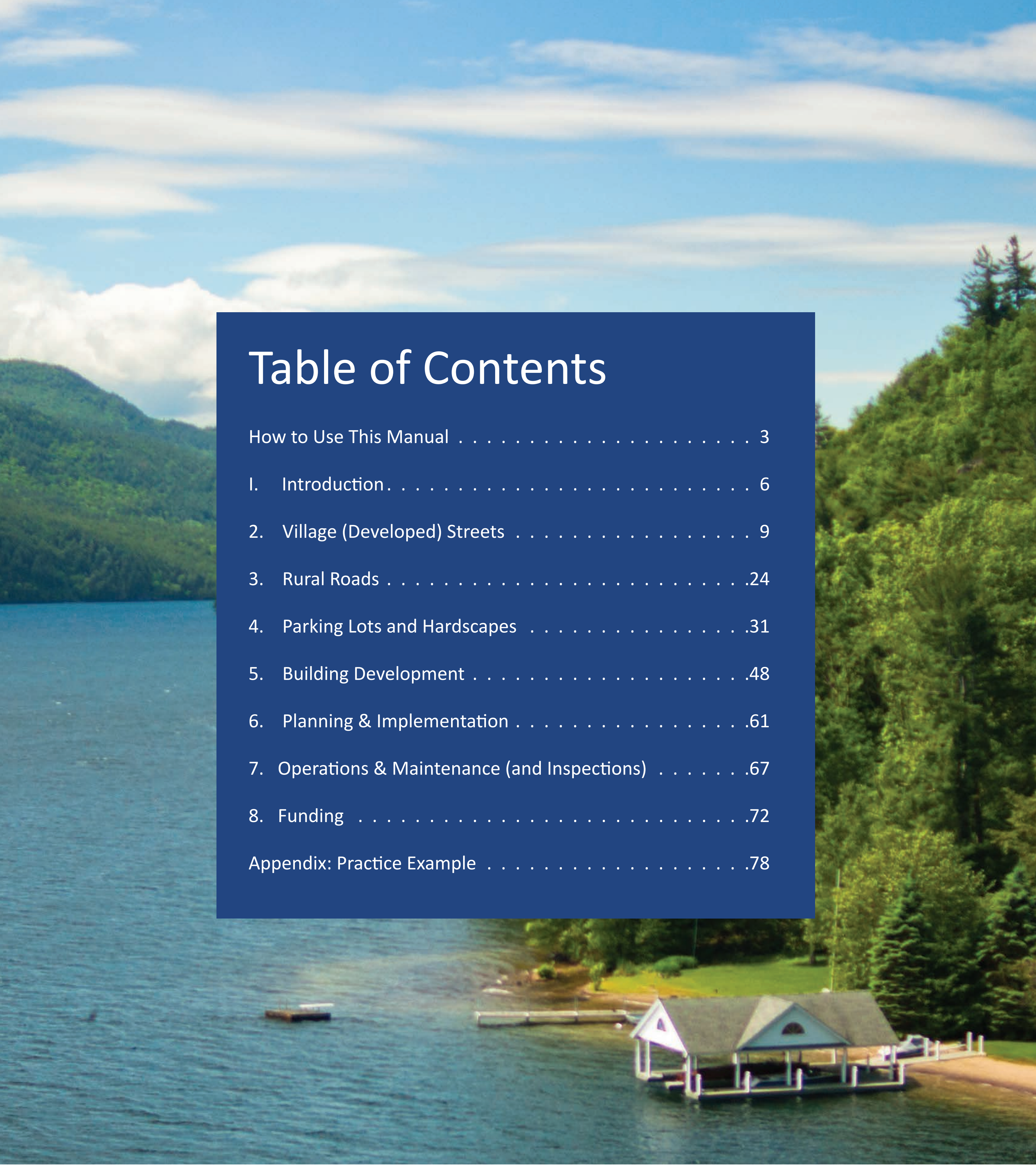
Green Infrastructure for Stormwater Management:

Guidance for Municipal Officials in New York's Lake Champlain Basin

February 2017



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Lake Champlain Basin Program

NEIWPCC New England Interstate Water Pollution Control Commission

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How to use this manual

This manual is organized according to four distinct developed environments – Village Streets, Rural Roads, Parking Lots and Hardscapes, and Buildings. Most sites will commonly have a mix of these environments – for example a municipal office will have the building roof's impervious footprint, the associated parking area's impervious footprint, the access road to the parking area and building, as well as any outside spaces that have been hardscaped like sidewalks or patios.

Important note:

This manual is intended to supplement, but not replace, the New York State Stormwater Management Design Manual. If you have a project that would legally require a stormwater permit because of its scope or scale, you must use the framework provided by that manual to achieve your stormwater management needs. This manual can assist in choosing solutions or strategies to accomplish that, but cannot replace the NYS Stormwater Management Design Manual's guidance or requirements.

Once you've determined the environment you are primarily designing for, use the decision tree to preliminarily identify which practices you might want to use. Using that list, look at each specific chapter – in each chapter there is a brief description of the environment type, the water quality issues and design challenges typically found in each, as well as Case Studies of GI practices in similar environments that can help you further decide if a particular practice is the right one. Case Studies are drawn from locally-implemented examples in New York and Vermont. Also, in each chapter is a reference to the Practice Example appendix which contains one-page descriptions of a wide variety of stormwater management practices. Use that to supplement your design decisions. These are not necessarily practices that have been implemented locally, but that would be appropriate for the environment.

Once you've made some initial practice selections, refer to Chapter 6 – Planning and Implementation – to determine the best steps to achieve the project, from identifying opportunities to integrating with municipal master plans, all the way through funding, design, permitting, and construction.

After you've figured out your Planning and Implementation process, refer to Chapter 7 – Operation and Maintenance to gain a clearer understanding of the long-term implications and costs of your chosen practice. Up-front construction costs are important, but considering the entire life-cycle cost of a practice is critical too.

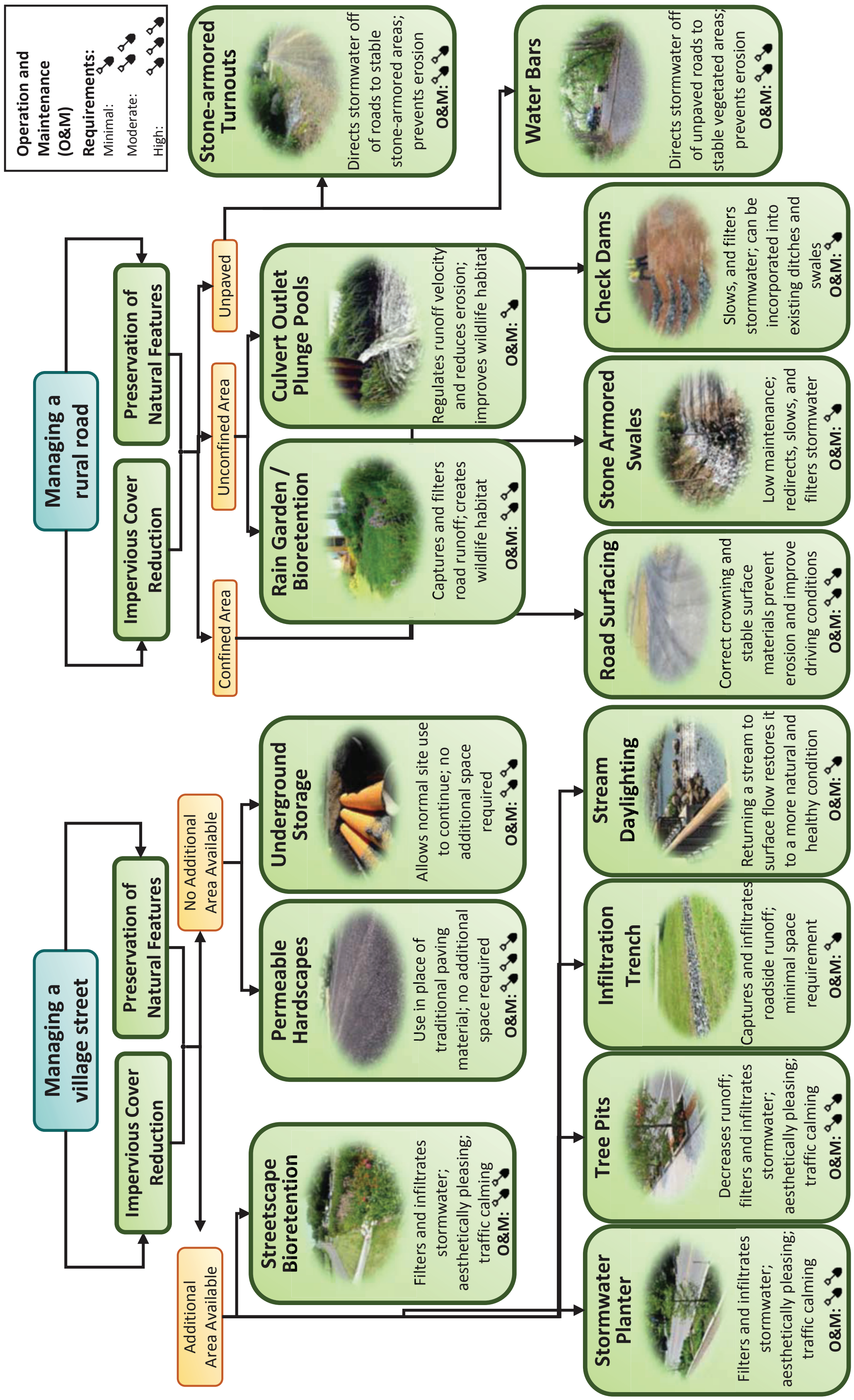
Finally, Chapter 8 – Funding lists a number of different grant opportunities that can help you achieve a project from initial planning stages through to construction. All sources of funding listed can be used in the NY portion of the Lake Champlain Basin.

How do I know which practice to use?

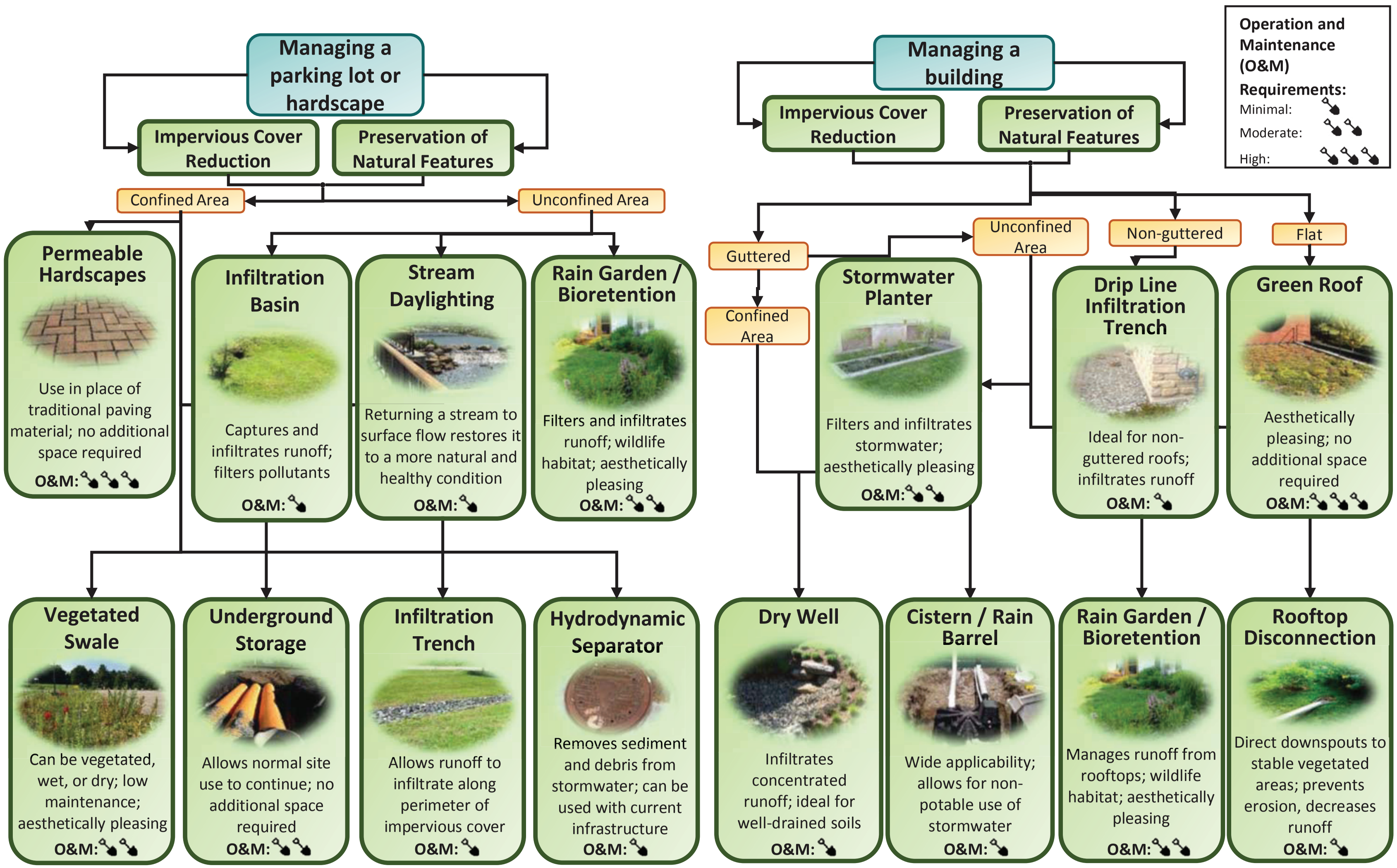
There are a lot of options for managing stormwater runoff – the hardest part of the process can be choosing which one. The easiest way to start is by determining what type, or types, of impervious cover you'll be managing as part of your project. This manual breaks them down into the following four categories:

- Village Streets
- Rural Roads
- Parking Lots and Hardscapes
- Buildings

This decision trees on the following two pages should help start the decision-making process.



Operation and Maintenance (O&M) Requirements:
Minimal:
Moderate:
High:
Managing a rural road
Impervious Cover Reduction
Preservation of Natural Features
Confined Area
Unconfined Area
Unpaved
Stone-armored Turnouts
Directs stormwater off of roads to stable stone-armored areas; prevents erosion
O&M:
Water Bars
Directs stormwater off of unpaved roads to stable vegetated areas; prevents erosion
O&M:
Rain Garden / Bioretention
Captures and filters road runoff; creates wildlife habitat
O&M:
Culvert Outlet Plunge Pools
Regulates runoff velocity and reduces erosion; improves wildlife habitat
O&M:
Road Surfacing
Correct crowning and stable surface materials prevent erosion and improve driving conditions
O&M:
Stone Armored Swales
Low maintenance; redirects, slows, and filters stormwater
O&M:
Check Dams
Slows, and filters stormwater; can be incorporated into existing ditches and swales
O&M:
Managing a village street
Impervious Cover Reduction
Preservation of Natural Features
Additional Area Available
No Additional Area Available
Streetscape Bioretention
Filters and infiltrates stormwater; aesthetically pleasing; traffic calming
O&M:
Permeable Hardscapes
Use in place of traditional paving material; no additional space required
O&M:
Underground Storage
Allows normal site use to continue; no additional space required
O&M:
Stormwater Planter
Filters and infiltrates stormwater; aesthetically pleasing; traffic calming
O&M:
Tree Pits
Decreases runoff; filters and infiltrates stormwater; aesthetically pleasing; traffic calming
O&M:
Infiltration Trench
Captures and infiltrates roadside runoff; minimal space requirement
O&M:
Stream Daylighting
Returning a stream to surface flow restores it to a more natural and healthy condition
O&M:


Managing a parking lot or hardscape
Impervious Cover Reduction
Preservation of Natural Features
Confined Area
Unconfined Area
Permeable Hardscapes
Use in place of traditional paving material; no additional space required
O&M:
Infiltration Basin
Captures and infiltrates runoff; filters pollutants
O&M:
Stream Daylighting
Returning a stream to surface flow restores it to a more natural and healthy condition
O&M:
Rain Garden / Bioretention
Filters and infiltrates runoff; wildlife habitat; aesthetically pleasing
O&M:
Vegetated Swale
Can be vegetated, wet, or dry; low maintenance; aesthetically pleasing
O&M:
Underground Storage
Allows normal site use to continue; no additional space required
O&M:
Infiltration Trench
Allows runoff to infiltrate along perimeter of impervious cover
O&M:
Hydrodynamic Separator
Removes sediment and debris from stormwater; can be used with current infrastructure
O&M:
Managing a building
Impervious Cover Reduction
Preservation of Natural Features
Operation and Maintenance (O&M) Requirements:
Minimal:
Moderate:
High:
Guttered
Confined Area
Unconfined Area
Non-guttered
Flat
Stormwater Planter
Filters and infiltrates stormwater; aesthetically pleasing
O&M:
Drip Line Infiltration Trench
Ideal for non-guttered roofs; infiltrates runoff
O&M:
Green Roof
Aesthetically pleasing; no additional space required
O&M:
Dry Well
Infiltrates concentrated runoff; ideal for well-drained soils
O&M:
Cistern / Rain Barrel
Wide applicability; allows for non-potable use of stormwater
O&M:
Rain Garden / Bioretention
Manages runoff from rooftops; wildlife habitat; aesthetically pleasing
O&M:
Rooftop Disconnection
Direct downspouts to stable vegetated areas; prevents erosion, decreases runoff
O&M:

Chapter 1 - Introduction

The impetus for this manual comes from a pressing need to improve water quality in Lake Champlain, which has been designated as impaired for phosphorus pollution by the US EPA. The Lake Champlain Basin Program has long worked to address the needs of the Lake by promoting clear needs and actionable goals.

This manual seeks to provide a supplement to the *New York State Stormwater Design Management Manual* in identifying specific environments that municipalities manage and specific case studies and practice examples of Green Infrastructure for stormwater management that municipalities may be able to implement in the course of improvements to infrastructure (streets, parking lots, etc.). These practices are meant to be non-jurisdictional – that is, they would not necessarily be projects of a scope that would trigger stormwater permitting regulations, but are rather meant as smaller projects that could have a meaningful impact on the water quality in local streams, rivers, and lakes, as well as the overall health of Lake Champlain. Any projects that do trigger stormwater regulations must follow the NY State Stormwater Design Management Manual.

This manual was produced as part of a joint effort between the Lake Champlain Basin Program's Technical Advisory Committee and the New England Interstate Water Pollution Control Commission.

What are Impervious Surfaces and Stormwater Runoff?

Impervious surfaces are any sort of developed land surface that does not allow rain to soak into the soil underneath and filter into groundwater or be taken up by plants. Impervious surfaces lead to stormwater runoff because rain and snow can't soak into soil. Most rain that falls on land surfaces does not run off because it gets into small depressions and soaks into the accumulated organic material and soil like a sponge. Plants then use most of this water for growth. Developing land and turning such pervious surfaces into impervious surfaces creates stormwater runoff – and the need to manage it to preserve water quality.

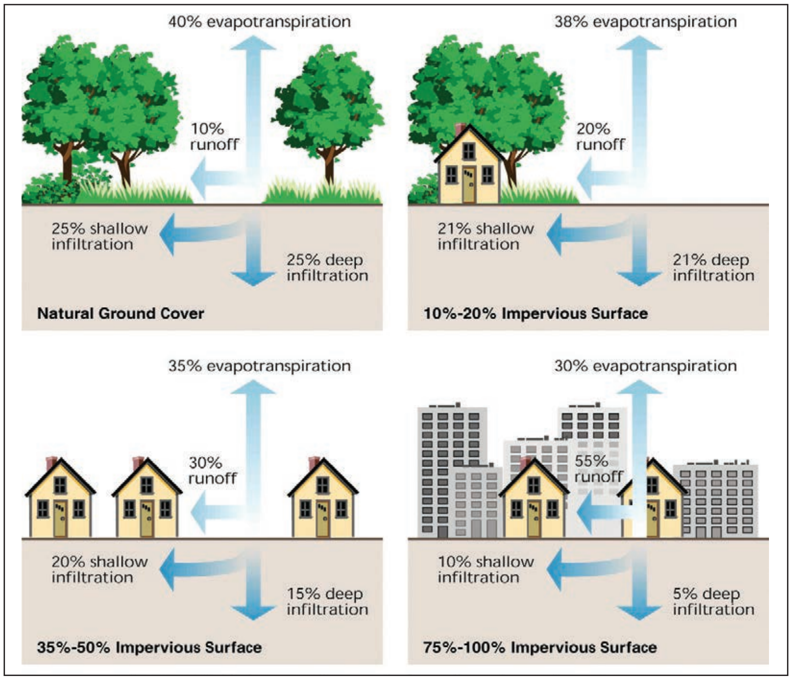


Image 1-1. Increasing impervious surfaces increases stormwater runoff – and the need to manage it

What is Green Infrastructure?

Green Infrastructure (GI), sometimes called Green Stormwater Infrastructure (GSI), is a toolbox of methods and practices to manage stormwater runoff from developed land and mimic natural hydrology. Traditional stormwater management practices use catch basins, storm drains, and pipes (also known as 'gray' infrastructure) to convey water from developed land to water bodies without doing anything along the way to improve water quality or reduce water quantity – this has a negative impact on water bodies.

Green Infrastructure is a complimentary, alternative system that seeks to improve water quality and reduce water quantity by capturing runoff as close to the source as possible (i.e. where the rain drop falls) and infiltrating, filtering, detaining, or otherwise storing runoff for reuse.

Examples of GI include vegetated depressions in parking lots (bioretention or 'rain gardens') that collect and infiltrate or filter runoff, underground storage chambers that collect and infiltrate or detain runoff, permeable pavement or pavers that allow rain to soak into the ground, or even rock- or vegetation-lined ditches that slow runoff, filter it, and encourage it to infiltrate into soil.

In New York, sites creating certain amounts of impervious cover, conducting certain industrial activities, or disturbing more than an acre of soil during development must get a stormwater permit - and those sites must meet regulations. But during improvements to municipal properties, green infrastructure can, and should, be incorporated. Municipalities have found that not only does GI improve water quality, it can also provide a cost-savings over installing traditional 'gray' infrastructure.

A note about vegetation

GI often relies on the use of vegetation as part of the practices. It is very important to always use native perennial plants, or native cultivars, that will thrive in the NY Lake Champlain Basin ecosystem. Above all, always avoid using non-native invasive species.

Image 1-2. Typical parking lot bioretention practice.

Image 1-3. Permeable hardscapes, like porous pavers, can help manage stormwater runoff.

Image 1-4. Underground storage and infiltration chambers let site use continue without taking up space.

Image 1-5. Stone armoring in rural road ditches can help prevent erosion into water bodies.



What is Runoff Reduction?

Runoff reduction is what it sounds like – a means by which the volume of stormwater runoff can be reduced through a variety of methods. By reducing the volume of runoff generated from on-site impervious surfaces, the potential pollutants associated with that runoff are more easily treated on-site.

As a regulatory strategy, the Runoff Reduction Method was developed in 2008 by the Center for Watershed Protection and the Chesapeake Stormwater Network to more completely address pollution issues associated with stormwater runoff in Virginia. It's a method that allows site designers to identify and preserve features on a site that can help preserve natural hydrology – such as permeable soils, mature vegetation, or wetland areas. In combination with minimizing the amount of land disturbed (re-graded or cleared) and the amount of impervious cover created, using such natural features to manage stormwater can reduce the overall impact of a new development.

Stormwater Management Planning - 6 Step Process

Step 1 – Site Planning
Attempt to minimize site disturbance
Refer to NY Stormwater Management Design Manual – Ch 5 section 5.1 – 5.2

↓

Step 2 – Apply Runoff Reduction Techniques
Refer to NY Stormwater Management Design Manual – Ch 4 section 4.1

↓

Step 3 – Determine Water Quality Volume (WQv)
Refer to NY Stormwater Management Design Manual – Ch 5 section 5.3 & Ch 6 section 6.3 – 6.5

↓

Step 4 – Determine Runoff Reduction Volume (RRv)
Refer to NY Stormwater Management Design Manual – Ch 5 section 5.3 & Ch 6 section 6.3 – 6.5

↓

Step 5 – Apply Additional Practices to Manage WQv
Only in certain instances
Refer to NY Stormwater Management Design Manual – Ch 6

↓

Step 6 – Apply Additional Practices to Large Volumes
Refer to NY Stormwater Management Design Manual – Ch 4 section 4.4 – 4.6

Image 1-6. The Runoff Reduction Method is a multi-step process that incentivizes site design that reduces overall impervious cover impact before requiring management of that impervious cover.

New York State has adopted Runoff Reduction as part of its stormwater regulations. A typical work-flow for site design is to first assess a site's drainage areas and which natural features can be conserved to help treat the new development's impervious cover. Following the assessment of the volume of water that can be treated with these natural features, designers can then specify additional practices to store runoff until it can infiltrate into the ground, evapotranspirate via plant uptake, or be reused on-site for irrigation or other purposes. The volume of water that these practices can treat (i.e., Runoff Reduction volume or RRv) is then subtracted from the entire site's Water Quality volume or WQv. The remaining volume is then treated by a stormwater treatment practice designed to remove pollutants. Finally, any larger volumes of water, like the Channel Protection or Overbank Flood volumes, are managed with conventional stormwater practices like wet ponds.

In the past, New York didn't do this – regulations just specified that the WQv had to be slowed down and managed, as did the larger volume storms. What this meant is that there was no incentive to minimize creating impervious cover – just regulations to require managing impacts. Runoff reduction starts with avoiding the creation of impervious cover, managing runoff as close to the source as possible, and then dealing with the rest of the volume that runoff reduction can't manage at the source.

Chapter 2 - Village (Developed) Streets

Introduction

The village (or developed) street environment can be one of the most challenging that municipalities face. Space is confined by the needs of vehicular and pedestrian traffic, private property access roads and driveways, building frontages, and utilities, both above and below ground. However, because of the existence in most cases of a publicly-owned right-of-way, village streets can be one of the largest opportunities for implementing green infrastructure.

Stormwater Issues Related to Village Streets

The stormwater issues typically associated with village streets are related to pollutant buildup on the road surface and the increase in runoff peak discharges and volumes. Typical pollutants on road surfaces include:

- Sediments - usually associated with vehicle tracking from unpaved roads or parking lots as well as winter sanding activities
- Phosphorus – often bound to sediment particles, but can also wash onto roads in the form of organic litter (leaves, grass clippings, etc.) and pet waste
- Heavy Metals – associated with vehicle passage
- Nitrogen – associated with organic litter (leaves, grass clippings)
- Large Debris – trash, as well as organic litter
- Hydrocarbons – associated with vehicle passage
- Bacteria – from pet and wildlife waste

Image 2-1. Stormwater pollution from village streets can mix many different pollutants making it an important source to treat.

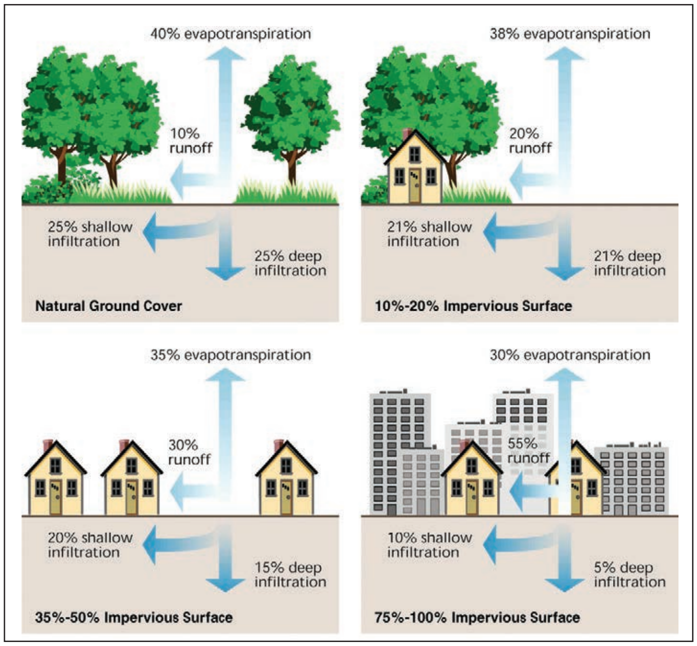


Image 2-2. Changes in land use result in changes in runoff. Urbanized areas can increase the volume of runoff leaving a site from 10% to 55%, depending on impervious cover amounts.

In addition to these pollutants, there is the issue of the amount of runoff water. Because road surfaces typically have closed catch basin and pipe systems to quickly drain them, runoff is collected, concentrated, and delivered to water bodies much faster than it would normally reach them, with more overall volume. This can result in erosion in the case of streams. It can also result in increased temperatures as runoff from impervious surfaces is usually warmed as it passes over them, versus infiltrating into the ground and seeping through soil into water bodies as cool baseflow.

Village Street-related Opportunities

Image 2-3. Streetscape bioretention practices are being implemented broadly in New York City, one of the most urbanized streetscapes in the world.

There are a number of opportunities that are specific to village streets, particularly because they are publicly-owned meaning that implementation does not necessarily have to take into account negotiation with private landowners. This does not mean that outreach should not be conducted. Public buy-in to projects on road rights-of-way is very important and should not be ignored. Opportunities for implementation within street rights-of-way include:

- Streetscape Bioretention
- Surface or sub-surface infiltration practices (trenches, basins, chambers)
- Water-quality swales
- Hydrodynamic swirl separators
- Permeable hardscapes (particularly for low-traffic areas or parking stalls)
- Tree planting or tree pits
- Catch basin retrofits (filters, sediment trapping sumps, inlet sediment traps)

Auxiliary Benefits of Streetscape GI Practices

Many street-related GI practices have auxiliary benefits beyond treating stormwater. Streetscape bioretention, if built into the travel way, can serve to calm traffic by narrowing travel lanes, as well as provide an aesthetic enhancement. Tree planting and tree pits can serve to provide shade, lessening the developed-area heat island effect. Water quality swales can provide an aesthetic enhancement to streetscapes and, in certain cases, provide separation between vehicle and pedestrian or bicycle travel lanes. Catch basin retrofits can protect downstream infrastructure and existing stormwater treatment features by reducing sediment loads.

Village Streets – Case Studies

This document presents SIX examples of village street retrofit projects.

This chapter includes three case studies from Lake George, NY. The first describes a multifaceted conveyance system that was installed in a highway exit cloverleaf (Exit 22) to treat runoff from several roadway sections. That system uses a variety of rock and vegetated features to slow down, filter and infiltrate the road runoff. The second Lake George case study describes a "green outfall" that uses geotextile matting and vegetation as an alternative to the rip-rap design that is typical of most storm sewer outfalls. The last case study is about a complete renovation of the Beach Road corridor in Lake George, using heavy duty permeable asphalt to reduce runoff from the road.

There is an additional case study involving the use of dry wells in the Lake George Area.

From Syracuse is a case study taken from the Save the Rain program. While not in the Lake Champlain Basin, the Syracuse Concord Place Green Street project highlights how other communities in New York are tackling stormwater issues within the public right-of-way. Along Concord Place in Syracuse, underground infiltration trenches were added underneath the street. The systems consist of a deep-sump catch basin to trap sediment before flooding runoff into a 6" perforated, stone-jacketed pipe which gradually loses water into the surrounding soil so it can infiltrate. Any excess runoff drains back into the City's storm sewer.

In Vermont, the town of Northfield has implemented several green infrastructure practices. The Streetscape Bioretention Infiltration Cells project illustrates how a small piece of publicly owned land directly adjacent to the road right-of-way can be turned into a narrow, terraced bioretention practice using timber framing to provide an aesthetic structure.

These case studies are not meant to provide an exhaustive list of practices that could be used, but rather are good examples of how similar communities have dealt with stormwater issues.

Village Streets – Practice Examples

In addition to the Case Studies, there are a number of other green infrastructure practices that can be used on village streets. These practices are outlined in more detail in the Practice Example Appendix and include:

- Streetscape Bioretention
- Swales
- Tree Pits
- Hydrodynamic Separators
- Stream Daylighting

Also, the following practices may apply to the village streets environment, but are outlined in other sections of the Practice Example Appendix:

- Bioretention and Rain Gardens
- Infiltration Practices
- Permeable Hardscapes
- Road Outlet Protection
- Stone Armoring for roadside swales
- Storage Chambers

As a supplement to these practices, it is important to note that any village street improvement project should take into account the practices of Impervious Cover Reduction and Preservation of Natural Features and Conservation. These are important. By reducing impervious surface, even if it means ripping up existing pavement to return it to grass or trees, the amount of runoff that is necessary to manage will be reduced. This will make other practices smaller and easier to implement and maintain. By preserving and conserving natural features that may provide stormwater treatment, the need to build and maintain additional features is alleviated. These two steps should not be overlooked when planning new projects.

Porous Asphalt Street, Lake George, NY

In 2013, a 1.1-mile section of Beach Road in Lake George, NY was transformed from a four-lane collector road with traditional asphalt paving to a multi-modal corridor that accommodates vehicle, pedestrian, bicycle, bus and horse-drawn carriage traffic. The rehabilitation uses heavy duty porous asphalt to limit the amount of stormwater runoff and associated hydrocarbon, salt, and other road pollution reaching the lake.

Drainage Area:

The rehabilitation project footprint was about 4.5 acres which included installing 2500 linear feet of porous pavement. The project reduced the impervious surface of this road corridor by nearly 50%.

Image 2-CS-1-1. Left lane shows choker stone layer ready for installation of porous asphalt and right lane shows the base course of asphalt ready for the final top course.

Sizing:

The porous asphalt cross-section of Beach Road eliminates stormwater discharge into Lake George for storm events of 5 inches or less in a 24-hour time period. This reduces the pollutant loading for all but the most severe rain events.

Design:

This rehabilitation project was designed by engineering firm, Barton & Loguidice (B&L), out of Albany, NY. Rainfall and snow that falls on the road percolates through two layers of porous asphalt and enters a crushed stone reservoir course with a 40% void space that can hold a great deal of stormwater. This large void space ratio also provides frost protection. Perforated underdrain pipes re-distribute water throughout the reservoir layer and the stormwater eventually infiltrates into the native soil. If the permeable asphalt is overwhelmed by a heavy storm, stormwater overflows into the center median and then gets diverted to hydrodynamic separators located underground.

Beach Road is the first roadway in New York State and the largest in the northeastern United States, to use a heavy duty porous asphalt system. Through this project, the firm worked with NYSDOT to develop specifications for the asphalt mix design, foundation and reservoir courses, installation procedures, testing and acceptance criteria. These are now NYSDOT standards state-wide for heavy duty porous asphalt.

Funding:

This project was paid for with a combination of federal, state, and local funds. This includes funding from a New York State Environmental Facilities Corporation *Green Innovation Grant*.

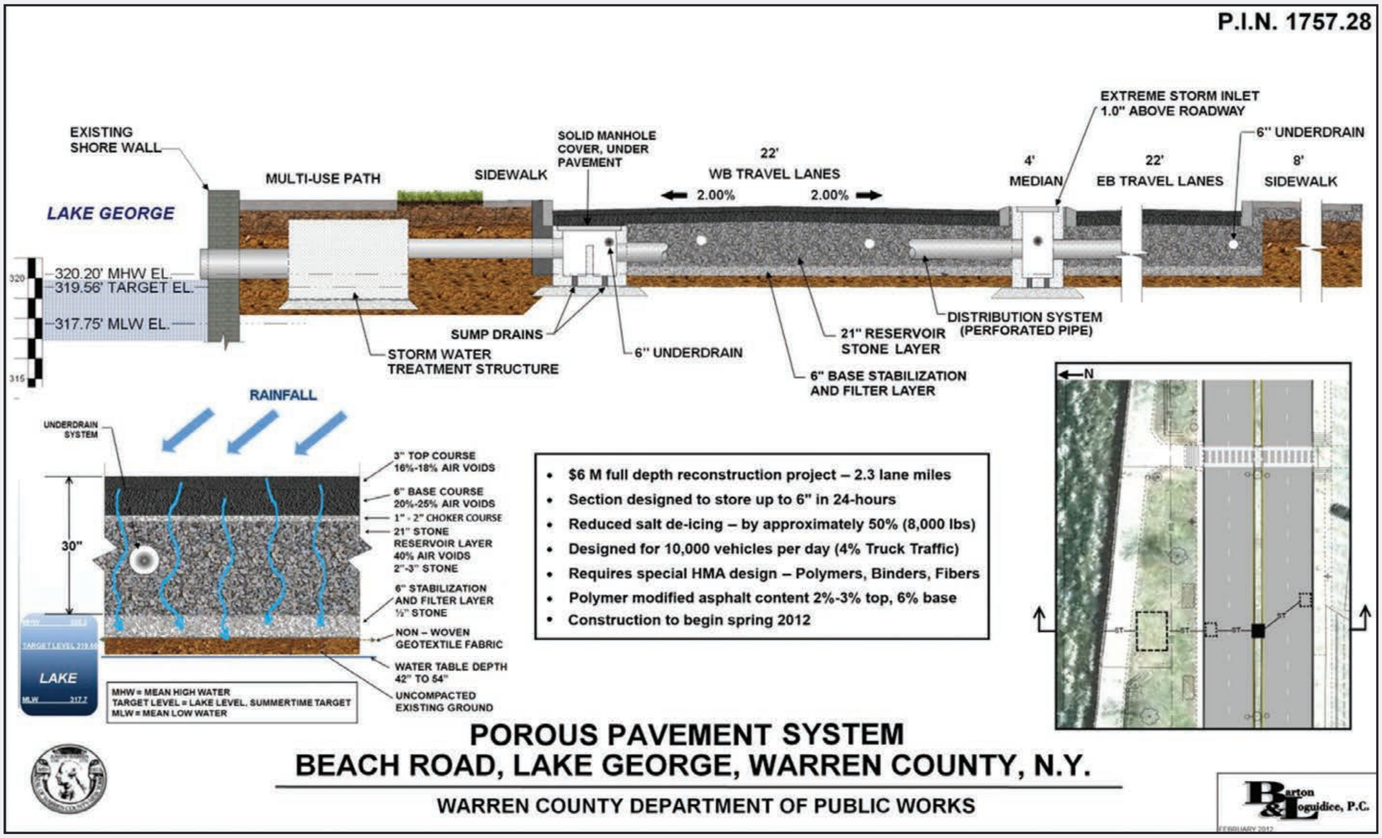


Image 2-CS-1-2. Cross-section of the heavy duty permeable asphalt road design used for Beach Road.

Operation and Maintenance:

Warren County Department of Public Works is responsible for maintaining Beach Road. The department hires an outside firm to vacuum the porous asphalt twice a year to remove trash and sediment. Specifically, the firm uses a *regenerative air* vacuum truck that blasts air onto the pavement to loosen the sediment on the surface.

Project Costs:

The total design and construction costs for this project total $7.5 million.

Contact (Designer)

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CASE STUDY

Green Outfall: Mountain Drive & Holly Drive – Lake George, NY

During the summer of 2016 in the Village of Lake George, a vegetated outfall was installed to fix an existing erosion problem. Located near a school bus garage at the intersection of Mountain Drive and Holly Drive, this outfall uses alternative materials from the typical rip-rap armoring. Prior to installment of this outfall, runoff from the street was by-passing an existing stormwater pond and flowing directly into the nearby stream where it had caused a head-cut. Now, two catch basins catch and convey the runoff to a drywell which then overflows into this vegetation-based outfall path and into the stormwater pond.

Drainage Area:

The drainage area for this practice is highly impervious. It primarily consists of runoff from the street and a small portion from the school bus garage property.

2-CS-2-1: The soon-to-be vegetated outfall in the Village of Lake George, shortly after installation.

Sizing:

Specific sizing calculations were not done for this project.

Design:

The Lake George Department of Public Works approached the Warren County Soil and Water Conservation District (SWCD) about getting their support to design and implement this stormwater retrofit project. Staff from the District created a concept design and secured grant funding to pay for materials. The Department of Public Works did all the grading with their equipment and District staff assisted with various elements of the installation.

The outfall design consists of coconut fiber coir netting covered with permanent geogrid mats that lock together and are secured to the ground with pins. On top of the geogrid layer sit several compost filter log check dams that are filled with composted bark mulch. Those are held in place with wooden stakes and slow the flow of stormwater coming down the slope. The outfall mats have holes in them that allow for grass and vegetation to grow up through them – a grass and wildflower seed mix was spread on the soil under the mats. Once the plants fill in, they will serve several functions: catch sediment, allow stormwater to infiltrate, and take up nutrients. This vegetated outfall design is a substitute for the traditional riprap approach, which also reduces the thermal pollution caused by large quantities of rock.

Funding:

The supplies and materials for this retrofit were paid for by a New York State DEC Water Quality Improvement program grant. Labor from the Village of Lake George and Warren County SWCD staff served as in-kind match for the grant.

Operation and Maintenance:

The Village of Lake George Department of Public Works owns and maintains the outfall structure and conveyance system. Their staff inspects the site in the spring and fall each year and removes any accumulated sediment and debris in the catch basins and dry well using a vacuum excavator.

Cost:

This project was part of a larger stormwater collection and treatment project. The supplies and materials for just the green outfall portion of the project was $2,600. Additionally, labor consisted of two staff for two days.

Contact (Designer)

Warren County SWCD
394 Schroon River Road
Warrensburg, NY 12885
518.623.3119
www.warrenswcd.org

Vegetated Conveyance: I-87, Exit 22 – Lake George, NY

In an effort to mitigate erosion and stormwater pollution in the English Brook watershed, a team of partners in the Lake George, NY area designed and installed a series of stormwater treatment practices in a large cloverleaf at Exit 22 at I-87 and Route 9 (NYSDOT property). Various phases of the project have been implemented over the course of 2015 and 2016. The project was initiated by the Fund for Lake George and Jarrett Engineers, Pllc. The Warren County Soil and Water Conservation District joined the project to acquire grant funding, develop the erosion and sediment control plan, oversee construction and provide hydroseeding/stabilization for the project. Village of Lake George Department of Public Works and NYSDOT also joined in as partners to provide input.

Drainage Area:

The treatment train that was installed slows down and filters runoff from the north side of the I-87 access ramp and a portion of Route 9 and conveys it to a basin in the cloverleaf. Prior to this project, runoff flowed through a paved flume directly into English Brook.

2-CS-3-1. Exit 22 cloverleaf before the retrofit was implemented.

Sizing:

The design addresses the summertime 100-year storm event and the frozen ground 10-year event. The system is designed to catch and treat the first flush of runoff and detain it for a short period. Higher flows bypass the new practices so as to not overwhelm and blow them out.

Design:

The retrofit, designed by Jarrett Engineers, includes the following treatment train (listed in order of the direction of flow):

1. A plunge pool at the inlet for energy dissipation – filled with native rock and cobble
2. A vegetated waterway for conveyance from the pool.
3. A forebay to act as a stilling pond and sediment trap.
4. A large detention and infiltration basin.

This project also used a variety of erosion control practices, including a permanent erosion control blanket with polypropylene and coconut fiber, a permanent rubber mat in place of rip-rap under the second culvert pipe to the basin (allows vegetated growth), a compost filter sock and specific grass seed and wildflower seed mixtures for the site. One approach that the team used that proved to be quite successful was to wait until the vegetation had become well established before installing the inlet and activating the system.

Funding:

A portion of the funding for supplies and materials came from the Fund for Lake George, but the majority of the costs were paid for with a NYSDEC Water Quality Improvement Program grant. Labor and equipment use from the Village of Lake George DPW served as match for the grant.

Operation and Maintenance:

The Village of Lake George Department of Public Works maintains this retrofit. Their staff visits the site to check for trash and debris once or twice a month. They also mow the grass areas about twice a year.

Cost:

Direct costs paid for by the grant included:

- Equipment rental - $9,000
- Supplies - $6,000
- In addition, several elements of construction were provided as match:
- Equipment - $13,500 (trucks, backhoe, etc.)
- Supplies – Outlet structure - $3,000
- Personnel - $11,500

Contact (Manager)

Warren County SWCD
394 Schroon River Road
Warrensburg, NY 12885
518.623.3119
www.warrenswcd.org

Contact (Designer)

Jarrett Engineers, Pllc
12 Washington St,
Glens Falls, NY 12801
(518) 792-2907

Image 2-CS-3-2. Completed plunge pool and vegetated conveyance during a rain event.

Image 2-CS-3-3. Aerial image of the cloverleaf and its associated drainage area.

Dry Wells: Town of Bolton

The following descriptions are adapted from the Warren County Soil and Water Conservation District's final report for the "Town of Bolton Stormwater Improvement Project":

During rainfall and snowmelt events, untreated sediment laden runoff flows from developed road networks in the Town of Bolton, much of which discharges directly to Lake George and its tributaries. Significant water quality declines have been noted in Finkle Brook by the Darrin Freshwater Institute, linked directly back to road runoff from town roads. This project begins an effort in the Town of Bolton that has seen great success in the Village of Lake George for addressing stormwater treatment.

The Warren County SWCD, Warren County DPW, The Lake George Association and the Town of Bolton worked cooperatively to develop a plan that meets the stated goals of this project. In early October of 2013, the project was completed and was successful in installing seven infiltration systems [dry wells] and rehabilitated an existing stormwater infiltration trench.

Drainage Area:

All of the dry wells treat road runoff. Some of these roads are quite steep, so their runoff is particularly susceptible to causing erosion. The dry wells serve to slow down and infiltrate this runoff.

Sizing:

See below.

Design:

Mohican Avenue: Two 4' x 8' drywells surrounded by 1' of #2 washed stone and filter fabric, located about 100' apart. Asphalt turnouts divert stormwater to a 24" high flow grate that will allow the water to enter the structures. Additionally, if the systems become fully charged, all overflow exits through a vegetated swale and into the woods where it can infiltrate at a much slower rate.


Borden Property: Single Drywell with Paved Swale


Stoffel Property: Side by Side Drywell with Paved Turnout and Vegetated Swale


Monroe Property: Single Drywell with Paved Turnout and Vegetated Swale

Image 2-CS-6-1. Photos showing construction and post-construction of the dry wells in Bolton.

Horicon Avenue: Two 12' x 12' holes 7' deep were dug to accommodate the installation of leveling rings, 4' x 8' drywells, traffic caps and a frame and grate. The county reconstructed the gutter of the road to direct stormwater to the structures. If the structures ever reached capacity or became clogged, the water would return to its original path along the edge of the road.

Edgecomb Pond Road: Significant blacktop on Edgecomb Pond Road and the highway garage allows for significant amounts of stormwater to run untreated to Finkle Brook. Over 11,000 sq ft of impermeable surface runs off the old highway garage and surrounding parking area. The District hired Kingsley Excavating to install one 4'x 8' drywell in the rear of the old garage to catch all of the stormwater that it sheds to the back of the building. Also, two drywells were installed side by each in the corner of the transfer station that sits below the old garage to catch the remaining storm water from the front portion of the roof and surrounding blacktop.

Funding:

The Soil and Water Conservation District received a 2010 Lake Champlain Basin Program Pollution Reduction Grant to pay for approximately half of the total costs of installing these practices. The other half of the costs incurred served as matching funds for the grant.

Operation and Maintanence:

Those dry wells that are located on a county road are maintained by the Warren County Department of Public Works. Those located along Town of Bolton streets are maintained by the town's Highway Department. The County was able to purchase a vacuum excavator through a grant, so it will be used to remove sediment from the dry wells, as needed. The Town will also have the ability to borrow it in order it to maintain their dry wells.

Cost:

The total project cost for installation was $52,327.50. This includes all costs paid for by the grant as well as matching costs. Approximately $14,000 of that total was for supplies, while the remainder of the costs were for personnel, travel costs, excavation contracting, and excavation equipment. The total project cost for installation was $52,327.50. This includes all costs paid for by the grant as well as matching costs. Approximately $14,000 of that total was for supplies, while the remainder of the costs were for personnel, travel costs, excavation contracting, and excavation equipment.

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CASE STUDY

Concord Place Green Street, Syracuse, NY

Image 2-CS-4-1. Photo of the project area on Concord Place.

The primary goal of this project is to capture runoff from the impervious surfaces of Concord Place. This project demonstrates a subtle approach to managing stormwater with the installation of underground infiltration trenches along the street corridor. Concord Place was the first “green street” projects in Syracuse. This type of project is unique among green infrastructure projects, although above the surface it appeared to be a traditional street paving process, below the street green infrastructure was installed to more effectively manage stormwater and protect water resources.

Drainage Area:

The infiltration trench will manage runoff from an estimated capture area of 39,000 square feet of Concord Place from Westcott Street to Allen Street within the Erie Boulevard Storage System sewershed.

Sizing:

The infiltration trenches will reduce runoff by 955,000 gallons per year without disrupting the underground utilities that already in this area.

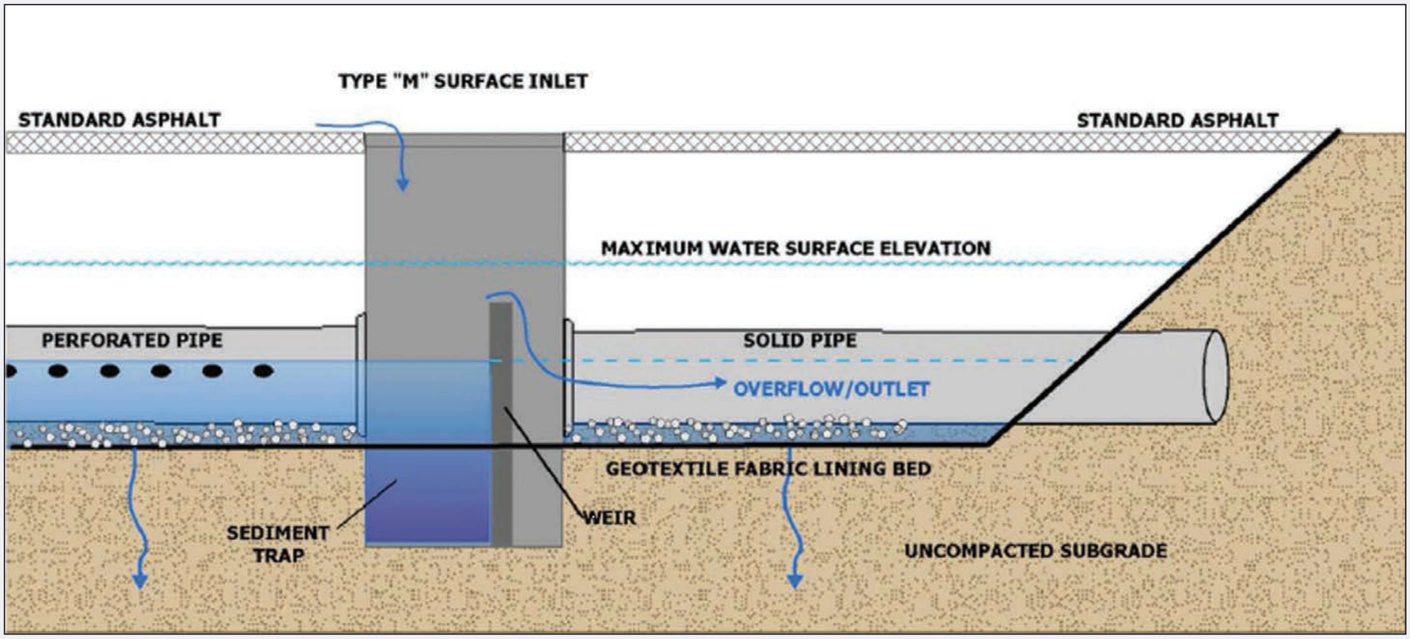

Image 2-CS-4-2. Conceptual design showing standard asphalt with the subsurface infiltration bed.

Design:

Image 2-CS-4-3. Construction of the underground infiltration trench.

Stormwater enters the system through the existing storm drain connections in the street. Instead of the collected water flowing to the sewer system, as was previously the case, the water is directed to an underground trench filled with a stone base. As the water enters the trench, it slowly filters through the stone and soil, eventually releasing into the ground water. In addition to the underground infiltration system, Concord Place also received a new mill and pave application to the street surface.

Funding:

The Concord Place project was constructed using the existing City Street Structures Contract. This was done by utilizing a change order to the contract, paid for by the County. This process allowed for a lower construction cost for the project. Furthermore, Concord Place was on the City's Road Reconstruction List, and as a result was reconstructed by the City after the completion of the green project.

Operation and Maintenance:

The City DPW will need to continue monitoring and cleaning the catch basins on Concord Place regularly so that sediment and other materials do not clog the infiltration system. Performance of the infiltration bed system will be monitored visually via the cleanouts and observation wells that exist in the system for buildup of sediment. In the event that the system is found to be filling with sediment, it will be cleaned so that it operates efficiently in the future.

Cost:

The project cost for the installation of this underground infiltration trenches was $78,900.

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Streetscape Bioretention Infiltration Cells, Northfield, VT

In the summer of 2015, the Town of Northfield installed a bioretention practice featuring bioretention infiltration cells on a hillside next to a paved road. Designed as part of a stormwater master planning study for the town, this type of planning and implementation is funded by the Ecosystem Restoration Program administered by the VT DEC.

Image 2-CS-5-1. View from the top of the west filtration planter.

Drainage Area:

The drainage area is 6.5 acres, 2.75 acres of which are impervious. Impervious surfaces managed within this area include village residential streets and driveways, as well as residential rooftops.

Sizing:

The practice is sized to fully infiltrate the Water Quality volume (WQv) storm. Anticipated runoff volume reduction is approximated at 165,600 ft^3 (1,240,000 gal).

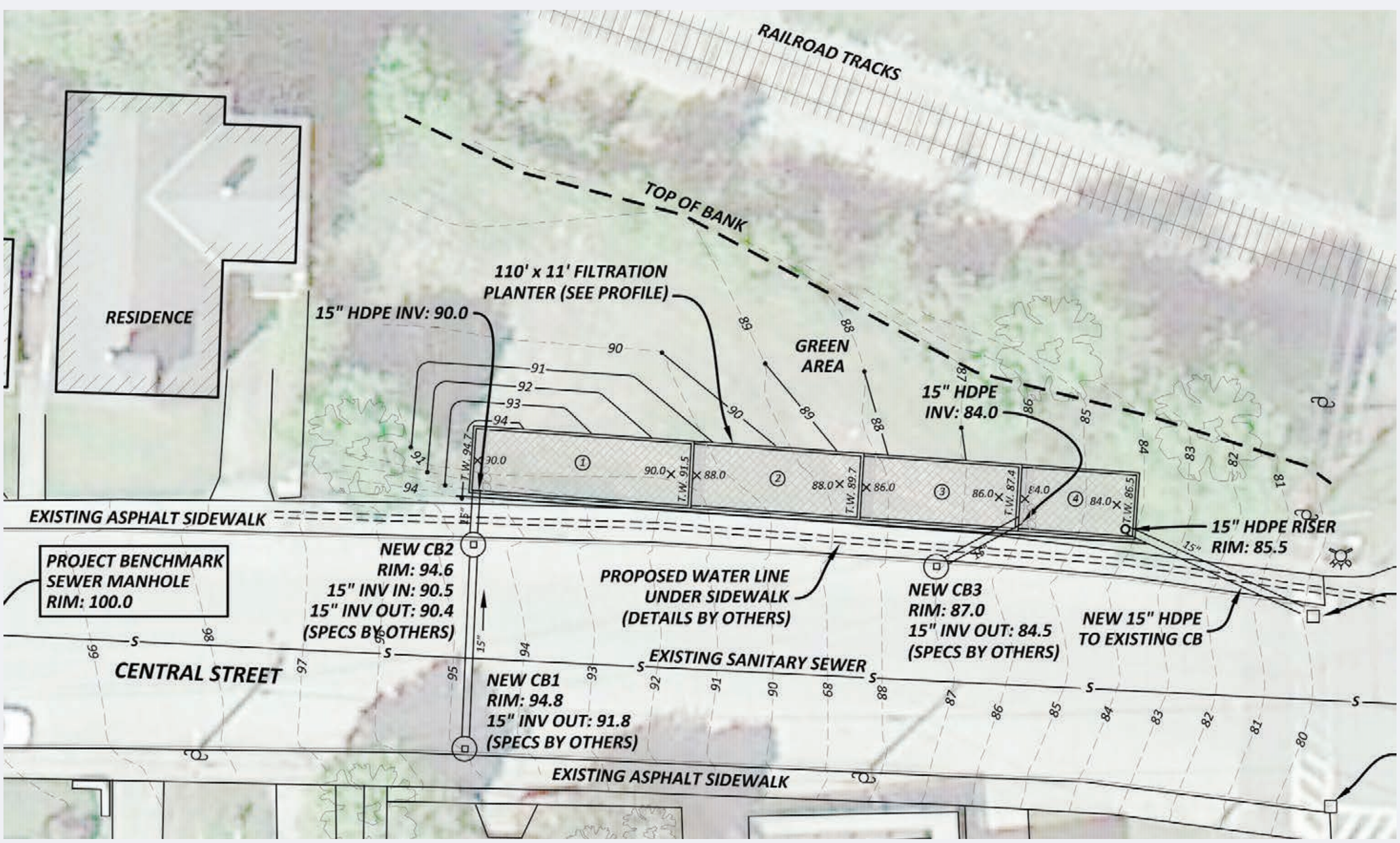

Image 2-CS-5-2. Plan view of west filtration planter plan detail.

Design:

The practice was connected to the existing storm sewer with a newly installed catch basin and pipe. The site is relatively constrained between the road right-of-way and a steep bank sloping towards the railroad tracks. In order to accommodate the steep slope of the open space in the road right-of-way, terraced beds were created out of timber, then backfilled with amended and native soils to maximize treatment. Bed planting and installation of low hedges around the structure is planned for a later date.

Funding:

Project funding was provided by the VT DEC's Ecosystem Restoration Program grant, a sub-section of the EPA 319 Clean Water Act grant program. Construction of the project was undertaken by the Town's public work department.

Operation and Maintenance:

The Town is supposed to clean the sediment out of the first cell of the structure, as well as replace stone at the inlet to prevent erosion. Once planted, the perennials used will need regular maintenance like any other publicly-maintained garden. Sediment removal and maintenance of plants will be on an annual basis, with additional plant maintenance as needed. The maintenance regime is relatively easy and not out of the scope of normal maintenance activities performed by the Town.

Project Costs:

Final project cost for this installation came to $42,707.

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Chapter 3 - Rural Roads

Introduction:

Rural roads, in particular unpaved rural roads, may not seem like a high-priority area for stormwater management as the level of development is relatively low with fewer impervious surfaces overall. However, rural roads tend to cross or parallel many water bodies, at times in steep areas. These crossings, and particularly the roadside swales, may have a large impact on water quality by delivering sediment from the road surface as well as large volumes of runoff water to these water bodies. This can have an adverse impact on water quality. Fortunately, stormwater management solutions for rural roads can be simpler and easier to implement that management solutions in more developed areas and are usually very easy to incorporate in improvement or maintenance projects.

An excellent resource is the *New York Rural Roads Active Management Program* (RRAMP) manual which details a large number of rural road related practices designed to improve water quality.

Stormwater Issues Related to Rural Roads:

The stormwater issues typically associated with rural roads are similar to those associated with village (developed) streets. There is usually some pollutant buildup on the road but the real issue can be the road surface itself. Because this surface is more erodible than pavement it can be a source of pollutants. Roadside swales also increase runoff peak discharges and volumes. Typical pollutants associated with rural roads include:

- Sediments – primarily associated with the road surface itself
- Phosphorus – usually bound to sediment particles, but can also be associated with leaf litter on the road surface and in ditches
- Heavy Metals – associated with vehicle passage
- Nitrogen – associated with organic litter, primarily leaves in rural settings
- Hydrocarbons – associated with vehicle passage
- Bacteria – from pet, or other animal, waste – less common on rural roads

Image 3-1. Some rural roads are built with whatever native soils are at hand, which can lead to the road losing its water-shedding shape and eroding badly.

In addition to pollutants, runoff volume is also an issue. Though usually lacking catch basins and pipes like village streets, rural roads usually have roadside swales which collect and concentrate runoff. If these swales outlet to water bodies, the delivery of both pollutants and large runoff volumes is assured. This not only pollutes the water body, but it can also cause significant erosion in streams or sedimentation in ponds and wetlands. Temperature effects similar to village streets are also possible.



Rural Road-related Opportunities:

There a number of opportunities that are specific to rural roads because these roads typically occur in areas where there is often open space directly adjacent to the road. Depending on ownership and owner-willingness, there can be stormwater management practice implementation outside of the road right-of-way. However many rural road practices, because of the smaller drainage areas associated with them, can be implemented within the right-of-way. Opportunities for implementation associated with rural roads include

- Stone armoring of roadside swales
- Stone check dams within roadside swales
- Outlet protection (plunge pools or similar)
- Road surfacing
- Infiltration practices (typically surface only – not underground)
- Water-quality swales

Auxiliary Benefits of Rural Roads Practices:

While most rural road stormwater management practices don't have the same aesthetic benefits as some of the urban streets practices, they do serve one notable and important function; by more effectively managing erosion through better road surfacing or stone armoring and check damming roadside swales, the amount of road material that is lost annually can be reduced. This will protect a municipality's investment in its infrastructure. Rural roads and their swales will last longer, reducing budgets for maintenance and re-building.

Image 3-2. Roads that have been re-surfaced with either a clean bank run gravel with a high percentage of fine particles, or something like Stay-Mat (crushed ledge product) will tend to hold their shape longer, though construction tends to be more expensive.

Rural Roads – Case Studies:

This document presents examples of rural road stormwater management improvement projects from Vermont, where the Vermont Better Backroads Program, on which the NY RRAMP is largely based, has been active for many years with numerous examples of successfully implemented projects throughout the state.

The first case study presents the initial step in conducting stormwater management on rural roads: inventorying the roads for issues that affect water quality and prioritizing them with potential solution types and costs. The example comes from the Dishmill Brook Watershed in East Burke, VT where numerous unpaved roads, along with a ski resort development, have contributed excessive sediment to the brook.

The second case study is from the Mad River Valley in Vermont where an inventory had already been conducted and local advocacy groups, along with public road crews and the VT Better Backroads Program staff, have been working on implementing on the ground solutions including stone armored swales, narrowing roads, vegetating swales and road shoulders, and installing new culverts.

Rural Roads – Practice Examples:

In addition to the Case Studies, there are a number of other practices that can be used on rural roads. These practices are outlined in more detail in the Practice Example Appendix and include:

- Road Outlet Protection
- Road Surfacing
- Stone Armoring of roadside swales
- Stone Check Dams in roadside swales
- Water Bars

These practices may also apply to rural road situations:

- Infiltration Practices
- Bioretention (not as typical for most rural road applications, but may work in certain situations)

As a supplement to these practices, it is important to note that rural roads projects should always take into account the practices of Impervious Cover Reduction and Preservation of Natural Features and Conservation. These are important. By reducing impervious surfaces the amount of runoff that is necessary to manage will be reduced. This may be difficult in the case of already-narrow rural roads but it should not be ignored as a possibility as this will make other practices smaller and easier to implement and maintain. By preserving and conserving natural features that may provide stormwater treatment, the need to build and maintain additional features is alleviated. These two steps should not be overlooked when planning new projects.

Image 3-3. Stone armoring of roadside swales is often a simple and effective solution to slow runoff and filter out sediment and other pollutants.

CASE STUDY

Dishmill Brook Scoping Study and Solution Selection, East Burke, VT

As part of a larger Stormwater Master Plan study, numerous sections of rural roads (unpaved) in East Burke, Vermont's Dishmill Brooke watershed were evaluated for susceptibility to erosion. Each section was given a rank based on the potential severity of erosion and its impact on water quality. Sites with badly eroded road surfaces or ditches that would have no impact on water quality were not evaluated. After each site was ranked, simple road erosion solutions were chosen from the Vermont Better Backroads Manual and supplemented with additional solution details as necessary. The result was a ranked list with preliminary solution suggestions, along with more detailed maps showing the approximate type and location for each erosion solution. The solutions presented on these maps were given material amounts, types, and approximate costs to facilitate construction.

Image 3-CS-1-1. Example of one of the assessment and solutions maps generated for the project showing type and location for materials.

Drainage Area:

The drainage areas for each solution varies with the common factor being the road surface which is always unpaved. Some sites were limited to only the road surface, while others had larger contributing drainage areas that were largely open grass land or forested. Contributing drainage areas tend to complicate solution selection and sometimes require more site work to divert flows from contributing drainage areas.

Sizing:

Practices were sized according to guidelines put forth in the Vermont Better Backroads Manual. Much of sizing guidance in this manual is used in the New York Rural Roads Active Management Program manual. At times, existing space dictated the sizing as most solutions were confined to the road right-of-way.

Image 3-CS-1-2. Eroding material from the road surface passes through a formerly stone-lined ditch that is now failing. Below the accumulated sediment is a steep drop to a stream.

Funding:

The project was funded by a State of Vermont Ecosystem Restoration Program Grant, which is funded by US EPA Section 319 grant funding. The funding only extended to the scoping study and solution selection. Implementation was undertaken by the road manager (in this case a private ski resort development).

Operation and Maintenance:

Typically for the practices specified in this case study, annual maintenance consists of inspection to ensure that all features are functioning properly and have not failed. Depending on erosion over the course of the year, stone-lined ditches and turnouts need to be cleaned of sediment. This is accomplished using a small excavator or other power equipment like a power-broom. This material should not be disposed of where it could possibly enter a water body, but should be returned to the road surface to be re-incorporated during road re-grading activities. Cleaning these features should take place prior to road re-grading.

Project Costs:

N/A – Dependent on local materials costs and size/type of solution

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CASE STUDY

Mad River Valley Road Erosion Solutions, Mad River Valley, VT

The Mad River Valley is mostly rural watershed in Vermont that drains to the Winooski River, a major tributary to Lake Champlain. Its steep valley slopes have numerous areas of residential development and most roads in the Valley are unpaved. Because of this there are many areas where local water bodies, such as small tributary streams, ponds, and wetlands, are being impacted by stormwater runoff from unpaved rural roads. The Friends of the Mad River has worked with local town road crews and the VT Better Backroads Program to identify and implement solutions, starting with a Valley-wide inventory and prioritization, then proceeding to implementation.

Image 3-CS-2-1. Photo of the ditch along Kew Vasseur road before the project. Note the active downcutting and erosion occurring.

Sizing:

Practices were sized according to guidelines put forth in the Vermont Better Backroads Manual. Much of the sizing guidance in this manual is used in the New York Rural Roads Active Management Program manual. At times, existing space dictated the sizing as most solutions were confined to the road right-of-way.

Image 3-CS-2-2. Photo of the project after completion showing the narrower road with vegetated shoulder and stone armored broader, flatter ditch.

Funding:

These projects were funded by a State of Vermont Ecosystem Restoration Program Grant, which is funded by US EPA Section 319 grant funding. The grant funding was only for materials. Labor and machine time was provided by each town as part of their in-kind donation to the grant.

Operation and Maintenance:

Typically for the practices specified in this case study, annual maintenance consists of inspection to ensure that all features are functioning properly and have not failed. Depending on erosion over the course of the year, stone-line ditches and turnouts need to be cleaned of sediment. This is accomplished using a small excavator or other power equipment like a power-broom. This material should not be disposed of where it could possible enter a water body, but should be returned to the road surface to be re-incorporated during road re-grading activities. Cleaning these features should take place prior to road re-grading.

Project Costs:

N/A – Dependent on local materials costs and size/type of solution

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Image 3-CS-2-3. Photo of the ditch and road before project implementation – note the relative lack of ditch along the left-hand side of the road.

Example 1: Narrowing road width, re-vegetating, and stone-lining roadside swales

The Kew Vasseur road in Fayston, VT was evaluated for erosion. Its primary issue was the roadside swale. It was too narrow and was actively downcutting, eroding material into a local tributary. In the summer of 2015, approximately 700 feet of road was narrowed by 5 feet. Vegetated erosion matting was installed along the lowest 500 feet of road shoulder to slow runoff entering the ditch. The ditch itself was widened, angled less steeply, and lined with large rip-rap rocks to slow runoff and filter out sediment.

Image 3-CS-2-4. Photo of the project after completion showing the narrower road width with the vegetated roadside swale along the left. One rock check dam is visible in the middle of the photos.

Case Study 2: Narrowing road width and creating a vegetate roadside swale

The Center Fayston Road, in Fayston, VT was evaluated for erosion. The primary issue was the road with, road shape, and the lack of a broad, vegetated roadside swale to receive drainage. Runoff would simply run down the surface of the road, concentrating until it reached a small tributary at the bottom of the road. 1100 feet of the road was reduced in width by 3 -5 feet to reduce impervious coverage. The roadside swale was also broadened using the road width reduction area and vegetated using a hydroseeder. Erosion matting and stone check dams were installed along the steeper upper portion of the road. A culvert at the bottom of the road was replaced, re-aligned, and armored with stone at the inlet and outlet to filter our erosion at the inlet and prevent scour at the outlet.

Chapter 4 - Parking Lots & Hardscapes

Introduction:

Parking lots and hardscapes often feature large swaths of consolidated (versus linear) impervious cover bordered by green space that can be used to locate green infrastructure practices to manage stormwater runoff. Compared to streets, they tend to have relatively few underlying utilities which allows plenty of room for underground stormwater management structures to detain and treat stormwater. A unique advantage of parking lots and hardscapes is that the pavement itself can serve as a stormwater management feature if porous materials are used. This preserves parking spaces and limits or eliminates the need to dedicate other land area for managing stormwater.

Image 4-1. Permeable paver materials for parking lots and hardscapes come in many styles. They reduce or eliminate runoff from a site by allowing rainfall and snowmelt to infiltrate into the ground below the parking lot.

Stormwater Issues Related to Parking Lots & Hardscapes:

The stormwater issues typically associated with parking lots are related to pollutant buildup on the pavement surface and the increase in runoff peak discharges and volumes. Typical pollutants on parking lot surfaces include:

- Sediments - usually associated with vehicle tracking from unpaved roads or parking lots as well as winter sanding activities
- Phosphorus – usually bound to sediment particles, but can also settle on to parking lots and hardscapes in the form of organic litter (leaves, grass clippings, etc.)
- Heavy Metals – associated with vehicle passage
- Salt/Chlorides – application of de-icing materials in winter months
- Nitrogen – associated with organic litter (leaves, grass clippings)
- Large Debris – trash, as well as organic litter
- Hydrocarbons – associated with vehicle passage and leaks

Image 4-2. Parking lots tend to accumulate pollutants as a result of car traffic importing various substances from other places, or, as shown here, can become pollutant sources themselves through fuel leaks.

In addition to these pollutants, there is the issue of the volume of runoff water. Because parking lots are often drained by catch basin and pipe systems, runoff is collected, concentrated, and delivered to water bodies much faster than it would normally reach them, with more overall volume. This can result in erosion of streams. It can also result in increased temperatures as runoff from impervious surfaces (especially dark surfaces) is usually warmed as it passes over them, versus infiltrating into the ground and coming out into water bodies cooled down as baseflow through soil.

The pollutants and flow issues related to this environment are managed with GI using combinations of filtration through vegetation and soil, infiltration into soil, evapotranspiration of runoff by plants, pollutant uptake by plants, and retention of runoff in soil void spaces.

Image 4-3. Green infrastructure practices that are integrated with hardscapes can serve as interesting and pleasant landscape features.

Parking Lots & Hardscape Opportunities:

There are a number of types of green infrastructure practices that are especially useful for treating stormwater in this environment. Opportunities for implementation within or next to parking lots and hardscapes include

- Permeable hardscape materials (particularly for low-traffic areas or parking stalls)
- Bioretention & rain gardens
- Water-quality swales
- Surface or sub-surface infiltration practices (trenches, basins, chambers)
- Hydrodynamic swirl separators
- Tree planting or tree pits
- Catch basin retrofits (filters, sediment trapping sumps, inlet sediment traps)

Additionally, several communities have found success using simple level grassy areas as intermittent overflow parking. Attention should be paid to lighting and parking alignment concerns, and not all soil types will be appropriate for this (soils that remain saturated should not be used without additional drainage for example). Also, it may be necessary to uncompact soils in these areas after several years as compaction will cause even seemingly pervious areas to act like impervious ones. Tilling or deep-ripping of soils will return them to their original hydrologic function.

These practices are outlined in more detail in the Practice Example Appendix. As a supplement to these practices, it is important to note that any parking lot or hardscape restoration project should take into account the practices of Impervious Cover Reduction and Preservation of Natural Features and Conservation. These are important. By reducing impervious surface, even if it means ripping up existing pavement to return it to grass or trees, the amount of runoff that is necessary to manage will be reduced. This will make other practices smaller and easier to implement and maintain. By preserving and conserving natural features that may provide stormwater treatment, the need to build and maintain additional features is alleviated. These two steps should not be overlooked when planning new projects.

Auxiliary Benefits of Parking Lot & Hardscapes GI Practices:

Many of these GI practices have auxiliary benefits beyond treating stormwater. Permeable paving and hardscape materials can reduce the amount of de-icing materials needed in winter months because melting snow infiltrates into the pavement and does not re-freeze on the surface. Bioretention cells and water-quality swales can provide an aesthetic enhancement and serve as landscape islands to separate parking aisles. Tree planting and tree pits can provide much-needed shade in the summertime, lessening the urban heat island effect. Catch basin retrofits can protect downstream infrastructure like piping and existing stormwater treatment features by reducing sediment loading.

Parking Lots & Hardscapes – Case Studies:

The seven case studies contained in this chapter depict a broad variety of types of green infrastructure, reflecting how flexible one can be in choosing stormwater management approaches for parking lots and hardscapes. In fact, some of these case studies listed below describe sites that use multiple categories of GI practices rather than just one type.

- Beach Day Use Facility Green Infrastructure, Lake George, NY – porous asphalt, rain gardens, swales, bioretention, pre-cast porous concrete, a hydrodynamic separator for non-porous areas, and grassed and vegetated pre-treatment areas.
- U.S. Oval Parking Lot Bioretention, Plattsburgh, NY – bioretention practice with grass swale conveyances at a public parking lot
- Lewis Park Porous Pavers, Syracuse, NY – installation of porous pavers to improve a basketball court surface, as well as part of a parking lot
- Mossy Point Boat Launch Green Infrastructure, Ticonderoga, NY – bioretention, permeable paver level spreader, and pocket wetlands.
- Hydrodynamic Separator and Infiltration Basin, Northfield, VT – infiltration basin coupled with a hydrodynamic separator to remove solids at a public parking lot in Vermont
- Farrell Street Pond Adaptive Flow Outlet, South Burlington, VT – adaptive retention time outlet control system at a wet pond in Vermont
- Underground Storage Chambers, Duxbury, VT – proposed system of underground infiltration chambers beneath a high school parking lot in Vermont

These case studies are not meant to provide an exhaustive list of practices that could be used for parking lots and hardscapes, but are rather good examples of how some communities in the Lake Champlain region have dealt with stormwater issues.

Parking Lots and Hardscapes – Practice Examples:

In addition to the Case Studies listed above, there are a number of other practices that can be used in this environment. These practices are outlined in more detail in the Practice Example Appendix and include:

- Bioretention and Rain Gardens
- Permeable Hardscapes
- Storage Chambers
- Infiltration Practices

These additional practice examples may also be useful in the parking lots and hardscapes environment:

- Hydrodynamic Separators
- Surfacing (for unpaved parking)
- Stream Daylighting (where applicable)
- Swales
- Tree Pits

CASE STUDY

Beach Day Use Facility Green Infrastructure, Lake George, NY

In May 2015, NYSDEC revitalized a beach day use area facility – boat launch, parking, pedestrian & bicycle access features – along the southern shore of Lake George that features a wide variety of green infrastructure. The engineering firm, Barton & Loguidice, designed and oversaw construction of the project. To manage stormwater, the site incorporates three acres of heavy duty porous asphalt, a bioretention system in the center of a roundabout, an underground detention and infiltration backup system, vegetated infiltration swales, pre-cast porous concrete, a hydrodynamic separator for non-porous areas, and grassed and vegetated pre-treatment areas.

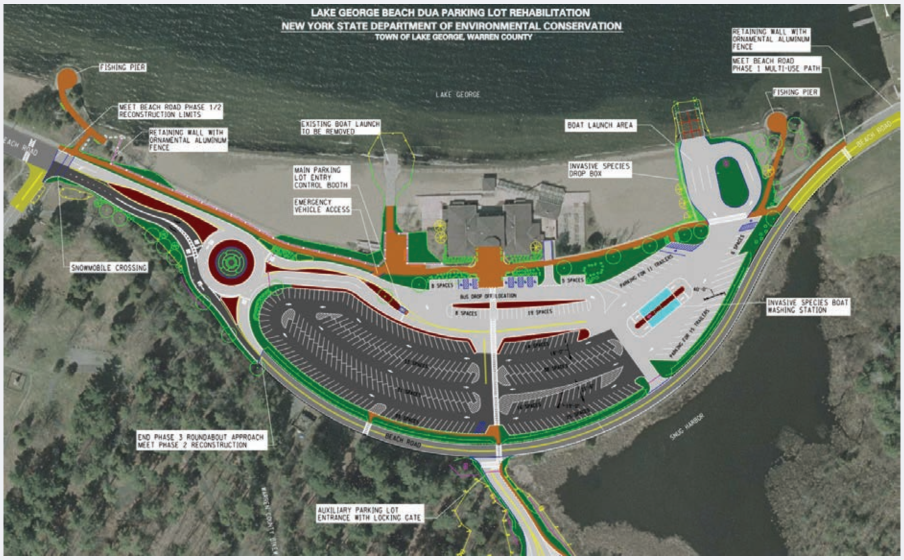

Image 4-CS-1-1. Plan-view image of the 2015 rehabilitation of the beach day use area in Lake George, NY.

Drainage Area:

Stormwater from the entire 10.1-acre site is managed and treated by one or more practices and there is very little run-on from outside the site. This re-habilitation project reduced the impervious cover on the site from 94% to 50%. Ultimately, stormwater either infiltrates into the underlying sandy soils or passes through several practices before being discharged to a nearby wetland adjacent to the lake.

Sizing:

Taken in combination, the stormwater management practices at this site can store and treat a 6” rainfall over a 24-hour period without overflowing. The underlying stone reservoir course below the parking lot can hold 140,000 cubic feet or 1 million gallons of stormwater. The native soils, which are quite sandy, have variable infiltration rates of 1 to 3 inches per hour.

Design:

Barton & Loguidice designed this project with help from NYSDEC who was very open to trying out the innovative GI practices described in this case study. Three acres of the site are comprised of porous asphalt with an underlying stone reservoir which rarely produces any runoff. For portions of the site that do produce runoff (regular asphalt drive lanes, sidewalks, etc.), the stormwater flows into either rain gardens, bioretention cells, a grass strip with amended soils, or underground infiltration chambers. A soil mix (80% sand and 20% topsoil) was brought in for the vegetated swales, rain gardens, and bioretention cells to serve as a filter medium.

This area of Lake George has significant historical value. During the archaeological digs that preceded construction, a spear point estimated to be 6000 to 8000 years old was found. Many other relics were found, making it clear that the design of this project should take into account the preservation of any remaining artifacts. Therefore, B&L created a special design for the parking lot and entrance road by elevating it 4 feet and using light-weight materials (i.e., the porous asphalt mix is 40% lighter than traditional road construction materials. Raising the parking lot and driveways also reduces flooding impacts from the lake.

Image 4-CS-1-2. Several GI practices on west end of site: rain garden in foreground behind the railing, bioretention in center of roundabout, and permeable asphalt in parking lot.

This project received the following awards: ACEC NY State Diamond Award as Top Environmental Project of the Year 2016, ACEC National Environmental Recognition Award 2016, NY State APWA Transportation Award 2016, *Stormwater Solutions* Magazine National Top 10 Projects Award 2015, and *Engineering News Record* Magazine Best Green Project 2015 in NY State.

Funding:

This project was 100% funded by NYSDEC.

Operation and Maintenance:

NYSDEC is responsible for maintenance of the site, following a specific maintenance plan. The agency has its own vacuum truck that it uses to remove sediment and debris from the porous asphalt areas. They vacuum the porous asphalt areas on a monthly basis. This truck also has attachments that enable it to clean out sediment that has collected at the inlets of the rain gardens and bioretention cells. DEC staff maintains the vegetated practices twice a year, in spring and fall. This involves weeding, mowing, and removing trash and sediment.

Project Costs:

The overall project cost approximately $7 million to design and build.

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U.S. Oval Parking Lot Bioretention, Plattsburgh, NY

Completed in 2015, the U.S. Oval Bioretention Basin was implemented by the City of Plattsburgh and local contractor Northern Snow & Dirt Inc., in Plattsburgh, NY, as part of a larger study to identify stormwater treatment options within the City. The site for the basin was selected as it was already an open area of land with few utilities, had sandy soils for infiltration purposes, and was above the seasonal high water table. This project has been well-received by the public and local government and has prompted the City to pursue more projects which reduce stormwater runoff from impervious surfaces.

Image 4-CS-2-1. View of the bioretention showing the NY native plantings.

Drainage Area:

Prior to this installation, catch basins and pipes were collecting runoff from the adjacent parking lot and roadway within the basin's drainage area. New catch basins and pipes were added to allow this runoff to enter the basin. Additionally, there is a catch basin and pipe to the basin from a grass swale which captures and pre-treats runoff along the edge of the parking lot. Overall, the basin treats a 2.5-acre drainage area, 1.5 acres of which is impervious. Impervious surfaces within this area include a paved roadway and parking lot.

Image 4-CS-2-2. Aerial view of infrastructure plan.

Sizing:

The bioretention basin was sized at approximately 1,200 ft^2 based on available space. The total volume of the basin is 9,700 ft^3 and is designed to infiltrate 50% of the 1-year storm (yields 8,300 ft^3 from the drainage area, at 1" rain per 24 hour period). Calculation for all sizing was accomplished using the NY Stormwater Management Design Manual. Onsite soil investigations indicate sandy soils which will act to filter and infiltrate stormwater runoff within the basin.

Design:

Existing available space determined the implementation of a bioretention basin. A number of designs were evaluated in how to best convey the runoff from the site's drainage area to the basin including swales, pipes, and sheet flow. Additionally, aesthetics, as well as handicap, public, and maintenance crew access had to be taken into account. Preliminary designs took these factors into consideration and were vetted by City engineering staff, public officials, and public works staff.

All plantings are native to the state and deep-rooted to maximize the plants' longevity and increase nutrient and water uptake. A seed mix that could tolerate flooding and drought was also found for the bioretention sump.

Image 4-CS-2-3. Bioretention inlet with stone armoring to prevent erosion.

Funding:

The project was funded by a grant from the Lake Champlain Basin Program. As this project was taken on voluntarily by the City of Plattsburgh and relied exclusively on the use of Green Infrastructure, it was eligible for this funding.

Operation and Maintenance:

The bioretention practice creates additional maintenance for the City's Public Works Department, but is relatively simple and primarily limited to sediment removal from catch basins and the sump of the bioretention basin, and plant maintenance and mowing. Sediment removal should be completed annually. Plant maintenance should be done seasonally and as-needed, and any plants which fail to thrive should be removed and replaced. According to the City, it has not made an appreciable difference in the budget.

Project Costs:

Total project cost was $112,000.

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Green Park: Lewis Park - Syracuse, NY

This project was a collaborative effort between Save the Rain and the City of Syracuse Parks Department. It provides improved basketball courts and a new parking lot, while helping to reduce stormwater entering the combined sewer system annually.

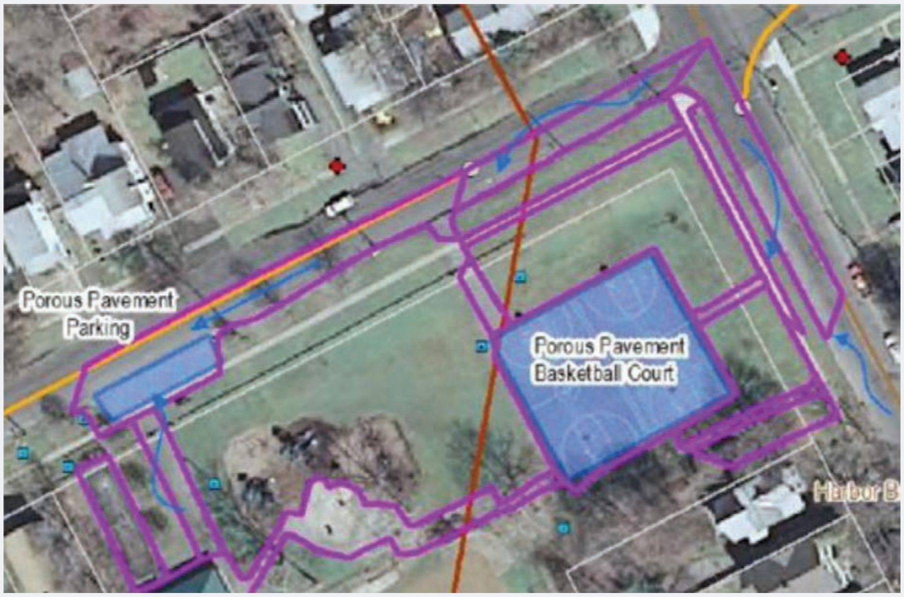

Image 4-CS-3-1. Conceptual green infrastructure design and drainage areas.

Drainage Area:

The capture area of Lewis Park is 30,000 square feet at 305 Lewis Street and 825 Milton Avenue within the Harbor Brook sewerehsed that is a part of the 063 and 003 combined sewer overflows.

Sizing:

This project, including porous asphalt and porous pavers will reduce runoff by an estimated 524,000 gallons per year.

Design:

A prominent feature of the enhancements made to Lewis Park is a new basketball court made of porous asphalt. This allows stormwater to infiltrate directly through the asphalt surface, eliminating ponding and making the court playable immediately after a rain storm. Runoff is collected from Lewis Street to the north, Milton Ave to the east, walkways within the park, and the court itself. This was the third basketball court completed in conjunction with Courts4Kids, an initiative of the Jim and Juli Boeheim Foundation and the Carmelo K. Anthony Foundation. Another green infrastructure component of this project was the replacement of the parking area with porous pavers to help collect runoff from structures and walkways within the park as well as from Lewis Street along the north side of the park.

Image 4-CS-3-2. Porous asphalt installation for basketball court.

Funding:

Funding for this project was a collaborative effort between Couts4Kids, the City of Syracuse, the Department of Parks and Recreation, and Onondaga County.

Operation and Maintenance:

Maximo Asset Management software is used by the Onondaga County to track operations and maintenance on sites. At Lewis Park typical monitoring and protocol will take place to ensure that the porous pavement remains functional. In the event the pavement surface becomes clogged with fine sediments the surface will be vacuumed with a commercial cleaning unit.

Cost:

The total bid amount for this project was $207,152.

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Image 4-CS-3-3. Renovated porous basketball court at Lewis Park.

Mossy Point Boat Launch Green Infrastructure, Ticonderoga, NY

A NYSDEC boat launch and parking lot located on the west side of Lake George in Ticonderoga, NY was retrofitted with three different types of green infrastructure practices: a bioretention cell, stormwater pocket wetland, and a permeable paver level spreader. These retrofits, completed in 2014, were originally recommended in a local stormwater study conducted by the Warren County Soil and Water Conservation District. Previous to these retrofits, stormwater runoff from the parking lot (and the pollutants it carries) was flowing straight into the lake.

Image 4-CS-4-1. Excavation and installation of rock weirs for the bioretention cell at Mossy Point.

Drainage Area:

The entire 3.5-acre site, which includes an asphalt drive, cinder stone parking lot, and several grass islands is included in the drainage area to the GI practices. The permeable paver level spreader receives runoff from asphalt surfaces only, while the bioretention and pocket wetland features receive runoff from both asphalt and cinderstone surfaces. Therefore, there is a greater sediment load entering the vegetated practices. Any stormwater overflow from these practices goes into the lake as sheet flow.

Image 4-CS-4-2. Pocket wetland cells filled with water after a rain event.

Sizing:

The three GI practices at this site can capture and store runoff from at least the first 0.5” of rainfall that falls on the site. The footprint of the bioretention practice is 600 square feet and the pocket wetland footprint is 1000 square feet. The maximum ponding depth for both practices is approximately 7 inches. The permeable paver level spreader is 10 feet wide by 100 feet long.

Design:

Warren County Soil and Water Conservation District created the design for the three GI practices at this site. The bioretention design is relative straight-forward: Soil was excavated to create a depression and native plants from a nearby nursery were added into the existing soils. A rock weir holds back water in the bioretention until it either infiltrates into the ground or flows over the top before entering the lake. The pocket wetland is a system of three consecutive cells divided by 4" tall rock weirs that allow water to pool. The cells were filled with native plants tolerant of standing water. The native soils at the site are quite clayey, but the designs for the bioretention and wetlands did not involve any soil amendments or replacement.

The permeable paver level spreader is comprised of an underlying layer of 1A stone with a True Grid paver mesh on top, and pea gravel at the surface to fill the voids in the paver mesh. After the site was in use for some time, it became apparent that the gravel was getting kicked out of the level spreader from the trucks and trailers driving over it. As a solution, the pea gravel was replaced with larger, more angular stone that is less mobile and provides better grip for tires.

Image 4-CS-4-3. Pea gravel being added to fill the TrueGrid paver mesh in the permeable level spreader.

Project Costs and Funding:

Monetary support for this project came from a grant through the Lake Champlain Basin Program ($15,000), supplemented with $5000 from the Lake George Association. The project also involved a lot of in-kind services for design and construction. The total cost of the construction project was approximately $22,000.

Operation and Maintenance:

Staff from the Town of Ticonderoga and the Lake George Association have agreed to take care of any immediate maintenance needs for the GI practices. NYSDEC will eventually take over maintenance. In its first two years the only maintenance needed has been to re-apply grass seed to some of the slopes around the bioretention and pocket wetland to get vegetation cover properly established. The sediment was removed in the spring and fall (from the inlets to the bioretention and wetland) and will likely remain a regular part of the maintenance regime for the site. Eventually True Grid pavers and stone will have to be removed to clean out sediment.

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Hydrodynamic Separator and Infiltration Basin, Northfield, VT

An infiltration basin and a HydroInternational Downstream Defender, a hydrodynamic swirl separator (HSS), were installed in the Town of Northfield, VT, by local contractor G & N Excavation in 2016. The practice is located on Town land at the edge of a parking lot bordering the Dog River, a tributary of the Winooski River. This project is part of a town-wide stormwater retrofit study and will affect the Town's permitting needs in regards to the emerging requirements under the Lake Champlain TMDL.

Image 4-CS-5-1. Hydrodynamic swirl separator by the Dog River in Northfield, VT.

Drainage Area:

The drainage area encompasses approximately 14 acres, and manages 8.5 acres of impervious surface. The surfaces collect runoff from a mixture of public roads, private driveways and roofs, public spaces including parks, and private parking lots within the Town's downtown area.

Sizing:

Designed to infiltrate the 1-year Channel Protection volume (CPv) storm, the infiltration basin and HSS are anticipated to result in a 100% runoff volume reduction for both the Water Quality and Channel Protection volumes.

Image 4-CS-5-2. Infiltration basin by the Dog River in Northfield, VT.

Design:

The HSS-basin combination was chosen for this site as the HSS will decrease sediment loading to the basin. This will alleviate the need for a forebay and facilitate maintenance by the local public works department. The basin will then decrease the volume of stormwater runoff entering the river during storm events. The basin was placed at the edge of the parking lot as the land is publicly owned. No parking spaces were taken to accommodate the basin. A new catch basin structure also had to be installed to serve as a flow-splitter to feed runoff into the HSS and basin. Larger flows will bypass the HSS and basin. This type of 'offline' configuration is favored as higher flows won't scour sediment out of the basin, resulting in re-suspension of settled pollutants.

Due to the timing of project completion, the basin was not planted. Planting is anticipated to occur during spring 2017. Plants to be used within this bioretention feature include native, perennial, salt-tolerant, bare-root plants.

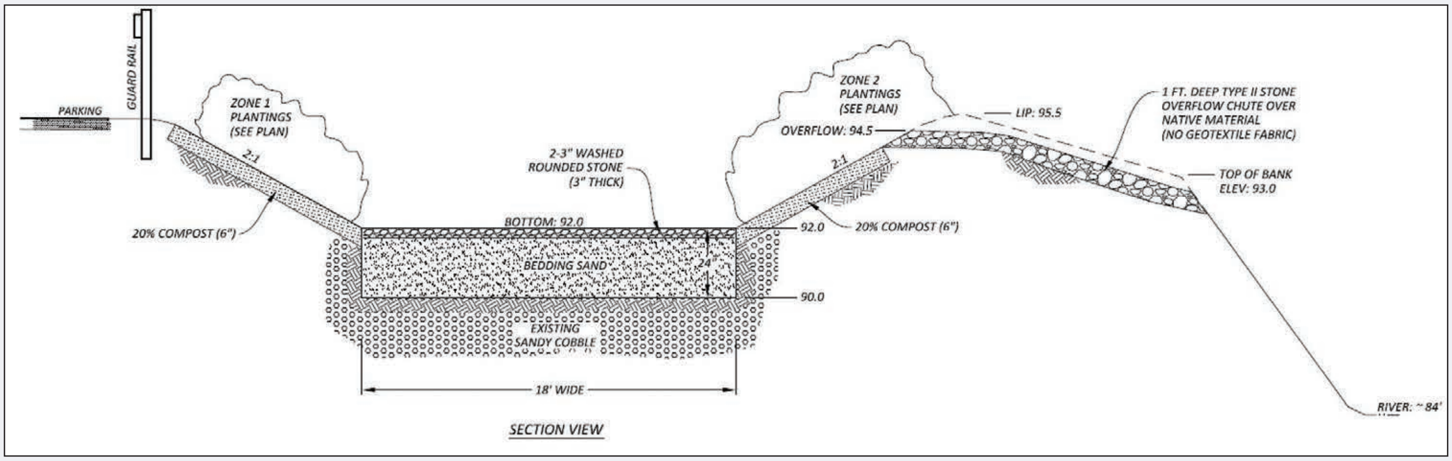

Image 4-CS-5-3. Bioretention infiltration basin detail from project design plan.

Funding:

Funding for this project was provided by the VT DEC's Ecosystem Restoration Program grant, administered by the Central Vermont Regional Planning Commission on behalf of the Town of Northfield.

Operation and Maintenance:

Maintenance of the infiltration basin is simple and required biannually in the spring and fall. This involves weeding of plants, replacing any plants which fail to thrive, and eradicating invasive species such as Japanese Knotweed.

The HSS requires a yearly clean out. This is moderately difficult and requires special equipment which can be expensive. The HSS is cleaned by a vactor truck with a small hose attachment to reach the sediment pump. The catch basin must be inspected during this time and cleaned out as well. It is recommended that this occur in the spring after winter sediment has been washed off the drainage area's surfaces.

Project Costs:

Final design and engineering costs including survey work, plan preparation, construction oversight, and design certification came to $16,372. Construction costs of labor and materials including the proprietary HSS structure was $37,585.

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Farrell Street Pond Adaptive Flow Outlet, South Burlington, VT

In 2007, a standard wet detention pond was installed by the South Burlington Department of Public Works managing 12 acres of impervious surfaces in a nearly 40-acre drainage area. In 2016 the outlet structure of the pond was retrofitted with a Continuous Monitoring and Adaptive Control (CMAC) system manufactured by Opti. The CMAC is designed to continuously monitor precipitation, holding runoff in the pond during dry conditions and releasing it prior to storms. This increases retention time, which improves treatment, and reduces flows to receiving waters, which lessens impacts on local water bodies.

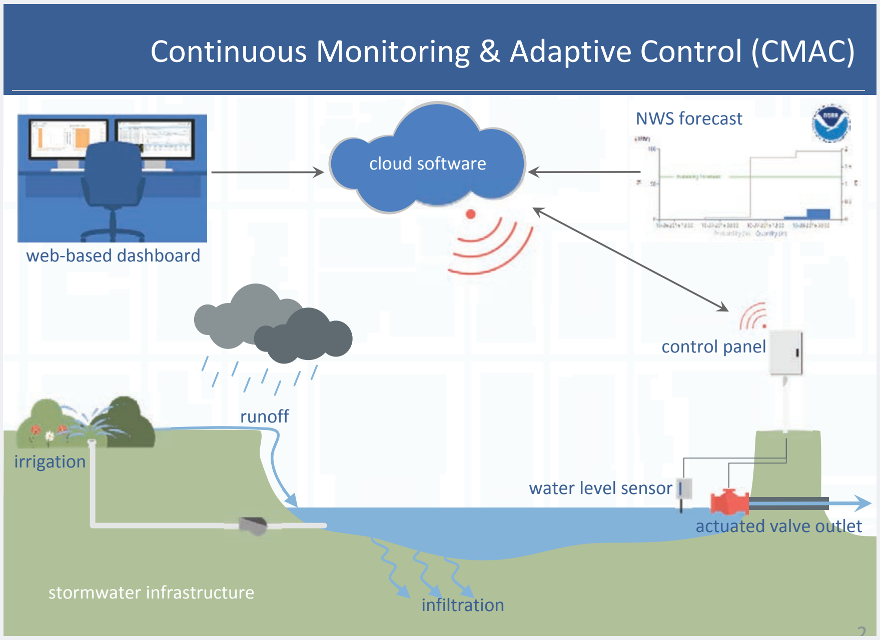

Image 4-CS-6-1. Illustration of how a typical CMAC works from monitoring weather to actuating the release valve.

Drainage Area:

The drainage area for the pond is nearly 40 acres, with 12 acres of impervious surfaces consisting of rooftops (residential and commercial), parking lots, municipal roads, and driveways.

Sizing:

The pond was originally designed to capture and slowly release the 1-year Channel Protection storm volume of nearly 50,000 cubic feet. The CMAC retrofit handles that volume, but retains it longer than a typical wet detention pond. No runoff infiltrates, so there is no runoff reduction associated with this practice – it is for volume control only.

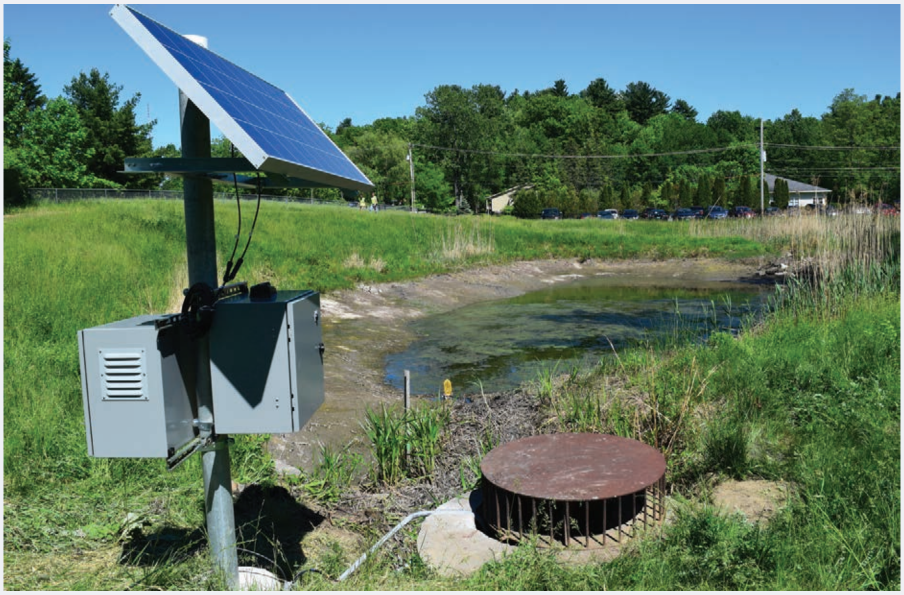

Image 4-CS-6-2. The Opti CMAC installed at the Farrell Street pond showing the control and communication box (solar-powered). The valve controlled by this infrastructure is located in the outlet works.

Design:

The City of South Burlington Department of Public Works (City) partnered with OptiRTC (Opti) to evaluate continuous monitoring and adaptive control (CMAC) technology on the Farrell Street Detention Pond as tool to maximize the existing storage capacity and thereby reduce downstream wet weather flows and improve water quality. Farrell Street Pond lies within the 4,673 acre Potash Brook Watershed which ultimately drains into Lake Champlain. The Potash Brook and its tributaries are Class B waters, which have been listed on the Vermont 303(d) as impaired due to *E. coli* and unmanaged stormwater runoff. In response, the State of Vermont has developed flow-based stormwater TMDLs for Potash Brook and 11 other watersheds. For the purposes of the Potash Brook Stormwater TMDL, VT DEC determined that flow in Potash Brook would have to be reduced by 16.5% under the "high" flow condition, which corresponds to a 1 year storm event (design storm 2.1 inches of rain over a 24 hour period).

Funding:

The pond retrofit was funded by the City of South Burlington's Department of Public Works. The City's stormwater projects are funded in part by a City-wide stormwater utility fee.

Operation and Maintenance:

Beyond the normal maintenance required for a wet pond, the CMAC hardware includes level sensors (3-5 year expected life) actuated valve (10+ years expected life), control panel (10+ years expected life) and a battery (3-5 years expected life). There may be some decommissioning done over the winter months if conditions warrant.

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CASE STUDY

Underground Storage Chambers, Duxbury, VT

Harwood Union School in Duxbury, VT, in partnership with a local watershed advocacy group, Friends of the Mad River, contracted the services of Watershed Consulting Associates, LLC as part of a campus-wide stormwater master plan. This plan includes the creation of stormwater management solutions to help the school meet future stormwater regulatory requirements. Integration of underground storage chambers in the school's parking lot is a part of the master planning process renovation plan.

Image 4-CS-7-1. Concept illustration of underground storage chambers; sub-parking lot installations are common.

Drainage Area:

The school property includes nearly 9 acres of impervious surfaces including a mixture of flat roofs, parking lots, and landscaped areas. Runoff from these surfaces are currently collected in roof drains and catch basins, and piped to a stream behind the campus. This stream is a small tributary of the Mad River, which ultimately drains to Lake Champlain.

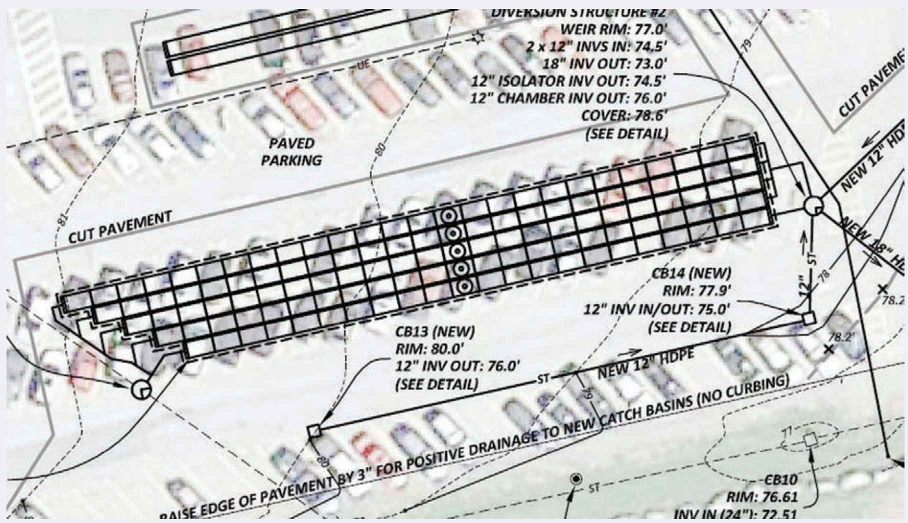

Image 4-CS-7-2. Plan view of the final design for the underground storage chamber system.

Sizing:

The underground chambers are designed to nearly infiltrate the 1-year storm, yielding approximately 2 inches of rain within a period of 24 hours. This is anticipated to reduce 90% of the Channel Protection volume, and 100% of the Water Quality volume. Onsite soil investigations indicate sandy soils which can infiltrate up to 6 inches per hour. Well-drained soils are critical to this design.

Design:

Sub-surface chambers were chosen as space is limited on the school's campus. Surface features, such as bioretention or gravel wetlands, were rejected because there was not enough available space for them to treat the volume of stormwater produced on campus.

In an effort to maximize the system's runoff capture, the parking lot surface was reconfigured with a pavement shim and catch basins were added to ensure runoff delivery to the chambers. This increased the overall project cost. Additionally, there were some concerns regarding Vermont's Underground Injection Control program and the potential for runoff from the bus storage area to reach the chambers. This is not permitted and was avoided by creating the pavement shim which separated the bus yard from the chamber drainage area.

Funding:

Project design was funded by an Ecosystem Restoration Program grant from the VT DEC. Project implementation is expected to be funded in part by the VT DEC and the school's capital budget.

Operation and Maintenance:

An isolator row receives the first flush of runoff which is typically dirtier than runoff generated later on in a storm event. This row is wrapped in a double-layer of geotextile fabric to filter out suspended sediments. When sediments along the entire bottom surface reach 3 inches in depth, the row must be cleaned using a wide-angle water jetter and vacuum cleaning truck. This should happen semi-annually. Additionally, it is recommended that all catch basins be vacuumed annually to prolong cleaning intervals for the isolator row. Maintenance is fairly simple if proper equipment is available.

Project Costs:

Total cost of materials as placed is projected at $190,743.

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Chapter 5 - Building Development

Introduction:

Buildings are perhaps the most pervasive feature of our urban landscapes, and thus represent a huge pool of potential GI projects. In addition, buildings are the "top of the drainage system" and associated GI practices meet the objective of treating runoff close to its source. If runoff can be captured, diverted, and reduced from building surfaces, then that reduces the burden for downstream stormwater practices in the conveyance system. This chapter provides several case studies for practices implemented at the building scale.

Image 5-1. Rain that falls on the Golden Arrow Lakeside Resort roof in Lake Placid, NY is collected and retained in the soil and plants on their green roof, slowing down peak discharge to stormwater sewers and natural water bodies.

Stormwater Issues Related to Parking Lots & Hardscapes:

Building rooftops may not be the dirtiest part of an urban site or watershed. However, there are pollutant and flow issues associated with buildings. Rooftops represent collection and delivery systems for urban pollutants associated with dry deposition from atmospheric sources (such as nitrogen) as well as organic debris, such as leaves and bird feces which contain phosphorus. Rooftops can also raise the temperature of runoff, which can adversely affect cold-water species. However, from a stormwater perspective, the chief benefit of rooftop GI is to reduce the volume and peak rate of flow to the downstream system.

While buildings represent a huge potential for runoff capture, there are several key challenges for this management environment. A few are noted below.

Integration with Architecture and Structural Engineering: Our building and design professions are quite comfortable working within their individual silos, but GI associated with buildings must bust out of those silos. Civil engineers and stormwater planners must necessarily work with allied professionals to assess the design and structural elements of practices, such as vegetated roofs and rainwater cisterns. In a northern climate where snow loading to roofs can be an important factor, roof structures must be design to meet the load of both green-roofing or roof-top cisterns, as well as seasonal snow-load. Fortunately, the green building movement has already laid a strong foundation for this type of collaboration.

The Building is Only Part of a Larger Site: In ultra-urban settings, the building footprint may constitute a substantial proportion of the entire site. In these cases, GI practices focused on the building are very appropriate. In the more common case where the building is part-and-parcel of a larger site that also includes parking lots, travelways, courtyards and sidewalks, and landscaped areas, building-based GI must be evaluated on a cost-benefit basis compared to landscape-based practices. In either case, green roofs and rainwater harvesting systems can be attractive parts of a "treatment train" stormwater system.

Building Opportunities:

There are many opportunities available when considering how to manage rooftop runoff from stormwater. Many of these opportunities have relatively small footprints, meaning that constrained spaces aren't necessarily a problem. Additionally, stormwater from roofs is usually cleaner, so GI practices treating that runoff don't usually need elaborate or expensive pre-treatment, and operation and maintenance costs are typically lower due to the reduced need to clean and maintain the practices. Some practices widely available are

- Green Roofs
- Rain Barrels or Cisterns
- Rooftop Disconnection (where suitable open, permeable, well-drained soils can be used)
- Stormwater Planters
- Rain Gardens or Bioretention (primarily used for overflow of cisterns, or as treatment for gutter downspouts)

These practices are outlined in more detail in the Practice Example Appendix. In addition to these structural practices, it is important to remember the Runoff Reduction general practices of Impervious Cover Reduction and Preservation of Natural Features. These are important, particularly for new building development. By reducing the impervious footprint of a building through more efficient use of building space or vertical expansion, both of these general practice goals can be met. It may also be possible in the case of existing buildings to tear down portions of a building that are largely unused and remediate the landscape and soils underneath it. These two practices should not be overlooked when planning new buildings, or assessing current building resources.

Image 5-2. A simple rooftop runoff rain garden at the Morrisville Public Library in Morrisville, VT serves to infiltrate rooftop runoff that would otherwise spill across pavement and transport pollutants to the stormwater sewer.

Auxiliary Benefits of Parking Lot & Hardscapes GI Practices:

Building GI practices can have significant co-benefits, and most of these are acknowledged in LEED and the green building movement. These benefits include reducing the urban heat island effect by decreasing absorbance of solar radiation to darker roofing material and increasing the cooling effects of plant-based evapotranspiration. This can also reduce energy consumption as cooler buildings will require less air conditioning. They can also reduce demand for treated potable water for non-potable applications (washing vehicles, irrigation, toilet flushing) but capturing and re-using rainwater to accomplish these tasks. Additionally, creating attractive rooftop gardens can increase a building's aesthetic value which can also increase its real estate value.

Parking Lots & Hardscapes – Case Studies:

There are five case studies in this chapter that illustrate the diverse ways in which stormwater runoff from building roofs can be managed with green infrastructure.

- Rainwater Harvesting Project – Town of Lake George Museum Complex, Lake George, NY – rainwater harvesting and irrigation with a cistern and pump system.
- Golden Arrow Hotel Green Roof – Lake Placid, NY – green roof for stormwater retention and aesthetics.
- Syracuse War Memorial Arena Cistern – cistern to re-use stormwater for ice-making at a public hockey arena
- City Garage Cistern Retrofit for Vehicle Washing, St. Albans, VT – in-ground cistern used to capture rooftop runoff and wash municipal vehicles with an overflow to a small bioretention practice.
- Public Library Rain Garden, Morrisville, VT – rooftop runoff rain garden interception runoff from a downspout at a public library.

Parking Lots and Hardscapes – Practice Examples:

There are diverse opportunities for stormwater treatment associated with buildings. Some of the most common are

- Green Roofs
- Rain Barrels or Cisterns
- Rooftop Disconnection (where suitable open, permeable, well-drained soils can be used)
- Stormwater Planters
- Rain Gardens or Bioretention (primarily used for overflow of cisterns, or as treatment for gutter downspouts)

These practices are outlined in more detail in the Practice Example Appendix. In addition to these structural practices, it is important to remember the Runoff Reduction general practices of Impervious Cover Reduction and Preservation of Natural Features. These are important, particularly for new building development. By reducing the impervious footprint of a building through more efficient use of building space or vertical expansion, both of these general practice goals can be met. It may also be possible in the case of existing buildings to tear down portions of a building that are largely unused and remediate the landscape and soils underneath it. These two practices should not be overlooked when planning new buildings, or assessing current building resources.

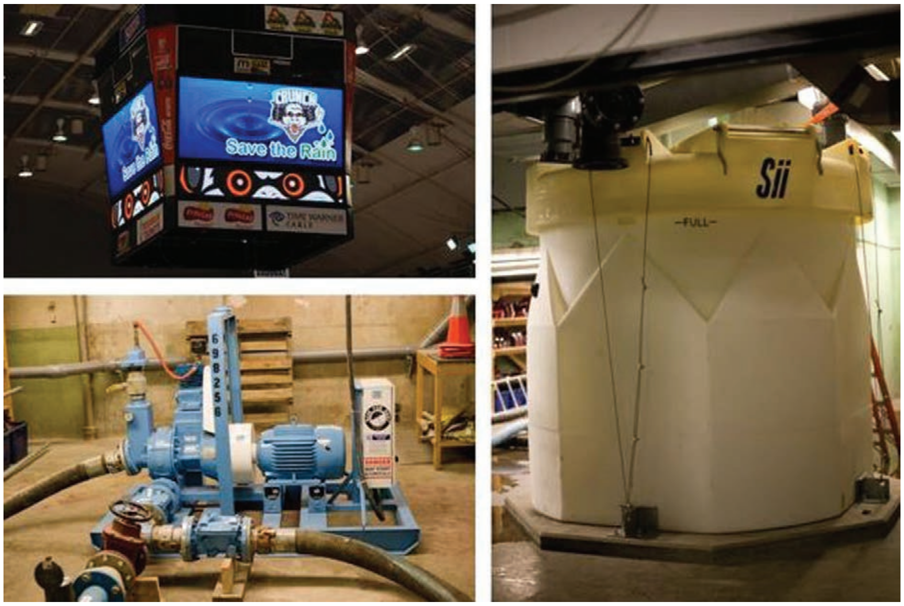

Image 5-3. A stormwater cistern system installed in the War Memorial Arena serves to capture rooftop runoff from the arena. It is then filtered and re-used primarily for ice-making for Syracuse's America Hockey League team.

Rainwater Harvesting Project – Town of Lake George Museum Complex, Lake George, NY

The Rainwater Harvesting Project at the Town of Lake George Museum Complex is a project that seeks to collect rainwater from the roof of the museum complex to irrigate gardens and lawns around the museum. This project decreases or eliminates the museum's need to purchase municipal treated water to accomplish this purpose. Additionally, collecting this water and spreading it over the entire site as irrigation will help eliminate erosive high-flows from eroding nearby Shepard's Park.

Image 5-CS-1-1. Cistern site prior to construction.

Drainage Area:

The drainage area for the cistern is the museum's guttered roof. Some adjustments had to be made to the gutters on the museum roof in order to accommodate the new downspout. A 0.5" rain event fills the tank.

Sizing:

The cistern is a 1,100 gallon plastic structure furnished by FW Webb. The system is equipped with a Rain Sensor system override that can divert water away from the cistern downspout when the cistern is full if irrigation activities haven't drawn it down. To date, the harvested rainwater seems to be adequate to meet irrigation needs.

Image 5-CS-1-2. Photo montage of various parts of the cistern system after the cistern had been painted by local students.

Design:

The site was evaluated to determine the infiltration rate of the soils on-site for overflow events (whenever the cistern overflows). Additionally, a Rain Sensor is installed on the system to help prevent overflows by shutting off flows to the cistern when it's full. To prevent potential buildup of contaminants in the cistern, a leaf-screen was installed on the downspout, and a first-flush filter was incorporated into the downspout pipe. This diverts the dirtiest water away from the cistern, decreasing potential pollutant buildup in the cistern, which could clog the pump intake.

The cistern sits on permeable pavers to encourage overflow events to infiltrate into the ground. Quarry rock pavers form a small dam around the pad, with an outlet to a small rock-lined swale to disperse overflow and discourage erosion. A small 1.5hp in-line pump was installed at the base of the cistern to pump water to a system of sub-surface irrigation hoses and sprinkler to water the museum's lawn.

Finally, the cistern was painted by the local high school's art school students to improve it aesthetically.

Funding:

Funding for the project was provided by the Lake Champlain Basin Program's Technical Assistance Grant program, with construction provided by the Town of Lake George's Buildings and Maintenance Staff.

Operation and Maintenance:

Town staff take care of maintenance for this practice. The cistern must be taken off-line in the winter in order to prevent damage from freezing, etc. The leaf-screen needs to be periodically swept free of leaves to prevent damming of the intake pipe and the first-flush diverter needs to be periodically cleaned out by removing the bottom cap and allowing accumulated materials to drain out. Overall, maintenance is minimal.

Cost:

Final project cost for this practice (materials and equipment) came to $2,875. This does not include In-kind services for installation.

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CASE STUDY

Golden Arrow Hotel Green Roof – Lake Placid, NY

Golden Arrow, a hotel in the small town of Lake Placid on Mirror Lake, has taken large steps toward becoming the greenest resort in the United States. Golden Arrow encourages guests to adopt a green state of mind during their stay, offers organic and local food options at their Generations restaurant, and has also gone as far as to install a green roof, thermal solar panels, a hot water heat recovery system, and beach made with crushed limestone to help neutralize acid rain on Mirror Lake.

Drainage Area:

The green roof sits on a flat segment of the Golden Arrow's 3,400 square foot roof.

Sizing:

The GreenGrid Green Roof System that was installed is about 3,000 square feet.

Design:

The green roof was designed to attract native birds and insects, provide habitat for native species, improve air quality, minimize urban heat, act as climate control for the building, and reduce stormwater and erosion. The planting plan consisted of plants and shrubs native to the North Country Region that would be able to survive the harsh climates and return year after year without heavy maintenance. The GreenGid Green Roof System comes with square pre-vegetated grids that are put together to cover a roofs surface.

Image 5-CS-2-1. Photo of the completed GreenGrid Green Roof System

Funding:

Since opening in the 1970's the Golden Arrow Lakeside Resort has been run by the same family. They continue to make changes that benefit them and the earth around them. Funding for the green roof comes from their business.

Image 5-CS-2-2. Photo of the green roof (middle of photo) and its proximity to Mirror Lake.

Operation and Maintenance:

The green roof is very low maintenance because native species were chosen that could survive mainly on rainwater and require no special nutrition needs. After being installed in 2008 the green roof was watered and left untouched to thrive until 2012. Chive slowly dominated the green roof's diversity and in 2012 the Golden Arrow decided to replant one third of the roof each year until entirely replaced in 2015 for aesthetic reason. Bringing in more diversity allowed the roof to be more appealing to the eye throughout the year.

Cost:

The cost for this type of project in 2008 was estimated to be $15-20 per square foot for materials and installation. For Golden Arrow's 3,000 square foot roof the cost for the GreenGrid Roof materials and installation is estimated to be between $45,000 and $60,000.

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References:

"Golden Arrow First Resort to Install Green Roof." *Lake Placid News*. N.p., 12 June 2008. Web. 21 Nov. 2016. <http://www.lakeplacidnews.com/page/content.detail/id/500181/Golden-Arrow-first-resort-to-install-green-roof.html?nav=5008>.

Gunther, Shea. "The Golden Arrow Resort in Lake Placid, N.Y., Goes Green." *MNN - Mother Nature Network*. N.p., 22 July 2013. Web. 21 Nov. 2016. <http://www.mnn.com/lifestyle/eco-tourism/blogs/the-golden-arrow-resort-in-lake-placid-ny-goes-green>.

CASE STUDY

City Garage Cistern Retrofit for Vehicle Washing, St. Albans, VT

Identified by the Northwest Regional Planning Commission, the City of St. Albans retrofitted their public city garage with underground cisterns in 2008. This project features two 430 gallon rooftop runoff underground cisterns with an overflow to a bioretention practice. Prior to this installation, the City had been using potable water to wash vehicles.

Image 5-CS-3-1. Cistern placement and connection to cisterns.

Drainage Area:

The drainage area for the cistern is the City's public garage roof. The roof has been guttered to route runoff into the cistern.

Sizing:

The underground cisterns are designed to hold a total of 860 gallons of municipal rooftop runoff.

Design:

The underground cisterns are designed to hold a total of 860 gallons of municipal rooftop runoff. Runoff is collected in gutters on the roof of the City's public garage. A pump system then supplies hoses inside the garage to wash the City's vehicle fleet. Any overflow above the 860 gallon capacity is directed to a 250 ft^2 bioretention practice. All wash-water is collected in floor drains and sent to the municipal wastewater treatment facility.

Funding:

This project was grant-funded by the VT DEC's Ecosystem Restoration Program, and an EPA grant to the Northwest Regional Planning Commission to implement stormwater management practices and water quality improvements in the local Stevens and Rugg Brook watersheds.

Image 5-CS-3-2. Gutter downspout connection to underground cisterns.

Operation and Maintenance:

Maintaining this system is relatively simple and involves annual inspections of the overflow, gutters, and pipes. These tasks must be completed annually. Inspection of the overflow is to ensure no erosion is occurring at the outlet site. Gutters and pipes must be checked for and cleaned of any debris.

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Image 5-CS-3-3. Water is pumped into the garage for vehicle washing.

Re-Use Cistern System: War Memorial Arena - Syracuse, NY

The OnCenter War Memorial Arena Rainwater Re-use System Project is located on the site of the Onondaga County War Memorial Arena, bounded by Madison, South State, Harrison, and Montgomery streets. Since 1951, the War Memorial has been home to countless concerts, conventions, and various community events. The arena is currently the home of the Syracuse Crunch Hockey team of the AHL.

Image 5-CS-4-1. Photo of the Rainwater Reuse System used to make ice for the War Memorial Arena.

Drainage Area:

The drainage area for the cistern is about 44,000 square feet of impervious cover consisting of stormwater from the arena roof.

Sizing:

The cisterns are designed to provide 15,000 gallons of below-ground rainwater storage and 400,000 gallons of runoff reduction each year.

Image 5-CS-4-2. Areal locational diagram of cisterns and rainwater receiver tank at War Memorial Arena.

Design:

The innovative water re-use system will be located within the basement of the Arena and involves the design and construction of approximately 15,000 gallons of below-ground rainwater storage, in addition to the installation of filtration, disinfection, and water re-use technology. The project is intended to recapture rain water and snow melt runoff from the War Memorial Arena roof, reusing the captured runoff primarily for ice production and ice maintenance for events at the arena, including sporting events and family entertainment.

Funding:

Onondaga County received a $750,000 grant through the New York State Environmental Facility Corporation's Green Innovation Grant Program (GIGP) for the War Memorial Cistern System.

Operation and Maintenance:

The cistern is monitored closely and regularly making any adjustments, cleaning, or replacements necessary to ensure it is functioning optimally and safely.

Cost:

Final project cost for this installation came to $1,229,251.

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CASE STUDY

Public Library Rain Garden, Morrisville, VT

A rain garden was installed in Morrisville, VT, by the Town of Morristown's Public Works Department in 2015. The Centennial Public Library rain garden features a rooftop downspout disconnection as an irrigation source. Designed to filter and infiltrate runoff from the roof, this feature was implemented as part of the Lamoille County Conservation District's program to integrate highly visible projects throughout the county. These projects focus on reducing stormwater runoff, and increasing community involvement in the implementation of watershed restoration practices to improve water quality.

Image 5-CS-5-1. Newly-installed rooftop runoff rain garden. Stones instead of mulch were used as mulch will float and move around (and contains phosphorus, which can be exported into groundwater).

Drainage Area:

The library's drainage area encompasses approximately 0.03 acres of impervious rooftop runoff.

Sizing:

Designed to infiltrate the 1-year storm (which yields 2 inches of rain in a 24 hour period), the rain garden is anticipated to result in a 75-100% runoff volume reduction. Soils within this area are well-drained and gravely. Well-drained soils are ideal for surface features such as rain gardens.

Design:

A rain garden was chosen for the entryway area of the library property because it would be relatively simple to implement, effective, and visually pleasing. To demonstrate the use of native species in local landscape design, the garden was planted with indigenous perennial plants.

Funding:

The library rain garden was funded by the Lake Champlain Basin Program as part of Lamoille County Conservation District's Stormwater Solutions Project.

Operation and Maintenance:

Rain garden maintenance should be seasonal and as-needed. Any plants that fail to thrive must be replaced, and any weeds or invasive species removed. This requires time but is relatively simple and maintains the garden's aesthetics as well as ensuring proper functioning of the practice.

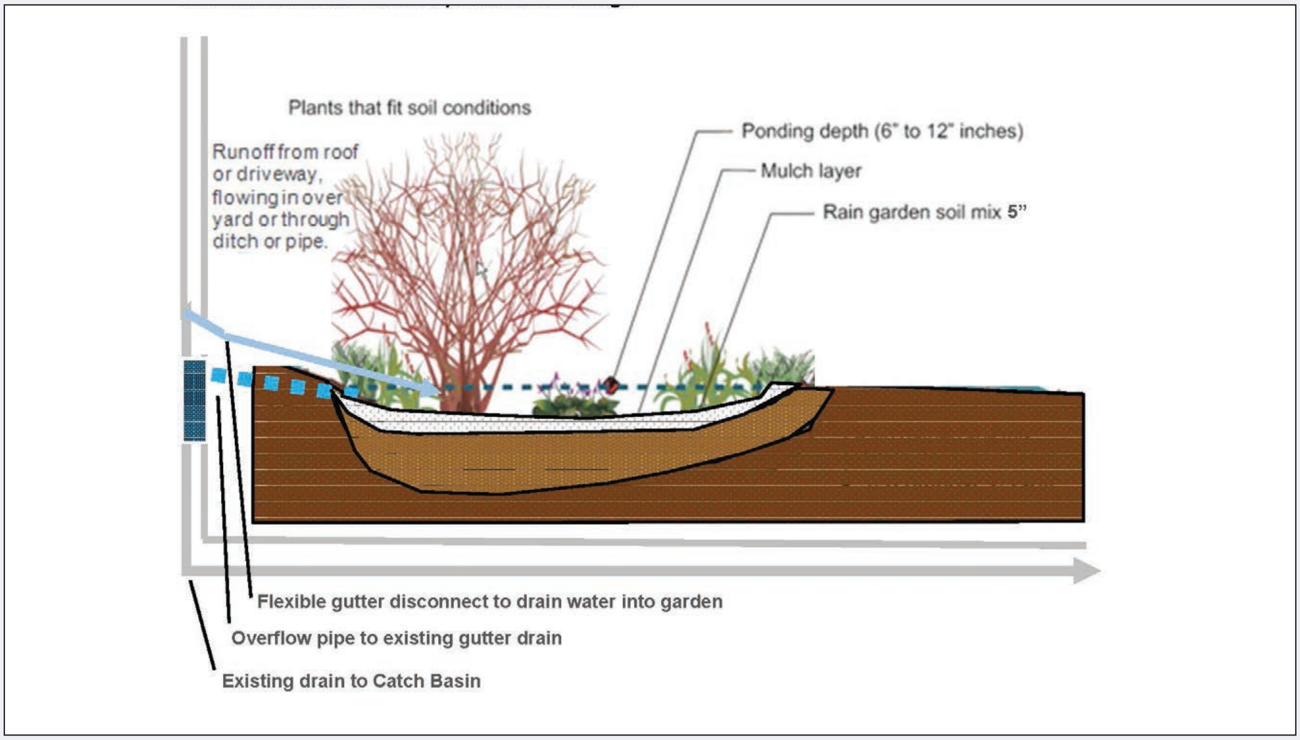

Image 5-CS-5-2. Cross-section of the rain garden design

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Chapter 6: GI Stormwater Planning & Implementation Process

When one sees a GI project on the ground, it is not always apparent that there is a backdrop of planning that made that project possible. Planners, design engineers, municipal capital improvement staff, and finance professionals are all involved in this planning process. A coordinated planning and implementation process is needed to envision how GI can be incorporated into other infrastructure projects, funded, designed, installed, and maintained. This chapter provides an overview of this process, with references to more detailed guidance. The chapter focuses on the process for integrating GI with other ongoing infrastructure projects (e.g., transportation, schools, parks, and other municipal properties). This type of integration has obvious efficiencies in terms of planning, procurements, and construction, but also comes with increased planning and coordination.

Overview of the Planning & Implementation Process

This section provides a generic overview of the various steps to be conducted during different stages of the planning and implementation process. Each municipality will have a unique process, but these steps are important considerations. The categories highlighted below include:

- **Prerequisites**: The municipal backdrop of codes, procedures, and institutional capacity that can help streamline GI implementation.
- **The Early Process**: Planning steps that should be conducted at an early stage to lay the groundwork for design, installation, and maintenance.
- **Planning & Design**: Some tips and considerations as the project moves through the design process.
- **Project Construction/Installation**: Additional considerations for project management and inspections for infrastructure projects that incorporate GI.
- **Maintenance**: While listed last, the awareness of this topic must be infused into each of the other steps.

Prerequisites

Prerequisites include the municipal framework that either streamlines or imposes impediments on GI implementation. Some of these prerequisites include:

- **Local Codes & Regulations**: Do local codes and regulations authorize the use of GI? Sometimes local codes for transportation, public safety, facilities, zoning, and other categories contain provisions that either forbid GI or make it very difficult. Examples would be requiring certain standards for pavement (or not allowing permeable materials), requiring curb and gutter, disallowing vegetated conveyances, or preventing rainwater collection and reuse. If this is the case, a good early step would be to conduct a codes review and roundtable discussion to clarify the purpose behind the codes and some broadly-supported amendments that may help streamline GI (CWP, 1998).
- **Local and Regional Capacity & Partners**: Successful GI implementation does require a certain level of capacity to champion and steward a project along each step of the implementation process. Many municipalities may lack this capacity at the local level, due to funding, staffing, and technical limitations. In some cases, it is advisable to look beyond municipal boundaries to seek partners and collaboration with regional agencies, neighboring jurisdictions, watershed groups, state transportation departments, and others.
- **Identify Co-Benefits of GI**: GI promoters often realize that elected officials, public works directors, planners, ratepayers, taxpayers, community groups, and citizens are motivated more by issues other than stormwater benefits. Such issues include flooding and drainage, drinking water protection, creating community green spaces and health benefits, or providing new green jobs. In many communities, emphasizing these "co-benefits" of GI may garner more project support than how many pounds of pollutant are removed.



The Early Process

Once pre-requisites are assessed, there are steps that should take place early in the planning process. These “behind the scenes” activities will certainly help with a smoother implementation process down the road.

- **Candidate Project Identification & Prioritization**: What are the best GI projects for your community? Many can be envisioned (e.g., every large parking lot should be permeable), but many of these may be too expensive compared to the benefits, not capture enough runoff, have utility conflicts, or have other constraints. On the other hand, a smaller list of projects can be elevated because they have multiple benefits for the community and meet key feasibility criteria. The planning process involves picking the ripe plums from a broader list of candidates. There are many examples of this type of planning across the country (CWP, 2007; VT DEC, 2013; Monroe County, NY, Stormwater Coalition; New Jersey Stormwater, 2004*)*. This process is necessary to identify specific projects to seek funding and integrate into the capital planning process (see below).
- **Funding & Financing**: Many GI projects rely heavily on grants. However, the availability and timing of grants do not always line up with capital improvement project timelines. For some projects, the grant schedule is shorter than the realistic timeline for planning and implementation for integrated projects that involve multiple players and departments. Also, grants sometimes don’t pay for critical project stages, such as feasibility, planning, and prioritizing among candidate projects. Without these “early” steps, many projects can meet significant challenges with feasibility. It is important to map out the timelines of grants and seek multiple funding sources to cover critical project planning steps. Partnering with transportation agencies or other public entities can be another option for joint funding, and several models exist for community-based public/private partnerships (U.S. EPA, 2015).
- **Capital Improvement Program (CIP) Planning**: One cannot overstress the importance of incorporating GI into the CIP process. GI projects must be envisioned, evaluated, and planned long before they are actually implemented. Much of this upfront work has to do with ensuring that GI is at least considered with other capital projects, and that candidate projects are prioritized on the basis of feasibility, cost/benefit, and other factors. This is also a critical time for engaging other municipal staff in the benefits of GI and how it can enhance their respective infrastructure projects.
- **Technical Resources & Standards**: The early planning stage is certainly not too early to consider what technical standards will be followed, and identifying key GI treatment objectives, such as runoff captured and pollutant removal targets. The New York State Stormwater Management Design Manual has detailed BMP design guidance for projects that require a stormwater permit. As many GI infrastructure projects are retrofits, other technical resources may also be relevant in that they can provide more design flexibility for retrofit conditions (CWP, 2007; VT DEC, 2017 (in draft); MA DEP, 2016).

Planning & Design

The planning and design stage includes multiple activities, such as procuring design and construction services, administering the contracts, and plan review by municipal and possibly state agencies, among other steps. This section does not seek to be a comprehensive review of this process, which is dictated by local standards and protocols, but rather to highlight a few aspects of the process that are often overlooked with regard to GI integration.

The discussion above about regional coordination is also relevant, as several models exist for cooperative purchasing and bidding for design and construction services.

- **Feasibility**: Part of the due diligence in the design process is looking for hidden “project killers” that would be very problematic if encountered during the latter stages of design, procurement, or construction. An example would be unmapped utilities that end up being extremely expensive or even infeasible to relocate. A feasibility step can include (among other items) utility mapping, infiltration/soil/geotechnical testing, assessment of tree or wetland impacts, and analysis of other constraints. The feasibility step can also identify parts of a project that don’t necessarily have to be full GI, such as handicap ramps and walkways and certain parking areas. This type of blending of GI components (e.g., permeable pavement) with other traditional infrastructure can sometimes help a project get over significant hurdles and can also help with meeting project budgets.

- **Consider Long-Term Maintenance in Design**: The actual design will often be farmed out to a consulting firm. Municipal owners and project managers should ensure that the long-term maintenance capabilities of the responsible organization are considered during the design process. For instance, a bioretention design may come with a complex landscape plan with multiple species of trees, shrubs, and herbaceous plantings. However, the maintenance crews may not be equipped to maintain such a practice, with its required weeding, pruning, mulching, watering, and supplemental planting. If this is identified up-front in the design process, a more realistic planting plan can be developed with fewer species and a prescribed maintenance regime (e.g., bush-hogging an herbaceous meadow planting in the early spring) (Watershed Stewards Academy, 2015).

Project Construction/Installation

As with the category above, this is a local process governed by standards and protocols. The following are a few items specific to the GI components.

- **Coordinated Project Management & Inspection:** For infrastructure projects that integrate GI, there will likely be a main project manager and inspector from the municipal department that "owns" the project (e.g. public works, schools, parks). However, these staff may need technical support from other staff that are more knowledgeable about the GI components, but may also be reluctant about multiple chains of authority or the exact process for decision-making. If these issues are clarified up-front, then the coordination will be more successful. All construction projects experience unforeseen challenges and circumstances, and GI can certainly add to that experience.
- **Sign-Offs and As-Builts**: The "GI Expert" should be involved in field modifications, sign-offs at construction milestones, and the approval of as-built plans or record drawings. The latter is the critical bridge between construction and long-term maintenance.

Maintenance

This is often the *Achilles heel* of GI projects. Local resources are often stretched thin, and many public works managers are skeptical of GI due to its perceived maintenance burden. This must be acknowledged and addressed in the design process, as discussed above. **Chapter 7** of this manual addresses the operation and maintenance considerations for GI, including various maintenance program models.

From a programmatic standpoint, there may be opportunities to partner with watershed or community groups, master gardeners, adopt-a-spot programs, regional agencies, or neighboring jurisdictions (e.g., joint procurement of a maintenance contractor). In fact, that type of collaboration may engender more of a sense of community ownership of the projects. Of course, the municipality will be the responsible party for health and safety concerns and ensuring an acceptable level of service is met for all implemented projects.

Recommendations

In 2016, a workshop sponsored by the Alliance for the Chesapeake Bay was held in Pennsylvania on the topic of integrating green infrastructure in other municipal infrastructure projects. Attendees came from various sectors, including local, state, and federal government, local elected officials, transportation agencies, regional planning agencies, private consultants, funding agencies, and non-profit organizations. The attendees developed some specific recommendations on successfully integrating GI with other infrastructure projects (ACB, 2016).

Tables 6-1 and **6-2** below summarize some of the key recommendations, many of which are also addressed in the sections above. **Table 6-1** addresses municipal processes and planning, and **Table 6-2** considers pooling of resources and regional collaboration. The recommendations in the tables are organized by increasing order of complexity or the level of effort required to implement the idea. The intent of these tables is to convey that some actions may be able to be implemented as early or incremental steps towards a larger goal of regular and ongoing integration of GI into other infrastructure projects.

Table 6-1. Recommendations for Municipal Processes, Planning & Prioritization Organized as increasing levels of sophistication	
1. Tools & Increased Communication & Coordination *Can likely be implemented with existing staff resources, interns, organization partners, or other means.*	• Identify and engage partners (utilities, public works, capital improvement administration, parks, schools, etc.) very early in the process; start with capital improvement program (CIP) planning. • When communicating, clearly establish purpose, need, and context for GI. Be sure to identify and perhaps quantify co-benefits for drainage, drinking water, community health, employment opportunities, etc. • Be sure to educate elected officials, keeping the message simple and compelling. • Add GI sites to geographic information system (GIS) and infrastructure maps available to the public (this could also be done regionally).
2. Changing or Enhancing Municipal Codes, Policies & Processes *Would require a more involved process to develop new plans and change or add policies, perhaps involving more staff time and institutional commitment.*	• Identify and change local codes and policies that present impediments for GI. • Adopt policies to at least consider GI with all departmental concept and CIP planning. • Develop a watershed plan that identifies and prioritizes specific GI projects; this enhances chances for funding (grants and CIP). • Develop procedures to identify and prioritize candidate GI projects. • Build a feasibility step into project planning. This should include (among other items) utility mapping, infiltration/soil/geotechnical testing, analysis of constraints, and, importantly, ranking and prioritizing candidate projects. The feasibility step can also identify parts of a project that don't have to be full GI, such as handicap ramps and walkways, certain parking areas, etc. • Ensure that all projects have maintenance agreements with a duration of at least 10 years.
3. Staffing *Will require further commitment to add staff and fund ongoing training programs.*	• Have a "GI champion" within the local government (or at a regional agency) to serve as a point person for coordination. • Provide ongoing training to deal with staff turnover. • Provide in-house training, career advancement, and other incentives to build capacity for long-term GI maintenance. Alternately, this function could be out-sourced to help create green jobs in the community. Utilize appropriate certification programs, such as certifications for permeable pavement installers. • Conceivably, these functions could be managed through shared regional positions (see table below on pooling resources & regional collaboration). In either case, build maintenance knowledge and capacity at the local or regional levels.

Table 6-2. Recommendations for Pooling Resources & Regional Collaboration **Organized as increasing levels of regional collaboration**	
1. Platform for Peer-to-Peer Learning *Can likely be handled with an incremental level of coordination by existing regional agencies with local cooperation.*	• A platform for practitioners to share case studies, lessons learned, credible guidance, and other resources. • Regional tours, awards, recognitions. • Share GIS and data through open data platforms.
2. GI Regional Expert *Would require supplemental funding and local buy-in to authorize enhanced coordination.*	• Local entities within a region could pool resources, supplemented by grants, to retain the services of a regional expert. The term "circuit rider" is sometimes used for this concept. • This could also be operated through an existing regional entity, such as a soil & water district, regional planning agency, or similar consortium. • This model already exists for other governmental functions, such a solid waste, libraries, parks, etc.
3. Cooperative/regional programming *Requires actual programmatic shifts and some surrender of local autonomy.*	• Cooperative programming for funding, GIS, project identification and prioritization, CIP planning, procurement and purchasing, project management, and other functions directly related to implementation.

Resources

<u>Center for Watershed Protection</u>

The following are generally available at CWP's Online Watershed Library (OWL): http://owl.cwp.org/

Urban Stormwater Retrofit Practices, Manual 3 of the Urban Subwatershed Restoration Series

Various retrofit studies

Better Site Design: A Handbook for Changing Development Rules in Your Community & locality-specific Better Site Design reports

Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program

Environmental Protection Agency

Community-Based Public-Private Partnerships (CBP3) & Tool for Integrated Green Stormwater Infrastructure. https://www.epa.gov/waterfinancecenter/community-based-public-private-partnerships

<u>New York & Regional Resources</u>

Vermont Stormwater Master Planning Guidelines. http://dec.vermont.gov/sites/dec/files/wsm/erp/docs/SWMPFinal6-23-16.pdf

Monroe County, New York – Stormwater Coalition. Website has several examples of regional stormwater master plans. http://www2.monroecounty.gov/des-stormwater-coalition

References

Alliance for the Chesapeake Bay. 2016. Workshop Report: *Streamlining Integrated Infrastructure Implementation Workshop: Dig Once Strategy Development, DRAFT.*

Center for Watershed Protection. 2007. *Urban Stormwater Retrofit Practices, Manual 3, Urban Subwatershed Restoration Series.*

Center for Watershed Protection. 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community.*

New Jersey Stormwater. 2004. *New Jersey Stormwater Best Management Practices Manual – Chapter 3 – Regional and Municipal Stormwater Management Plans.* http://www.njstormwater.org/bmp_manual/NJ_SWBMP_3%20print.pdf

Massachusetts Department of Environmental Protection. 2016. *Massachusetts Stormwater Handbook*. http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

Monroe County, NY. Stormwater Coalition - http://www2.monroecounty.gov/des-stormwater-coalition

U.S. Environmental Protection Agency. 2015. *Community-Based Public-Private Partnerships (CBP3) & Tool for Integrated Green Stormwater Infrastructure.* https://www.epa.gov/waterfinancecenter/community-based-public-private-partnerships

VT Department of Environmental Conservation. 2013. *Vermont Stormwater Master Planning Guidelines*. http://dec.vermont.gov/sites/dec/files/wsm/erp/docs/SWMPFinal6-23-16.pdf

VT Department of Environmental Conservation. 2017 (draft). *Vermont Stormwater Management Manual*. http://dec.vermont.gov/watershed/stormwater/manual_update

Watershed Stewards Academy. 2016. *Rainscaping Manual.* http://aawsa.org/wsa-rainscaping-manual-2

Chapter 7: Operation & Maintenance (and Inspections)

This chapter summarizes inspection and operations & maintenance (O & M) activities that are typical for a wide variety of GI practice types. Inspections are designed to identify key maintenance issues before they become more serious, and to help keep up with routine maintenance tasks.

Who Conducts Inspections and/or O & M?

Property owners and managers

This category includes property owners, property managers, municipal maintenance staff, interns, and volunteers. These individuals would typically have no or only very limited training in stormwater maintenance and inspection. They complete routine inspections and maintenance activities. For most GI practices, the majority of maintenance and inspection activities can be conducted at this skill level.

Trained municipal staff

This category includes municipal employees or hired consultants and contractors who have completed training on stormwater maintenance. These individuals often conduct semi-annual inspections of the GI practices as required by the municipality (typically once per 3-5 year period) or when non-routine problems happen with a GI practice.

Qualified professionals

These are individuals with specific skills and certifications, such as a certified plumber who has experience working with rainwater harvesting practices. "Qualified professionals" may include professional engineers, landscape architects, certified horticulturalists, and other professionals. These professionals are only typically involved in inspection or maintenance when a GI practice needs major repairs or needs to be re-constructed.

Table 7-1 describes some specific maintenance activities that these three O & M groups might conduct.

Table 7-1. Maintenance/ Inspection Responsibilities

	Citizens and Untrained Staff	Trained Municipal Staff	Qualified Professionals
Qualifications/ Training of Inspectors	No special training, but person is provided educational materials.	On-the-job training and/or short workshops	Professional License or certifications, such as a PE, RLA or CPESC.
Typical Maintenance Activities	Routine mowing. Trash removal. Plant care and upkeep. Mulching as needed. Removal of small amounts of sediment from pretreatment areas of the practice.	Removal of larger amounts of sediment. Structural damage repair. Minor regrading and scarification of soil surface to restore permeability.	Redesign an improperly functioning practice. Includes re-grading of the contributing drainage area, replacing soil media and plantings (new planting plan), or modifying conveyance structures.

Inspection Process

Regardless of which type of GI practice you are inspecting, some key procedures and equipment are necessary. A basic Inspection should be conducted at least annually for all practices, and is often supplemented with additional visits during/ after events such as large storms or seasonal changes.

Consult the plan file and maintenance agreement to ascertain the responsible party. Confirm that there is right of access through the local code, signed maintenance agreement, or other means. Contact the responsible party at least three business days in advance of the proposed inspection. If the responsible party cannot be found or contacted, make a reasonable effort through file research to contact a property representative, and document these efforts in writing. For publicly-owned and managed BMPs, the responsible party will likely be the municipality or other regulated MS4.

In general, the inspection should follow a consistent, logical approach, such as outlined below.

Insert Image 7-1. Municipal staff conduct a maintenance inspection of a bioretention in the road right-of-way.

- Conduct a quick walk-around of the practice to quickly identify any obvious issues and to identify important components: inlets (number, location), surface area, overflow structures, berms or impoundments, outfalls, downstream. Check these components against the design plan or as-built drawing (as available).
- Starting at the outlet or low point, use the checklists provided in **the Operation and Maintenance Chapter of the NYSDEC Stormwater Management Design Manual** to evaluate the practice. The inspection will proceed from the outlet or outfall to the practice area, berms, side slopes, inlets, and drainage area. Make sure to fill in key information on the inspection form, such as BMP identifier number, site name, inspector name, date, and weather conditions.
- Take photos of important components or maintenance concerns, and mark photo locations and direction on a sketch.
- Review the inspection form before leaving the site to make sure that all necessary information has been collected.

What to Take in the Field

For basic and advanced inspections, the following equipment can be useful:

- Safety equipment: safety vest, steel-toed shoes, traffic cones if working near traffic, etc.
- Approved plan and as-built (record drawing), if available
- Records of previous inspections, if available
- Engineering scale
- Hand level and pocket rod if needed to measure relative elevations
- Digital camera
- Several copies of O & M checklist if paper forms are used
- Clipboard and pencils if paper forms are used
- Dry erase white board and marker (optional) to include in photos to keep track of GI tracking # in database
- Letter on municipal letterhead granting access and/or agency photo badge
- Pipe wrench to open underdrain clean-out caps

- Flashlight to look into underdrain clean-outs and/or manholes
- Manhole puller
- Soil probe or auger
- 100’ tape & measuring tape
- Shovel
- Bug spray

Follow-Up Actions

Immediate follow-up actions include entering the inspection information in the appropriate data base or hard copy file, downloading and labeling photos, and providing other necessary documentation.

Another follow-up action involves communicating problems and corrective measures to the responsible party (private or public). This may involve instructing the responsible party to undertake a more thorough inspection (by a qualified professional) to find solutions for significant problems or to provide a timeframe for correcting simpler issues. Many local programs have existing procedures for sending letters or activating a compliance procedure. These procedures include verifying that repairs and corrections are completed by the responsible party.

Typical Maintenance Activities

Table 7-2: Common Inspection/Maintenance Issues

Issue	Description
Contributing Drainage Area – Pollutant Sources	Sediment or pollution sources in the Drainage Area
Physical Obstructions	Physical obstructions to maintenance access, overflow, or emergency spillway
Erosion	Erosion on sides slopes, practice bottom, at inlet or outlets. Rills and gullies forming where there should be sheetflow.
Departures from Design Dimensions	Practice dimensions have been altered, either due to filling with sediment, redesign or filling in, or improper implementation.
Improper Flow Pathways	Flow is short-circuiting the practice, or drainage pathways have been otherwise modified.
Sediment Build-Up	Sediment has accumulated in a pool, practice bottom, pretreatment area, or vault.
Clogging	The soil media or other components are clogged and there may be standing water for longer than intended.
Vegetation	Excessive, inadequate, and/or unhealthy vegetation to support a practice.
Embankment and Overflow condition	Issues with an embankment, or overflow weir or channel.
Structural Damage	Hard infrastructure, such as concrete or metal elements, has been damaged.
Pool Stability	Permanent pool of water is at the improper elevation.
Pool quality	Permanent pool of water suffers from poor quality due to algal growth or other issues.

Planning for Maintenance

Image 7-2. Sediment removal can often be done by hand.

Often, stormwater practices fall into disrepair because there is no plan in place for ensuring that they are maintained over time. As a result, maintenance can become reactive in nature, resulting in high costs for repairing damaged practices, or practices becoming ineffective over time. Local program requirements will influence who performs ongoing maintenance, and this will play an important role in how to develop a comprehensive maintenance plan.

Although there are many options for implementing a maintenance plan, these can be described by three broad categories, including: 1) Private Maintenance 2) Local Program and 3) Hybrid Approach. Understanding the program in the local community will influence the best techniques for developing the maintenance plan (**Table 7-3**).

Option 1: Private Maintenance

In this option, maintenance is the responsibility of the private land owner. In regulated MS4s, the land owner will periodically report to the local government, however. In this model, it is important to ensure that the maintenance plan is very easy to understand, includes pictures of key practice elements. If possible, include a list of contractors who will be able to perform maintenance items, and how much these will cost. Finally, materials should point homeowners to resources so that they can learn more about the practices on their property. The DEC's Maintenance Photo Library and Training Materials website can be a useful tool for this purpose. To find this database, Internet-search NYSDEC Maintenance Photo Library and Training Materials.

Option 2: Local Government Maintenance

In this scenario, the local government takes over maintenance responsibility for all stormwater practices. While it is still important to develop a clear and simple plan, the designer can assume some level of training or supervision for the individuals conducting inspections and maintenance. For publicly-maintained practices, it is helpful to find out what resources the local government has in place for developing the plan. These resources may be in the form of existing reporting and tracking procedures, which can be modified for the specific practice, or equipment such as vacuum sweepers.

Option 3: Hybrid Approach

In the hybrid approach to stormwater maintenance, larger practices or practices on public land are maintained by the local government, and smaller practices on private property are maintained by the owner. There are other hybrid models, however. For example, the local government may take responsibility for inspections, but leave the owner responsible for maintenance items identified during the inspection.

Table 7-3. Maintenance Considerations for Three Program Options		
Program Option	**Inspection/Maintenance Performed By:**	**Key Considerations for the Designer**
Option 1: Private	Homeowner or HOA; Private Contractor; or Certified Contractor	• Make the plan very simple and graphic intensive. • Include a list of contractors if applicable. • Provide links to educational materials.
Option 2: Local Program	Interns or Untrained Staff; Trained Local Staff; City/Town Engineer or other individual hired by the city or town.	• Learn about the resources the local program has at its disposal. • If government staff is being trained, develop a maintenance plan that is consistent with their knowledge and terminology. • Be aware of equipment and materials on hand in this community.
Option 3: Hybrid Approach	Inspection & maintenance is typically divided, where larger practices, or those on private property are maintained by the public entity.	• Understand how this maintenance is divided, and develop a plan that is consistent with this arrangement.

Since many of the Green Infrastructure practices included in this manual, such as Tree pits, Streetscape Bioretention, Infiltration Practices, and Rain barrels or cisterns, are implemented at a very small scale, they present a unique challenge in terms of stormwater maintenance. . Maintenance plans for these small practices should be as simple as possible, and the designer should ensure that maintenance can be completed with readily available materials.

Image 7-3. Ensure that small practices can be maintained with simple materials that are on-hand.

Chapter 8: Funding

Obtaining funding for green stormwater infrastructure projects is a critical, but often difficult, step in the design and implementation process. Fortunately, the State of New York has a number of existing grant-making programs that either explicitly fund GI projects, or fund GI projects as parts of other larger development initiatives.

These programs are drawn from a mix of New York State-specific, Federal-level, and sometimes local grant-making organizations.

We have compiled a table on the following pages that outlines

- Grant Program (overarching agency)
- Funding Source
- Eligibility Requirements
- Summary of the Program with Respect to GI
- Type of Funding Available (Planning/ Pilot/Implementation, etc.)
- Frequency of Grant Availability
- Amount Typically Awarded (where information is available)
- Contact Information (website / specific contact information)

Image 8-1. Lake Placid and Whiteface Mountain from McKenzie Mountain

Much of the information pertaining to these grant programs was drawn from a document produced by the NYSDEC entitled 'Green Infrastructure Funding Opportunities.' This document was intended for use in the entire State – this manual lists only those Federal, State, and local opportunities applicable to the Lake Champlain Basin.

Navigating the grant-funding landscape can be difficult at times. Establishing a good relationship with professionals who understand this landscape can be beneficial. The following names are contacts who could be of assistance and have experience, either as an administrator or grantee, with some of these programs.

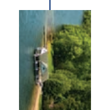
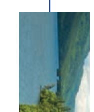
In New York:

Ryan Waldron
NYSDEC – Environmental Engineer, Division of Water
Ryan.waldron@dec.ny.gov

Kevin Farrington
City of Plattsburgh – City Engineer
farringtonk@cityofplattsburgh-ny.gov

For Lake Champlain:

Lake Champlain Basin Program
General Inquiries
(802) 372-3213
lcbp@lcbp.org

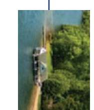
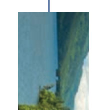




NYSDEC Funding

Funding Source	Eligibility	Summary of Program w/ Respect to GSI	Funding For	Frequency of Grant	Amount Awarded	Website	Contact
Water Quality Improvement Project (WQIP) Program	Municipalities | Municipal Corporations | Soil/Water Conservation Districts	2013 - $4 million was available for green stormwater infrastructure projects. GSI projects fall under the Non-agricultural, Nonpoint Source Abatement and Control category.	Implementation	Varies	Varies	http://www.dec.ny.gov/pubs/4774.html	Susan Van Patten, Division of Water, 518-402-8179, DOWinformation@dec.ny.gov
Clean Water Act Section 604(b) Funding	Regional Planning Organizations	2014 RFP lists green infrastructure planning as an Optional Water Quality Management Planning Objective under the Baseline Planning Program category.	Planning	Every 3-5 years	Varies	http://www.dec.ny.gov/lands/53122.html	Susan Van Patten, Division of Water, 518-402-8179, DOWinformation@dec.ny.gov
Environmental Justice Community Impact Grant Program	Community Organizations (various criteria)	Green infrastructure demonstration projects, generally involving education, stewardship, and/or monitoring activities related to parks, opens space, community gardens, or green infrastructure.	Pilot Projects	Varies	Varies - ~$10-50K	http://www.dec.ny.gov/public/31226.html	Office of Environmental Justice, 518-402-8556, justice@dec.ny.gov
Environmental Facilities Corporation Green Innovation Grant Program (GIGP)	Public entities (towns/cities, etc.), as well as other organizations empowered to develop a project (subject to review).	Provides funding for permeable pavement, bioretention, green roofs and green walls, stormwater street trees/urban forestry programs, riparian buffers, floodplains and/or wetlands, downspout disconnection, stream daylighting, and stormwater harvesting and reuse specifically.	Planning, Pilot, and Implementation (must include implementation)	Annually	Varies - ~$100K or more	http://www.efc.ny.gov/Default.aspx?tabid=228	Suzanna Randall, Manager of Green Policy, Planning and Infrastructure, 518-402-7461, GIGP@efc.ny.gov

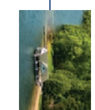
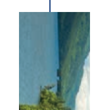
NYSDEC Funding

Funding Source	Eligibility	Summary of Program w/ Respect to GSI	Funding For	Frequency of Grant	Amount Awarded	Website	Contact
Department of State Local Waterfront Revitalization Program	Public entities located along New York's coasts or inland waterways designated by Executive Law, Article 42	Provide matching grants to revitalize communities and waterfronts both both planning and implementation - parts of the project may include green infrastructure.	Planning and Implementation	Annually	Varies - ~$10-400K	http://www.dos.ny.gov/opd/grantOpportunities/epf_lwrpGrants.html	Department of Planning and Development, New York State Department of State, 518-474-6000
NYS Energy, Research, and Development Authority Cleaner Greener Communities Program Phase II Implementation Grants	Local governments, private companies, NGOs, and other entities with projects in NYS	Funds implementation of large-scale, high-profile projects that support goals of a region's sustainability planning efforts. Category 2 (Planning Inititiatives) Projects may include green infrastructure.	Planning, Pilot, and Implementation (must include implementation)	Uncertain - future grant announcements TBD (two more rounds expected)	Varies	http://www.nyserda.ny.gov/All-Programs/Programs/Cleaner-Greener-Communities/Implementing-Smart-Development-Projects	New York State Energy Research and Development Authority, CGC@nyserda.ny.gov
NYS Homes and Community Renewal Community Development Block Grnat - Public Infrastructure Funds	Municipalities with <50K population, counties with population <200K	Funding available for drinking water, clean water, and stormwater. Green infrastructure may be part of these larger projects.	Implementation	Annually	Varies - generally >$100K	http://www.nyshcr.org/AboutUs/Offices/CommunityRenewal/FundingOpportunities.htm	New York State Homes and Community Renewal, Office of Community Renewal, 518-474-2057, HCRinfo@nyshcr.org
Climate Smart Communities Grant Program	Municipalities in NYS	Funding is for implementation projects that construct natural resiliency measures, reduce flood risk, and conserve or restore riparian areas.	Implementation	Annually	Varies	http://www.dec.ny.gov/energy/76910.html	Office of Climate Change, 518-402-8448, climatechange@dec.ny.gov

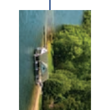
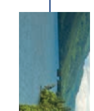
NYSDEC Funding

Funding Source	Eligibility	Summary of Program w/ Respect to GSI	Funding For	Frequency of Grant	Amount Awarded	Website	Contact
Engineering Planning Grant	Munipalities in NYS	This grant funds communities for the initial planning phase for a Clean Water State Revolving Fund project. Grant funds pay for engineering and/ or consultant fees for engineering and planning.	Planning	Annually	Varies - up to $100K	http://www.dec.ny.gov/pubs/81196.html	NY DEC Division of Water, 518-402-8267, CFAWATER@dec.ny.gov
Environmental Protection Fund	Organizations in NYS	Funds capital projects that protect the environment and enhance communities. Usually these are large projects for land acquisition or construction - restoring habitat, and upgrading local municipal infrastructure would be examples of projects where communities could involve green infrastructure.	Implementation	Annually	Varies	http://www.dec.ny.gov/about/92815.html	Office of Communication Services, 518-402-8013, contact@dec.ny.gov

Federal Funding

Funding Source	Eligibility	Summary of Program w/Respect to GSI	Funding For	Frequency of Grant	Amount Awarded	Website	Contact
National Fish and Wildlife Foundation Urban Waters Restoration	Community Organizations (various criteria) - can be in partnership with state/federal agencies as partners (but agencies may not serve as grantee) unless special permission is granted	In 2014, project priorities include addressing developing educational programs to provide training to schools, businesses, community groups and homeowners on how to implement green infrastructure practices including sustainable forestry practices; or designing projects intended to control rain water though green infrastructure tools such as tree canopy, permeable pavement, green street designs, bioswales, planter boxes and green roofs, to reduce stormwater flow, controlling flooding and slowing run-off into surface water.	Planning	Annually	Varies	http://www.nfwf.org/fivestar/Pages/home.aspx#.VDbIP I OZ I gp	Sarah McIntosh, National Fish and Wildlife Foundation, sarah.mcintosh@nfwf.org
FEMA Hazard Mitigation Grants	States, local governments, tribes, private non-profit organizations	Provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. FEMA Hazard Mitigation grants will fund green infrastructure if a benefit-cost analysis shows that the damages saved from the project exceed the cost of the project.	Planning and Implementation	Only following Disaster Declaration	Varies	https://www.fema.gov/hazard-mitigation-grant-program	Richard Lord, New York State Office of Emergency Management, 518-292-2370, rlord@dhses.ny.gov
Watershed Environmental Assistance Program (Lake Champlain Basin Program and U.S. Army Corps of Engineers	Governments (or organizations representing governments)	The goal of the Lake Champlain Watershed Environmental Assistance Program is to provide assistance with planning, designing and implementation of large scale projects that protect and enhance water quality, water supply, ecosystem integrity and other water related issues within the watershed. LCBP administers the grant, which grants U.S. ACOE services instead of cash funding.	Planning and Implementation	Annually	Varies	http://www.lcbp.org/about-us/grants-rfps/available-grants/watershed-environmental-assistance-program/	Lake Champlain Basin Program, 802-372-3213, www.lcbp.org

Federal Funding

Funding Source	Eligibility	Summary of Program w/Respect to GSI	Funding For	Frequency of Grant	Amount Awarded	Website	Contact
EPA Urban Waters Small Grants	States, local governments, other designated governing organization, public/ private universities/ colleges, public/ private non-profits, intertribal consortia, interstate agencies	Grants for research, investigations, experiments, training, studies, surveys, and demonstrations that will advance restoration of urban waters though activities that improve water quality and support communit revitalization.	Planning, Pilot, and Implementation	Varies	Up to $60K	https://www.epa.gov/urbanwaters/urban-waters-small-grants	https://www.epa.gov/urbanwaters/forms/contact-us
U.S> Forest Service Urban and Community Forestry Challenge Cost Share Grant Program	U.S. non-Federal organizations and Tribal agencies	Funds projects that incorporate urban forests as green infrastructure into urban planning that will result in improvements for ecologically underserved areas. Also focuses on green infrastructure to manage urban stormwater. Projects must have national or multi-state application and impact.	Planning and Pilot	Annually	Varies	http://www.fs.fed.us/ucf/nucfac.shtml	Phillip Rodbell, U.S. Forest Service Northeastern Area Office, 610-557-4133, prodbell@fs.fed.us
National Fish and Wildlife Foundation Environmental Solution for Communities	Non-profits, State/ local/municipal governments, tribal governments, educational institutions	Funds improvements made to public facilities, parks, stormwater management and flood control practices using green infrastructure.	Pilot Projects	Annually	Varies	http://www.nfwf.org/environmentalsolutions/Pages/home.aspx#.VDbjf1OZ1gp	Carrie Clingan, National Fish and Wildlife Foundation, carrie.clingan@nfwf.org

Practice Example Appendix

Introduction

This appendix is intended to provide additional guidance on potential green infrastructure practices to use in the four environments that are the focus of this manual. The information presented here may overlap with information presented in each chapter's Case Study examples. The Case Studies are intended to illustrate on-the-ground examples of how individual practices are implemented, how they can be combined with other practices, and how they are adapted to fit site-specific opportunities and constraints.

We have divided the Practice Examples in this Appendix into categories based on where they are primarily implemented. There are however numerous instances where practices can be implemented in different environments, for example an infiltration practice can be built on both a parking lot as well as a building site. Refer to each individual case study chapter for cross-referenced practices.

Sections:

Village Streets –

- Streetscape Bioretention
- Swales
- Tree Pits
- Hydrodynamic Separators
- Stream Daylighting

Rural Roads –

- Road Outlet Protection
- Road Surfacing
- Stone Armoring of roadside swales
- Stone Check Dams in roadside swales
- Water Bars

Parking Lots and Hardscapes –

- Bioretention and Rain Gardens
- Permeable Hardscapes
- Storage Chambers
- Infiltration Practices

Buildings –

- Green Roofs
- Rain Barrels or Cisterns
- Rooftop Disconnection
- Stormwater Planters
- Rain Gardens or Bioretention

General Practices –

- Conservation Measures
- Impervious Cover Reduction

Streetscape Bioretention

See NY Stormwater Management Design Manual – various chapters – for additional guidance on design)

Primarily Intended For: Urban Streets (can also be used in Parking Lots and Hardscapes)

What is it?

Streetscape Bioretention is a planted infiltration practice located in a street or road right of way. They are typically small, linear practices that can be located in narrow streetscapes. Some can be located on sidewalk areas (sometimes called right of way bioswales) and some are located in the street (called a stormwater green street). Typically they treat smaller drainage areas contributing runoff from roads, sidewalks, and adjacent buildings. Always use native plant species that are adapted to your area – and never use non-native invasive species.

Image PE-1-1. Right of Way Bioswale – illustration and basic function

Image PE-1-2. Stormwater green street installed in a neighborhood in New York City.

How does it work?

Runoff is collected via curb inlets and allowed to pond in the center of the practice. This water is filtered by plants and infiltrated into soils. In areas where soils have low infiltration capacity, underdrains can be installed.

Sizing/Siting Considerations:

Streets typically have numerous utilities buried underground. A detailed utility survey will be necessary, as will a site-specific infiltration test. Streetscape Bioretention is most appropriate for Water Quality volume treatments and Runoff Reduction. Be careful locating these near buildings with basements – special provisions may have to be made as infiltration can cause wet basements. Alternatively, lined systems with underdrains can be used to prevent this issue. Runoff is still filtered and retained, but will not recharge to groundwater. Make sure adequate fencing around these practices is provided to prevent trampling or vehicle traffic from driving through.

Maintenance Concerns:

These practices can accumulate a lot of sediment and large debris (street trash). They will have to be maintained regularly by landscape professionals, both to remove debris and to maintain plants. Avoid using mulches as this material will float and exit the practice, or potentially clog outlet pipes or weirs. Make sure that infiltration is occurring – if the soil surface has clogged, it may be necessary to replace it. In the meantime, clogged soils can result in nuisance ponding and insect breeding.

Vegetated Swale

See NY Stormwater Management Design Manual – various chapters – for additional guidance on design

Primarily Intended For: Urban Streets (can also be used in Parking Lots and Hardscapes)

What Is It?

Vegetated swales are shallow channels that slow, infiltrate, and redirect stormwater runoff to areas where it can be further treated, infiltrated, or dispersed. They slow and clean stormwater using native plants and optional check dams.

How does it work?

Creating a shallow, linear depression allows water to enter the swale and infiltrate into the ground. Vegetation and optional check dams in the swale will increase filtration of sediment and other pollutants in runoff. If using plants in a swale, always use native perennial plant species – never use non-native species.

Sizing/Siting Considerations:

Install swales where runoff already flows and make sure they are gently sloped – 1" drop per 1' run is average. Swales are flat in the middle, with shallow side slopes (3:1 or gentler). Swales are usually most effective along driveways or the edges of parking lots. Consider armoring the inlet of the swale to prevent erosion.

Maintenance Considerations:

Frequent removal of accumulated sediment may be necessary – this may require using hand tools.

Any plants in the swale will have to be maintained. Grassed swales can be mowed and accumulated organic debris removed periodically.

Image PE-2-1. This is an example of a vegetated swale planted with native perennials – though this requires more maintenance than a grass swale, it improves the site. Perennials also say 'Don't walk on me!'

Image PE-2-2. This swale makes use of option check dams to further slow water and filter out pollutants. Use the table to determine spacing.

Swale Slope (%)	Check Dam Spacing (ft)
1	200
2	100
4	50
6	30
9	25

Tree-based Practices

NY Stormwater Manual pages 5-59 – 5-63

Primarily Intended For: Urban Streets (can also be used in Parking Lots and Hardscapes, Building Development)

What Is It?

Tree-based practices can be divided into two types – 'normal' street trees and 'bioretention' style trees. Normal street trees are planted in the road right of way and serve to intercept rain as well as evapotranspirate runoff via root uptake and leaves. Bioretention-style trees are similar to right of way bioswales and stormwater green streets in that they allow water in to a constructed pit or box filled with soils. These boxes promote tree health. These practices absorb and infiltrate more water than a 'normal' street tree. The use of structural soils (typically a sand- or gravel-based soil mix that increases soil pore space) enhances tree root growth and survival.

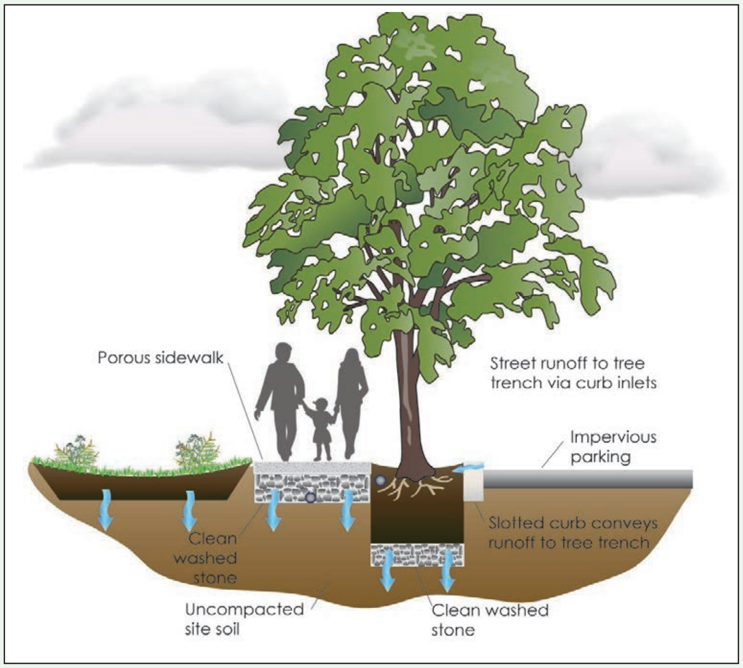


Image PE-3-1. Tree box with contributing porous concrete sidewalk – typical illustration

How does it work?

Normal trees intercept rain and use root uptake from soils to reduce runoff, while bioretention style trees work similarly to bioretention in that runoff is infiltrated into soils and pollutants are removed that way. Typically, normal trees do not receive significant Water Quality or Runoff Reduction credits, while bioretention style trees can.

Image PE-3-2. Photo of a dual tree box installation with curb inlet to allow runoff to reach the tree roots

Sizing/Siting Considerations:

Install trees as close as possible to impervious surfaces to promote rainfall interception – the canopy should overhang the impervious surface. See the NY State Stormwater Management Design Manual for reduction crediting. If using tree pits with structural soils – size and site similarly to streetscape bioretention as they are essentially the same. The infiltration capacity of the underlying soil becomes the most important criteria. Don't compact soils around the roots – the trees will die.

Maintenance Considerations:

Tree pits will tend to accumulate sediment from the street or parking lot – ensuring annual cleanouts (minimum) will help trees survive. Trees in urban environments tend to require more maintenance – hiring a qualified arborist to ensure tree health will prolong tree's lifespans. Any plants in the swale will have to be maintained.

Hydrodynamic Separators

NY Stormwater Manual Ch. 9 - pages 9-7 - 9-8

Primarily Intended For: Urban Streets (can also be used in Parking Lots and Hardscapes)

What Is It?

Hydrodynamic separators such as gravity and vortex separators are devices that move water in a circular, centrifugal manner to accelerate the separation and deposition of primarily sediment from the water. They are suitable for removal of coarse particles, small drainage areas, and are more effective in an offline configuration.

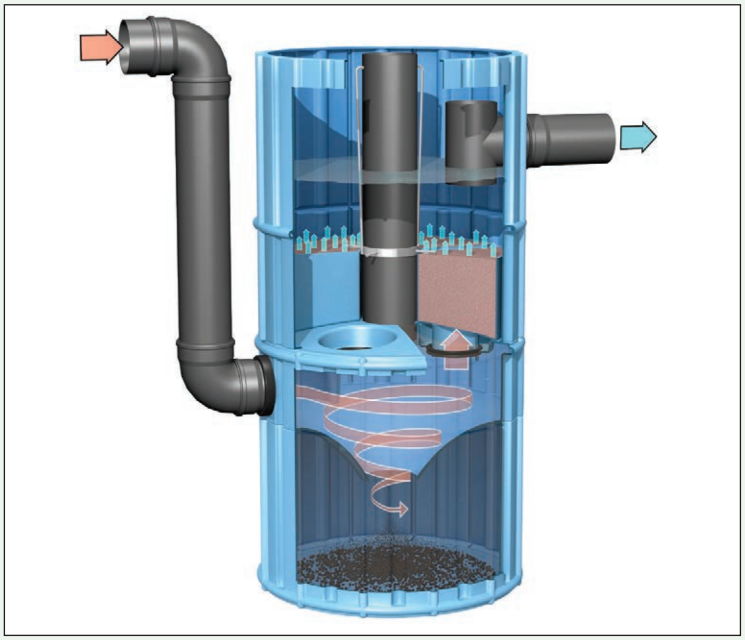


Image PE-4-1. Runoff is collected in hydrodynamic separators in one pipe where water swirls around and particles separate to the bottom. Clean water rises to the outlet pipe.

How does it work?

By taking water an encouraging it to either swirl with a conical plate, or encouraging particles to settle using plates, larger, and sometimes smaller, sediment particles can be removed from runoff. Cleaner water rises to the outlet pipe (higher than the inlet pipe) and sediment is stored in the sump of the separator. When it reaches a certain level, it must be removed. Separators can be sized for different flow conditions (higher flows, larger drainage areas), but they typically work best when high flows are capped to prevent sediment scour. This is best accomplished by configuring the separators 'offline' or parallel to storm sewer pipes.

Image PE-4-2. The separator shown here is installed in an 'in-line' and is being used for pre-treatment for sub-surface chambers. Separators' small sub-surface footprint make them an ideal choice for constrained sites.

Sizing/Siting Considerations:

Separators must be sized according to expected flows. These must be modeled using drainage area characteristics and pipe network sizing. They can be installed 'in-line' where storm sewer pipes enter them directly, but high flows during large storms can scour sediment out of the sump. They are more effective when installed 'off-line' using a flow-splitter to cap high flows. Separators are small, so can be used in a variety of land-constrained situations. While they are good for larger particles, they may not be completely effective at treating dissolved pollutants, like dissolved phosphorus. Separators can be used as pre-treatment for other practices, like bioretention or infiltration basins.

Maintenance Considerations:

Separators need to be maintained annually, much like catch basins. They can be maintained using a vactor truck unit which will suck sediment out of the sump.

Stream Daylighting

NY Stormwater Manual Ch. 5 - pages 5-68 - 5-70

Primarily Intended For: Urban Streets (can also be used in Parking Lots and Hardscapes)

What Is It?

Stream Daylight previously-culverted/piped streams to restore natural habitats, better attenuate runoff by increasing the storage size, promoting infiltration, and help reduce pollutant loads where feasible and practical. Daylighting streams may also help to reduce impervious cover.

How does it work?

By daylighting streams, the stream is returned to its original, natural function – this can improve flood capacity, ecological functioning, and promote the removal of pollutants through natural processes. The formerly culverted stream will have to be restored – digging it up usually isn't enough. Planting riparian vegetation and placing natural stream bed materials will be necessary to complete the daylighting.

Image PE-5-1. Part of the Saw Mill River in Yonkers, NY prior to stream daylighting. The river is culverted below the parking lot.

Image PE-5-2. The Saw Mill River after daylighting. In addition to improved ecological function, the river now attracts resident and visitors to its attractive public spaces.

Sizing/Siting Considerations:

Ensure that daylighting the stream won't cause nuisance flooding or adversely impact property owners – extensive outreach will be necessary to facilitate this process. Ensure that any stream that is daylighted has adequate space during high flow events so that it doesn't scour its bed or continuously overtop its banks. If daylighting an entire stream isn't possible due to downstream constrictions, the practice can still be employed – daylighting a portion of the stream will still have benefits for treatment of stormwater, as well as aesthetic benefits.

Maintenance Considerations:

Maintenance of daylighted streams can be intensive during the first years when the stream is newly establishing. Vegetation will need to be maintained, encouraged, and at times replaced. Invasive species will need to be removed for certain sites. The stream bed material may also need to replaced or augmented as it cements into place over periods of high and low flow. Once established, maintenance becomes more routine – trash removal, mowing, and general plant maintenance are all that is necessary.

Outlet Protection

(New York Rural Roads Active Management Program (RRAMP) Manual – pages 31-35

Primarily Intended For: Rural Roads (can also be used on Urban Streets, Parking Lots and Hardscapes)

What is it?

Outlet protection controls erosion at the outlet of a culvert or a channel. It works by reducing the velocity of water and dissipating its energy. Outlet protection should be installed at all pipes, culverts, swales, diversions, and other water conveyances where the velocity of the water may cause erosion at the outlet and in the receiving channel. Depending on the situation, there are a variety of outlet structures than can be used. Examples of outlet protection include turnouts, rock aprons, riprapped channels, and splash or plunge pools. They can also include filter zones, which are simple undisturbed, low-gradient filter zones between a stormwater outlet and the receiving water.

How does it work?

Outlet protection reduces runoff water velocity, which controls erosion and encourages sedimentation. Protection measures do this by hardening and roughening surfaces, which traps runoff and runoff-bound sediment particles. This ensures that most pollutants will drop out of runoff by filtration and sedimentation before reaching water bodies.

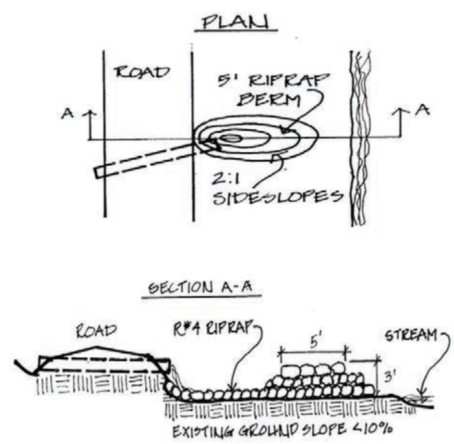
Sizing/Siting Considerations:

Sizing and siting of these practices is very site-specific, but excellent guidance can be found in the RRAMP Manual for New York on pages 31-35.

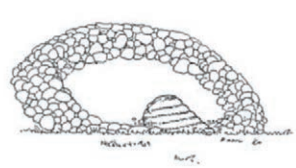
Maintenance Considerations:

Typical maintenance concerns for these types of practices include removal of accumulated sediment and inspection for areas of erosion downstream of the outlet protection practice. This can indicate that the practice is either under-sized or not functioning as originally designed and built. If erosion is found, consider upsizing or replacing the practice.

Image PE-6-1. This photo shows an excellent example of outlet protection using larger, well-anchored stones. Hay bales are not part of a permanent solution, but can be useful as temporary velocity controls.



SPLASH/PLUNGE POOL



PLUNGE POOL

Splash/Plunge Pool Capacity Requirements		
Distance Between Culverts	Pool Capacity (cu ft.)	
	Crowned Road	Banked Road
500	230	460
400	180	360
350	160	320
300	140	280
250	120	240
200	100	200

Image PE-6-2. This illustration, taken from the VT Better Backroads and NY RRAMP Manuals, shows a typical splash pool. For sizing information, refer to the RRAMP Manual, pages 31-35.

Road Surfacing

Primarily Intended For: Rural Roads (can also be used on Parking Lots and Hardscapes if unpaved)

What is it?

Road surfaces are designed to shed water quickly. This is especially important on gravel roads as water that remains on the road surface will saturate the road, causing road deformation due to moisture. Runoff during rain events will also tend to run down the road surface and not into roadside ditches – this will cause erosion. If road surfaces are easily erodible as is the case with some gravel mixes, these problems will be magnified. Adding a surfacing material made of a crushed ledge product (Stay-Mat or other various trade names) can minimize road erosion in some cases.

How does it work?

Crushed ledge products have a mixture of flatter, angular pieces mixed with a high percentage of fine materials. Once laid down and compacted, these fine particles will lock together like concrete creating a more durable surface that is less susceptible to erosion.

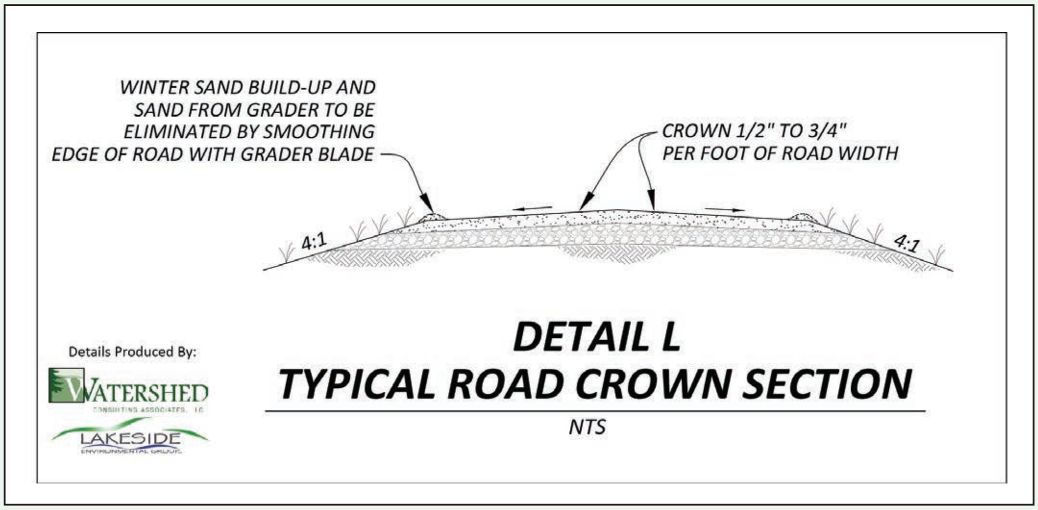


Image PE-7-1. Example of a properly shaped road – this is perhaps the most critical step in ensuring that roads don't erode. Surface material is important, but shape is the primary consideration.

Sizing/Siting Considerations:

Since many crushed ledge projects are more expensive than typical road surface materials, using them only in steeper, more erodible sections of road is advised. This can vary widely and should be gauged using local, observed conditions. See the NY RRAMP Manual, page 9, for additional surfacing recommendations and specifications.

Maintenance Considerations:

If a well-drained, compacted subbase is installed under a crushed ledge product surface, and the surface is well-shaped, lifespan can be expected to be around 10 years, depending on traffic conditions and vehicle types (more traffic and heavier vehicles will degrade the surface faster).

Image PE-7-2. A road with a durable crushed ledge product (Stay-Mat) surface.

Stone Armoring

Primarily Intended For: Rural Roads (can also be used on Urban Streets with unpaved drainage swales, Parking Lots and Hardscapes for conveyance swales)

What is it?

Stone armoring refers to the practice of lining a well-shaped ditch above 5% in slope with stone to prevent the ditch from eroding and potentially threatening the stability of the road subbase.

How does it work?

By preventing the ditch from eroding, material transport from the ditch's bed surface is minimized. This material has phosphorus bound up in it. This phosphorus can negatively impact water bodies.

Image PE-8-1. This stone-lined ditch in Vermont is protecting a culvert inlet from sediment clogging.

Sizing/Siting Considerations:

The New York Rural Roads Active Management Program (RRAMP) manual has numerous specifications for the placement, sizing, and siting of armoring material. Many of these specifications are adapted from Vermont's Better Backroads Manual, which can also be referenced.

For a general overview of when specific types of armoring should be used, use the table (bottom right).

Refer to page 17 of the RRAMP manual for more information.

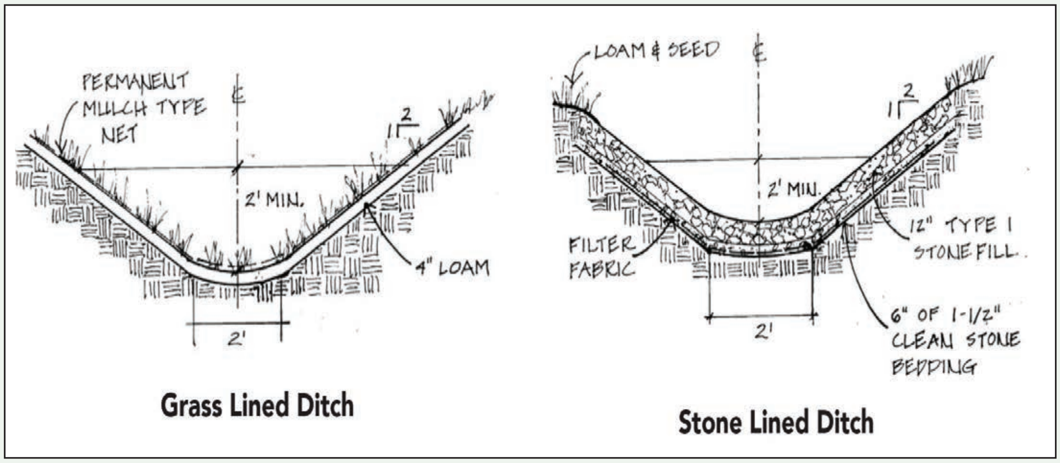


Image PE-8-2. These specifications can be found in New York's Rural Road Active Management Program Manual and have been adapted from the VT Better Backroads Manual.

Maintenance Considerations:

Over time, stone linings can fill with sediment. When this occurs, the surface roughness of the lining, that formerly slowed and filtered runoff, will cease to function properly. The RRAMP manual suggests cleaning out sediment when stone capacity has been reduce to 60% of its original volume. Stone can be removed, washed of sediment, and replaced. Prevent sediment washed from the stone from reaching water bodies.

Ditch Linings		
Channel Slope	Lining	Thickness
0-5%	Grass	
5-10%	R#3 (2-3 inch) diameter rock	7.5"
>10	R#4 (3-12 inch) diameter rock	12"

Stone Check Dams

Primarily Intended For: Rural Roads (can also be used on Urban Streets with unpaved swale drainage)

What is it?

A small dam constructed in a gully or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment. Check dams can be made of stone (typically larger than 2”), wood, or constructed from mounded, compacted, and vegetated earth.

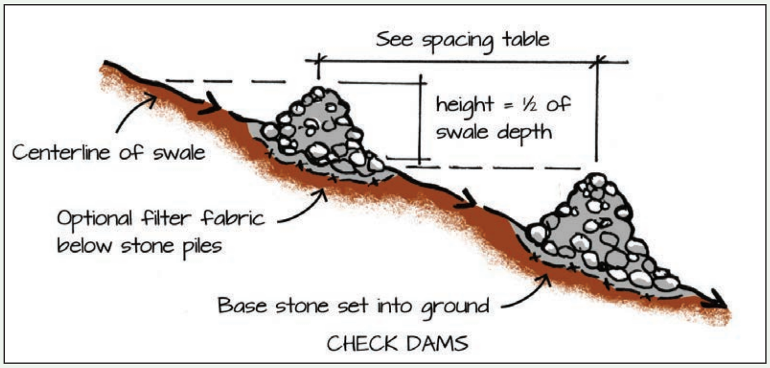


Image PE-9-1. Typical design detail of a rock check dam for roadside ditch projects.

How does it work?

The water flows slowly through the porous material, which slows and filters the stormwater that doesn’t infiltrate. They also prevent erosion. It’s not recommended check dams be used for slopes greater than 8% and it is not recommended that hay bales be used as check dams.

Image PE-9-2. Rock check dams in a roadside ditch in West Virginia with erosion control fabric lining the ditch between them.

Sizing/Siting Considerations:

For swales with shallower slopes (>5%) where lower runoff velocities are expected, check dams can be made of less durable materials like mounded earth, sand/gravel bags, or fiber socks. For steeper slopes (>5%) with higher runoff velocities, use more durable materials like stone or wood.

Check dam spacing is key – use the table (bottom right) to assist with spacing.

Swale Slope (%)	Check Dam Spacing (ft)
1	200
2	100
4	50
6	30
9	25

Maintenance Considerations:

Check dams will accumulate sediment upslope of the dam’s face. This will need to be removed to ensure that there is an adequate pool and that runoff does not continuously overtop the dam.

Over time, solution channels around or under the dam may develop – the dam will need to be replaced, or material added, to ensure that these channels don’t allow water escape and cause erosion.

Water Bars

Primarily Intended for: Rural Roads

What is it?

Water bars intercept water flowing down unpaved paths or driveways and redirect it to stable, vegetated areas.

How does it work?

Water bars redirect water off of unpaved roads, which helps to mitigate erosion. It also prevents road sediments from reaching waterways as water bars are always directed to stable, vegetated areas. This slows and infiltrates stormwater, improving water quality.

Image PE-10-1. Water bars being installed in Van Cortlandt Park, New York. These water bars will direct stormwater off of this path to the stable vegetation to the side.

Sizing/Siting Considerations:

Choose location to install water bar(s) based on the existing runoff patterns at the site. Water bars should be placed where runoff flows on the road. A trench is dug at a 30° angle across the road, extended beyond both sides of the road.

Select 6”-8” diameter logs or timbers. Obtain enough timber so that you can span the entire road width. Dig a trench the height of the timber and place timber snug and level and almost flush with the downhill side. To secure, partially bury large stones on the downhill side or use rebar stakes. For rebar stakes, drill a ½” hole into the timber, 6” in from each edge on either side of wood. Pound stakes in until flush. Dig another trench along the uphill side, 1’ wide by ½’ deep, and line with non-woven geotextile fabric. Fill trench with washed drainage stone, leaving a few inches of the wood exposed. Build up the downhill side of the water bar until level with the road by backfilling with soil and gravel.

Image PE-10-2. Water bars are easy to install and construction can be completed with just hand tools.

Ensure that water bars are constructed where they can outlet to a stable, vegetated area to prevent erosion. The water bar outlet can be reinforced with a flared apron of washed drainage stone if erosion concerns are present.

Maintenance Considerations:

Water bars must be well-marked in areas that are plowed so the operator can lift the plow when going over the bars. The bars need to be periodically clean of debris. Some repair may be needed after large rainfalls. Check to ensure that no erosion is occurring at the outlet.

Bioretention

See NY Stormwater Management Design Manual – various chapters – for additional guidance on design.

Primarily Intended For: Parking Lots and Hardscapes (can also be used on Urban Streets, Building Development)

What is it?

Bioretention practices are similar to rain gardens, though are generally much larger and treat larger drainage areas – usually over 2,000 square feet. Bioretention practices are essentially shallow depressions on the ground surface that collect stormwater. Once water enters the bioretention, it will flow through soil, where pollutants will filter out before the filtered runoff is returned to the storm sewer system. Bioretention is usually planted with perennials – always use native species, never non-native invasives.

Image PE-11-1. The illustration shows a typical bioretention installed in a parking lot between parking aisles. This practice has an underdrain with a cleanout.

How does it work?

Water enters a shallow depression on the ground surface. Larger sediment can settle out on the surface of the ground or get filtered out by the plants (typically grasses and flowering perennials). As water infiltrates into the soil, pollutants are further filtered out by soil particles and soil microbes. Bioretention can be open to native soils underneath (acting more as an infiltration basin) or return filtered runoff to the storm sewer system. Not only do bioretention practices filter out pollutants, they also reduce peak discharges from storms, resulting in less stream erosion at storm sewer outfalls.

Sizing/Siting Considerations:

Optimal sites for bioretention are areas where water already collects, or could easily collect. Areas where there are storm sewer outfalls, or nearby pipe connections that could be brought into the bioretention are also good. If large areas of sheet flow (non-piped flows over parking lots, etc.) are directed to an open area, these are also good spots for bioretention. Native soils do not have to have high infiltration capacity if water is being returned to the storm sewer – an underdrain will be necessary in those instances. Don't locate bioretention too near to building foundations – greater than 10' is usually the minimum. Always protect the inlet point(s) as erosion can easily occur there – stone armoring or other hardened material is usually used.

Maintenance Considerations:

Sediment will tend to accumulate in bioretention, clogging the surface soils and preventing infiltration. Regular inspection and removal of sediment is critical for good function. Plants, a key component of bioretention's aesthetics and function as their root systems promote soil microbe communities that remove pollutants, must be maintained like regular landscaping gardens. Waste plant material should be removed and composted off-site. Underdrains should be inspected for clogging and cleaned when necessary.

Infiltration Practices

See NY Stormwater Management Design Manual – Ch. 6, pages 6-31 - 6-42 – for additional guidance on design.

Primarily Intended For: Parking Lots and Hardscapes (can also be used on Building Developments, Urban Streets, Rural Roads)

What is it?

Infiltration Practices are gravel-filled trenches or pits that store runoff until it infiltrates Unlike most of the other practices described in this manual, these practices do not necessarily incorporate vegetation into their design. They rely on soils to absorb runoff and filter pollutants.

How does it work?

Creating a shallow depression on the surface, which is augmented by a trench filled with stone, encourages runoff to pool and infiltrate. Pollutants will filter out through the stone voids and be further filtered by native soils underneath.

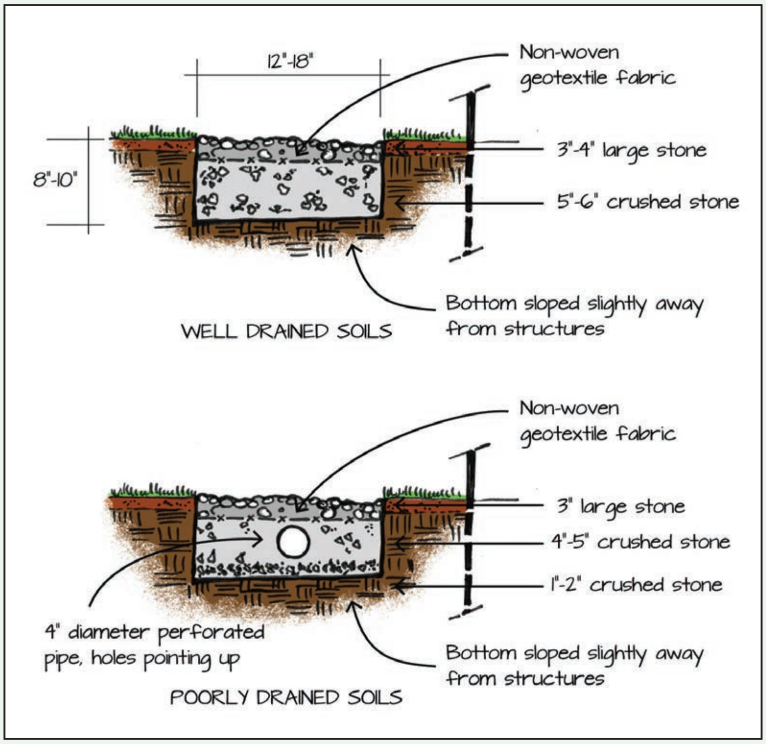


Image PE-12-1. Infiltration trenches can be installed to catch roof runoff, as well as parking lot drainage. They typically do not incorporate vegetation which can lessen maintenance.

Sizing/Siting Considerations:

Soils under infiltration practices must allow for good infiltration. Be careful of locating infiltration practices near to basements as this can cause nuisance flooding. Small infiltration practices for one or two downspouts or small paved areas, can usually easily be installed by contractors. Larger infiltration practices (those treating over 2,000 square feet) should be designed and installed by qualified professionals.

Image PE-12-2. This illustration shows a typical infiltration trench for both well- and poorly-drained soils.

Maintenance Considerations:

Carefully inspect infiltration practices for clogging – runoff should typically infiltrate within 48 hours of a storm – longer than 72 hours may indicate that there is clogging in the stone voids or the underlying native soils caused by excess sediment.

Protect the top of infiltration practices from clogging by installing vegetated (usually grass) filter strips to trap some sediments. Leaf clogging can be an issue as well.

If a filter fabric was used during construction, this can be a source of clogging. Remove the stone above and around the filter fabric to check this layer, and consider removing this fabric.

Permeable Hardscapes

NY Stormwater Management Design Manual – pages 5-105 – 5-116)

Primarily Intended For: Parking Lots and Hardscapes (can also be used on Building Developments, Urban Streets)

What is it?

Permeable Hardscapes are alternatives to traditional paving materials that allow water to seep into the ground rather than become runoff. The surface materials used can be pavers that have spaces between them or porous concrete or asphalt.

For lower-use areas simple level grassy areas can be used as well. In order to preserve hydrologic function over time, it may be necessary to uncompact the grassy area after several years of use as compacted soils can often turn seemingly pervious areas into impervious ones.

Image PE-13-1. Permeable paver parking installation – light commercial scale.

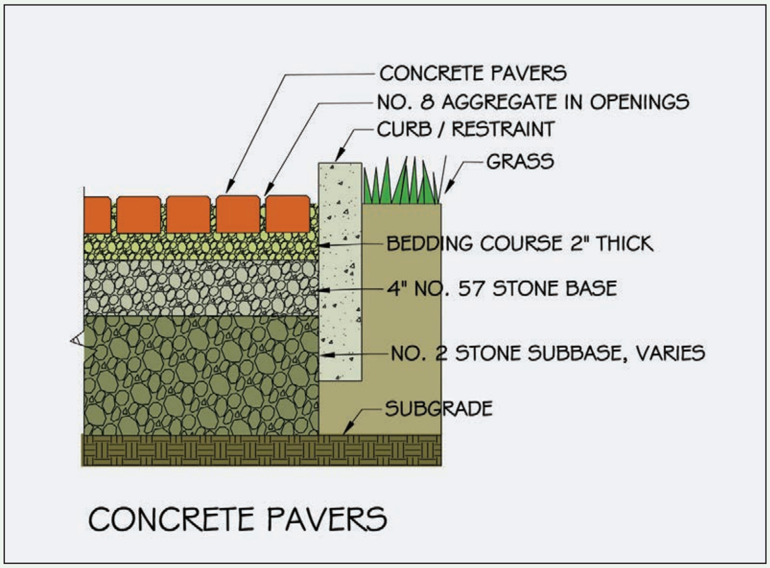


Image PE-13-2. Permeable Concrete Pavers with typical underlayers. Refer to NY Stormwater Manual for specific underlayer guidance.

How does it work?

After infiltrating through the surface layer, rainfall seeps into a thick layer of gravel below. This gravel stores and then slowly infiltrates runoff. Permeable hardscapes at the residential and small commercial or institutional scale are typically used for walkways, patios, or parking spots. Pollutants are removed through interactions in soil.

Sizing/Siting Considerations:

Clogging of runoff inlet pores is the single largest concern with these materials. Ensure that runoff does not carry an excess of fine sediment on to the porous surface. If this does occur, clean the material out of the pores as soon as possible.

Permeable Hardscapes can be used for Runoff Reduction credits, Water Quality requirements, and in certain cases Channel Protection volume reduction.

Maintenance Concerns:

Clogging is the largest issue with permeable hardscapes of all types. Conducting spot-checking with an infiltration test (ASTM C1701) or observation of infiltration patterns during rainfall will indicate the need to clean hardscapes. Do not jet with water – use a street-sweeper with vacuum function to loosen and lift particles out of the pores to ensure infiltration can occur.

Storage Chambers

Primarily Intended For: Parking Lots and Hardscapes (can also be used on Building Developments, Urban Streets)

What is it?

Underground storage chambers are designed to fit under existing land uses, like parking lots, park open spaces, or even streets in some cases. Most are U-shaped structures open at the bottom and embedded in stone on the bottom, sides, and top. Runoff is channeled to the chambers using normal storm sewer pipes.

Image PE-14-1. This illustration shows sub-surface chambers installed below a parking lot.

How does it work?

Runoff enters the chambers using a regular storm sewer network of catchbasins and pipes. The chambers are buried underground, meaning that land on top of them can still be used. When runoff enters the chambers, it is allowed to infiltrate into the stone bed and the native soil below (provided the soil below has good infiltration capacity). Sediment and other pollutants are filtered out by the stone and native soil. Flows are significantly reduced as runoff will now enter surface waters as base flow through groundwater.

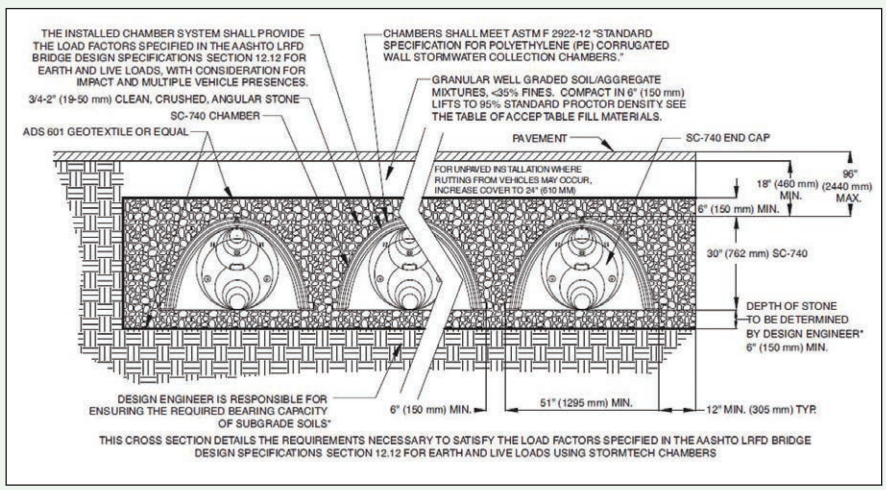


Image PE-14-2. The schematic illustrates a typical installation showing a stone bed below the chambers, stone separating each row of chambers, and stone covering the chambers, with a parking lot surface of pavement and pavement subbase above that.

Sizing/Siting Considerations:

The most important consideration for chambers is the suitability of native soil to infiltrate water. If water won't easily infiltrate the chambers can still be used for retention (holding runoff temporarily and bleeding it off slowly through a controlled outlet) but not necessarily for runoff reduction or water quality control. Depth to groundwater must also be considered as adequate separation from groundwater is key to chamber function. If locating chambers under a parking lot, adequate burial depth must be assured as the amount of cover over the top of chambers determines their load capacity.

Maintenance Considerations:

Install an isolator row (a row of chambers wrapped in fabric) to filter out most sediment and preserve the lifespan of the other rows. This row must be cleaned out regularly – an annual inspection is mandatory, and cleaning should occur when 3" or more of sediment have accumulated.

Green Roofs

See NY Stormwater Management Design Manual – Ch. 5 – pages 5-80 – 5-89 – for additional guidance on design.

Primarily Intended For: Building Developments

What is it?

Green roofs consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof.

Image PE-15-1. Small-scale green roof on a flat residential roof.

How does it work?

The rooftop vegetation captures rainwater allowing evaporation and evapotranspiration processes to reduce the amount of runoff entering downstream systems, effectively reducing stormwater runoff volumes and attenuating peak flows. Green roof designs are characterized as extensive or intensive, depending on storage depth. Extensive green roofs have a thin soil layer and are lighter, less expensive and generally require low maintenance. Intensive green roofs often have pedestrian access and are characterized by a deeper soil layer with greater weight, higher capital cost, increased plant diversity and more maintenance requirements.

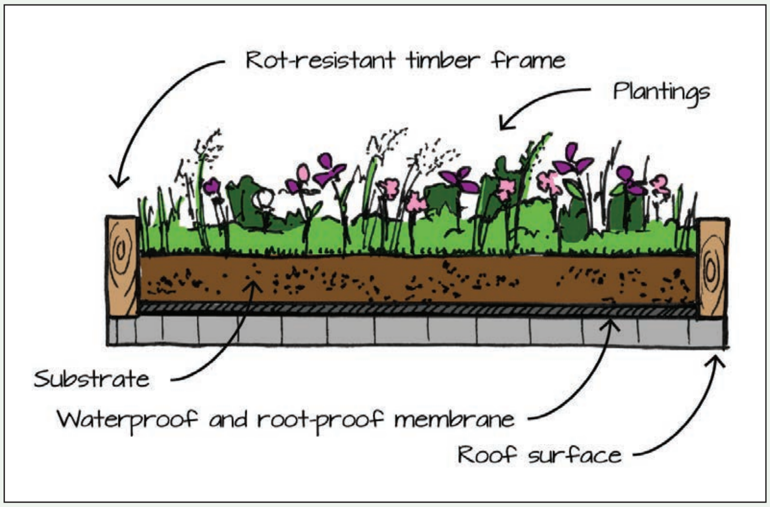


Image PE-15-2. Typical layers of a green roof – make sure that any green roof project include a good waterproof membrane underneath the planting media.

Sizing/Siting Considerations:

Sizing of green roofs is primarily dictated by roof type and load bearing capacity. Increasing the amount of soil in order to store and eventually evapotranspirate more rainfall is only possible on stronger roofs. Roofs can be sized for the water quality volume – see the NY Stormwater Management Design Manual for specific calculations. Plants should also be selected to be hardy in conditions usually found on a roof – often very dry, exposed to the sun, and windy. Proper plant selection for green roofs is critical. The NY Stormwater Management Design Manual has numerous suggestions. Always try to use native plants, if possible, or non-native non-invasives otherwise. Never use non-native invasive plants for green roofs.

Maintenance Considerations:

In the first year, maintenance of plants is critical – weeding and fertilization may be necessary as plants establish and adapt. Any roof drains present will need to be inspected for clogging and cleaned. Additionally, it is critical to check under the roof for any leaks in the waterproof membrane. After the first year, maintenance tasks are typically limited to a bi-annual weeding and inspection of drain inlets.

Rain Barrels and Cisterns

See NY Stormwater Management Design Manual – Ch. 5 – page 5-53 – 5-58 – for additional guidance on design.

Primarily Intended For: Building Developments

What is it?

Rain barrels are designed to intercept and store runoff from guttered rooftops and allow for use, typically for irrigation. A series of connected rain barrels can be considered if you have a larger roof and/or will be utilizing all stored water frequently. Note that a larger storage volume increases the risk for water stagnation to occur. Cisterns are larger versions of rain barrels and can be buried underground to save space on your site.

How does it work?

Rain barrels or cisterns are connected to gutters and downspouts – if your roof is not guttered you will have to install gutters. Connect your gutter downspout to the rain barrel or cistern. Most rain barrels and cisterns will have attachments for a standard garden hose – cisterns will typically have provisions for a pump. Typically collected water is used for irrigation, but can also be used for vehicle washing, or other cleaning applications.

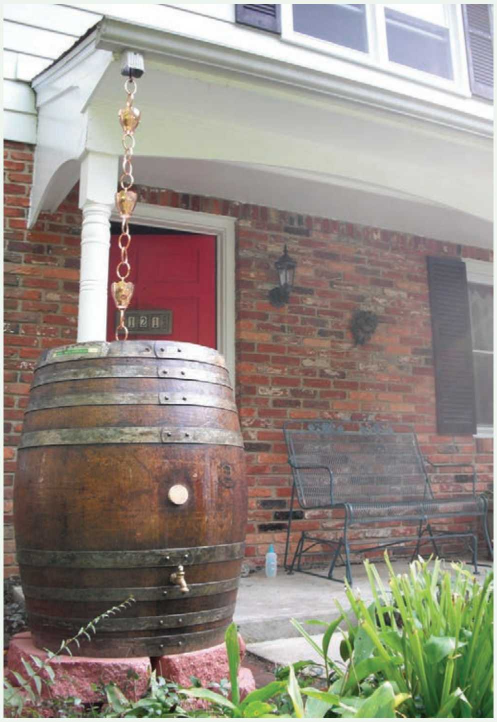


Image PE-15-1. Simple, attractive residential rain barrel using a rain chain to route water from the gutter to the barrel. Note the hose spigot at the bottom of the barrel.

Sizing/Siting Considerations:

Be sure to have an area where collected water can overflow in larger storms, otherwise erosion can occur. Rain barrels are good for smaller roofs, especially if installed in-series (multiple barrels linked with hoses). However larger roofs will require cisterns. Always ensure that mosquito proof caps or screens are used – most commercial barrels and cisterns will come with this installed. You may also want to investigate 'first-flush' diverters to keep debris out of the barrels.

Maintenance Considerations:

Drain between storm events to maximize storage capacity. Drain and store upside down in the winter (rain barrels). Inspect annually for cracks.

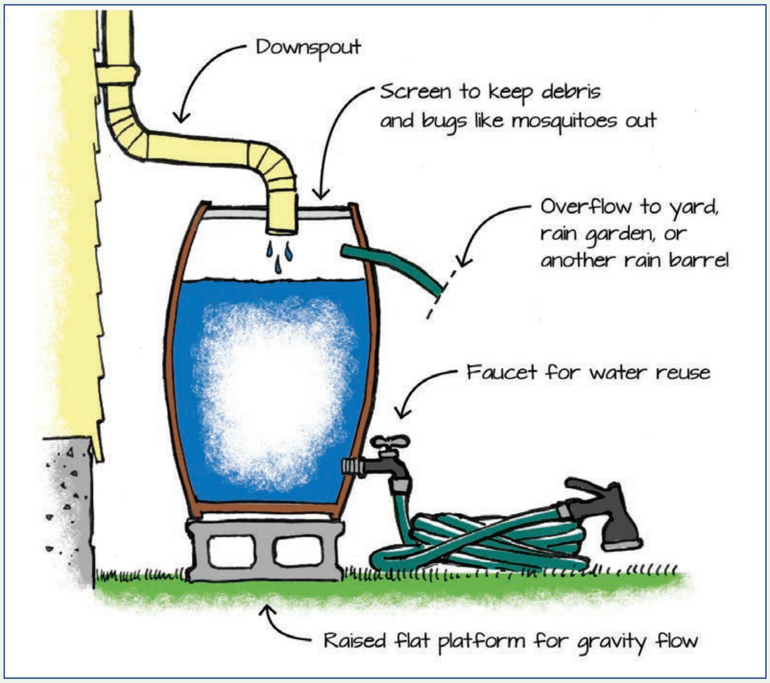


Image PE-15-2. Sample rain barrel illustration.

Rooftop Disconnection

See NY Stormwater Management Design Manual – Ch. 5 – pages 5-64 -5-67 – for additional guidance on design.

Primarily Intended For: Building Developments

What is it?

Disconnection of rooftop runoff to designated filtration or infiltration areas through site grading is a simple way to reduce runoff. Areas where rooftop runoff is directed must have good infiltration capacity and must possess slopes less than 5% average.

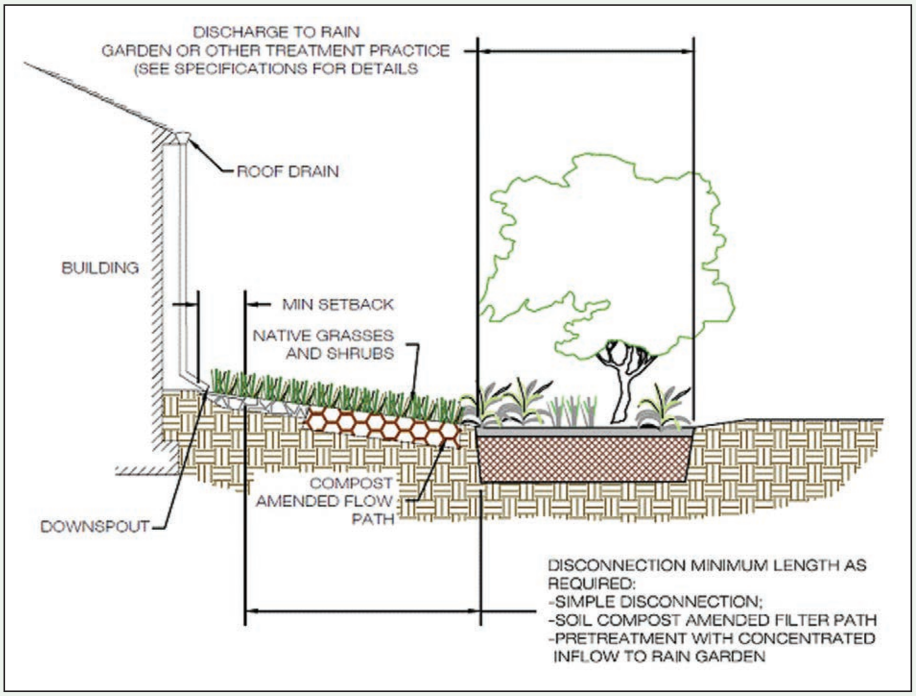


Image PE-17-1. Rooftop disconnections are simple ways to remove stormwater runoff from roofs from the storm sewer system and ensure that runoff is slowed down and filtered through soil before reaching local water bodies as groundwater.

How does it work?

Disconnecting relatively clean rooftop runoff to a designated low-slope vegetated area will act much the same way as an infiltration practice – runoff will slowly sink into the ground, instead of entering the storm sewer through direct connection (pipes) or through connected impervious surfaces (like driveways). While rooftop runoff is typically cleaner than street or parking lot runoff, reducing peak flows is still a good practice.

Sizing/Siting Considerations:

Ensure that there is a designated low-slope vegetated area with good underlying soils (soils classification of Hydrologic Soil Group A or B is acceptable without soil amendments). Ensure that these areas are at least 10' away from other ground level surfaces to discourage re-connection. If possible, route runoff as far away from basements as the site will allow to prevent wet basements. Refer to the NY Stormwater Management Design Manual for further specifications regarding disconnection area sloping and maximum contributing drainage area.

Image PE-17-2. Example of a residential rooftop disconnection to a designated vegetated area.

Maintenance Considerations:

Ensuring that the disconnection remains intact is critical – allowing it to be developed will negate its benefits. Encouraging runoff to infiltrate near poorly sealed basements may result in even more water in the basement – ensure that there is a plan to deal with this possibility before disconnecting rooftop runoff.

Stormwater Planter

See NY Stormwater Management Design Manual – Ch. 5 – pages 5-90 – 5-97 – for additional guidance on design)

Primarily Intended For: Building Developments

What is it?

Stormwater planters are small landscaped stormwater treatment devices that can be placed above or below ground and can be designed as infiltration or filtering practices. Stormwater planters use soil infiltration and biogeochemical processes to decrease stormwater quantity and improve water quality, similar to rain gardens and green roofs. Three versions of stormwater planters include contained planters, infiltration planters, and flow-through planters. Always use native perennial plants adapted to your area – never use non-native invasive species.

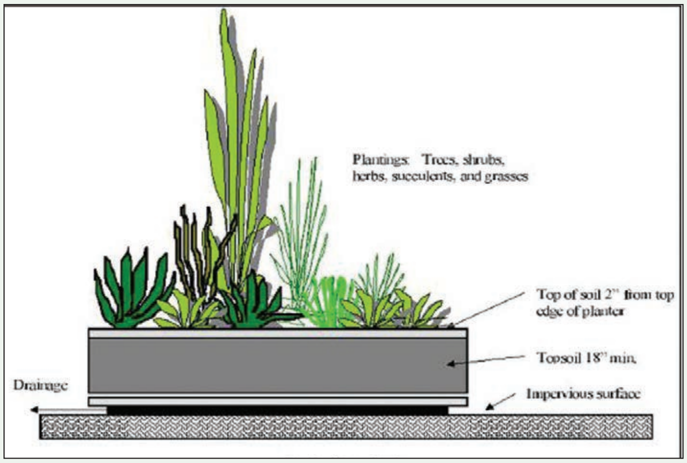


Image PE-18-1. This illustration shows a contained stormwater planter – excess runoff can only exit by overflowing the planter's top edge. This type of planter is best suited for small drainage areas.

How does it work?

Water, usually from rooftops, is directed into the planter where it can pool on the surface and then infiltrate into the soil. Water will remain in the void spaces between soil particles. Any particles will be filtered out by the plants and soils. Runoff volume will be reduced through plant uptake and evapotranspiration. In the case of infiltration planters, runoff will enter the ground whereas contained planters will overflow after all the soil is saturated or flow through to impervious surfaces under the planter in the case of flow-through planters.

Image PE-18-2. Photo of a simple downspout connection to a stormwater planter.

Sizing/Siting Considerations:

Planters are usually small-scale and not suited for parking lot / road runoff. They are well-suited for rooftop or plaza/ courtyard runoff. They are usually sized only for water quality storm volume (WQv) – larger storms will overwhelm them. If installing infiltration planter, place it greater than 10' from foundations. The maximum area that should be routed to a planter is 15,000 square feet. Where water enters the planter, stones, or other hard armoring, should be used to prevent erosion. Refer the NY Stormwater Management Design Manual for additional design criteria.

Maintenance Considerations:

Since planters usually receive rooftop runoff, sediment is not a huge concern, but can accumulate over time, especially if the drainage area for the planter contains plaza/courtyard runoff. Plants will need to be maintained and may even require watering during dry periods of the year. Containers may degrade over time – use as durable a container as possible during initial installation (concrete or similar).

Rain Garden

See NY Stormwater Management Design Manual – Ch. 5 – pages 5-71 – 5-79 – for additional guidance on design.

Primarily Intended For: Building Developments (can also be used on Parking Lots and Hardscapes, Urban Streets – similar to Bioretention)

What is it?

A rain garden is a shallow landscaped depression that receives runoff from surrounding rooftops, driveways, or yard areas. Compared with traditional landscaping, which is usually raised a few inches above the surrounding landscape, rain gardens are graded as shallow depressions that accumulate runoff from surrounding areas. Use native perennials adapted to your area – not non-native invasives.

How does it work?

A rain garden simulates the runoff treatment provided by natural areas, such as forests or meadows. The primary component of a rain garden is the filter bed, which can consist of the existing soil (if it percolates well) or an assembled mixture of sand, soil, and organic material, topped with plants.

Sizing/Siting Considerations:

Rain gardens are typically small – 60-180 square feet. Good soil conditions are critical for infiltration – if soils don't infiltrate at a rate greater than 0.5"/hour, then an underdrain may be necessary. Finding a natural low spot on your site will make it easier to install a rain garden. Don't use a location that remains wet for several days after rain.

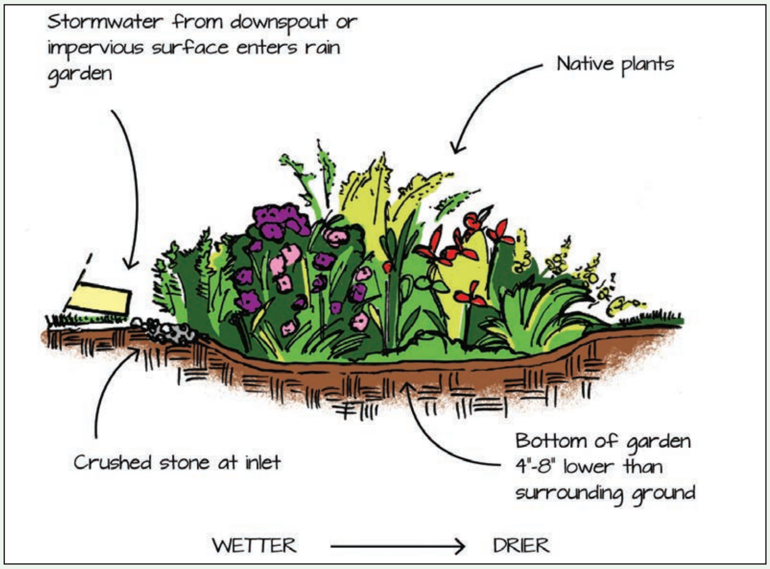


Image PE-19-1. Rain gardens can take many forms. This one shows the garden collecting water from a gutter downspout – they can also collected water sheet flow from driveways or directly from rooftops.

Image PE-19-2. Residential rain garden fed by a gutter downspout in Albemarle County, VA.

Maintenance Considerations:

Armor the inlet of the rain garden with stone, or other durable material to prevent erosion. If planted with native perennials, make sure to maintain the plants as required – overgrown rain gardens aren't appreciated by the public. Avoid using wood-based mulches – this can act as a source of phosphorus and will float when water is ponded. If there is a pipe outlet for the garden, mulch will plug it. If a rain garden receives runoff laden with sediment, removal of sediment will be necessary on a semi-annual basis.

Conservation Measures

NY State Stormwater Management Design Manual – Ch. 5, Section 5.1.

What is it?

The first step in site planning for a new project should involve avoidance or minimization of land disturbance by preserving natural areas. This is the first step in the Runoff Reduction Method required by NY State Stormwater Regulations.

Table 5.1 Planning Practices for Preservation of Natural Features and Conservation Design	
Practice	**Description**
Preservation of Undisturbed Areas	Delineate and place into permanent conservation undisturbed forests, native vegetated areas, riparian corridors, wetlands, and natural terrain.
Preservation of Buffers	Define, delineate and preserve naturally vegetated buffers along perennial streams, rivers, shorelines and wetlands.
Reduction of Clearing and Grading	Limit clearing and grading to the minimum amount needed for roads, driveways, foundations, utilities and stormwater management facilities.
Locating Development in Less Sensitive Areas	Avoid sensitive resource areas such as floodplains, steep slopes, erodible soils, wetlands, mature forests and critical habitats by locating development to fit the terrain in areas that will create the least impact.
Open Space Design	Use clustering, conservation design or open space design to reduce impervious cover, preserve more open space and protect water resources.
Soil Restoration	Restore the original properties and porosity of the soil by deep till and amendment with compost to reduce the generation of runoff and enhance the runoff reduction performance of post construction practices.

Image PE-20-1. Summary of Conservation Measures from the NY Stormwater Management Design Manual.

How does it work?

By preserving natural features that intercept rainfall and help to filter or infiltrate runoff, the impact of development is reduced. Rather than just create a large amount of impervious cover, then manage the runoff from it for water quality and quantity, runoff, and its associated pollution and volume, is reduced from the beginning. This reduces the cost of stormwater management, and can reduce the cost of development as well.

Sizing/Siting Considerations:

The main practices that preserve natural features include

- Preservation of Undisturbed Areas
- Preservation of Water Body Buffers
- Reduction of Clearing and Grading
- Locate Development in Less Sensitive Areas
- Open Space Design
- Soil Restoration

Each of these has specific siting and sizing considerations outside the scope of this manual. Please refer to the NY State Stormwater Management Design Manual – Chapter 5, Section 5.1 for detailed information.

Image PE-20-2. 'Cluster' development is a good way to preserve natural areas and reduce impervious surfaces.

Maintenance Considerations:

Each of these practices has specific maintenance considerations – however, the unifying criteria is that each practice requires preservation. Development of any kind cannot be permitted on these areas. That specification must be made clear to any users of the development, as well as abutters.

Impervious Cover Reduction

NY Stormwater Management Design Manual – Ch. 5 – Section 5.2 pages 5-23 – 5-39 – for additional guidance on design.

What is it?

Reduction of impervious cover is a design step that usually follows the conservation of natural features. It is critical to the Runoff Reduction method of stormwater management. By first preserving beneficial features, then reducing the amount of runoff generated by impervious cover, the total amount of runoff to manage will be reduce. Doing things reducing roadway, sidewalk, and driveway widths, reducing the impact of cul-de-sacs, shrinking building footprints, or reducing the overall amount of paved parking will help accomplish this.

How does it work?

Reducing impervious cover reduces the amount of runoff, meaning there is less to manage. Stormwater management practices can then be smaller and easier to site within the landscape.

Sizing/Siting Considerations:

Each 'practice' has its own specific considerations for implementation. The NY Stormwater Management Design Manual is the best source for this information. Additionally, any of these practices will have to take into account local regulations which may require certain widths for roads, sidewalks, etc. Part of implementing these practices may be to examine local code requirements to see if meaningful changes can be made to accommodate use while reducing impacts from stormwater runoff.

Maintenance Considerations:

Perhaps the best aspect of impervious cover reduction practices is that they reduce the overall maintenance burden for any site. Less impervious surfaces means less plowing, less pavement to maintain, and less stormwater to manage. Subsequently stormwater management practices are easier to build and maintain over time.

Table 5.4 Planning Practices for Reduction of Impervious Cover

Practice	Description
Roadway Reduction	Minimize roadway widths and lengths to reduce site impervious area
Sidewalk Reduction	Minimize sidewalk lengths and widths to reduce site impervious area
Driveway Reduction	Minimize driveway lengths and widths to reduce site impervious area
Cul-de-sac Reduction	Minimize the number of cul-de-sacs and incorporate landscaped areas to reduce their impervious cover.
Building Footprint Reduction	Reduce the impervious footprint of residences and commercial buildings by using alternate or taller buildings while maintaining the same floor to area ratio.
Parking Reduction	Reduce imperviousness on parking lots by eliminating unneeded spaces, providing compact car spaces and efficient parking lanes, minimizing stall dimensions, using porous pavement surfaces in overflow parking areas, and using multi-storied parking decks where appropriate.

Image PE-21-1. A variety of impervious cover reduction strategies are available when designing a site. These are taken from the NY Stormwater Management Design Manual.

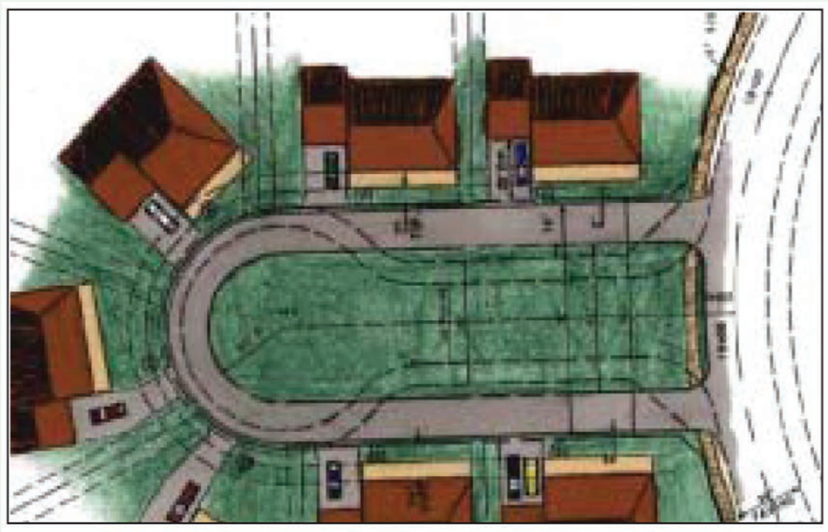


Image PE-21-2. A 'loop road' with a pervious green space can both reduce impervious cover and provide a space for runoff to infiltrate back into the ground.

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Image 1-5:Friends of the Mad River – http://www.friendsofthemadriver.org/

Image 1-6: Watershed Consulting Associates, LLC (adapted from the New York Stormwater Management Design Manual)

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Chapter 5:

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