DECEMBER 2016

GREEN INFRASTRUCTURE PLAN
for the Lower Brodhead Watershed

Brodhead Watershed Association
BWA
www.brodheadwatershed.org

GREEN INFRASTRUCTURE PLAN FOR THE LOWER BRODHEAD WATERSHED

Prepared by the

Brodhead Watershed Association

and

Hanover Engineering Associates

in partnership with

Monroe County Conservation District

Monroe County Planning Commission

Stroud Township

Borough of Stroudsburg

Borough of East Stroudsburg

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Executive Summary

In 2012 and 2013, Brodhead Watershed Association (BWA) volunteers and the Pennsylvania Department of Environmental Protection (PA DEP) partnered to study water quality and sample fecal coliform at points along the Brodhead, McMichael, and Pocono Creeks through the boroughs of East Stroudsburg and Stroudsburg and in Stroud Township. Several sample locations within the study area exhibited high fecal coliform counts, resulting in the PA DEP determining the lower Brodhead streams are "Non-Attaining for Recreational Use" (i.e., not safe for swimming and other water contact). Finding the source(s) of the contamination and determining appropriate solutions have become priorities for BWA and partner municipalities.

Urban stormwater runoff is increasingly recognized as a source of pollution to streams. As land is developed with more impervious surfaces, more rainfall discharges to streams as surface runoff, carrying with it sediments, salt, oil and grease, pet and other animal waste, excess fertilizers, and pesticides. In addition, water temperatures increase as stormwater runs over warm impervious surfaces, increasing the temperature of receiving waterbodies.

This project focuses on the lower Brodhead watershed where studies indicate declines in water quality through the urbanized areas. No single point source of impact can be identified in the study area, suggesting impairments are the result of runoff from surrounding land uses. Impervious surfaces make up approximately seventeen percent (17%) of the land cover of the study area, with the boroughs of East Stroudsburg and Stroudsburg each having more than thirty percent (30%) impervious cover.

One of the measures of stream water quality is a study of the aquatic insects present in the stream. Aquatic Research Consultants studied the Brodhead Creek from above the boroughs of East Stroudsburg and Stroudsburg to below. That study, which is summarized in Appendix 1, demonstrates the gradual decline of stream health over the length of the Brodhead Creek. Similar studies led by the Monroe County Planning Commission show declines in the McMichael and Pocono creeks as they flow through the project area.

Recognizing that the continued discharge of stormwater is negatively impacting the waters within the lower Brodhead watershed, BWA, volunteers, and partners have mapped locations of stormwater discharges to streams and developed this Green Infrastructure Plan to reduce the negative impacts of stormwater, increase awareness of the stormwater through education, and ultimately improve the water quality within the lower Brodhead watershed.

Introduction

Urban stormwater runoff, in the form of precipitation and snowmelt, is an increasing problem that is degrading our streams and posing potential harm to public health. As stormwater runs off the landscape and over impervious surfaces such as streets, parking lots, roofs, and sidewalks, it carries along pollution that eventually ends up in our streams. Pollutants such as sediments, salt from streets and sidewalks, oil and grease from cars and trucks, animal waste, excess fertilizers, and pesticides are collected in storm sewers and carried to local streams.

Streets, parking lots, roofs, and sidewalks disrupt the natural water cycle because rain and melting snow cannot flow through the hard "impervious" surfaces, thus prohibiting stormwater from filtering into the ground. Instead, stormwater runs off the hard surfaces into storm drains or directly to streams.

Historically, stormwater collection systems were designed to quickly remove water from around buildings and off streets and pipe it to the nearest waterway, analogous to a "gray funnel" as depicted in the image below. At the time, the damaging effect of stormwater pollution was not fully recognized, resulting in increased pollution loading to streams.

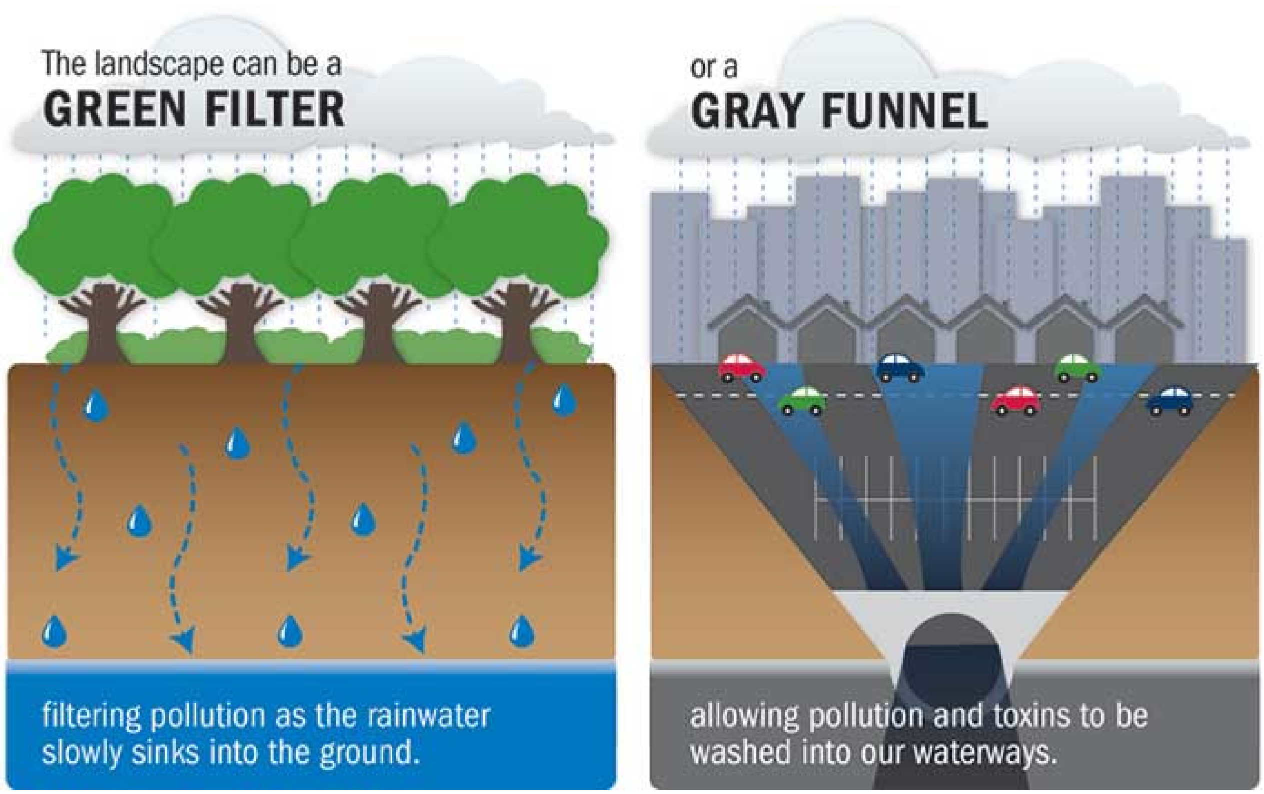


Figure 1. The landscape can be a green filter or a gray funnel. Reprinted from About the Bay-The Issues-Polluted Runoff, In *Chesapeake Bay Foundation*, n.d., Retrieved December 8, 2016, from http://www.cbf.org/about-the-bay/issues/polluted-runoff. Copyright 2016 by Chesapeake Bay Foundation.

Currently there is a growing body of understanding about alternative stormwater management practices, collectively known as "Green Infrastructure," that is designed to mitigate the impact of stormwater runoff. It is the intent of this "Green Infrastructure Plan" to show ways that stormwater can be managed by mimicking the natural water cycle. When green infrastructure is included in stormwater management design, stormwater can infiltrate back into the ground and/or be taken up by plants, thereby reducing the volume of runoff and filtering contaminants before reaching nearby streams.

Runoff, Recharge, and Impervious Surfaces

When development occurs and more impervious surface is added, natural landscapes are destroyed and opportunities for stormwater runoff to mimic the natural water cycle are diminished. Figure 2 below provides a visual example of stormwater in a natural landscape versus an urbanized area consisting of 75-100% impervious surface. In the natural landscape example, 90% of the stormwater either infiltrates back into the ground or is taken up by trees and/or evaporation. In the urban area, which consists of mainly impervious surfaces, more than half of the stormwater runs off the surface contributing to water pollution.

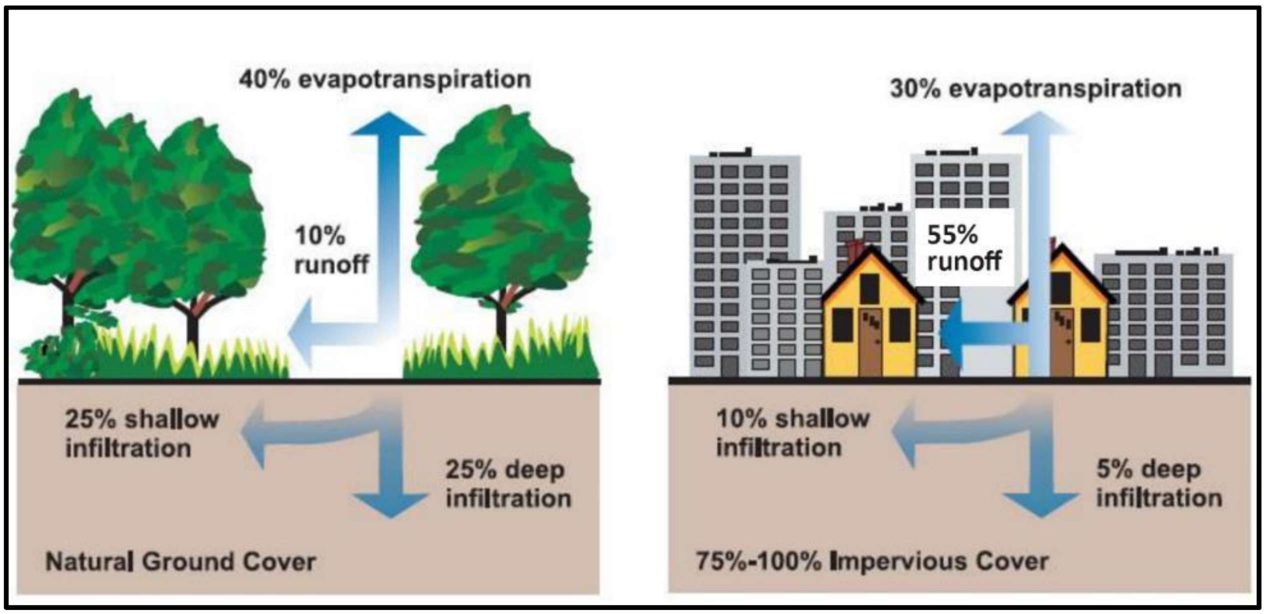


Figure 2: Runoff and Recharge. Adapted from "Protecting Water Quality from Urban Runoff," by United States Environmental Protection Agency, EPA 841-F-03-003, p. 1. Copyright February 2003 by the US EPA.

The Project Area

The project area (Figure 3) for this Green Infrastructure Plan includes the Borough of East Stroudsburg, Borough of Stroudsburg, the heavily developed corridor of Interstate 80 and Route 611 along the lower Pocono Creek, and the watersheds for streams that flow into the lower Pocono Creek in Stroud Township, encompassing approximately 11,250 acres (approximately 18 square miles).

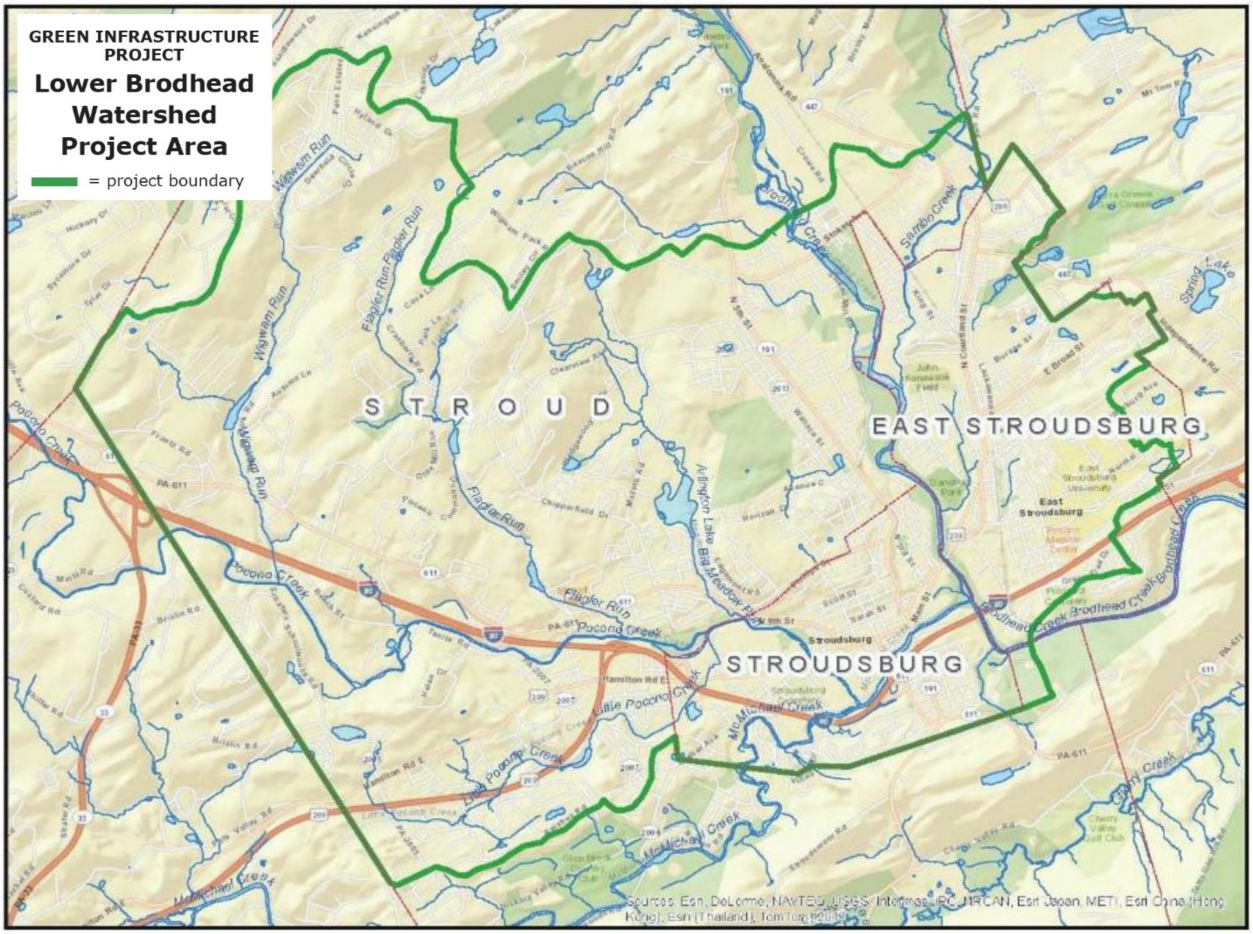


Figure 3. Project study area, Lower Brodhead Watershed.

In cooperation with the University of Vermont and assistance from the Monroe County Planning Commission, an analysis of the land cover within the project area was conducted. Land cover within the project area has been broken out as shown in the table below.

Table 1: Land Cover Within the Project Area				
Land Area Type	**Borough of East Stroudsburg**	**Borough of Stroudsburg**	**Stroud Township**	**Total (Acres)**
Tree Canopy	629	497	5,581	6,707
Grass/Shrub	405	220	1,716	2,341
Bare Soil	13	25	53	91
Water	19	24	131	174
Buildings	142	103	268	513
Roads/Railroads	151	120	408	679
Other Paved Surfaces	211	121	417	749
Total	1,570	1,110	8,574	11,254

Stormwater in the boroughs of East Stroudsburg and Stroudsburg and the urbanized parts of Stroud Township is captured in storm drains and then carried in pipes to discharge directly to streams, with no prior treatment. At least 67[1] pipes or conveyances discharge directly to the Brodhead, McMichael, and Pocono creeks in the approximate 18 square mile project area.

It is important to note that the existing stormwater collection systems within the project area are designed to carry strictly stormwater, and transport it directly to streams. Wastewater, carried in "sanitary sewers" is completely separate from stormwater piping and is transported to municipally owned wastewater treatment plants. It is also important to note that the undeveloped and mainly forested areas of the upper watershed send clean water to the urbanized areas of the lower watershed.

New development, and most development that has occurred since 2006, is required to control stormwater on the site by regulations consistent with state and federal clean water requirements and local ordinances developed under the Brodhead-McMichael Stormwater Management Plan; however, there is no requirement that existing municipal roads and parking lots and older development treat stormwater, and untreated runoff continues to be discharged into streams in the lower Brodhead watershed.

Summary of Existing Conditions

This plan focuses on the lower Brodhead watershed, specifically the lower Brodhead Creek, McMichael Creek, and Pocono Creek. All three (3) waters are classified[2] as High-Quality, Cold Water Fishes (HQ-CWF) upstream of the project area. Once these waters travel into and through the urbanized area, or receive water from tributaries flowing through the urbanized areas, classification of both the Brodhead Creek and McMichael Creek changes. The Brodhead classification changes to Cold Water Fishes (CWF) protection (loses its high quality protection) at Mill Creek Road. The McMichael Creek changes to Trout Stocking (TSF) from the confluence with the Pocono Creek, thereby losing its protection for cold water fish, i.e. trout.

Results of a study of benthic macroinvertebrates (insects and small animals that live in streams) at nine (9) stations on the Brodhead Creek in the fall of 2013 and spring of 2014 is shown in Figure 4. The types and quantities of organisms present were analyzed and each site given a score, known as the Index of Biotic Integrity (IBI), which ranges from 0-100, with 100 being the best. Station 1, the furthest upstream station was located at the ForEvergreen Preserve in Analomink, upstream from the project area. Station 1 shows very good water quality. The stations then proceed downstream, with Station 9 located just below the East Stroudsburg wastewater treatment facility discharge. This chart shows a steady decline of IBI scores in the Brodhead Creek.

[1] Quantity of outfall pipes and/or conveyances based on BWA creek walks conducted in 2014 and 2015.
[2] The classification of streams is required by the Federal Clean Water Act, but developed and enforced by the PA DEP. The classification determines what level of protection the stream will get when a permit is issued for a discharge.

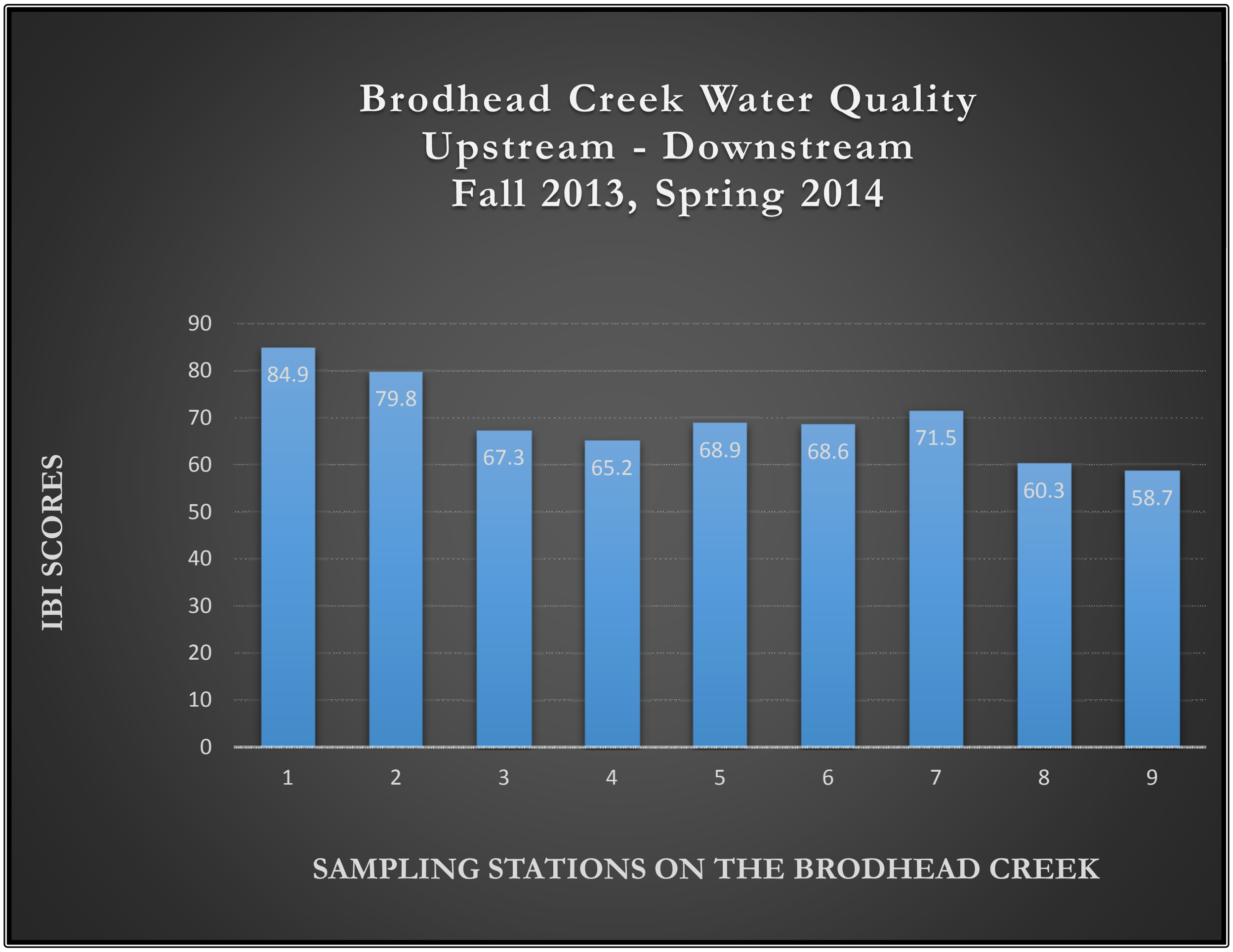


Figure 4. Brodhead Creek index of biotic integrity (IBI) scores.

Additional information on the macroinvertebrate testing on the Brodhead Creek and the IBI Scores are provided in Appendix 1. Accompanying information regarding the water quality testing conducted during development of this plan is also included in Appendix 2.

In addition to the stream classification described above, PA DEP publishes a biennial report showing whether streams meet their designated use or are "impaired." The impairments within the project area are explained below in Table 2 and depicted in Figure 5.

Table 2: Stream Impairments and Causes

Waters Name	List of Impairment(s)/Reach
Brodhead Creek	Non-Attaining Recreation – Source Unknown – Pathogens. Reach – downstream of the confluence of the Sambo Creek to mouth.
Sambo Creek	Non-Attaining Aquatic Life – Source Construction – Siltation; Urban Runoff/Storm Sewers; Cause Unknown. Reach – approximately 1.9 miles to mouth (confluence with Brodhead Creek).

McMichael Creek	Non-Attaining Recreation – Source Unknown – Pathogens. Reach – From the confluence of Pocono Creek to mouth (Brodhead Creek).
Pocono Creek	Non-Attaining Recreation – Source Unknown – Pathogens. Reach – west of the Giant Shopping Center in Bartonsville (Hamilton Township) to the mouth (confluence with McMichael Creek).
Flagler Run	Non-Attaining Aquatic Life – Source – Urban Runoff/Storm Sewers – Unknown Toxicity; Urban Runoff/Storm Sewers – Siltation; Hydromodification – Other Habitat Alterations; Road Runoff – Flow Alterations. Reach – Pond outlet adjacent to Stroud Mall to mouth (confluence with Pocono Creek).
Little Pocono Creek	Non-Attaining Aquatic Life – Source – Urban Runoff/Storm Sewers – Siltation; Road Runoff – Siltation. Reach – Headwaters to mouth (confluence with Pocono Creek).
Big Meadow Run	Non-Attaining Recreation – Source Unknown – Pathogens. Reach – Headwaters to mouth (confluence with Pocono Creek).

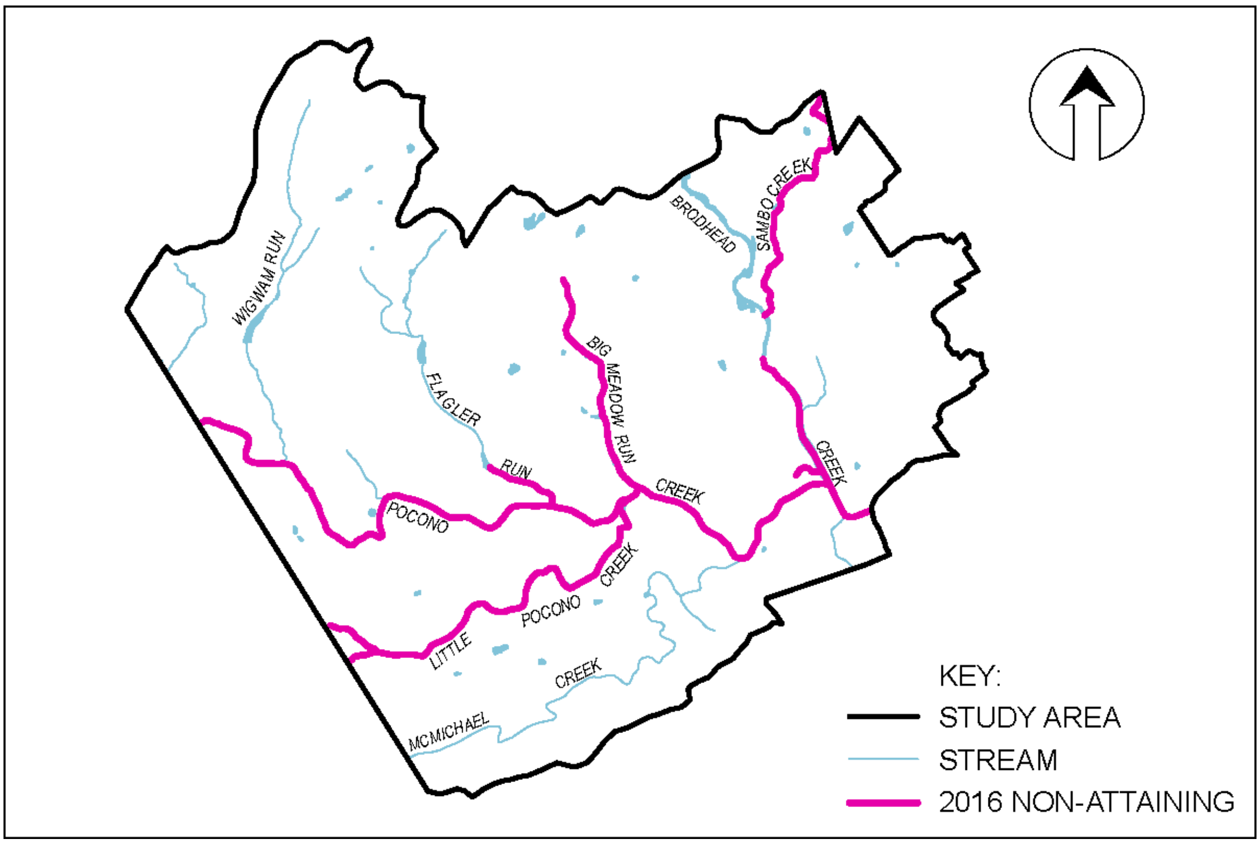


Figure 5: Impaired streams in the Lower Brodhead Watershed.

Water quality studies indicate there is a correlation between the stream impairments observed and the surrounding land uses. Specifically, the Brodhead Creek, McMichael Creek, and Pocono Creek all become impaired once they begin flowing through the more densely populated and highly developed areas of the Boroughs of East Stroudsburg and Stroudsburg and Stroud Township. The negative effects of the stormwater runoff has become increasingly apparent. As a result of the increased urbanization within the lower Brodhead watershed and the continuous discharge of untreated stormwater, our creeks and streams have been degrading over time.

Low-Impact Development

The term "Low-Impact Development" is used to describe development that incorporates a number of the green infrastructure practices described below to develop a site with as low as possible impact on natural systems. At both the site and regional scale, low impact development/green infrastructure practices preserve, restore, and create green space using soils, vegetation, and rainwater harvest techniques. Low impact development is an approach to land development (or redevelopment) that works with nature to manage stormwater as close to its source as possible.

What is Green Infrastructure?

Green infrastructure is designed and constructed to mimic the natural water cycle. Stormwater runoff is captured, taken up by plants, evaporated, and infiltrated back into the ground before entering the stormwater system. Green infrastructure varies greatly in design elements but all have the same goal: to capture stormwater and remove pollutants before the stormwater is discharged to local streams. Additional benefits of green infrastructure include, but are not limited to, recharging groundwater, reducing discharge volumes to streams, creating stormwater facilities that are harmonious with the natural landscape, and providing habitat for local flora and fauna.

In addition to the many stormwater benefits green infrastructure provides, it can also promote better health and economics for our communities. Utilizing green infrastructure and encouraging more green space (parks, open space, and riparian buffers), provides jobs; improves air quality by filtering particulate matter in the air and aids in reducing smog effects associated with increased air temperatures, emissions, and air pollutants; encourages recreation and exercise through the availability of green and open spaces; and increases property values by incorporating more trees into designs and natural landscaping.

Each type of green infrastructure element has a specific niche, goal, or intended purpose, yet many can be adapted and designed for residential, commercial, or even industrial use. Some types of green infrastructure are designed for small scale capture and reuse while others are designed as large infiltration areas. Green infrastructure is typically grouped into structural and non-structural categories: structural green infrastructure typically requires some earth moving and physical construction and non-structural green infrastructure employs green practices, such as those listed in the Non-Structural Green Infrastructure section below and many of those included in the "Top 10 Tips for Residents and Businesses" workshop presentation which can be found in Appendix 4. The list below explains in greater detail the more common types of green infrastructure used. Although some of the green infrastructure examples below can be relatively simple to employ, careful consideration should be made when siting any structural green infrastructure.

Structural Green Infrastructure

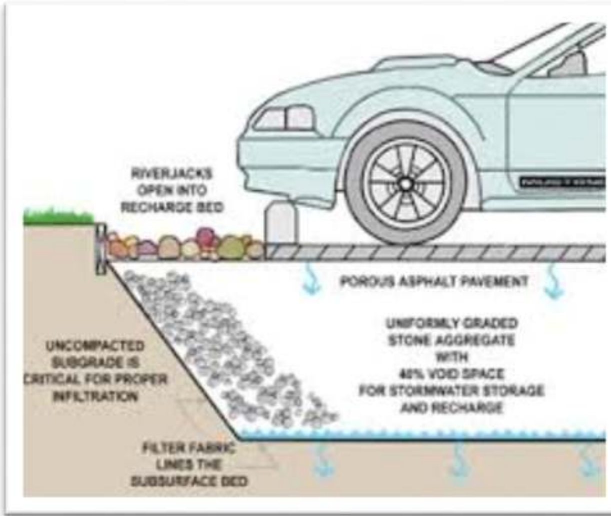
- **Rain gardens** are shallow, vegetated depressions that collect runoff, promote the settling of sediments, allow for evaporation and uptake by plants, and promote infiltration. Construction of a rain garden begins with grading around the selected site to promote surface runoff to enter the rain garden. When constructing in parking lots, it will be necessary to install methods for runoff to flow off the impervious surface and into the rain garden. Existing soil is then removed from the selected site and replaced with a more suitable soil (loam) that promotes infiltration. Carefully selected native plants are then planted in the rain garden, followed lastly by a mulch or organic layer of material. Overflow devices may be installed in an effort to discharge runoff when rain garden storage capacities are exceeded. Rain gardens are designed to allow runoff to pond for a short period of time which results in temporarily capturing runoff and allowing for evaporation. What is not evaporated is then either infiltrated into the ground and/or taken up by the plants. The plants as well as the added mulch/organic material also remove pollutants.

  Rain gardens are essentially small ecosystems that very effectively mimic the natural water cycle. These ecosystems function as a community of living and non-living components whereby the living parts (plants, animals, and organisms) interact with not only each other, but the non-living things that are introduced. Each part plays a significant role in aiding in water infiltration, plant uptake, and pollution removal. Rain gardens are typically designed to handle and treat smaller volumes of water, such as runoff from small parking lots or individual residential lots, but can be designed to effectively handle larger volumes of runoff. Regardless of volume of water a rain garden is designed to treat, it is specifically designed to infiltrate the volume in a time not less than 24 hours but not more than 72 hours. This infiltration rate holds true for every infiltrating green infrastructure facility listed below.

- **Bio-retention swales/Vegetated swales** are both very similar to rain gardens but they are typically constructed in a long, linear fashion. And because they are both "swales" their intended purpose is usually to convey stormwater away from a specific site or location as well as provide functions that improve water quality, reduce runoff volume, and create aesthetically pleasing environments. Additionally, there are many times these terms are used interchangeably depending on the source or literature being referenced. Generally speaking, bio-retention swales tend to encourage more infiltration whereby vegetated swales may be designed to convey stormwater runoff to other stormwater systems or eventual discharge points, with less infiltration. Regardless of the specific type of swale, these green infrastructure elements provide

more treatment and volume control than typical roadside curbs and gutters. For this reason, bio-retention swales/vegetated swales are ideally suited and often encountered along streets and parking lots. The swales are planted with dense, closely packed vegetation (including trees, shrubs, and grasses) to aid in high pollutant removal, and are designed to treat larger volumes of water (primarily from adjacent impervious surfaces) and control runoff volumes. Sometimes the word xeriscape is used to describe these types of green infrastructure. Xeriscape is simply a term used to describe a means of landscaping that requires minimal maintenance because it is designed to be very drought tolerant and virtually self-sustaining.

- **Pervious pavement** is a pervious (penetrable) hard surface that is overlain on an aggregate sub-base. The surface is primarily either pervious asphalt, pervious concrete, or pavers. In the case of asphalt and concrete, the smaller "fine" particles typically associated with these standard surfaces are removed and only the larger material is left. This creates more void space which allows water to infiltrate the surface and seep into the sub-base. By allowing stormwater to infiltrate, surface runoff is significantly minimized and in most cases, avoided. This type of surface is most often implemented in parking lots, playgrounds, walkways/sidewalks, and alleys.



- **Pavers** essentially function in the same manner as pervious asphalt and concrete but because of the costs associated with pavers and the different aesthetics, pavers are more often used in smaller areas such as patios, courtyards, and perhaps smaller parking areas.

  Other examples of hard surface treatments are reinforced turf and gravel filled grids. In both cases, a mat or grid, capable of providing structural support, is placed on an aggregate sub-base and either vegetation (turf) is promoted as growth or gravel fills the voids. Regardless of which product is used, both have pervious qualities and promote infiltration. These green infrastructure examples are typically used in lower impact and smaller areas that receive less vehicular traffic. Often times, they may be used in overflow parking situations and used to achieve required travel lane widths, e.g. emergency access, yet allowing for a reduction in the amount of impervious surface.

- **Infiltration trenches**/facilities are long trenches, typically covered with grass or gravel and used for infiltration of most stormwater and sometimes as a conveyance of larger stormwater flows. Infiltration trenches are typically connected to other types of green infrastructure or stormwater system and aid in mainly volume reduction. These types of green infrastructure are often installed adjacent to roads, parking lots, or other impervious surfaces. Other times, the trenches are used as part of existing storm sewer or as green infrastructure for a small treatment area. The trenches are dug and filled with stone for drainage. A perforated pipe (pipe with holes to allow water to both enter and exit the pipe) is then installed in a level, stone filled trench designed with positive overflow. During normal/small storm events, stormwater enters the trench and seeps through the perforated pipe. Smaller flows are typically infiltrated while larger volumes of stormwater tend to pass through the pipe and exit the pipe at an outlet.

- **Planter boxes** are most often encountered in urbanized areas and are designed to collect runoff from streets, sidewalks, and parking lots. Runoff is then infiltrated and/or taken up by the plants contained within the planter boxes. Given the ability to mimic the natural water cycle, planter boxes are similar in function and value of most stormwater treatment green infrastructure elements, but used in much smaller yet more frequent applications. Planter boxes are also a key element in "streetscaping" and green streets concepts (discussed in more detail later in the plan).

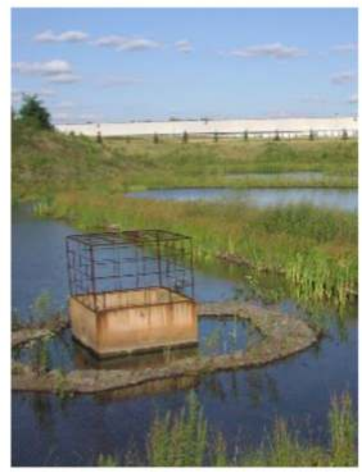
- **Dry wells** are typically used to capture and infiltrate stormwater runoff from roofs of buildings or residential homes. Roof leaders or downspouts are directed into an excavated hole or pit that is filled with stone for drainage purposes, wrapped in a material (geotextile) to prevent sediment from filling the stone voids, and provided with an overflow to handle large volumes of runoff. Under normal circumstances, the collected runoff infiltrates into the surrounding soils. When the volume of runoff exceeds the dry well storage capacity, the overflow will discharge the runoff to another location away from the structure.

- **Green Roofs** are perhaps one of the most unique types of green infrastructure and require some of the most stringent design criteria. It is important to note that careful consideration must be made prior to constructing a green roof. This green infrastructure element requires a relatively flat roof or a roof with minimal pitch (no more than 30% slope). Aside from the structural design considerations, mostly focused on load bearing capacity, key components include a waterproof barrier, insulation, drainage, engineered growth media (to support plant

growth/root structure), and plants. Of course, not all green roofs are suited for all roof types and variations to typical key components will change dependent upon factors such as climate, roof pitch, and type of drainage necessary for specific designs. (Photograph above is from the Hughes Cancer Center, in East Stroudsburg. This green roof has been designed for a portion of their building).

Green roofs are unique in they not only control stormwater runoff by collecting and storing rainwater for evaporation, filter pollutants and heavy metals from rainwater, and facilitate the transpiration through the uptake of rainwater through the roof vegetation, but they also contribute to added benefits such as improved insulation, habitat for insects, birds, and other wildlife, and aid in the reduction of the urban heat island effect.

- **Constructed wetlands** are more complex systems that are engineered to treat stormwater runoff. Wetlands act as incredibly efficient filters whereby soil, water, and plants all contribute to the natural filtering ability of these unique features. Constructed wetlands are often used for both stormwater and wastewater treatment due to their highly efficient filtering capabilities and engineered systems are capable of closely replicating natural processes.



Two different designs are considered for **constructed wetlands**: subsurface flow (vertical and horizontal) and surface flow. Both designs typically include a forebay as pretreatment. The forebay acts as a storage space for sediments that are initially separated from the runoff. Once sediments are removed, the runoff leaves the forebay and enters the constructed wetland for additional treatment.

Subsurface flow is designed to move either vertically or horizontally through the constructed wetland in a submerged sandy substrate with rooted vegetation. An advantage of subsurface flow is these systems are designed with water capacity below the surface and avoid common concerns with open water and potential mosquito breeding grounds. Surface flow, on the other hand, is suitable for treating stormwater runoff but not as effective as subsurface flow. Again, the natural filtering of plants, coupled with natural biological and chemical reactions, result in effective treatment of stormwater runoff.

These systems tend to be quite large, however, they do provide many aesthetic and habitat benefits.

- **Extended detention ponds** are constructed depressions or natural impoundments that provide temporary storage of stormwater runoff for extended periods in an effort to abate flooding issues. Extended detention ponds provide little treatment compared to similar structures with permanently wet bottoms and provide little volume reduction, yet these were the most popular type of early stormwater control structures. Both extended detention ponds and wet bottom ponds contain forebays for sediment removal. Many opportunities exist for retrofitting these structures to improve treatment and infiltration properties.

Non-Structural Green Infrastructure

- **Rain barrels** are perhaps one of the most common examples of green infrastructure being installed today. Local municipalities, conservation districts, and watershed groups are encouraging the use of rain barrels for homes and businesses because of their ease of set up and water conservation benefits. This element of green infrastructure collects rainwater, typically from downspouts, and holds the water until a time when the collected water is needed for another use, usually for watering gardens, indoor plants, and lawns. Additionally, rain barrels contain overflows which allow excess water to be diverted to well vegetated lawns or rain gardens where the collected water is infiltrated as opposed to entering the storm sewer system.

- **Buffer restoration** has garnered a lot of attention in recent years because streambank losses were occurring at alarming rates. Riparian buffers are vegetated, usually forested, strips of land adjacent to streams and waters that provide a multitude of important environmental benefits. Buffers stabilize streambanks to prevent erosion and increased sediment loading of streams, filter pollutants from stormwater runoff, provide important shade which keeps water temperatures cool for biological activity, and provide critical habitat for various species. When riparian buffers are lost due to construction activities, it can take upwards of 20-40 years to replace. Buffers within the project area are regulated by local ordinances and vary depending on the specific stream and municipality, but on average range from 75-150'.

- **Lawn conversion** is an example of green infrastructure where typical turf lawns are planted with native perennial species. Native species are adapted to the current climatic conditions and therefore require less fertilizers, herbicides, pesticides, and most importantly, water than traditional turf lawns. This results in less time, money, and effort maintaining the converted native lawn. Planting native species also provides much needed habitat and food sources for native flora and fauna.

- **No-Mow Zones:** Typical turf grass lawns provide little benefit for stormwater management. Turf grass has relatively shallow roots, often requires application of chemicals such as fertilizers and pesticides, and is relatively compacted from repeated mowing. No-mow zones are an alternative to traditional turf grass landscaping that provides several ecosystem services. These are meadow type installations comprised of diverse native plant species such as wildflowers and fescues that typically have a deeper root structure and denser cover than typical turf grass. These areas provide stormwater infiltration and evapotranspiration, add beneficial habitat, and reduce the carbon footprint compared to traditional lawns. While no-mow zones are promoted as a lower maintenance option for stormwater management, they can be aesthetically pleasing especially if they incorporate wildflower plant mixes. Typical maintenance requirements for no-mow zones include removal of invasive species and cutting back vegetation annually. It is recommended that no-mow zones be delineated with fencing or other physical markers to ensure these areas are maintained as no-mow fixtures. No-mow zones may be practical along parts of the levee system to discourage ducks and geese from gathering.

How Effective is Green Infrastructure?

Green infrastructure is an effective means of reducing sediment and nutrient pollutant loading to streams; however, not all green infrastructure facilities perform this task equally. Numerous factors must be considered for every installed green infrastructure facility, e.g. type of soil (A/B well drained or C/D poorly drained), physical siting, use of underdrains, etc. A discussion on pollutant loading and water quality parameters is provided in Appendix 3. The table below describes the effectiveness of several green infrastructure practices. The table provides percentages of Total Nitrogen (TN), Total Phosphorous (TP), and sediment removal efficiencies.

Table 3: Green Infrastructure Effectiveness Table

Green Infrastructure BMP	BMP Effectiveness Values		
	TN	TP	Sediment
Rain Gardens (w/o underdrain – A/B soils)	80%	85%	90%
Rain Gardens (w/ underdrain – A/B soils)	70%	75%	80%
Rain Gardens (w/ underdrain – C/D soils)	25%	45%	55%
Bio-retention Swale	70%	75%	80%
Pervious Pavement (w/o underdrain – A/B soils)	75%	80%	85%
Pervious Pavement (w/ underdrain – A/B soils)	50%	50%	70%
Pervious Pavement (w/ underdrain – C/D soils)	10%	20%	55%
Infiltration Practices (A/B soils only)	85%	85%	95%
Planter Boxes (approximate percentages)	50%	50%	85%
Dry Wells/Seepage Pits	30%	85%	85%
Green Roofs	30%	85%	85%
Constructed Wetlands	20%	45%	60%
Extended Detention Ponds	20%	20%	60%
Buffer Restoration	25%	50%	50%
Lawn Conversion	50%	85%	85%
Rain Barrels (cisterns, underground tanks, etc.)	100%	100%	100%

Table 3: BMP Effectiveness Values Table. Adapted from PA DEP document 3800-PM-BCW0100m. May 2016.

Impervious Surfaces within the Project Area

Within the project area, 17% of the land cover is impervious with the greatest density occurring in the boroughs of East Stroudsburg and Stroudsburg. A breakdown of impervious surface is shown below, providing insight to opportunities to retrofit green infrastructure into the urban landscape. While there are opportunities to implement green infrastructure for each use and type, targeted strategies can be developed based on cost effectiveness.

Table 4: Impervious Surfaces			
Percent of Total Impervious Surfaces	**Borough of East Stroudsburg**	**Borough of Stroudsburg**	**Stroud Township**
Buildings	28%	30%	25%
Roads	30%	35%	37%
Parking lots	42%	35%	38%
Impervious as % of total area	32%	31%	13%

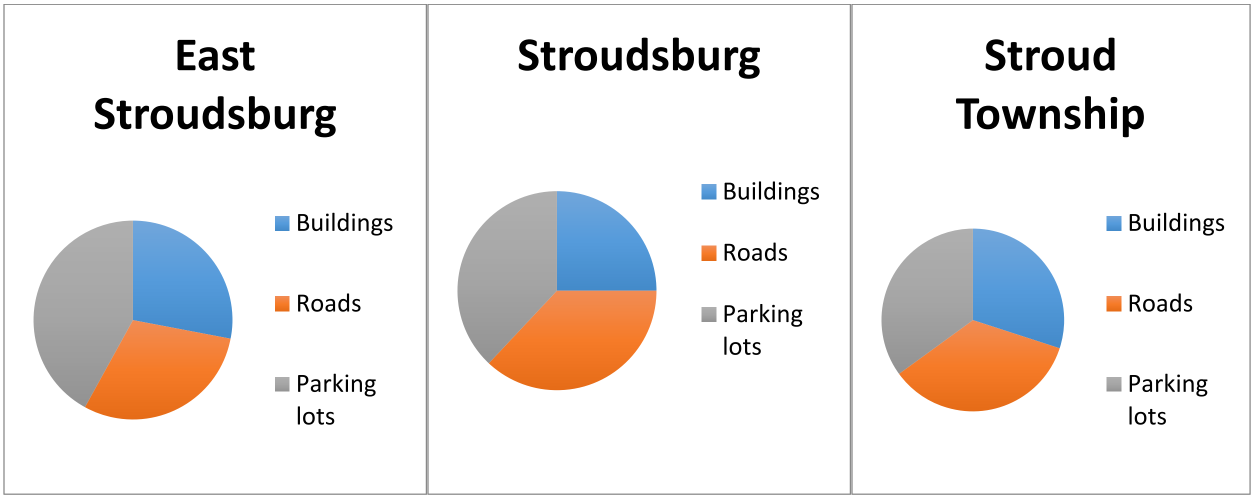


Figure 6. Impervious surfaces in each municipality

Because most of buildings and parking lots are privately owned, strategies for developing partnerships with private landowners and businesses should be considered. Municipalities are encouraged to work in partnership with private landowners and businesses to educate these groups on the types and benefits of green infrastructure and encourage the use of green infrastructure at these larger impervious areas. Otherwise, most opportunities for municipalities to install their own green practices are along municipally owned streets, sidewalks, parking lots, and open space. Although the municipally owned green infrastructure projects will benefit water quality, privately owned impervious areas must also be addressed to meet larger goals of reducing and treating stormwater runoff.

How Municipalities Can Use Green Infrastructure

Municipal Green Streets / Complete Streets

Green streets, sidewalks, and alleys incorporate a number of green infrastructure practices into existing streets and public rights-of-way to manage stormwater and control polluted runoff. Sidewalk planters, tree trenches, pavers, porous pavement, and curb extensions with accessible (ADA) ramp upgrades, are all good techniques to consider. As street repair and upgrade projects are planned, green infrastructure should be included in plans. For example, when ADA ramp projects are planned, and sidewalks are being removed for the ramp, infiltration trenches along the nearby sidewalk could be added to the plans.

Many downtown improvement projects have included “green alleys,” opening alleyways as pedestrian malls, incorporating rain gardens, flow-through planters, and pavers into a green design.

Quaker Alley in Stroudsburg and the alley between Crystal Street and Dansbury Terrace in East Stroudsburg are both candidates for green projects that would increase infiltration of stormwater while providing an attractive place for shoppers to visit and encourage walkable neighborhoods.

The term "complete streets" is another term used to include green infrastructure into street planning when bicycle and walking paths are part of street improvement projects.

Figure 7: Quaker Alley by Sarah Street Grill, before and after (concept)

Increasing the tree canopy by planting trees along streets and in parking lots is another important component of green streets.

Municipal Green Parking Lots

Municipal parking lots offer excellent opportunities for installing green infrastructure in a cost effective manner if done when pavement is being replaced or the lot redesigned. Green parking lots are created by excavating a portion of the pavement and installing a stone subsurface infiltration bed with a porous pavement surface or water quality inlets that redirect stormwater into the stone bed. Runoff from adjacent areas such as streets and buildings can be redirected into the infiltration bed. Tree trenches can be integrated with the design to increase the tree canopy and promote evapotranspiration.

Municipal Ordinances

Recognizing the problems that unmanaged stormwater was causing in the more developed areas of the state, the Monroe County Conservation District and Monroe County Planning Commission developed a stormwater management plan for the Brodhead and McMichael Creek watersheds. Included in the plan was a model ordinance that when adopted by municipalities, would control stormwater runoff and prevent flooding in the lower Brodhead watershed. All three (3) municipalities in the project area have adopted stormwater management ordinances that meet the goals of the plan.

The current ordinances focus primarily on controlling post-development stormwater runoff rate, volume, and quality to replicate pre-development conditions. Currently, if there is no change from pre- to post-development stormwater runoff volume, rate, and quality, accelerated stormwater runoff is considered avoided and impacts prevented. The regulations contained in the current ordinances effectively address the volume, rate, and quality concerns; however, the ordinances only relate to new development. Additionally, the current ordinances can still be improved upon to encourage or ideally mandate the use of green infrastructure in project design.

Despite the positive movement toward cleaner stormwater in new development, concerted efforts need to be made to address the volume, rate, and quality of runoff from existing development.

Ordinance Changes

Much of the development occurring in the project area is within the urbanized and commercial areas where space is limited and land is at a premium. Although low impact development and green infrastructure are typically the method preferred by designers to address stormwater requirements, the site space limitations and other existing ordinances, such as lane widths and parking space quantities, tend to be so restrictive that underground stormwater facilities are the only means in which to meet the stormwater requirements. In addition to these constraints, some current ordinances specify the use of certain landscaping, e.g. requiring raised islands for traffic channelization, and fail to reference green infrastructure that would achieve the same landscaping function as that prescribed under the ordinance and address stormwater issues and requirements.

When the municipalities update their stormwater ordinances, they should also review other ordinances, such as parking and landscape design, to see if there are more opportunities where low impact development and green infrastructure can be applied.

PA DEP has completed the "2022 Model Stormwater Management Ordinance" as a guide for municipalities when updating their stormwater ordinances. A link to the model ordinance is provided in Appendix 6 to help municipalities taking that next step to promote the use of green infrastructure and improve water quality in the local streams.

Municipal Good Housekeeping

Municipalities play a unique role in effecting positive change with the way stormwater is handled. The boroughs of East Stroudsburg and Stroudsburg and Stroud Township are significant land owners within the project area and have the ultimate responsibility over stormwater management. As such, it is important for them to make sure the stormwater that is generated and collected from not only the facilities in which they have direct control over, such as municipally owned buildings, maintenance garages, parks, and open spaces, and streets and sidewalks, is as clean as possible. It is equally important to have well established stormwater management policies and programs, including education and training for municipal officials and staff.

Public Works Department staff have the most direct contact with residents and business owners and have the ability to educate and set good examples for residents and business owners. Thus, their training can have a ripple effect throughout the community.

Public Education and Outreach

Municipalities are key to providing the information their residents need to help protect local streams and drinking water supplies. Municipal officials and public works staff are most knowledgeable about where stormwater problems occur, where stormwater drains lead, and where pollutants may enter storm drains. They also have frequent contact with business owners and developers who may need a better understanding about their role in protecting water quality.

Educational materials can be provided to residents and businesses through municipal websites, newsletters, and social media. Much information can be obtained from agencies such as EPA and PA DEP, the Monroe County Conservation District, and the Brodhead Watershed Association. Including any of these resources in municipal outreach avenues or printed flyers in public gathering places can effectively get the word out about the issues surrounding stormwater and the impacts on the lower Brodhead watershed.

Penn State Cooperative Extension, through its Penn State Master Gardener and Master Watershed Steward programs, is another important resource for municipalities developing an education and outreach program.

Published information may not always be the most effective means of getting important information to the target audience, so the direct distribution of material often aids in getting the message out. The municipality should use a variety of methods to distribute information, such as print and radio advertising, posters, direct mail flyers, and presentations. BWA has found that the best way to reach an audience is to go to their functions, rather than invite them to yours.

The BWA is dedicated to protecting and improving water resources and already has programs that provide much of the education and outreach required. A sample public outreach program, "Ten Tips for Residents and Businesses," which BWA has presented at local workshops, is included as Appendix 4. Municipalities are encouraged to reach out to BWA to continue to provide assistance to provide educational information to their residents

MS4 and the Lower Brodhead Green Infrastructure Program

The boroughs of East Stroudsburg and Stroudsburg and Stroud Township, the municipalities that this Green Infrastructure Plan covers, are required by recent federal and state regulations to obtain permits or waivers for their stormwater discharges to the Brodhead, McMichael, and Pocono creeks. The permits, called MS4, or Municipal Separate Storm Sewer System permits, must include descriptions of what steps the municipalities will take to lessen the impact of their polluted stormwater runoff which is presently conveyed, untreated, in a system of pipes, swales, and man-made channels directly to the streams.

As stormwater travels into and through the project area, it does not stop at municipal boundaries. Any pollution that is generated upslope ultimately becomes the obligation of the downstream municipality with the stream discharge point to improve. For this reason, municipalities are encouraged to work together for a common vision of protecting and improving the quality of water in the streams that run through their municipalities. Not only will the streams in the project area (and downstream) benefit from municipal collaboration, working together will help each municipality meet regulatory obligations mandated by the MS4 program.

Municipalities are just beginning to take the necessary steps to meet permit requirements. It is the intent of this plan to offer assistance in understanding what green infrastructure is and how it can be implemented throughout the project area to improve and protect water quality in local streams as well as meet requirements of the MS4 program.

Financing / Funding

Implementing green infrastructure projects can be expensive. Although some projects, like rain barrels and rain gardens have minimal costs, others will require additional funding to implement. Some possible funding sources to aid municipal partners in achieving the goal of improving water quality in their waterways are listed in Appendix 5. Funding through adopting a stormwater fee structure and incentivizing green infrastructure installation is discussed below.

Across the country, municipalities have established Stormwater Utility (SWU) fees as a means of funding stormwater projects. Western Kentucky University began conducting its Stormwater Utility Survey (SWU) in 2007 and determined at that time that there were more than 600 communities and municipalities with established SWUs. As of the 2016 study, there were almost 1,600 SWUs in the United States and Canada. As identified in the initial 2007 report, the fees ranged from zero to $35 per month and were calculated using three (3) methods as explained below:

- Equivalent Residential Unit (ERU) – The ERU was the most common method used to assess SWUs. This method used the average, single-family residential square footage of impervious surface and assigned a value as a monthly fee. For larger impervious areas, such as commercial and business properties, a monthly fee is calculated based on total impervious surface on the property using the ERU as a base and a multiplier based on increased impervious surfaces for these types of properties.
- Fee Categories – Some municipalities established "fee categories" for each property. Examples include using multiple tiers for residential and non-residential or using the municipality's zoning classification to determine fees.
- Fee vs. Stormwater Runoff – The last method considered a runoff factor for residential and non-residential properties. The determined runoff factor would then be multiplied by the amount of impervious surface on the property to determine a monthly fee.

The City of Philadelphia utilizes a type of SWU whereby the city's cost of treating stormwater is reflected in monthly water bills. For residential customers, the city has established a standard amount based on the average impervious surface (similar to ERU above). In addition, through the city's "Rain Check" program, residents can learn how they can treat stormwater on their properties and receive free stormwater tools, like a rain barrel or help installing a rain garden. Rates for commercial properties are based on the actual amount of impervious surfaces on the property. Businesses can reduce their monthly bill by implementing green infrastructure projects such as planting trees, re-directing downspouts so they do not discharge to pavement, and installing pervious pavements or green roofs. By incentivizing the use of green infrastructure, the burden on the city's storm sewer system is reduced, businesses see a reduction in their bill, stormwater discharges are cleaner, and infiltration is promoted.

Prince George's County in Maryland is using a similar program to offer incentives to landowners, called "Rain Check Rebate" to install rain gardens and other green infrastructure to reduce their stormwater fee, currently at $372 per acre.

Another Pennsylvania municipality, Highspire Borough in Dauphin County, has recently established a Stormwater Fee in response to the EPA mandate to reduce stormwater pollution and as a way for the borough to fund the program. The borough provides an excellent explanation on their website regarding what MS4 is, how stormwater impacts the Chesapeake Bay and the Borough, and why they deemed the fee necessary. A link to the Highspire Borough explanation has been provided in Appendix 7.

These are just a few examples of ways SWUs are being utilized across the country. The BWA recommends that any fee program be coupled with a way to reduce the fee with incentives that promote green infrastructure. For more information on the Western Kentucky University study, the City of Philadelphia's program, or the Prince George's County program links are provided in Appendix 7.

Demonstration Projects

Figure 8: Before and after photos of the installed rain garden at Retro Fitness in Stroud Township.

As part of the Green Infrastructure Project (which includes this plan) several demonstration green infrastructure projects have been completed in the project area.

The Borough of Stroudsburg prepared the site for a rain garden on Ann Street that will capture runoff from the municipal parking deck. The borough will install piping to divert flow from the upper deck to the garden. That runoff currently goes directly to McMichael Creek via the borough's stormwater system.

Also in Stroudsburg, borough staff and officials are working with Monroe County Commissioners to install a green "pocket park" at the corner of Quaker Alley and Sixth Street. Pavers, to allow infiltration of stormwater, will be included in the design of that park.

The Borough of East Stroudsburg prepared sites for rain gardens at Dansbury Depot and East Stroudsburg Firehouse. At the Depot, runoff from the roof is captured in the gardens. At the firehouse, parking lot runoff goes to the rain garden.

Also in East Stroudsburg, maintenance staff from East Stroudsburg School District prepared two (2) sites at the parking lot in front of the administration building and students planted gardens at those sites.

In Stroud Township, staff at Glen Brook golf course prepared a rain garden site to capture runoff from Glenbrook Road that was causing sediment to reach McMichael Creek. Municipal workers and students from Blair Academy planted the garden as well as a riparian buffer along McMichael Creek.

Two commercial properties, Sarah Street Grill in Stroudsburg and Retro Fitness in Stroud Township, worked with BWA to install rain gardens on their properties to help treat runoff from their parking lots.

BWA has designed a rain garden sign for each of these projects. Signs will be installed in the spring.

As municipalities complete additional projects, signage should be erected and information about the projects should be included in municipal outreach material. Similarly, as residents and businesses install green practices, efforts should be made to publicize the projects.

More information on each of these projects can be found at: http://www.brodheadwatershed.org/

Partnerships

Partnerships are often synergistic, accomplishing more together than either partner could alone. That has been the case with this Green Infrastructure Project. Working with municipal and county partners and a great number of volunteers from the community, the project has been able to install twice as many demonstration projects as originally planned and reach many more community members than proposed. The Brodhead Watershed Association plans to build on that synergism and apply for funding in 2017 to add green projects to Stroudsburg Borough's five (5) year multi-modal transportation plan.

A list of possible sites for green infrastructure projects in each municipality is included in Appendix 8. These lists barely scratch the surface of where projects could be installed to improve water quality in local streams and "green" the project area.

Conclusion

This Green Infrastructure Plan, like the demonstration projects described above, has been developed to assist East Stroudsburg, Stroudsburg, and Stroud Township in protecting and improving the water quality of the streams that flow through them. Clean water is essential to life. It is also an amenity that residents value, and will work to protect. However, residents, business owners, and municipal officials all need help in understanding their role in protecting clean water. It is the hope of the Brodhead Watershed Association and the many partners in the Green Infrastructure Project that this plan will further that goal.