GREEN INFRASTRUCTURE GUIDELINES

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A summary of this report will be translated into Spanish. Readers may request a full translation into alternate languages by contacting Michael Donchez, Senior Transportation Planner, Lehigh Valley Planning Commission, 961 Marcon Boulevard, Suite 310, Allentown, Pennsylvania 18109-9397, (610) 264-4544, mdonchez@lvpc.org. Efforts will be made to provide translated documents in a reasonable timeframe.

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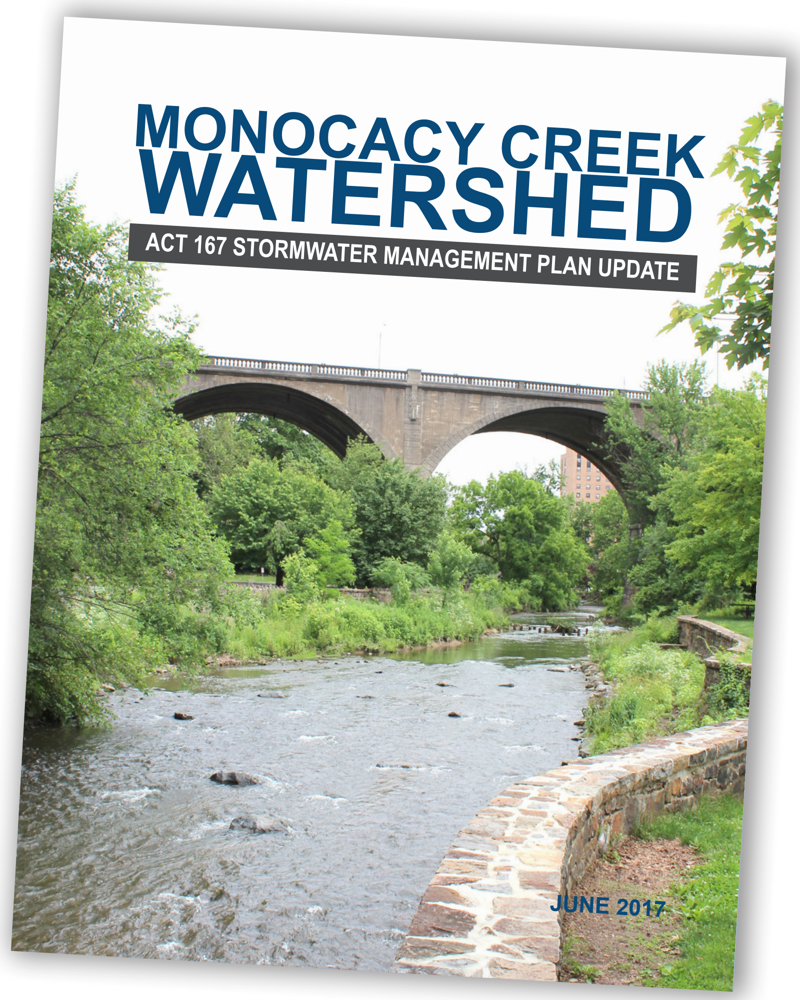
Introduction

The Green Infrastructure Guidelines document was prepared in conjunction with the *Monocacy Creek Watershed Act 167 Stormwater Management Plan Update*, 2017. The Guidelines are important for reinforcing the message of the outstanding natural resources present in the Lehigh Valley and their wide variety of essential services and benefits to local residents and visitors, describing the best practices available for community and site design to preserve or enhance those resources, and defining improved stormwater management site design practices to better mimic natural systems. The Guidelines provide 1) an overview of green infrastructure at a regional scale and the associated benefits and 2) engineering guidance for site-specific stormwater management practices to help designers understand and comply with the water balance and green infrastructure provisions of the updated Act 167 Ordinance.



What is Green Infrastructure?

Green infrastructure is defined differently by various groups and agencies depending on the goals and objectives of the organization or project. As seen in the definition examples below, the basic categories are landscape or regional to site-specific scales. At the landscape scale, green infrastructure includes natural areas and working lands, with the site-specific scale providing stormwater best management practices. Together the whole system reduces stormwater impacts and contributes social, economic and environmental benefits for communities.

ArtsQuest in Bethlehem, photo by Craig Kackenmeister/LVPC

- **Green infrastructure can be thought of as the sum of all our natural resources**. It includes all the interconnected natural systems in a landscape, such as intact forests, woodlands, wetlands, parks and rivers, as well as those agricultural soils that provide clean water, air quality, wildlife habitat and food.[1]
- **Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits**. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social and economic benefits.[2]
- **The traditional use of the term by the conservation planning community refers to the network of natural lands across the landscape—forests, wetlands, stream corridors, grasslands—that work together as a whole to provide ecological benefits**. This broad definition includes both landscape-scale natural features and site-scale practices ranging from reduction of impervious cover to stormwater best management practices, such as bioretention and stormwater wetlands, and everything in between.[3]

For purposes of this document:

Green infrastructure is all the natural assets of a region—the interconnected network of woodlands, parks, wetlands, surface waters, meadows, agricultural soils and other open spaces—and site design practices. The natural environment provides a variety of essential functions, including flood protection, stormwater management, clean air and water, wildlife habitat, food, and recreational opportunities, among others, and are vital to the health and well-being of a community.

GREEN infrastructure

is

agricultural soils
+
meadows
+
open spaces
+
parks
+
surface waters
+
wetlands
+
woodlands

The Value of Green Infrastructure

Green infrastructure benefits as a whole are greater than the sum of its key three benefit components — Social, Economic and Environmental.

However, each component does not have to operate independently. Effective projects that carefully facilitate interconnected outcomes in all three areas will result in a "triple bottom line"[4], or overall benefit of sustainable development and quality of life. These benefits contribute not only to the community in which the project is implemented but strengthen a far-reaching network of benefits with other sustainable developments. This is the most desirable approach because projects that prioritize one benefit outcome above the others will most likely lead to missed opportunities, potential lack of long term support and maintenance or other threats to long term success. Beyond the intrinsic value, open space lands (e.g., forests, wetlands, meadows and farmland) provide these vital services free of charge. Once lost, natural system services are costly and difficult or even impossible to replace. The protection of natural resources should be a top priority for communities to maintain the services nature provides at no cost.


GREEN INFRASTRUCTURE SUPPORTS
ECONOMIC
viable
equitable
livable
ENVIRONMENTAL
SOCIAL
SUSTAINABLE DEVELOPMENT + QUALITY OF LIFE

Social Benefits of Green Infrastructure

Attachment to Place

What makes a community a desirable place to live?

Gallup and the John S. and James L. Knight Foundation launched the Soul of the Community project in 2008 with this question in mind. Interviewing almost 43,000 people in 26 communities nationwide over three years, the study found that three main qualities attach people to place: [5]

SOCIAL:

Places for people to meet each other and the feeling that people in the community care about each other.

OPENNESS:

How welcoming the community is to different types of people, including families with young children, minorities and talented college graduates.

AESTHETICS:

The physical beauty of the community, including the availability of parks and green spaces.

Attachment to place is an important metric to communities. Those who identify a lack of attachment, more often than not, feel a lack of complete social inclusion as well. These people may represent a minority, which reveals specific gaps in the offerings of an equitable and welcoming community. Open spaces represent an opportunity to foster inclusion and accessibility for people of all abilities, economic status and backgrounds.

PBS studio in Bethlehem, photo by Craig Kackenmeister/LVPC

Social Benefits of Green Infrastructure

Health and Wellness

How communities are planned, designed and built can greatly impact people's health.

The built environment influences people's levels of physical activity, the safety of travel, the quality of the outdoor air, access to jobs and services, access to healthy food choices, and opportunities to enjoy local recreation opportunities like local parks, pools and ball fields. The annual County Health Rankings (a collaborative program between the Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute) measure vital health factors, including high school graduation rates, obesity, smoking, unemployment, access to healthy foods, the quality of air and water, income, and teen births in nearly every county in America. The County Health Rankings have two components:

Health Outcomes – measured by length of life and quality of life.

Health Factors – health behaviors, clinical care, social and economic, and physical environment, all of which may influence healthy outcomes.

In the 2017 Rankings for all 67 Pennsylvania counties, Lehigh County and Northampton County ranked 40th and 15th, respectively, in Health Outcomes and 26th and 21st, respectively, in Health Factors (with 1 being the best and 67 being the worst).[6]

In 2016, the Health Care Council of the Lehigh Valley also released a community health needs assessment titled *The Road to Health*. The report builds on the County Health Rankings and compares current statistics with those from previous years. One key metric is heart disease-related deaths per 100,000 population decreased by approximately 30% for both counties between 2005 and 2013.[7]

Bob Rodale Cycling & Fitness Park, photo by Craig Kackenmeister/LVPC

Economic Benefits of Green Infrastructure

Return on Environment

Natural areas add value to the economy, with benefits accruing to businesses, governments and households.

Several studies have documented the economic value of natural areas.

- American Forests estimated that trees in the nation’s metropolitan areas contribute $400 billion in stormwater benefits by eliminating the need for expensive stormwater retention facilities.[8]
- A large mature oak tree can transpire 40,000 gallons of water per year; that is water that is not entering storm drains, thereby decreasing runoff, excessive stream flows and downstream erosion.[9]
- In a study of 27 U.S. water suppliers, researchers found that watersheds with a greater percentage of forest correlate to fewer water treatment expenditures: for each 10% increase in watershed forest cover, there is about a 20% decrease in treatment costs.[10]

The Lehigh Valley Planning Commission and Wildlands Conservancy prepared the *Lehigh Valley Return on Environment* study, which estimates the value of natural areas in the Lehigh Valley by measuring impacts across four areas: 1) Natural System Services, 2) Air Quality, 3) Outdoor Recreation and 4) Property Value. Each of these areas generates the “natural capital” or economic value from the flow of goods and services supported by natural resources. These benefits represent the *Return on Environment* for the Lehigh Valley. The economic benefits generated by natural areas accrue in different ways—some are direct revenue streams to individuals or governments, some represent asset appreciation value, and some accrue in the form of avoided costs. The report explains why a strong economy requires plenty of connected, accessible natural areas and a healthy environment.

CALCULATED BENEFITS

$2.5 MILLION
Annual biological control services

$54 MILLION
Annual Carbon + pollution removal

$22.4 MILLION
Annual pollination value

$219.5 MILLION
Contribution to wildlife and plant habitat

$1.8 BILLION
Real estate premium attatched to open space proximity

$0.8 MILLION
Annual soil formation/ retention

$50.6 MILLION
Annual flood mitigation

$795 MILLION
Annual expenditures spent on recreation

$58.9 MILLION
Local/state tax contribution from recreation jobs

127,850
Homes within 1/4 mile of protected open space

9,678
Jobs generated from recreation

$59.7 million
Annual water supply + water quality

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Natural System Services – This component of the study estimates the avoided costs to residents associated with seven natural system services provided by natural areas: water supply, water quality, disturbance (flood) mitigation, wildlife habitat, pollination, biological control and soil formation/ retention. These represent natural system functions that, if lost, would require costly measures to replicate. Considering the importance of the Lehigh Valley's natural areas, it is essential to recognize the role that trees, fields, meadows and wetlands play in keeping the cost of living low by filtering water, cleaning the air, controlling flooding and providing other environmental services. Many structural practices are very expensive to engineer. An engineered natural system service like stormwater management or flood control may only provide a fraction of the services provided by natural system services.

Air Quality – Poor air quality is a common problem in many urban and suburban areas and can lead to a variety of human health problems. Additionally, air pollution can damage buildings and plants and disrupt many natural system services. Trees remove significant amounts of air pollution and, consequently, improve environmental quality and human health.

South Bethlehem Greenway Trail, photo by Craig Kackenmeister/LVPC

Outdoor Recreation – Natural areas generate value as residents enjoy engaging in recreation and exercise. Residents recognize that outdoor recreation and natural areas are key to healthy communities, contribute to a high quality of life, and very importantly, attract and sustain families and businesses.

Property Value – The proximity of residences to protected natural areas and parks can raise the value of a home. Whether a trail, park, scenic area or waterfront, people will pay a premium to be near open space. As a result, the Lehigh Valley's existing open space adds to the overall value of the housing stock.

Churchview Park, photo by Craig Kackenmeister/LVPC

Environmental Benefits of Green Infrastructure

Climate Change Mitigation and Energy Conservation

Communities across the country are facing the effects of climate change, including higher temperatures, more precipitation or drought conditions.

Higher temperatures result in increased energy demand needed to provide cooling during the summer. Higher intensity storms are anticipated to become more frequent in some parts of the country, increasing the likelihood for flooding. In other areas of the country, decreased precipitation is expected to occur, stressing community water supply sources. Planning in advance of an emergency situation is critical to reducing the risks from these effects. A hazard mitigation plan for Lehigh and Northampton counties has been in place since 2006, with an update completed in 2013. The Lehigh Valley Planning Commission is currently working with the two counties on updating the 2013 plan. In addition to hazard mitigation planning, the use of green infrastructure practices can provide an extra layer of community resiliency by mitigating climate change impacts and reducing energy consumption.

Carbon dioxide is considered by scientists to be the primary greenhouse gas contributing to recent climate change, resulting in global warming. Carbon dioxide occurs naturally in the atmosphere, the oceans and the Earth’s surface. The emission and removal of carbon dioxide by living organisms tends to balance as part of natural processes. However, human activities, such as burning fossil fuels and deforestation, result in increased carbon dioxide concentrations in the atmosphere. Trees function to remove or sequester the carbon from the atmosphere during photosynthesis and release oxygen as a by-product. Furthermore, in urban areas where natural land cover (trees, vegetation) is replaced by impervious areas that absorb and retain heat, such as buildings and pavement, urban heat islands are created that drive up energy demand. Employing green infrastructure practices, such as green roofs, street trees and increased urban green

Curbless parking lot at Shissler Recreation Center, Philadelphia, photo courtesy of Philadelphia Water Authority

spaces, have the effect of making buildings more energy efficient by reducing heating and cooling demands.

Flooding impacts resulting from climate change can be mitigated through the use of green infrastructure practices. Many natural landscapes (e.g., forests, wetlands, and floodplains) help provide a buffering function that protects the public from flooding events. As development continues and the natural landscape is disturbed and replaced with impervious surfaces, stormwater runoff is significantly increased. Green infrastructure practices, through infiltration and retention of stormwater, along with open space protection and floodplain management, can help reduce the amount of water entering the storm sewer system and surface waters, reducing flooding impacts.

Decreased precipitation in some parts of the country due to climate change causes stress on local drinking water supply sources. Rain falling on impervious surfaces runs directly into storm sewers or surface waters rather than infiltrating into the ground. Due to the infiltration capabilities of vegetation and soil-based green infrastructure practices, groundwater supplies can be replenished, relieving the stress on local water supplies.

Environmental Benefits of Green Infrastructure

Conserving Natural Green Infrastructure

The natural and working lands in a landscape that comprise green infrastructure provide services as individual components.

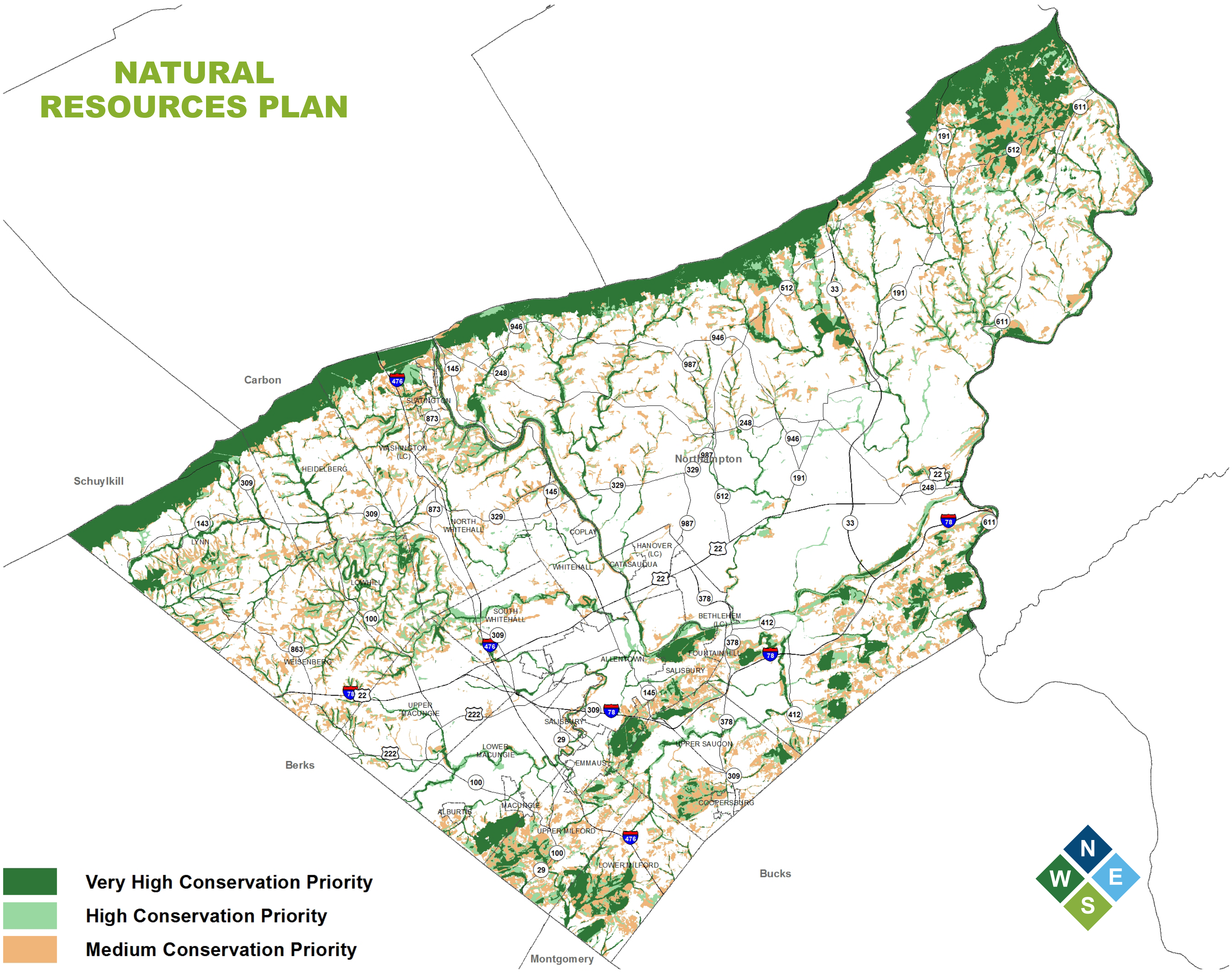
In some cases, these natural features may occur in the same locations, increasing the value of that area. A community may desire to not only document their green infrastructure assets, but also prioritize those areas that have multiple natural features for conservation purposes. The process may include inviting partners from various organizations and documenting the existing green infrastructure within the community.

In the Lehigh Valley, as part of the *Comprehensive Plan The Lehigh Valley...2030*, the Lehigh Valley Planning Commission developed a Natural Resources Plan that identifies natural resource conservation priority areas. The Lehigh Valley has many significant natural resources that are worthy of protection, including high quality streams, rare plant communities, critical wildlife habitat, woodlands, steep slopes, floodplains and wetlands. In the Natural Resources Plan, areas are weighted to assure that the areas with the greatest combination of important natural resources are given highest priority in future conservation activities. Very high conservation priority areas should be given first consideration for public and private conservation acquisition programs. High conservation priority areas should also be considered for acquisition, especially if they are part of a larger natural feature identified as very high conservation priority. Medium conservation priority areas should be protected through zoning regulations, conservation subdivision design and conservation farming practices.

The Lehigh Valley Planning Commission prepared a series of guides/model ordinances for use by municipalities to protect natural resources:

- Steep Slopes Guide/Model Ordinance
- Woodlands Guide/Model Regulations
- Riparian and Wetland Buffers Guide/Model Regulations
- Floodplain Guide/Model Regulations
- Conservation Subdivisions

NATURAL RESOURCES PLAN



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Environmental Benefits of Green Infrastructure

Water Resources and Green Infrastructure

Everything that happens on the land impacts, to some degree, the quality and/or quantity of groundwater and/or streams, and causes singular—and cumulative—impacts to water resources that can be difficult and costly to remedy.

A few of the problems that can arise from not fully considering the impact of land use decisions on water resources are: impaired surface and ground waters, frequent flooding, stream warming, increased water supply/wastewater treatment costs, rapid growth pressure on community water and wastewater systems, eroded riparian properties, overstressed aquifers, reduced water-based tourism and damaged aquatic ecosystems. Attempts to address these problems often created a program to fix a single problem at a fixed moment in time. Water issues are often considered in isolation both from one another and broader land use decisions, and often only within municipal boundaries.

Minimizing adverse water resource impacts while managing water use to support growth often involves conflicting planning objectives, which, without a balanced and integrated approach, can lead to unintended consequences to either water resources, growth management—or both. This integrated approach, referred to as Integrated Water Resources Management, is defined by the American Water Resources Association as “The coordinated planning, development, protection, and management of water, land and related resources in a manner that fosters sustainable economic activity, improves or sustains environmental quality, ensures public health and safety, and provides for the sustainability

Rock-lined swale near intersection of Brodhead Road and Christian Spring Road, photo by Craig Kackenmeister/LVPC

of communities and ecosystems." The County Planning Directors' Association of Pennsylvania has recognized the complexities involved with an integrated approach to water planning and has developed guiding principles and priority actions to help facilitate Integrated Water Resources Management planning throughout Pennsylvania. Green infrastructure considerations across all water themes help keep a balanced approach to land use decisions.

Environmental Benefits of Green Infrastructure

Transportation and Green Infrastructure

Successful green infrastructure is not exclusive of other built systems. In fact, integrating green infrastructure with transportation planning for improved infrastructure functionality is especially critical.

Whether on roads and bridges or along the trail network, the Lehigh Valley's transportation infrastructure facilitates the movement of *all* goods and people and their modal choices of walking, riding or driving. The Lehigh Valley Planning Commission's *MOVELV Long Range Transportation Plan* has identified a goal of constructing transportation improvements that are compatible with the built and natural environments. Some of the policies established to help achieve this include:

- Study, design and construct major highway and bridge projects in accordance with the most recent environmental regulations.
- Reduce Lehigh Valley greenhouse gas emissions. Air quality conformity determinations of the Transportation Improvement Program and *Long Range Transportation Plan* will document that hydrocarbon, nitrogen oxide and small particulate matter emissions from vehicles do not exceed the emissions budgets established by the U.S. Environmental Protection Agency.
- Protect, conserve and enhance natural ecosystems to provide long term resilience to climate change.
- Apply considerations for the existing built and natural environments during transportation improvement design.
- Integrate stormwater management practices in the form of green infrastructure into the design of new or improved rights-of-way.

With particular regard to stormwater, roads are hot spots that create easy routes for built-up pollutants to eventually flow into rivers, streams or other natural resources during rain events. Pollutants may include sediments with toxic materials from construction sites or heavy traffic areas and are detrimental to the health of fish and wildlife habitat. The flowing, ground-level pollutants are not the only negative byproduct of the road network, however. The *Long Range Transportation Plan* identified that the Lehigh Valley regional highway network supports 13.7 *million* daily vehicle miles traveled. According to the U.S. Environmental Protection Agency's calculations, this equates to 175,820 *tons* of carbon dioxide emitted into the air daily. Therefore, it is essential that the secondary function of transportation infrastructure is to protect the health of natural resources and to offset the severe public health, economic and environmental effects that vehicle use generates.

Successful precedents are taking place across the country, including the U.S. Green Building Council's PARKSMART program, which has established guidelines for designing sustainable parking lots. By increasing consciousness about the potential positive outcomes of a thoughtfully designed road and trail network, transportation infrastructure can be elevated to that of a proactive and green contributor to achieving the triple bottom line.

View of traffic on Route 22, LVPC file photo

Green Infrastructure Design within Context

The potential aesthetic and interactive appeal of incorporating green infrastructure into site design should be considered a top priority during the planning process. This not only contributes to the qualitative benefits that result from the triple bottom line but also increases compatibility for green infrastructure with various types of development. The following principles relate to the contextual integration of green infrastructure and should be used as a guide to inform the overall design approach:

Permeable pavers at Lehigh University, photo by John von Kerczek/LVPC

Creative

In urbanized areas with higher density, space for green infrastructure is not necessarily as important as creativity. There is a real opportunity for green infrastructure to emerge from the background as a central and engaging focal point. Vertical living walls and living/green roofs are increasing in popularity in cities, such as found on the award-winning STEPS (Science, Technology, Environment, Policy and Society) building at Lehigh University in the City of Bethlehem. Green roofs absorb carbon dioxide and can be incorporated as part of the building's rainwater drainage system.

Living roof on STEPS Building at Lehigh University, photo courtesy of J. Craig

Madison Farms, photo by Whitney Burdge/LVPC

Flexible

There are many ways to achieve the same type of results in a green infrastructure project, which makes it easily adaptable to both new and existing development. When structural adjustments are not feasible in an existing development, many combinations of non-structural approaches can make an equally effective impact on stormwater control. For new developments, there may be limitations to the site or cost constraints. Clustering uses is one such option that is not only sensitive to the natural landscape but may also be eligible for density bonuses. From bridge re-designs to planter boxes or vegetated swales, such as those in the new Madison Farms development in Bethlehem Township, green infrastructure can *always* be implemented at some scale.

Harmonious

One of the benefits of green infrastructure is that most of the time it cannot be recognized immediately for its functional purpose. Successful projects should seamlessly interact with the natural surroundings and be designed to fit within the context of the site, such as taking advantage of natural slopes and drainage flows when developing a new site. At first glance, the winding Rife Run tributary and its banks in Logan Park, Manheim, Pennsylvania look completely untouched. However, an extensive excavation and floodplain restoration project were responsible for its beautiful integration into the landscape.

Floodplain restoration, Logan Park, Rife River Run in Manheim, PA, photo courtesy of Land Studies Inc., 2016

Upper Saucon Township Water Authority rain garden, photo by Craig Kackenmeister/LVPC

Local/Native

Green infrastructure projects should prioritize the use of native plant species and be designed to accommodate local wildlife. This approach not only reduces maintenance but increases biodiversity. Rain gardens are a great way of featuring local flowers or other climate-appropriate foliage, while attracting birds and pollinators. They also contribute to flood prevention and remove water pollutants. In Lehigh County, the Upper Saucon Township Water Authority's rain garden features a sign which serves as an educational tool. This contributes to the social aspect of the triple bottom line.

Maximize

Maximize existing viewsheds or other highly visible natural features that already have a maintenance support system (e.g., tourism, recreation) and prioritize opportunities to work with special characteristics in the natural environment whenever possible. Some sites contribute economic and social benefits to the triple bottom line through strategic programming. Two sites have incorporated riparian buffers in different ways: the riparian buffers of Bushkill Creek in Northampton County offer a prime fishing spot, while those at Lock Ridge Furnace Park in Lehigh County provide a scenic background to weddings and special events.

Riparian buffers at Bushkill Creek in Bushkill Township, photo by Teresa Mackey, LVPC

Retention pond at LVHN Maternal/Fetal Medicine Center in Bethlehem Township, photo by Whitney Burdge, LVPC

Multipurpose

Green infrastructure projects are multipurpose by nature. Vegetated swales double as a curb and gutter. Retention basins, such as next to a Lehigh Valley Health Network facility in Bethlehem Township, mitigate peak flow rates and act as a destination for water fowl. The strategic selection of materials can further expand the functions of a project. Traditional surface materials, such as asphalt in parking lots, can be replaced with pervious pavers. Pervious pavers are a visually pleasing alternative to asphalt, while effectively managing water drainage problems. Additionally, soil amendment practices may recycle waste through the use of compost to improve infiltration.

Stormwater Management and Green Infrastructure

In Pennsylvania, the Stormwater Management Act (Act 167) provides for planning at the county level for entire watersheds rather than solely within municipal boundaries.

In addition to the Pennsylvania Stormwater Management Act, the National Pollutant Discharge Elimination System Permit for Discharges Associated with Construction Activities and the National Pollutant Discharge Elimination System Permit for Municipal Small and Large Separate Storm Sewer Systems programs address stormwater management in the state. Under these programs, stormwater runoff volume, rate and water quality are managed to protect and maintain the chemical, physical and biological properties of receiving waters. Green infrastructure approaches can be a mechanism to bring more holistic water management to individual subject areas such as stormwater management.

The Pennsylvania Department of Environmental Protection, the state agency responsible for administering the federal and state regulations related to storm runoff, has prepared a guidance tool—the *Pennsylvania Stormwater Best Management Practices Manual*—that identifies a variety of methods to control stormwater runoff. These methods were designed to be used in combination to first prevent adverse impacts to natural systems and hydrologic functions and second to minimize the impacts where they are unavoidable. Best Management Practices (Practices) are the primary means for managing stormwater discharges as prescribed in the state manual and are classified as either Non-Structural or Structural. Non-Structural Practices preserve open space, protect natural systems and incorporate existing natural features into a site plan to prevent stormwater runoff. Non-Structural Practices are not fixed or specific to one location. Many can be applied to an entire site. Structural Practices include the conventional hardscape pipe and concrete type techniques, but can also incorporate vegetation and soil-based mechanisms. Structural Practices are more location specific in their form.

Historic Bethlehem, photo by Craig Kackenmeister/LVPC

In Pennsylvania, municipalities are ultimately responsible for adopting the regulations necessary to control stormwater runoff in their communities. Through ordinance adoption, municipalities can require site plan designs to incorporate Best Management Practices that take advantage of the existing natural resources on the site. By doing so, land clearing and grading, infrastructure, and stormwater management costs can be reduced, while increasing property values, environmental health and quality of life for residents.

Municipalities should perform a review of their plans and ordinances to identify conflicts with green infrastructure practices or provisions that limit opportunities for green infrastructure. Ordinance requirements that could limit or conflict with green infrastructure practices include those related to density, parking, and storm sewer and road infrastructure requirements, among others. Municipalities should amend ordinance language to provide for the use of and flexibility in green infrastructure design. Municipalities should also look for opportunities to educate developers on the benefits of green infrastructure approaches and promote their use through the subdivision and land development process.

Site Design Practices

The use of green infrastructure in managing storm runoff is becoming increasingly popular as a means of limiting the impacts of development on natural areas, including water, land and air resources.

At the site development scale, green infrastructure can be characterized as an environmentally sensitive approach, involving a combination of techniques that preserve natural systems and hydrologic functions on a site. Overall, green infrastructure techniques minimize the impacts of development (i.e. low impact development) on the natural environment, including clustering and concentrating development, minimizing disturbed areas and reducing impervious cover.

Non-Structural Practices involve vegetation, soils and natural processes and encourage stormwater treatment, infiltration, evaporation and transpiration on the site, as opposed to conveyance of stormwater off-site. Some Best Management Practices classified as Structural Practices in the state manual can be considered green infrastructure, because they are natural systems-based, involving vegetation and soil mechanisms, and can be used in combination with Non-Structural Practices. Site design practices provided in the state manual are described below.

Swale in Sands Bethlehem parking lot, photo by Craig Kackenmeister/LVPC

NON-STRUCTURAL PRACTICES

Protect sensitive and special value features:

To minimize stormwater impacts, land development should avoid impacting and encroaching upon areas that provide important natural stormwater functions (floodplains, wetlands, riparian areas, drainage ways, etc.) and with stormwater impact sensitivities (steep slopes, threatened or endangered species habitat, adjoining properties, etc.). Development should occur in areas where these sensitive/special value resources do not exist so that their valuable functions are not lost.

Protect/conserve/enhance riparian areas:

Riparian buffers are vegetated ecosystems along a waterbody that serve to buffer the waterbody from the effects of runoff by providing water quality filtering, recharge, rate attenuation and volume reduction, and shading of the waterbody by vegetation. Riparian areas also provide habitat and may include streambanks, wetlands, floodplains and transitional areas. This practice focuses on protection, maintenance and enhancement of existing riparian buffers.

NON-STRUCTURAL PRACTICES

Protect/utilize natural flow pathways in overall stormwater planning and design:

Most natural sites have identifiable features such as swales, depressions, watercourses, ephemeral streams, etc., which serve to effectively manage any stormwater generated on the site. By identifying, protecting and utilizing these features, a development can minimize its stormwater impacts. These features can be used to reduce or eliminate the need for structural drainage systems.

Cluster uses at each site; build on the smallest area possible:

Clustering requires natural features on a site to be set aside as permanently protected open space, while development is concentrated on the remainder of the site. Clustering development significantly reduces the amount of impervious cover that would be required for a conventional development while allowing the environmental features on the site to perform their natural functions.

Concentrate uses area-wide through smart growth practices:

Growth is directed to areas or groups of parcels in the municipality that are most desirable and away from areas or groups of parcels that are not. These smart growth techniques include transfer of development rights, effective agricultural zoning, urban growth boundaries, purchase of development rights, conservation easements, among others.

NON-STRUCTURAL PRACTICES

Minimize total disturbed area – grading:

Reduction of site disturbance by grading can be accomplished in several ways. The requirements of grading for roadway alignment and roadway slope frequently increase site disturbance throughout a land development site and on individual lots. Far less grading and a far less disruptive site design can be accomplished if the site design better conforms to the existing topography and land surface. For individual lots, conventional lot layout geometry can also impose added earthwork and grading that could be avoided.

Minimize soil compaction in disturbed areas:

Healthy soils that have not been compacted perform numerous stormwater functions, including minimizing runoff and erosion, and maximizing water-holding capacity, among others. Once compacted, these functions are diminished and can never be completely restored. This practice is intended to prevent compaction or minimize the degree and extent of compaction in areas that are to be pervious following development.

Revegetate and reforest disturbed areas using native species:

This practice emphasizes the selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides. Native species have the greatest tolerance and resistance to pests and require far less fertilization and chemical application than non-native species.

NON-STRUCTURAL PRACTICES

Reduce street imperviousness:

Streets can comprise the largest single component of imperviousness in residential design. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, vehicle leaks, etc. Increased imperviousness alters an area's hydrology, habitat structure and water quality. Pavement can be minimized by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii and using permeable pavers.

Reduce parking imperviousness:

In commercial and industrial areas, parking lots may comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry and parking ratios. Modifying all or any of these three aspects can serve to minimize the total impervious areas associated with parking lots.

Rooftop disconnection:

Building codes have historically encouraged the rapid conveyance of rooftop runoff away from building structures, specifying minimum slopes that serve to accelerate overland flow onto and across lawns, directed more rapidly toward streets and gutters. Disconnecting roof leaders from stormwater conveyance systems allows rooftop runoff to be collected and managed on site. Rooftop runoff can be directed to vegetated areas for on-site storage, treatment and volume control. Runoff may also be directed to dry wells, rain barrels and cisterns for stormwater retention and volume reduction.

NON-STRUCTURAL PRACTICES

Disconnection from storm sewers:

Roads and driveways account for a large percentage of post-development imperviousness. Conventional stormwater management has involved the rapid removal and conveyance of stormwater from these surfaces. Roads and driveways contribute toxic chemicals, oil and metals to stormwater runoff. A variety of alternatives exist for redirecting road and driveway runoff away from stormwater collection systems. In addition to vegetated swales, infiltration trenches or bioretention areas may be utilized. Curbing may be eliminated entirely or selectively.

Street sweeping:

Larger debris material and smaller particulate pollutants are removed by street sweeping equipment, preventing this material from clogging the stormwater management system and washing into receiving waterways/waterbodies.

STRUCTURAL PRACTICES

Pervious pavement with infiltration bed:

Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed that provides temporary storage for peak rate control and promotes infiltration. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts and other similar uses.

Infiltration basin:

An infiltration basin is a shallow impoundment that temporarily stores and infiltrates runoff over a level, uncompacted (preferably undisturbed) area with relatively permeable soils. The basin should avoid disturbance of existing vegetation, which promotes evaporation and transpiration.

Subsurface infiltration bed:

A subsurface infiltration bed provides temporary storage and infiltration of stormwater runoff by placing storage media of varying types beneath the proposed surface grade.

STRUCTURAL PRACTICES

Infiltration trench:

An infiltration trench consists of a continuously perforated pipe in a stone-filled trench designed so that storm events are conveyed through the pipe with some runoff volume reduction.

Rain garden/bioretention:

A rain garden is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff. Rain garden vegetation serves to filter and transpire runoff, and the root systems can enhance infiltration. Properly designed rain garden/bioretention techniques mimic natural forest ecosystems through species diversity, density and distribution of vegetation and the use of native species, resulting in a system that is resistant to insects, disease, pollution and climatic stresses.

Dry well/seepage pit:

A dry well is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. By capturing runoff at the source, dry wells can reduce the increased volume of stormwater generated by the roofs of structures.

STRUCTURAL PRACTICES

Constructed filter:

Filters are structures or excavated areas containing a layer of sand, compost, organic material, peat or other filter media that reduces pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons and other pollutants.

Vegetated swale:

Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems. Swales are heavily vegetated with a dense and diverse selection of native, close-growing, water resistant plants with high pollutant removal potential.

Vegetated filter strip:

Filter strips are gently sloping, densely vegetated areas that filter, slow and infiltrate sheet flowing stormwater. Filter strips are best utilized to treat runoff from roads and highways, roof downspouts, small parking lots and pervious surfaces.

STRUCTURAL PRACTICES

Infiltration berm and retentive grading:

Infiltration berms are linear landscape features located parallel to existing site contours in a moderately sloping area. They can be described as built-up earthen embankments with sloping sides, which function to retain runoff, promote infiltration and slow down or divert stormwater flows. They create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater.

Vegetated roof:

Extensive vegetated roof covers are usually six inches or less in depth and completely cover a conventional flat or pitched roof, providing the roof with hydrologic characteristics that more closely match surface vegetation.

Runoff capture and reuse:

Capture and reuse encompasses a wide variety of water storage techniques (including rain barrels and cisterns) designed to capture precipitation from rooftops or other impervious areas, hold it for a period of time and reuse the water. Spray irrigation is a form of capture/reuse.

STRUCTURAL PRACTICES

Constructed wetland:

Constructed wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best practices for pollutant removal, they can also mitigate peak rates and even reduce runoff volume to a certain degree. They use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Wet pond/retention basin:

Wet ponds are stormwater basins that include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. They do not achieve significant groundwater recharge or volume reduction but can be effective for pollutant removal and peak rate mitigation.

Dry extended detention basin:

A dry extended basin is typically an earthen structure constructed either by impoundment of a natural depression or excavation of existing soil that provides temporary storage of runoff to prevent downstream flooding impacts. The primary purpose of the basin is to reduce stormwater runoff peaks.

STRUCTURAL PRACTICES

Water quality filters and hydrodynamic structures:

A broad spectrum of practices have been designed to remove non-point source pollutants from runoff as part of the runoff conveyance system. These structural practices vary in size and function, but all utilize some form of settling and filtration to remove particulate pollutants from stormwater runoff.

Riparian buffer restoration:

A riparian buffer is a permanent area of trees and shrubs located adjacent to streams, lakes, ponds and wetlands that provide a number of benefits, including stormwater management functions. Riparian forests are the most beneficial type of buffer for the ecological and water quality benefits they provide. Restoration of this ecologically sensitive habitat is a responsive action to past activities that may have eliminated any vegetation.

Landscape restoration:

Landscape restoration is the general term used for sustainable landscaping practices that are implemented outside of riparian buffer areas. The landscape plays a vital role in mitigating the volume and rate of stormwater runoff. The practices include restoration of forest and/or meadow and the conversion of turf to meadow. Landscape restoration involves the careful selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides.

STRUCTURAL PRACTICES

Soil amendment and restoration:

Animals, farm equipment, trucks, construction equipment, cars and people cause soil compaction. Soil amendment and restoration is the process of restoring disturbed soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil’s long term capacity for infiltration and pollution removal.

Floodplain restoration:

Floodplain restoration tries to mimic the interaction of groundwater, stream baseflow and root systems. It is an effective tool to meet water quality and quantity requirements, prevent riparian problems from getting worse, and fix current problems caused by historical practices. A restored floodplain and stream may greatly enhance infiltration and storage of surface flow in the floodplain, which reduces flood flow stages, volumes and peak discharges.

Level spreader:

Level spreaders are measures that reduce the erosive energy of concentrated flows by distributing runoff as sheet flow to stabilized vegetative surfaces. They may also promote infiltration and improved water quality.

Special detention areas:

These are places such as parking lots and rooftops that are primarily intended for other uses but that can be designed to temporarily detain stormwater for peak rate mitigation.

Hanover Township (Lehigh County) Building, LVPC file photo

Water Balance Stormwater Standard

Water balance refers to the distribution of rainfall into the various components of the water cycle of runoff, groundwater recharge and evaporation/transpiration.

Runoff is that part of rainfall that leaves a site in an overland fashion and enters streets, storm drains, channels or water bodies. Groundwater recharge is that part of rainfall that infiltrates into the ground to replenish aquifers. Evaporation is that part of rainfall that goes directly back to the atmosphere. Transpiration is that part of rainfall that is taken in by plants and leaves the plants as water vapor. For a given rainfall, the portion that becomes each of these components is determined by site land cover conditions and the stormwater management practices employed. The goal of a water balance approach is to mimic a natural landscape with stormwater management designs.

Traditionally, stormwater management ordinances provided standards related to the rate of stormwater runoff leaving a site. Often, these ordinances provided a suite of alternatives for site designers to use with the goal of meeting a specific performance standard, such as controlling the peak rate of runoff after development to no greater than before development conditions. The site designer chose the specific practices to be used to meet this goal, which often led to hardscape designs.

More contemporary ordinances dealing with stormwater runoff volume and water quality considerations lead to better opportunities for implementing green infrastructure approaches. *The Monocacy Creek Watershed Act 167 Stormwater Management Plan Update* Model Ordinance addresses these issues by incorporating standards related to water balance and green infrastructure. Building off the state requirements for Post Construction Stormwater Management, the Model Ordinance requires that the volume of runoff not be increased from before development to after development for the 2-year return period event (the rainfall event that has a 50% chance of being equaled or exceeded in any given year). Controlling runoff volume translates into using approaches to either capture and re-use runoff or infiltrate runoff. Therefore, the Model Ordinance standard is that this 2-year change in runoff volume, referred to as the Water Quality Volume, be captured and treated with practices that include vegetative or infiltration approaches. A potential drawback of this general standard is that site designers may often decide to forego the vegetative approaches in favor of the infiltration approaches. In the Monocacy Creek Watershed, with about two-thirds of the watershed underlain by carbonate bedrock, infiltration of significant amounts of runoff needs to be accomplished with care given concerns with sinkhole development and groundwater quality. For this reason, the Model Ordinance incorporates provisions to better balance how rainfall is translated to runoff, recharge and/or evaporation/transpiration before and after development.

Natural or existing water balance can be inferred from various sources, including the Lehigh Valley Planning Commission's *Technical Best Management Practice Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed*, as well as data for the Monocacy and Jordan creeks based on stream gage analyses. Consistently through these sources, groundwater recharge is about 30% of annual rainfall, while runoff ranges from approximately 10% to 20%, depending on the extent of development in a watershed. Based on this data, the water balance in the "natural" condition is as follows:

RUNOFF

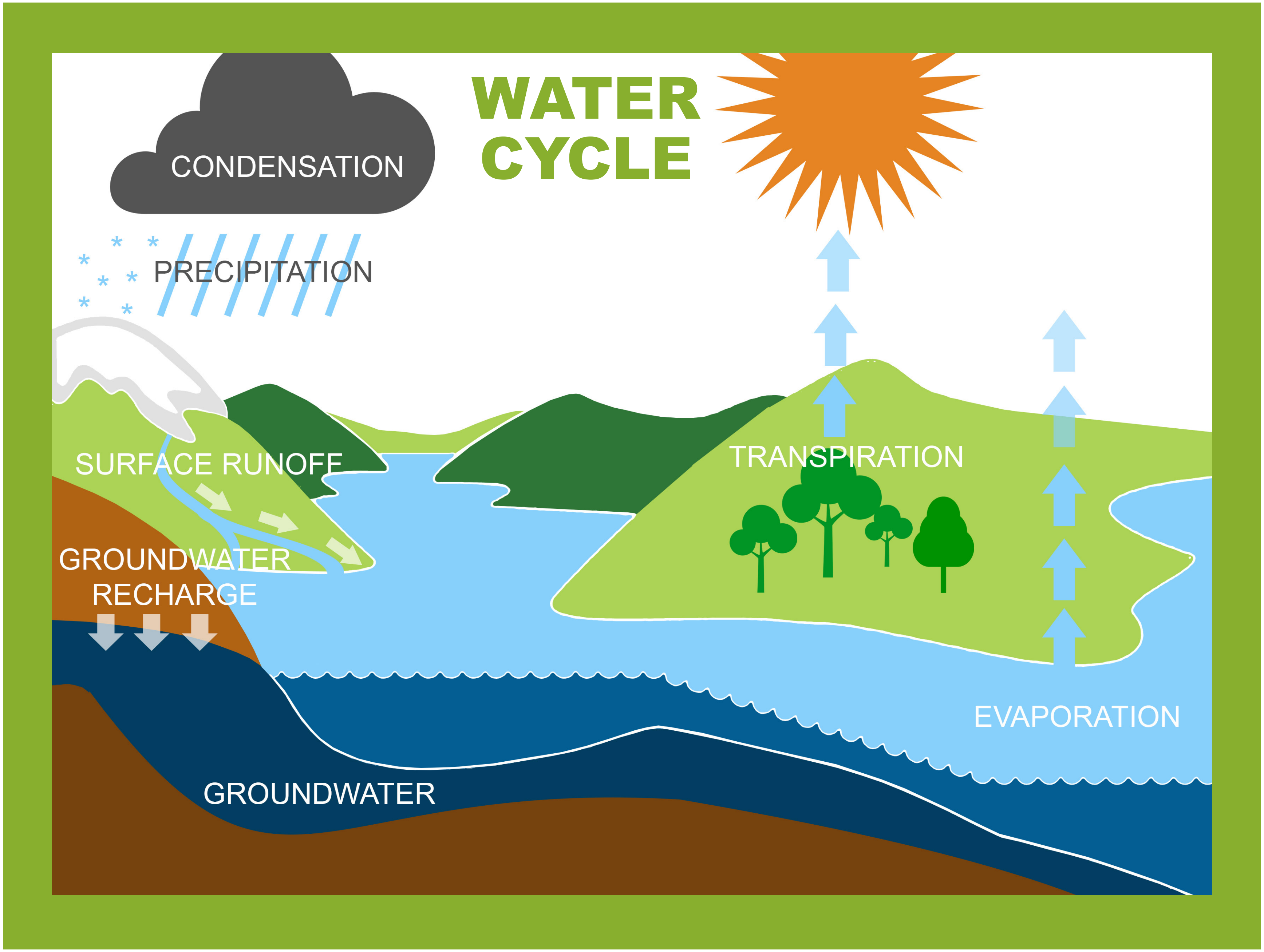
10% **of annual rainfall**

GROUNDWATER RECHARGE

30% **of annual rainfall**

EVAPORATION/TRANSPIRATION

60% **of annual rainfall**


WATER
CYCLE
CONDENSATION
PRECIPITATION
SURFACE RUNOFF
GROUNDWATER
RECHARGE
TRANSPIRATION
EVAPORATION
GROUNDWATER

The most critical aspect for determining post-development water balance is how rainfall produced by impervious surfaces is translated to runoff, groundwater recharge and/or evaporation/transpiration as passed through various Practices. Impervious surfaces produce a well understood "transform" of rainfall to runoff such that most rainfall will become runoff. The change from pervious cover to impervious cover with development can dramatically alter peak runoff rate and runoff volume. Practices can be employed to manage rate and volume impacts, but the annual water balance implications of those choices may not be understood or considered. Practices that are based on vegetative uptake and soil renovation of runoff and/or surface infiltration are termed Vegetated/Surface Practices. Practices that initially direct runoff to an underground infiltration surface are Direct Recharge/Subsurface Practices. Practices that mainly pass runoff volume through such that the volume leaves the facility as runoff are Runoff Practices.

For an assessment of how water directed to Best Management Practices ultimately leaves the site as runoff, groundwater recharge or evaporation/transpiration, operating rules are needed for each type of Practice. Two of the rules are quite simple. For Runoff Practices, all water directed to them is assumed to be eventually released as runoff. For Direct Recharge/Subsurface Practices, all water directed to them is assumed to be released as recharge. Vegetated/Surface Practices are different. Water directed to these Practices will have some fraction of the water become evaporation/transpiration, some fraction may become recharge and any runoff greater than the design capacity will leave the facility as runoff. These Practices most closely distribute water directed to them in a way that mimics the natural landscape. With this in mind, impervious areas of a site directed to Vegetated/Surface Practices should most closely reproduce a natural water balance. Given the above, only about one-third of the site as proposed impervious could be discharged to Direct Recharge/Subsurface Practices to preserve annual water balance.

Given the above, the key Model Ordinance provisions for water balance are as follows:

- The entire water quality volume shall be captured and treated by either Direct Recharge/Subsurface or Vegetated/Surface Practices.
- As much proposed impervious area as practical shall be directed to water quality Practices.
- Up to 33% of the site as impervious cover may be directed to Direct Recharge/Subsurface Practices designed to capture the water quality volume.

Green Infrastructure Stormwater Standard

For purposes of the *Monocacy Creek Plan Update*, the intent is to see how the Model Ordinance could encourage or mandate green infrastructure approaches for managing stormwater on a development or redevelopment site.

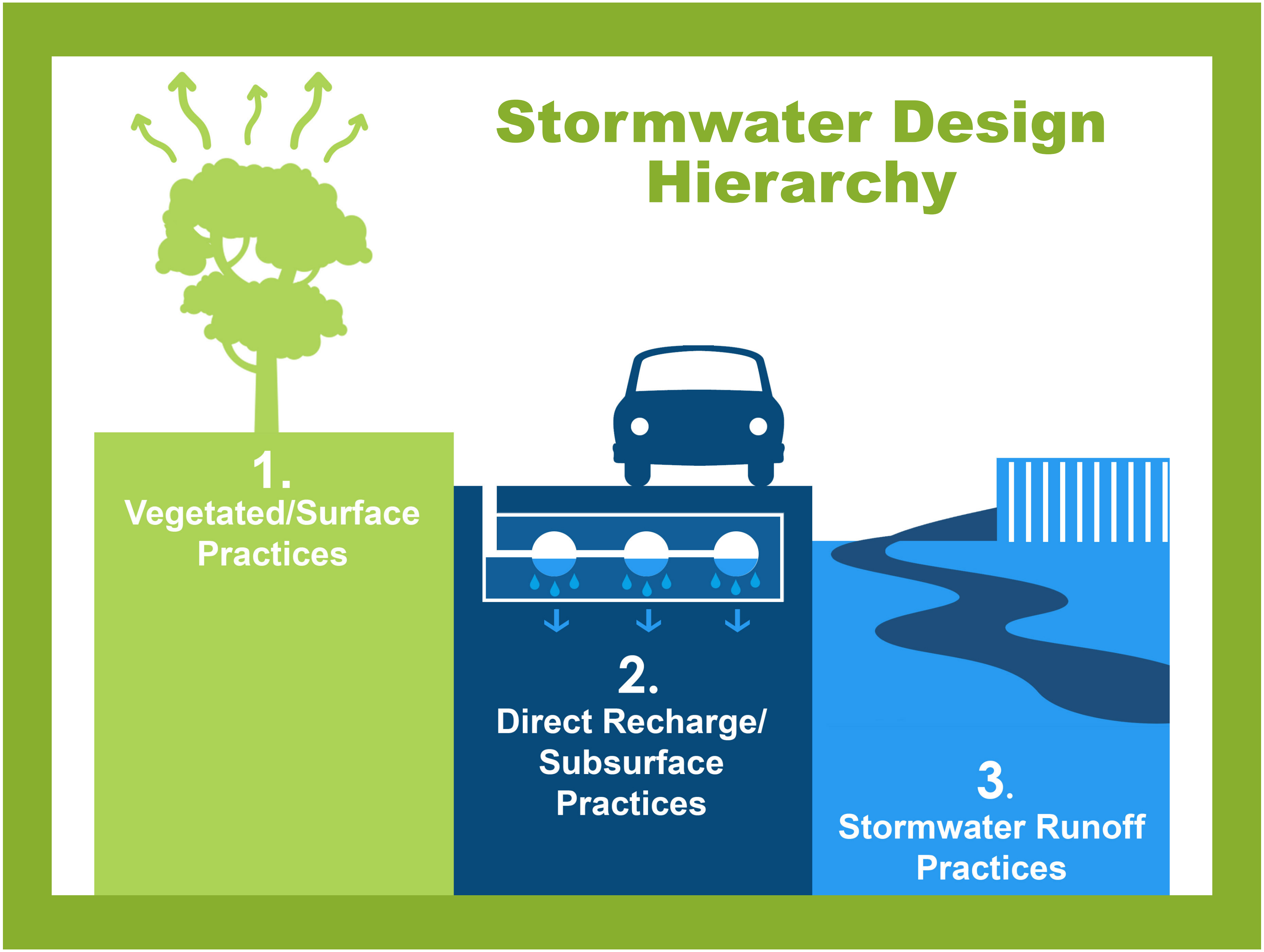
The U.S. Environmental Protection Agency prepared a summary of stormwater management green infrastructure ordinance approaches in various communities across the country in *Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure.* Many of the ordinance approaches involve mandating a certain volume of runoff to be infiltrated or treated by water quality Best Management Practices. In Pennsylvania, this standard is already implemented through the Post-Construction Stormwater Management Permit process for qualifying sites through the water quality volume standard. The same standard is included in the Model Ordinance for all regulated sites. One of the examples cited had a more proactive approach to green infrastructure by requiring a specific hierarchy for consideration of site runoff control practices. Runoff infiltration with vegetated infiltration facilities is required to the maximum extent practicable followed by options that overflow these facilities to subsurface infiltration facilities. In effect, this ordinance mandates green infrastructure approaches as a first option, depending on site characteristics that may limit its practicability.

The standard included in the Model Ordinance incorporates the “green infrastructure first” approach. Maintaining the natural water balance of evaporation/transpiration, groundwater recharge and runoff with development of a site requires that standards are needed to choose appropriate Best Management Practices in site design. Water quality and green infrastructure approaches to site design often means a decentralized approach to stormwater management, where there may be many smaller Best Management Practices applied to a site rather than concentrating all runoff into one large structure. The many Best Management Practices can have highly varied design concepts and can “capture” different amounts of rainfall/runoff. If all proposed impervious cover was treated equally in choosing and designing Best Management Practices, each square foot of impervious cover would require 0.38 inches of runoff to be treated first with Vegetated/Surface Practices. This standard is included in the Model Ordinance to best implement the green infrastructure approach and ensure that more natural approaches are accomplished in all site stormwater management designs.

The specific standard included in the Model Ordinance is as follows:

Vegetated/Surface Practices shall be employed “first” for the site to capture the equivalent of a minimum of 0.38 inches of runoff for each square foot of impervious area, unless proven not feasible by the applicant.

Pervious pavement on South Bethlehem Greenway Trail, photo by Craig Kackenmeister/LVPC


Stormwater Design Hierarchy
1.
Vegetated/Surface Practices
2.
Direct Recharge/ Subsurface Practices
3.
Stormwater Runoff Practices

Green Infrastructure Site Development and Management Recommendations

At the site development scale, green infrastructure can be characterized as an environmentally sensitive approach, involving a combination of techniques that preserve natural systems, incorporate context-sensitive design and preserve hydrologic functions on a site.

Stormwater management techniques include water balance-specific green infrastructure approaches. Water balance refers to the distribution of rainfall into the various components of the water cycle of runoff, groundwater recharge and evaporation/transpiration. Maintaining the natural water balance of evaporation/transpiration, groundwater recharge and runoff with the development of a site requires that standards are needed to choose appropriate Best Management Practices in site design. These Guidelines identify standards to limit the use of practices that could significantly alter the natural water balance. A further intent of these Guidelines is to encourage green infrastructure approaches for managing stormwater on a development or redevelopment site. A "green infrastructure first" approach is encouraged, whereby vegetated and surface infiltration practices would be employed "first" by the designer as part of the overall stormwater management concept. The Green Infrastructure Guidelines offer a simple approach to incorporating green infrastructure into site designs by recognizing and conserving natural assets, designing in context with these natural assets and employing stormwater management practices that further serve to mimic the natural water cycle. Municipalities should consider including their design guidelines within their subdivision and land development ordinances to take advantage of the various benefits provided by natural and man-made green infrastructure.

1. Identify and preserve natural resources on site

Document the natural resources that are located on the project site using an Environmental Resources Site Design Assessment as related to proposed grading and impervious cover, create a building design to maximize the preservation of "green" site assets, and identify Best Management Practices to mitigate any adverse impacts on natural resources on the site. Natural resources include, but are not limited to, agricultural soils, meadows, rivers and streams, woodlands, parks, wetlands and open spaces. The Lehigh Valley Planning Commission Natural Resources Plan provides a Lehigh Valley-wide assessment of priority natural resource areas, but site specific resources should be documented. Guidance on best practices to protect natural systems are available in the Lehigh Valley Planning Commission guides and model regulations as follows:

- Steep Slopes Guide/Model Ordinance
- Woodlands Guide/Model Regulations
- Riparian and Wetland Buffers Guide/Model Regulations
- Floodplain Guide/Model Regulations
- Conservation Subdivisions

2. Design within context

The potential aesthetic and interactive appeal of incorporating green infrastructure into site design should be considered a top priority during the planning process. This not only contributes to the qualitative benefits that result from the triple bottom line but also increases compatibility for green infrastructure with various types of development. The following principles relate to the contextual integration of green infrastructure and should be used as a guide to inform the overall design approach:

Creative – In urbanized areas with higher density, space for green infrastructure is not necessarily as important as creativity. There is a real opportunity for green infrastructure to emerge from the background as a central and engaging focal point.

Flexible – There are many ways to achieve the same type of results in a green infrastructure project, which makes it easily adaptable to both new and existing development.

Harmonious – One of the benefits of green infrastructure is that most of the time it cannot be recognized immediately for its functional purpose.

Local/native – Green infrastructure projects should prioritize the use of native plant species and be designed to accommodate local wildlife. This approach not only reduces maintenance but increases biodiversity.

Maximize – Maximize existing viewsheds or other highly visible natural features that already have a maintenance support system (e.g., tourism, recreation) and prioritize opportunities to work with special characteristics in the natural environment whenever possible.

Multipurpose – Green infrastructure projects are multipurpose by nature. The strategic selection of materials can further expand the functions of a project.

3. Follow a hierarchy of stormwater management practices based on the *Monocacy Creek Plan Update* Model Ordinance

In accordance with the Model Ordinance, the following hierarchy identifies which methods should be applied to meet the water balance and green infrastructure considerations:

- The entire water quality volume shall be captured and treated by either Direct Recharge/Subsurface or Vegetated/Surface Practices.
- As much proposed impervious area as practical shall be directed to water quality Practices.
- Up to 33% of the site as impervious cover may be directed to Direct Recharge/Subsurface Practices designed to capture the entire 2-year, 24-hour event (water quality volume).
- Vegetated/Surface Practices shall be employed “first” for the site to capture the equivalent of a minimum of 0.38 inches of runoff for each square foot of impervious area, unless proven not feasible by the applicant.

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