house maintenance, there may be opportunities to share equipment costs.

In addition to maintenance staff, an administrative staff is needed to coordinate activities, issue work orders and track progress. The administrative staff may also occasionally supervise maintenance staff to confirm that the maintenance activities are being performed correctly.

Specifically related to maintenance, examples of common missteps that can result in green infrastructure system failure with significant implications include under-watering new plants, cutting or removing desired plant species, or applying unnecessary fertilizer, resulting in excess nutrients. Other common missteps by untrained green infrastructure maintenance staff include failure to remove sediments that can clog bioretention and porous pavements and puncturing green roof waterproofing membranes, resulting in water damage to buildings. Additionally, a failure to log or track maintenance, which results in too few maintenance visits, and allowing mosquito growth and contamination in rainwater harvesting systems are other common mistakes.

The Need for National Green Infrastructure Training and Certification

5.7 TRACKING AND DOCUMENTING MAINTENANCE

Rain Garden Planting, Monroe County NY

Administrative staff will want to track maintenance for GI practices including:

- "Completed activities
- Staff time associated with activity completion;
- GI project conditions found in the field;
- Issues identified in the field that require additional maintenance; and
- Costs associated with the completion of both routine and non-routine maintenance activities" (A Survey of Green Infrastructure Maintenance Programs).

Tracking and documenting maintenance not only improves GI functionality and longevity, it also allows municipalities to better understand staffing needs and make further improvements to GI systems.

"Beyond providing structure and direction for a maintenance program, maintenance activity documentation and tracking can also assist programs with regulatory compliance... Depending on the regulatory driver and the specific requirements for CSO or stormwater reduction, requirements to report maintenance activities for compliance can vary widely. In preparation for complying with the regulatory requirements for documentation and tracking, GI programs need to be aware of the requirements for performance monitoring and maintenance activity tracking and create their maintenance programs to meet those needs" (A Survey of Green Infrastructure Maintenance Programs).

"An ideal goal of maintenance documentation should be to develop a computerized maintenance management system (CMMS) or asset management system that allows for electronic logging and integrates with GIS" (A Survey of Green Infrastructure Maintenance Programs). However, many municipalities start out with simpler maintenance tracking systems.

Documentation strategies may include:

- Paper checklists
- Spreadsheets and databases
- Asset Management Systems
- Geographic information systems (GIS)
- Computerized Maintenance and Management Systems (CMMS)

5.8 LESSONS LEARNED

One study showed that without using GI certified maintenance staff only 5% of projects passed inspections due to improper maintenance. After maintenance staff were GI certified, 95% of projects passed a second inspection.

Many GI maintenance and construction certification programs exist. The following document includes a list of many of these programs throughout the country.

Certifications for Green Infrastructure Professionals

http://environment.law.harvard.edu/wp-content/uploads/2015/08/certifications-green-infrastructure-professionals.pdf

Because GI is still relatively new GI practices may not always be readily identified by maintenance professionals. In addition, individuals who have not been trained specifically in GI maintenance best practices may inadvertently damage GI practices and cause unnecessary setbacks. Examples include:

- Removing intentional planted material such as sedges or grasses based on the perception that these plants are weeds;
- Mowing GI practices;
- Plowing porous concrete with metal edged plows, and
- Sealing porous pavement

Though these setbacks can be disheartening, they can be addressed through a combination of design changes and education. The following are a few recommendations for minimizing the possibility of these sorts of incidents:

- Make certain any maintenance staff working near a GI practices are aware of the boundaries of the GI practice. This includes private contractors who are not working directly on GI maintenance;
- Make certain Maintenance Agreement contracts are detailed and informative. Discuss Maintenance Agreement items with contractor prior to initial maintenance (See **Appendix 6, Sample Maintenance Agreement**);
- Encourage maintenance staff to attend a GI certification program;
- Supervise new staff to make certain maintenance activities are being performed correctly;
- Provide maintenance staff with resources such as weed identification guides and visual maintenance guides. A list of these resources is provided at the end of this chapter; and
- Design with maintenance in mind. A planted practice where like plants are grouped together will make weeds more easily identifiable than in a mixed bed.

5.9 MAINTENANCE COST ESTIMATES

Maintenance Cost Estimates vary widely, and because systematic GI use is relatively new there are limited records of existing programs. See **Appendix 7, Construction and Maintenance Costs**, for more information.

The following is an estimate of maintenance costs for the Monroe Avenue Green Infrastructure Project

GI TYPE	*REQUIRED MAINTENANCE*	*FREQUENCY*	*ESTIMATED ANNUAL COST ($)*
Porous pavements	Vacuuming of surface Inspection & Cleaning of drainage structures	2 times per year	Avg. $0.15 / SF
Rain Gardens	Water & Care Establishment Weeding, Pruning, Mulching Inspect & Clean overflow drainage Remove litter, debris, sedimentation	4 times per year (Spring & Fall critical)	Avg. $0.30 / SF
Bioretention	Water & Care Establishment Weeding, Pruning, Mulching Inspect & Clean overflow drainage Remove litter, debris, sedimentation Erosion Control, stone apron repairs	3 times per year (Spring & Fall critical)	Avg. $0.75 / SF

Rain Garden Planting, Monroe County NY

5.10 PERFORMANCE MONITORING

GI Exhibit, Rochester NY

Monitoring provides evidence of the impact of GI that can be used to seek further funding, and to do cost benefit analysis for GI projects. Monitoring also helps to refine standards for GI; ensuring the next generation of GI practices will be even more effective. In addition, working with universities increases student awareness of GI which will influence future designers, builders, and policy makers.

Monitoring is not necessary for all projects. However, Monroe County boasts exceptional educational institutions which are leaders in technical innovation. Where appropriate, working with universities and citizen science organizations to arrange monitoring of GI projects can be very beneficial.

When monitoring is incorporated into projects, a monitoring plan should be developed. The monitoring plan should contain the following information for monitoring each practice:

- Location of monitoring
- Monitoring method
- Monitoring Frequency
- Necessary Equipment/Supplies
- Cost
- Priority

Types of monitoring could include the following:

GENERAL DATA

Rain gauge - Measure total volume of precipitation.
Frequency - Continuous

Contaminants in Rainfall - Meteorological station / rain gauge
Frequency - Event Sampling

Overflow measurement - Capture overflow from GI practices -
Frequency - Continuous, downloaded periodically
Equipment and Supplies - Onset re-purposed conductivity/temp to detect presence/absence of water.

Plant Heavy Metal Content - Tissue Sample

Porous Parking Lot Installation, Rochester NY

POROUS PARKING LOTS

Infiltration
Frequency - Event sampling
Equipment and Supplies - Double Ring Infiltrometer

Pollutant Levels - Phosphorus, pH, Chloride, Nutrients, Suspended Solids, Heavy Metal Content
Direct measurement from water samples collected from stand pipe
Frequency - Event Sampling
Equipment and Supplies - collection basin, drain pipe, 4” standpipe, 4” elbow, cap, slotted pipe, bailer, collection bottles, water testing kits.

Inflow
Frequency - continuous during rain events, download periodically
Equipment and Supplies - Pressure transducer in weir/flume installed in sidewalk chase. Plasti Fab HS Flume

Outflow - direct measurement of water height in monitoring wells in bioretention / rain garden areas
Frequency - continuous during rain events
Equipment and Supplies - Pressure transducer, standpipe installed after construction.

BIORETENTION OR RAIN GARDEN

Infiltration - Direct measurement using infiltrometer in bioretention / rain garden areas
Frequency - Storm Events
Equipment and Supplies - Infiltrometers

Pollutant Levels -Phosphorus, pH, Chloride, Nutrients, suspended solids
Frequency - Event Sampling
Equipment and Supplies - Direct measurement from samples from weir box to evaluate effects of parking/ road on water chemistry
Underdrain to standpipe similar to pipe in parking lot can be collected by hand using a bailer or small hand pump.

Inflow
Frequency - continuous during rain events, download periodically
Equipment and Supplies - Pressure transducer in weir/flume installed in sidewalk chase. Plasti Fab HS Flume

Soil Moisture - Direct Measurement with moisture probe in soil on roof
Frequency - Before, During, After Storm Events
Equipment and Supplies - Moisture Probe

Rain Garden Planting, Monroe County NY

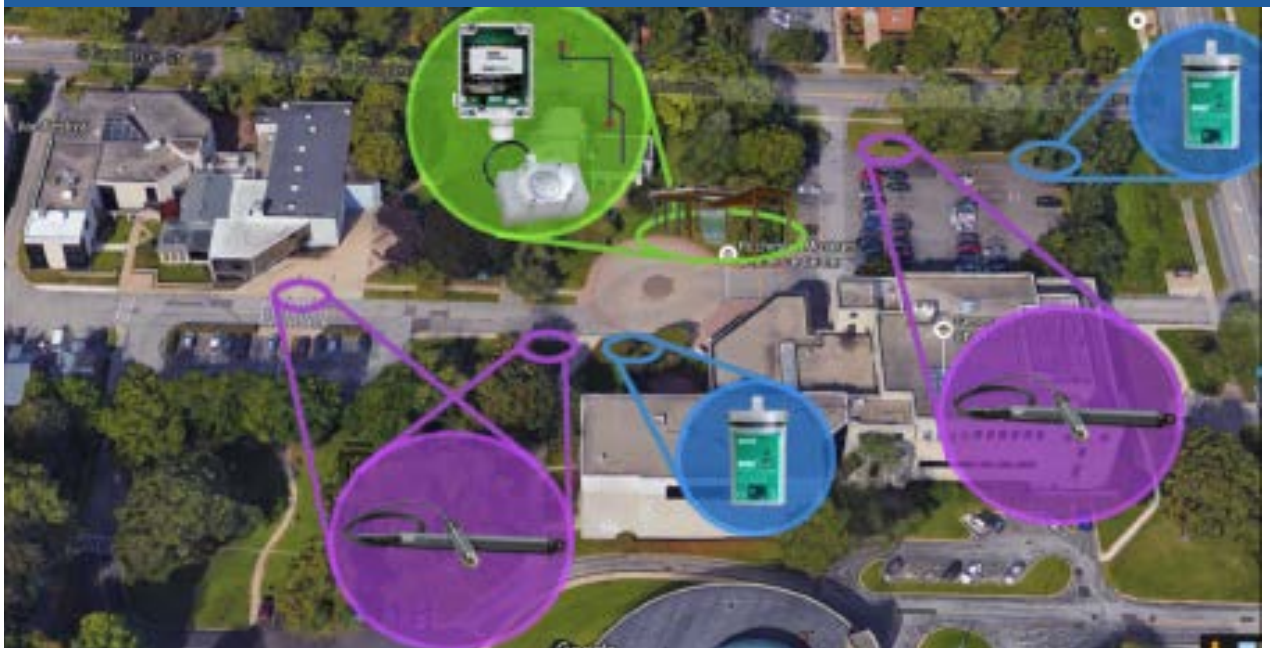
GREEN ROOF

Outflow - Direct Measurement by Collection in Rain Barrel at base of roof
Frequency - Storm Events
Equipment and Supplies - pressure transducer and stand pipe - will need to download data periodically.

Soil Moisture - Direct Measurement with moisture probe in soil on roof
Frequency - Before, During, After Storm Events
Equipment and Supplies - Moisture Probe

Pollutant Levels
Frequency - Event Sampling
Equipment and Supplies - valve for access to infiltrated water before collection barrel

PERFORMANCE MONITORING CASE STUDY



Performance Monitoring Equipment Placement, Rochester Museum and Science Center

PROJECT DESCRIPTION

The Rochester Museum and Science Center (RMSC) recently installed a number of GI practices on their campus as a part of the Museum's Regional Green Infrastructure Showcase. These include a green roof, numerous bioretention areas and rain gardens, pervious asphalt and concrete, stormwater tree pits, and rainwater harvesting. As part of this project, RMSC is partnering with the Rochester Institute of Technology (RIT) Environmental Science program, to monitor the impacts of the new GI practices.

Two RIT capstone projects have focused on developing and implementing the performance monitoring project. Further capstone projects will install additional equipment, monitor equipment, and analyze the performance of GI practices at RMSC.

PROJECT DATA

Rochester Museum and Science Center
Regional Green Infrastructure Showcase
657 East Avenue, Rochester NY, 14607

LESSONS LEARNED

The partnership between RMSC and RIT provides benefits to both organizations. RIT is provided with a laboratory for testing GI and an opportunity for students to participate in critical research. RMSC is able to use the results of the performance monitoring to teach the public about GI practices in a unique, hands on exhibit.

Both organizations have the opportunity to contribute to the growing body of information about the effectiveness of GI, and to be on the forefront of a vital, growing field.

Monroe County has a host of educational resources, including RIT. The RMSC Green Infrastructure Showcase could serve as a model for how working with educational organizations can increase the benefits of installing GI.

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