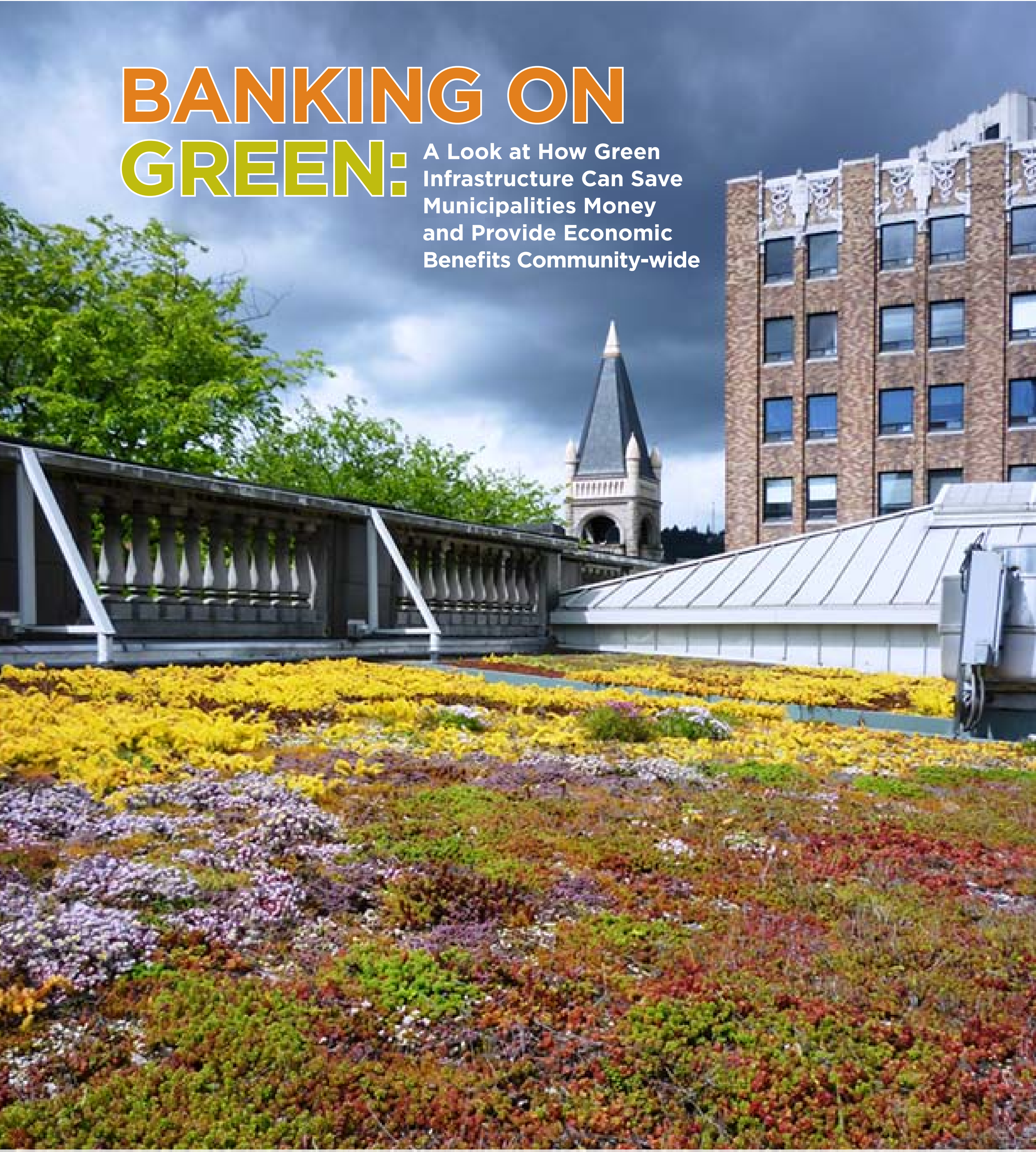
# BANKING ON GREEN:

## A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide



*A Joint Report by American Rivers, the Water Environment Federation, the American Society of Landscape Architects and ECONorthwest*

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## REPORT AUTHORS


American Rivers

Jeffrey Odefey
Stacey Detwiler
Katie Rousseau
Amy Trice

American Society of Landscape Architects

Roxanne Blackwell
Kevin O'Hara

ECONorthwest

Mark Buckley
Tom Souhlas

Water Environment Federation

Seth Brown
Pallavi Raviprakash


ADDITIONAL SUPPORT BY:

Dan Medina, Virginia Roach, Stephanie Hanses, and Robert Hawley

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# EXECUTIVE SUMMARY

This report focuses on the economic impacts caused by polluted urban runoff, also known as "stormwater," a significantly growing source of water pollution in the United States.[1] It's not intended to be an academic or technical document, but instead to be an "easy to read" compendium of current experiences, analysis and knowledge. Our goal is to provide something useful for municipal and utility officials, local, state and national elected representatives, and the general public. As stormwater professionals and researchers gather more information about the performance of green infrastructure, and refine the techniques that fall in this category of stormwater management, it's important to translate their findings into useful information for policy makers and others. Information about the economics of green infrastructure and about stormwater more broadly is critical to our ongoing conversations about the shape of our communities and the infrastructure they depend upon.

The impacts of stormwater pollution and the need to provide stormwater prevention, management, and treatment all create costs for communities and their residents. These costs can often be offset or reduced by making different choices about how we build communities and infrastructure. By incorporating "green infrastructure" practices in efforts to control stormwater runoff, communities and property developers can reduce energy costs, diminish the impacts of flooding, improve public health, and reduce overall infrastructure costs. In addition, these practices, which rely on natural processes like evaporation, infiltration, and plant transpiration, can effectively and affordably complement traditional "grey" infrastructure, giving stormwater managers the ability to create integrated solutions to better serve their communities. Shifting to this new paradigm also creates more sustainable communities that are better able to meet future challenges, especially in the face of a changing climate.

## The Problem of Stormwater

In many ways, our basic stormwater and wastewater infrastructure would be familiar to ancient Roman engineers who designed similar systems to manage water. Today, however, the scale of these challenges has significantly increased. As our cities, towns, and neighborhoods continue to grow, the amount of hard surfaces impervious to rainwater increases. Rain that once soaked into fields and forests now runs off hard surfaces like rooftops, parking lots, and highways in excessive amounts. Stormwater runoff from these surfaces flows into storm drains and ultimately into local rivers, lakes, and streams, carrying heavy metals, bacteria, and other pollutants that foul our waters and put our health at risk. High volumes of runoff can erode stream banks, cause localized flooding, and contribute to sewer overflows where raw sewage is directly discharged into local waters. The age old techniques that we use to channel waste and runoff from our communities now pose challenges to communities and utility managers that are striving to both provide protection against current storms and plan for future needs.

Many communities manage runoff through networks of pipes, tunnels and ditches that carry it quickly away from buildings and neighborhoods. Some communities use separate systems for sewage and stormwater, known as "separate storm sewer systems." In older urban communities, sewer systems were often designed to capture and transport stormwater and untreated sewage and wastewater from toilets and industrial drains to wastewater treatment plants as part of a "combined sewer system" (CSS). When rain or melting snow creates large volumes of runoff, the total volume of stormwater and wastewater in the combined sewers exceeds the capacity of the wastewater treatment plant. When the

Stormwater Services of Wilmington, NC

## Definitions

**Green infrastructure—**Green infrastructure is an approach to wet weather management that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire, and/or recycle stormwater runoff.[i]

**Grey infrastructure—**In the context of stormwater management, grey infrastructure can be thought of as the hard, engineered systems to capture and convey runoff, such as gutters, storm sewers, tunnels, culverts, detention basins, and related systems.

**Combined Sewer System—**Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body.[ii]

**Combined Sewer Overflow—**During periods of heavy rainfall or snowmelt, wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris.[iii]

**Sanitary Sewer System—**A sanitary sewer specifically transports sewage and industrial wastewater from houses and commercial buildings and industrial areas to wastewater treatment plants. Sanitary sewers are operated separately and independently of storm sewers.

**Sanitary Sewer Overflows—**Sanitary sewer overflows are occasional unintentional discharges of raw sewage from municipal sanitary sewers. These types of discharges have a variety of causes, including but not limited to blockages, line breaks, sewer defects that allow storm water and groundwater to overload the system, lapses in sewer system operation and maintenance, power failures, inadequate sewer design and vandalism. Additionally, aging sewer line infrastructure in many communities allows rain and snow melt to enter sanitary sewer systems. During significant wet weather events it is possible for influent flows to exceed the treatment capacity of existing secondary treatment units.[iv]

**Separate Sewer System—**In a separate sewer system, the storm sewer infrastructure is completely separate from the sanitary sewer system that carries wastewater (as opposed to a combined sewer system).

**Green Roof—**Green roofs employ vegetated roof covers, with growing media and plants covering or taking the place of bare membrane, gravel ballast, shingles or tiles. A green roof system is an extension of the existing roof which involves a high quality water proofing and root repellant system, a drainage system, filter cloth, a lightweight growing medium and plants.[v]

**Street Trees—**When properly designed, traditional tree plantings along street and road edges can capture, infiltrate, and transpire stormwater. These virtues can be expanded by incorporating trees into more extensively designed "tree pits" that collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants can be retained, degraded and absorbed.[vi]

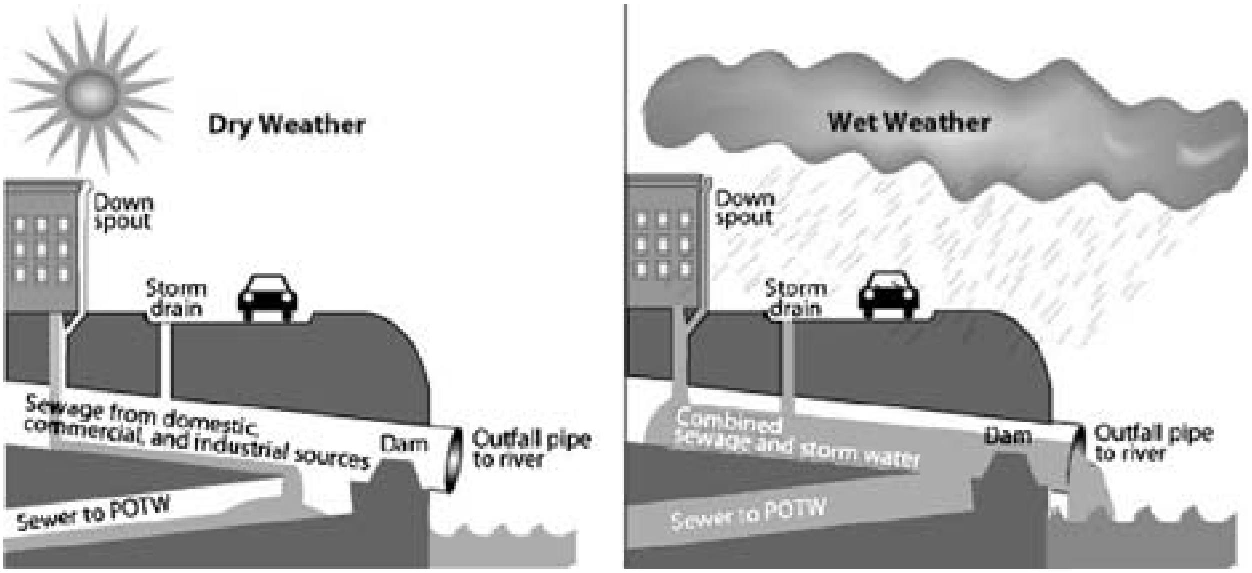
**Green Streets—**A green street is defined as a street-scape designed to: integrate a system of stormwater management within its right of way, reduce the amount of runoff into storm sewers, make the best use of the street tree canopy for stormwater interception as well as temperature mitigation and air quality improvement.[vii]

**Bioinfiltration—**Bioretention systems are soil- and plant-based facilities employed to filter and treat runoff from developed areas. Bioretention systems are designed for water infiltration and evapotranspiration, along with pollutant removal by soil filtering, sorption mechanisms, microbial transformations, and other processes.

**Rain Garden—**A rain garden is a strategically located low area planted with native vegetation that intercepts runoff. Other terms include mini-wetland, storm water garden, water quality garden, stormwater marsh, backyard wetland, low swale, wetland biofilter, or bioretention pond. Rain gardens are designed to direct polluted runoff into a low, vegetated area, where the pollutants can be captured and filtered.[viii]

**Stormwater (or, Runoff)—**Stormwater runoff is precipitation that becomes polluted once as it flows over driveways, streets, parking lots, construction sites, agricultural fields, lawns, and industrial areas. Pollutants associated with stormwater include oils, grease, sediment, fertilizers, pesticides, herbicides, bacteria, debris and litter.. Stormwater washes these pollutants through the storm sewer system and into local streams and drainage basins. In addition, because impervious surfaces prevent precipitation from soaking into the ground, more precipitation becomes runoff, and the additional volumes and velocities of stormwater can scour stream and river channels, creating erosion and sediment problems.

**Impervious Cover (Or, Impervious area, imperviousness)—**Any surface that cannot be effectively (easily) penetrated by water, thereby resulting in runoff. Examples include pavement (asphalt, concrete), buildings, rooftops, driveways/roadways, parking lots and sidewalks.




U.S. Environmental Protection Agency

During rain storms, runoff can overwhelm the capacity of combined sewers, sending untreated sewage and runoff into local waters.

system becomes overloaded, it diverts the mixture of stormwater and sewage and releases it directly into local rivers or coastal waters. These "combined sewer overflows," or CSOs, dump millions of gallons of raw waste and other dangerous pollutants into rivers, creeks and lakes—waters we may fish, swim or boat in, or which may be sources of drinking water.

Additionally, a changing global climate will place greater strain on local environments and water infrastructure. Around the country, communities are already experiencing changes to their long-term precipitation patterns. Storm frequencies, intensities and duration are shifting, and in many regions, more severe storms that occur more frequently are expected. Increased rainfall (and snowfall) will place increased demands on storm sewer and flood control systems and force developers and municipalities to adopt new strategies to manage larger volumes and rates of stormwater.

Widely established methods for managing urban stormwater can place high burdens on our communities, from the significant cost of managing and treating runoff in through expensive and often ineffective ways, to the costs associated with the pollution, flooding and health impacts. Aging stormwater infrastructure, along with the pressure to construct new facilities, adds billions of dollars to future municipal, state and federal fiscal needs. According to the Environmental Protection Agency (EPA), U.S. communities are facing a total of $106 billion in needed stormwater management and combined sewer correction upgrades or improvements.[2] These infrastructure needs are combined with budgetary restrictions at all levels of government that limit investments in these critical components of our environmental, public health and safety infrastructure.

Conversely, there is also a cost associated with failing to retain and utilize this rain water locally, before large volumes of runoff are channeled downstream. For instance, rainwater that might be used to recharge local groundwater supplies for drinking water may flow off in significant volumes due to urbanization and high levels of impervious surface. In 1997, the volume of stormwater runoff in the City of Atlanta would have been enough to supply average household needs of between 1.5 and 3.6 million people.[3] This number has only grown as Atlanta's suburbs continue to expand. The City of Los Angeles is beginning to incorporate green infrastructure practices to infiltrate water onsite as a viable strategy to augment the City's water supply.[4]

As we look toward the future, our water protection goals, fiscal limitations and water infrastructure needs are combining to push us toward solutions that integrate tried and true "grey" infrastructure with "green" infrastructure practices that can cost-effectively reduce runoff before it enters our community sewer systems and water resources.

## Green Infrastructure Practices Offer Cost-Effective Stormwater Management Strategies

Over the past few decades, many American communities have realized considerable financial and water quality gains by adding green infrastructure to their toolkit of approaches to reducing and managing stormwater. Green infrastructure techniques can include using rooftop vegetation to control stormwater and reduce energy use, restoring wetlands to retain floodwater, installing permeable pavement to mimic natural hydrology, and using or capturing and re-using water more efficiently on site. By attempting to mimic natural hydrologic functions, such as infiltration and evaporation, these approaches prevent stormwater from flowing into surface waters or overburdened sewer systems. As such, they are often a cost-effective way to supplement or replace traditional stormwater management practices, often referred to as "grey infrastructure" because they rely heavily on heavily engineered and structural solutions. In addition, green infrastructure approaches improve air quality, increase habitat and green space, enhance human health, and reduce flooding. Where green infrastructure solutions have been widely adopted, communities have found that the enhanced aesthetic experience of local residents has improved quality of life as well as property values. Local waters improved by reducing runoff can provide healthier aquatic habitats and water supplies, becoming resources that provide environmental and public health benefits to all residents.

In the face of a changing climate, green infrastructure can play an increasingly important role to reduce local impacts for community resources and waters. By reducing the volume of runoff entering sewer systems and increasing natural features that can soften the effects of storm surges and flooding, green infrastructure can add resiliency to local climate change adaptation planning.

Green infrastructure alternatives have demonstrated a positive economic effect in a number of communities, particularly for those using these approaches to both reduce polluted stormwater and CSOs. Communities across the country are demonstrating that CSO control plans that incorporate green infrastructure elements as a way to achieve pollution reduction goals add cost-effective complements to grey infrastructure and provide additional value to the local community. The lesson learned so far by early adopter communities who have already implemented green infrastructure in a significant fashion is that a wide-ranging commitment to including green infrastructure stormwater approaches, on public as well as private properties, can result in long-term fiscal savings for local governments as well as provide numerous, tangible economic and community benefits through related ecosystem services.

This report builds on the current understanding of the cost-effectiveness of green infrastructure and further documents four critical areas in which these green infrastructure approaches provide cost-effective ways for communities to save money while also creating safer and healthier places to live:

- ***Green infrastructure can be cost-effective—***
  Green infrastructure can provide less expensive, and more cost-effective, approaches to managing runoff. Municipalities and developers may benefit from lower capital costs, land acquisition requirements, operational expenses and other financial burdens when green infrastructure is integrated into new construction, redevelopment projects, or programs to reduce combined and sanitary sewer overflows.
- ***Green infrastructure increases energy efficiency and reduces energy costs—***
  Stormwater management practices built around natural hydrologic functions and increased use of vegetation can dramatically reduce energy consumption. Green roofs, street trees, and increased urban green spaces have the effect of making individual buildings more energy efficient by reducing heating and cooling demands. On a neighborhood or community level, the shading and insulation provided by these techniques cools urban heat islands, again reducing the energy required to cool indoor spaces during summer months. Additionally, by re-using harvested rainwater, some green infrastructure approaches

decrease the need to use potable water for landscaping, toilet flushing, or other industrial uses. In turn, this reduces municipal and utility expenditures to transport, treat, and deliver potable water.

- ***Green infrastructure can reduce the economic impacts associated with flood events—*** Poor stormwater management can be a significant factor in many localized flooding events, increasing damage to property and public infrastructure. Federal Emergency Management Agency (FEMA) estimates that 25% of the $1 billion in annual damages from caused by flooding are linked to stormwater.[5] By increasing infiltration and retention, green infrastructure can substantially reduce the overall amount of water entering local storm sewers or surface waters and reduce flooding-related impacts, including decreased property values and tax revenues associated with flooding, damages to public infrastructure and associated repair costs and damages to private and public property.

- ***Green infrastructure protects public health and reduces illness-related costs—*** The pollutants delivered by stormwater runoff are a major source of contamination of drinking water supplies, recreational waters, and productive fish and shell fishing areas. The medical and lost productivity costs associated with water-borne illnesses can be considerably reduced by preventing harmful bacteria and other pollutants from entering these waters. The EPA estimates that CSOs and separate sewer overflows (SSOs) cause at least 5,576 illnesses every year from recreational exposure at recognized recreational beaches across the country. The number of illnesses caused by recreational exposure to waters contaminated by CSOs and SSOs is likely much higher because EPA's analysis was limited to gastrointestinal illness alone and did not evaluate illness at inland or unrecognized beaches.[6] Clean waters are essential to the vibrancy and success of local businesses that depend on beachgoers and other recreational water users. Green infrastructure reduces the pollutants that enter our waters and can help to reduce the impact of these economic losses.

Given the cost-effectiveness of green approaches across a variety of categories, green infrastructure should be an integral part of stormwater management strategies. On a national scale, policies that favor or stimulate the wider adoption of green infrastructure strategies may go a long way toward reducing both the infrastructure funding needs facing the nation, and the gap between these needs and available financial resources.

# INTRODUCTION

## Polluted Stormwater Costs Communities: Problems and Solutions

Land use is inherently tied to water quality; as our urbanized areas increase so too does the area covered by rooftops, parking lots, roads and highways—hard surfaces that are impermeable to water. Rain that once soaked into unpaved lands now runs in excessive amounts into storm drains and our local rivers, lakes, and streams. As it flows across pavement, rooftops and lawns, this runoff transports pollutants that degrade our waters, reduce our ability to safely swim and fish, and put our health at risk. High volumes of runoff transported through storm drains and released into local waters can erode stream banks, cause flooding in low lying areas, and contribute to sewer overflows in some communities where raw sewage is directly discharged into local waters. Stormwater runoff is a significant and growing source of water pollution in many watersheds across the United States.[7]

Increased development and urbanization of land across the country is a major contributing factor to the steady increase in runoff-related water pollution.[8] Today, most Americans live in urban and suburban settings, with extensive roads, parking lots, and rooftops. Even as our cities and suburbs expand, redevelopment of older neighborhoods and commercial complexes is also on the rise. By one estimate, 42% of land currently considered "urban" in the United States will be redeveloped by 2030.[9] While both types of development have the potential to further challenge already overburdened waterways, they also present opportunities to shift our approach to methods which can preserve, protect, and even restore the waters that sustain and add value to our communities.

## Managing Stormwater to Protect Communities and Clean Water

Outdated and failing stormwater infrastructure combined with pressure to construct new facilities adds billions to future municipal, state and federal fiscal needs. According to the 2008 Environmental Protection Agency's (EPA) Clean Watersheds Needs Survey, the total wastewater and stormwater management needs for the nation are $298.1 billion, of which $106 billion are directly related to stormwater management and combined sewer correction.[10] The challenges implicit in this level of capital requirement are exacerbated by the scarcity of public funds available to meet the need. Even ten years ago, EPA estimated that the nation's communities faced a $270 billion funding gap for the construction, rehabilitation, repair, operation and maintenance of clean water infrastructure.[11] These infrastructure needs are combined with budgetary restrictions at all levels of government that limit investments in these critical components of our environmental and public health infrastructure. Despite the limited funds available to manage runoff, there remains a widespread reliance on traditional, centralized stormwater management approaches, such as concrete gutters, pipes, culverts, and tunnels that may have limited ability to improve water quality and are inherently costly.

## Moving Towards a New Stormwater Paradigm

In its 2009 report, the National Research Council (NRC) explored the limitations of traditional approaches to stormwater management, such as large, centralized basins that detain runoff peak flows without reducing their overall volumes. The NRC noted that these practices typically concentrate and intensify runoff flows and volume, disrupting the timing and function of watersheds that often are then unable to attenuate flows from frequent, smaller rainstorms.[12] As a result, the NRC advocates for increased reliance on approaches to development that restore hydrologic functions through runoff management techniques that harvest, evapotranspire, or infiltrate precipitation.[13] Commonly referred to as "green infrastructure," these runoff control measures reduce the accumulation of runoff and transport of pollutants by managing rain close to where it falls rather than conveying it downstream. Green infrastructure practices, such as rain gardens and green roofs that infiltrate water onsite or cisterns that gather rainfall for reuse in landscape irrigation or indoor plumbing, work by capturing and treating water where it falls. This approach to stormwater management reflects completely different values than traditional approaches. For centuries, communities treated stormwater as a threat and a waste to be disposed of by collecting and discharging it into local waters. Today, a new paradigm is developing where communities are beginning to use stormwater as a resource, recognizing the value in utilizing rainfall onsite to enhance green spaces, reduce urban temperatures, and replenish groundwater supplies.

Over the past few decades, communities across the country have realized considerable financial and water gains by turning to green infrastructure approaches to reduce and manage stormwater runoff. By working to mimic the natural hydrologic functions to the greatest extent possible, they minimize the volume of stormwater runoff delivered to receiving waters or overburdened sewer systems, and may reduce the amount of traditional drainage and stormwater management infrastructure construction. The evolution in runoff control techniques has largely been the product of leadership in the professional sector. The engineering and the landscape architecture communities, in particular, have been instrumental in advancing green infrastructure and related approaches to runoff reduction and on-site management.[14] As professional communities continue to drive improvements in green infrastructure practices, the acceptance of these practices among builders, developers, and the public continues to grow. As a result, some of the uncertainties and concerns about cost and performance have become less intractable, and the additional economic and community benefits of green infrastructure are playing a more important role in local government and agency decision-making.

There is a widening gap between the need for upgraded stormwater infrastructure and available sources of funding for these improvements, and ever increasing water quality impacts and financial strains caused by expanding rates and volumes of stormwater runoff. In this climate, municipalities may be able to realize substantial savings by incorporating green infrastructure practices into the construction or retrofit of public buildings and infrastructure. Green infrastructure can be less expensive, or more cost-effective, than comparable grey infrastructure options, reducing the cost of stormwater and CSO management. In addition, these approaches can deliver tangible financial and community benefits that translate into economic values for municipal governments and local communities. By shifting away from traditional "grey" infrastructure and stormwater management to green infrastructure approaches to runoff management, American communities may realize significant cost savings, and reap additional economic and community benefits—in effect, creating healthier, more livable communities while addressing pressing water quality needs.

## GREEN INFRASTRUCTURE PRACTICES OFFER COST-EFFECTIVE SOLUTIONS

Particularly under our current challenging economic conditions, developers and municipal decision makers often believe that they cannot afford to choose a more environmentally-sensitive infrastructure project under the assumption that doing so would be significantly more expensive than traditional options. In many cases, this belief may arise out of a lack of information about the relative costs and benefits of green infrastructure alternatives. Well-designed projects now in place around the country demonstrate the very real potential for cost savings, in part because green infrastructure projects can be more easily adapted to meet site-specific conditions than grey solutions. Even if the broad range of potential environmental, social, and aesthetic benefits provided by green infrastructure are ignored, the direct stormwater and wastewater management savings in avoided grey infrastructure installation costs, as well as reduced costs of treating combined sewage volumes, have justified the green infrastructure option in many cases. In instances where the initial investment in a green infrastructure option may be more costly, long-term costs, including operation and maintenance expenses, may compare favorably with traditional practices. When coupled with the additional benefits discussed in these pages, an investment in green infrastructure will very often have financial advantages.

A survey of members of the American Society of Landscape Architects (ASLA) concerning recent green infrastructure projects revealed many reasons that stormwater professionals select green infrastructure over grey. They reported that green infrastructure offers benefits not available from grey, green options were less costly, and that long term operation

### Green Infrastructure Practices Offer Cost-Effective Solutions

*American Society of Landscape Architect's Green Infrastructure Survey*

As part of its efforts to collect information about green infrastructure, EPA asked ASLA to collect case studies on projects that successfully and sustainably manage stormwater. ASLA members responded with 479 case studies from 43 states, the District of Columbia, and Canada. Not only do these projects showcase landscape architecture, they also demonstrate to policymakers the value of promoting green infrastructure policies. Green infrastructure and low-impact development (LID) approaches, which are less costly than traditional grey infrastructure projects, can save communities millions of dollars each year and improve the quality of our nation's water supply.

**Project type:**

| | |
|---|---|
| Institutional/Education | 21.5% |
| Open Space/Park | 21.3% |
| Other | 17.6% |
| Transportation Corridor/Streetscape | 11.9% |
| Commercial | 8.6% |
| Single Family Residential | 5.5% |
| Government Complex | 4.2% |
| Multifamily Residential | 3.7% |
| Open Space Garden/Arboretum | 2.9% |
| Mixed Use | 1.8% |
| Industrial | 1.1% |

**Green infrastructure type:**

| | |
|---|---|
| Retrofit of existing property | 50.7% |
| New development | 30.7% |
| Redevelopment project | 18.6% |

**Did use of green infrastructure increase costs?**

| | |
|---|---|
| Reduced costs | 44.1% |
| Did not influence costs | 31.4% |
| Increased costs | 24.5% |

### Analysis

- Over 300 ASLA members and other practitioners responded with 479 case studies from 43 states, the District of Columbia, and Canada.
- 55 percent of the projects were designed to meet a local ordinance.
- 88 percent of local regulators were supportive of the green infrastructure projects submitted.
- 68 percent of the projects received local public funding.

*Details about the study and its results are available here: www.asla.org/stormwater* and maintenance expenses could be less particularly when combined with other efficiencies such as those corresponding to LEED certification. The reported cost savings over grey approaches were particularly substantial when large new equipment capacity would be otherwise necessary, or new conventional equipment would require more space than was available. In some cases planners combined grey and green components to find the most cost-effective option.

## Green Infrastructure Can Be Less Costly

Examples of successfully implemented green infrastructure projects reveal the opportunities for cost-effective strategies to address stormwater and other water quality regulatory goals. Green infrastructure design and performance is generally more context-specific than grey infrastructure. This is true because these types of controls must be designed and built to suit the soil, terrain and hydrologic conditions of each individual site. As a result, however, they can be designed and implemented to address local concerns and values. Compared with the performance of grey infrastructure approaches, experiences with installed and functioning green infrastructure have revealed the following advantages:

- Reduced built capital (equipment, installation) costs
- Reduced land acquisition costs
- Reduced external costs (off-site costs imposed on others)
- Reduced operation costs
- Reduced repair and maintenance costs
- Reduced infrastructure replacement costs (potential for longer life of investment)

Many assessments of green infrastructure costs and benefits find that total benefits outweigh the total costs, particularly relative to grey infrastructure strategies and at comparable scales. For example, a 2007 U.S. EPA study found lower total costs for 11 of 12 green infrastructure projects when compared to equivalent grey infrastructure projects (Figure 1). The EPA study found the reliance on natural conveyance systems significantly reduced structural costs throughout the stormwater management chain. The opportunity to incorporate green infrastructure into other structures and landscaping also reduces the overall footprint of stormwater management infrastructure. Other categories of municipal costs, like flood control needs, can be reduced at the same time.

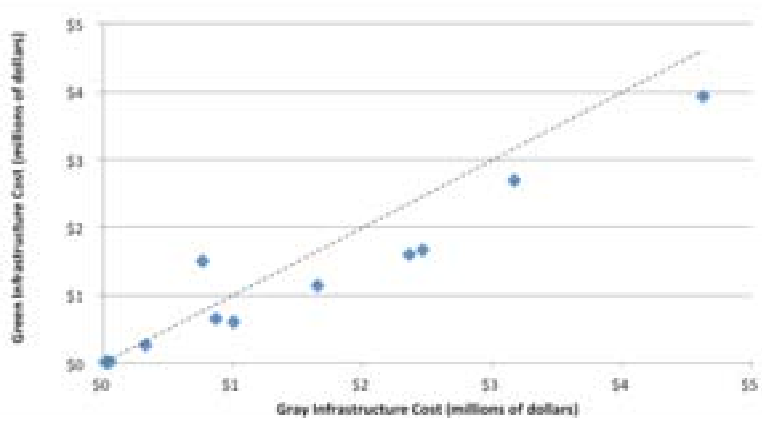



**Figure 1.** LID and Conventional Cost Comparison ($ Millions)

Green infrastructure project costs from EPA (2007) and equivalent grey infrastructure costs (n=12). Projects below the dotted line have lower green infrastructure costs than equivalent grey infrastructure costs. Only one project evaluated had higher green than grey costs. Source: U.S. EPA. 2007.

### Green Infrastructure Practices Offer Cost-Effective Solutions

*Saving Money with Green Infrastructure in Louisiana*

Chad Danos, Duplantis Design Group, PC

For many years, Episcopal High School in Baton Rouge, Louisiana, was troubled with severe flooding in the school's quadrangle because of an inadequate and aging drainage system. Estimates for re-piping the site were approximately $500,000. In 2008, BROWN+DANOS landdesign, Inc. designed bioswales and a rain garden for the five-acre space to capture one inch of rainfall and slow down the impact to the storm drain system, costing about $110,000 for design and construction. Not only does this project represent cost savings in reduced capital costs, but two years following implementation of the project, the quadrangle has yet to experience any flooding.

http://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20459%20Episcopal%20High%20School%20Stormwater%20Rain%20Garden,%20Baton%20Rouge,%20LA.pdf

## Green Infrastructure Can Be More Cost-Effective

The cost-effectiveness of green infrastructure has also been demonstrated through many municipal programs and research studies. Cost-effectiveness means value in terms of relatively low costs for the benefits provided. Both costs and benefits are critical to valuing cost-effectiveness. Green infrastructure contributes to greater cost-effectiveness than grey infrastructure by:

- Increased water quality reliability in municipal drinking water supplies, which can lower treatment costs
- Increased predictability of water quality, which can reduce long-term capital costs
- Increased longevity of water quality investments through reduced wear on system components
- Increased development benefits through increased demand and pricing for "green" properties, as shown through premiums for structures employing green infrastructure, reduced non-stormwater expenses such as heating and cooling costs, and increased lots per area available
- Multiple benefits to the public good such as flood control and groundwater recharge

## Stormwater Volume Control

Utilities, municipalities, and developers use stormwater controls to limit the volume of water that must be treated for pollutants and meet water quality and quantity regulations. By capturing, naturally treating, and infiltrating stormwater on site, these control costs are reduced or even avoided. The most straightforward assessment of green infrastructure cost-effectiveness then relies on cost comparisons to avoided grey infrastructure. The efforts in major cities across the U.S. demonstrate the potential cost savings and performance benefits. Green infrastructure approaches implemented in Chicago diverted over 70 million gallons of stormwater in 2009 from the CSO system.[15] New York City officials have proposed a plan to use green infrastructure approaches to reduce discharges into the City's combined sewer system. They project that this plan could save $1.5 billion over 20 years by including both grey and green investments rather than relying on traditional infrastructure alone.[16]

Sanitation District No. 1 (SD1) covers 220 square miles in northern Kentucky and signed a consent decree in 2007 to address combined sewer overflows and sanitary sewer overflows. The first plan developed to comply relied solely on grey infrastructure, but was seen as too costly. In response, SD1 developed an integrated watershed-based plan that provides cost savings of up to $800 million and reduced bacteria and nutrient pollution relative to the traditional grey-only plan initially developed.[17] It includes green infrastructure projects that will annually reduce CSO burden by 12.2 million gallons.

The City of Portland, Oregon has integrated green and grey approaches to stormwater management in its CSO abatement program. A cost-effectiveness analysis (using the marginal cost per gallon removed from the CSO system as a metric) demonstrated that downspout disconnections, curb extensions that include vegetated swales, and parking lot infiltration were among the most cost-effective options (including conventional) for meeting CSO abatement goals (Figure 2). The costs for these approaches ranged from $0.89 to $4.08 per gallon removed.[18]

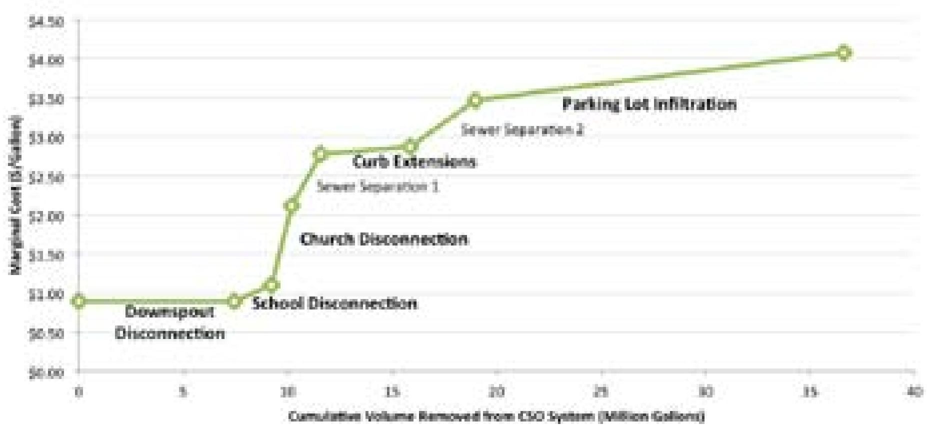



**Figure 2.** Costs and Cumulative Volume of Stormwater Removed from the CSO System through Various Grey and Green Strategies (Green in Bold). Source: ECONorthwest, with data from City of Portland 2005

© Environmental Services, City of Portland Oregon

The City of Portland, OR has been a leader in incorporating green infrastructure practices into its water management. This curb cut rain garden allows runoff from the street to flow into a rain garden where it can slowly infiltrate into the ground, rather than flowing directly into the storm sewer.

When comparing green vs. grey infrastructure improvements on a small scale, opportunities for cost savings remain. As shown in Figure 3, one general study of different options for reducing inputs into a densely urban CSO system compared various green infrastructure approaches to traditional storage tanks. This modeling showed that porous pavement would be the most cost-effective approach to diverting stormwater from the CSO system (in terms of gallons diverted), followed by a green street (rainwater harvesting that combines both treatment wetlands and curbside channels), then green roofs.[19]

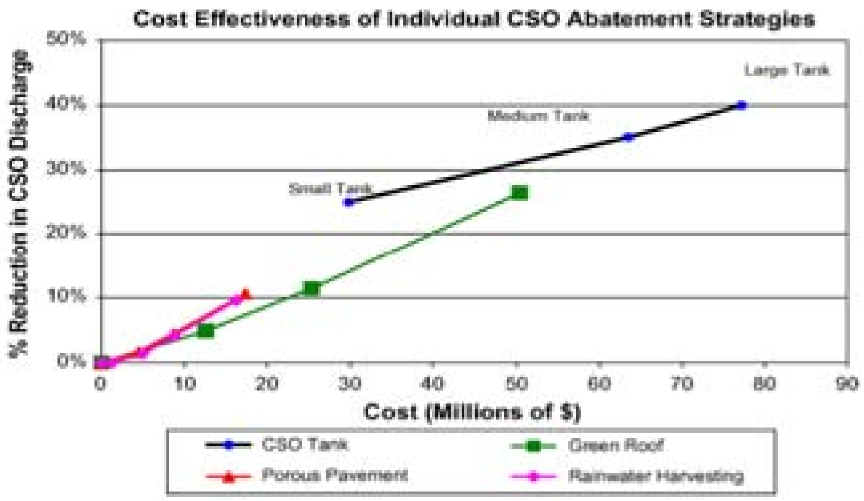



**Figure 3.** Comparison of General Green and Grey Options

Source: Montalto (2007)

## Broad Infrastructure Costs

Green infrastructure cost savings can increase when considering overall project costs beyond the direct stormwater management structures. Green streets in Seattle require less pavement, reducing pavement costs by 49%.[20] These overall project savings can extend into reduced opportunity costs. Somerset Subdivision in Maryland and Gap Creek Subdivision in Arkansas both eliminated the need for stormwater facilities that allowed the development of 6 and 17 additional lots respectively.[21] In Pelham, New Hampshire the Boulder Hills condominium development uses porous asphalt and other green infrastructure elements. While the roadways are more expensive than conventional, the overall construction costs are less than the conventional approach, particularly in the areas of drainage infrastructure, erosion control, and curbing.[22]

## Operation, Maintenance and Expected Life

Putting green infrastructure into practice requires a change not just in systems but in our approach to operations and maintenance (O&M) of stormwater systems. Properly functioning green infrastructure practices are premised on using natural processes rather than built systems, which requires a shift away from capital intensive, infrequent maintenance to less-invasive tasks that may be more frequent but less expensive overall. As grey infrastructure systems require increased operations and maintenance over time as equipment and materials wear down, green infrastructure practices are designed to increase in resilience and function as vegetation matures and adapts to local resource cycles. While green infrastructure solutions can become more effective over time, extending the infrastructure's life cycle and even performance level, it should be noted that performance may eventually diminish without proper maintenance. Coupled with the flexible, adaptable nature of green infrastructure, O&M efforts devoted to these systems can increase a community's ability to more resiliently respond to changing conditions, like increased precipitation or growth.

Like all infrastructure, most if not all green infrastructure will still require periodic maintenance for high-level functionality, although it holds the potential to be significantly less expensive over time than the equivalent gray infrastructure installation. Because the adoption of green infrastructure in the United States has accelerated only in the past ten years or so, there is limited long-term data on operational and maintenance costs. It's also important to note that a direct comparison is more difficult because O&M budgets and expenditures, for grey infrastructure systems frequently lag behind actual needs. Keeping green infrastructure working may require stormwater managers to shift to a new maintenance paradigm, and plan for regular, low capital rather than episodic, high-capital approaches.

In addition, the on-site aesthetic, energy, and other benefits that can accrue to people in the immediate vicinity provide opportunities for maintenance contributions and partnerships. Residents of Portland, Oregon report they are more willing to invest in on-site stormwater projects that provide scenic and other direct benefits in the neighborhood than those that simply reduce burden on wastewater treatment.[23] In a separate survey of Portland residents, over half reported that they would be willing to spend one to three hours per month maintaining green infrastructure vegetation unpaid.[24] Combined, the lessons of these surveys show that, where residents recognize the additional benefits of green infrastructure, the costs associated with regular maintenance may be reduced through community involvement and expanded sources of revenue.

Various other ongoing costs have been avoided as well by choosing green infrastructure. In New Hampshire, porous pavements are reducing the winter salting and plowing costs as freeze-thaw cycles cause melting and infiltration that would form ice layers on conventional pavements.[25] Similar benefits are being seen in Ann Arbor, Michigan where reports from a city street reconstruction using pervious pavement project indicate there is less ice and snow buildup than on the previous surface, and it requires less plowing and salting. During freeze-thaw cycles, melt water infiltrates rather than freezing as an ice layer. These benefits save public road maintenance expenses, improve water quality, and reduce public risk.[26] In Narragansett Bay (Providence, Rhode Island), sixty-seven privately financed LID projects remove nearly nine million gallons of stormwater per year from an overflow-prone combined sewer system. This reduction in volume saves the local utility about $0.006 per gallon ($9,000 per year) in operating costs for the CSO abatement project.[27] The City of Portland avoids conveyance costs of $0.0002 per gallon pumped ($100,000 per year) for its Swan Island CSO Pump Station by managing the water with green infrastructure.[28]

## Street Reconstruction

The Natural Drainage Projects in Seattle, Washington are some of the best-documented projects demonstrating that green infrastructure can be a cost-effective approach to rebuilding municipal rights-of-way. These projects replace portions of aging public streets, incorporating drainage features to improve the quality and reduce the quantity of stormwater runoff while maintaining or improving amenities for both vehicles and pedestrians. Data from Seattle Public Utilities, illustrated in Figure 4, indicate that the designs incorporating green infrastructure cost $217,253 less than a conventional street in overall construction costs and yield a cost savings equivalent to $329 per square foot.[29] Moreover, the green infrastructure approach has become more cost-effective over time, compared to the conventional approach. Chicago's experience with its Green Alleys programs has shown that investing in permeable pavements, downspout disconnection, rain barrels, and tree planting are estimated to be 3 to 6 times more effective in managing storm-water per $1,000 invested than conventional methods.[30] The cost estimates vary depending on the type of technology deployed. The installed cost for permeable pavement in green alleys is $0.10 to $6.00 per square foot with service life of 7 to 35 years, depending on the material employed.[31] When these costs are offset by the avoided cost of local flooding and stormwater capture and treatment, the benefits of a green streets or alleys program will frequently outweigh upfront costs.

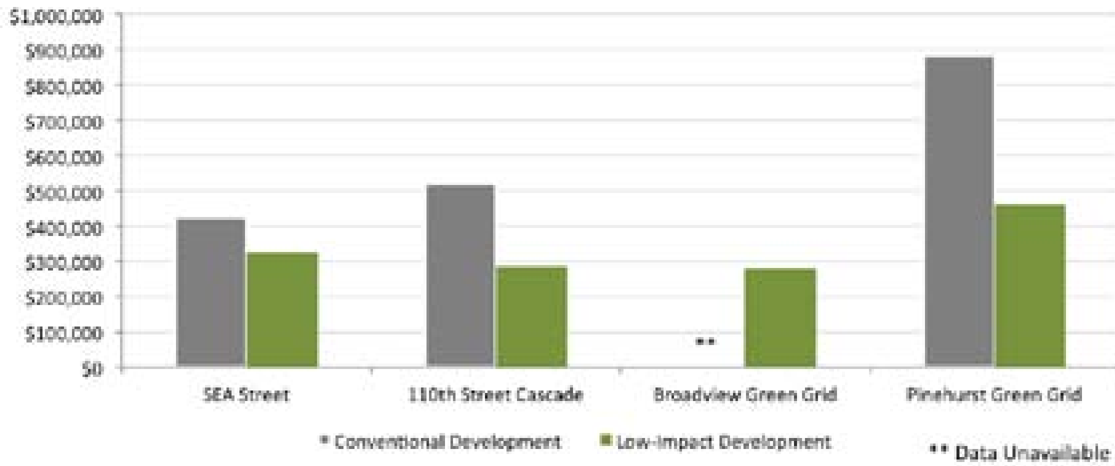



**Figure 4.** Cost Analysis of Seattle Public Utilities Natural Drainage Systems

Source: ECONorthwest, with data from Seattle Public Utilities 2002

In Seattle, city officials determined the green infrastructure approach to rebuild the Broadview and Pinehurst grids would be cost-competitive with conventional approaches, and could have saved millions of dollars if it had been fully incorporated into construction design from the beginning (the green infrastructure components of this project were added mid-project and required a modification to the contractor agreement). Across Puget Sound, the City of Bremerton, Washington received a Federal Surface Transportation grant to reconstruct its downtown commercial and residential streets. The project was designed to redevelop aging municipal infrastructure and improve bicycle and pedestrian transportation throughout the downtown area. Bremerton integrated green infrastructure into the design to address its CSO problem, through porous pavement and infiltration trenches.[32] Similarly, city employees in Ann Arbor, Michigan that worked on porous pavement construction projects saw the overall costs relative to a conventional street construction effort as competitive when comparing at the scale of new construction or reconstruction rather than simply repaving.

## Conclusions

Green infrastructure approaches offer many opportunities for cost savings and cost-effectiveness, even though their costs and performance are somewhat more dependent on local conditions than grey infrastructure. As a result, green infrastructure practices are valuable and flexible tools to complement or decrease reliance on traditional stormwater technologies. The range of costs, benefits, and effectiveness of green infrastructure techniques allows local stormwater managers to tailor solutions that are more resilient and affordable then grey-only systems. Further, as plantings mature the effectiveness of green practices may improve over time compared to more traditional, grey infrastructure, likely with diminished O&M requirements. A few important considerations to remember when considering green infrastructure costs and cost-effectiveness are:

- ***Green infrastructure construction costs can be lower than conventional costs***—Some green infrastructure projects often allow elimination or reduction of costly material components of projects, such as curbs and drains, and stormwater conveyance pipes and tanks. Others, such as green roofs, may be more expensive than traditional counterparts, but provide life-cycle efficiencies that make them less expensive over time. And finally, some green infrastructure materials might currently be more expensive than conventional versions, but because they reduce overall stormwater management needs, the total project construction costs can be reduced.

- ***Green infrastructure may not require the same extent of ongoing costs of conventional infrastructure***—A variety of costs in the conveyance, storage, and operation of stormwater infrastructure can be avoided when functioning natural systems are used to manage stormwater, even though operation and maintenance expenses may be more regular or born by different workers. With appropriate maintenance, green infrastructure practices can regenerate and strengthen over time rather than wearing down and requiring replacements leading to lower overall life cycle costs.

- ***Green infrastructure benefits can extend beyond stormwater for total project cost-effectiveness***—Green infrastructure cost savings can combine with other benefits in terms of avoided costs for other aspects of a project, such as space requirements, landscape requirements, and maintenance efforts such as to address erosion, flooding, snow, and ice. As we learn more about putting green infrastructure into practice, we will likely learn far more about these cost advantages.

## GREEN INFRASTRUCTURE SOLUTIONS REDUCE ENERGY COSTS

In today's economy, energy is money. Communities around the country are seeking ways to reduce energy consumption and spending. Implementing green infrastructure practices for runoff prevention and management can also help municipalities reduce current and projected expenses, while providing additional resiliency in the face of increasingly expensive energy supplies. These savings can be significant. One study found that adoption of widespread green infrastructure practices could save over 1.2 million megawatt-hours of electricity per year in California. These energy savings represent enough electricity to power more than 102,000 single-family homes for one full year.[33]

Green infrastructure approaches not only create benefits for water quality, but also can lead to measurable increases in energy efficiency, reduced energy demands from existing water infrastructure and a more secure power grid for local residents and businesses. Nationally and locally, considerable amounts of energy are used to heat, treat, and transport water. In fact, water and wastewater systems across the United States are some of the highest energy consumers, responsible for an estimated 3% of U.S. energy consumption annually.[34] Green infrastructure approaches to stormwater management can reduce this substantial use of energy.

Specifically, green roofs provide insulation and shade for buildings, thus reducing their need for both heating and cooling costs.[35] Street trees, when properly placed, can affect energy consumption by shading buildings, providing evaporative cooling, and by blocking winter winds.[36] Infiltration features, such as rain gardens, can reduce the amount of energy required for pumping by raising groundwater levels.[37] Water harvesting and reuse reduce the energy consumption of water utilities for conveyance and treatment.

As consumer and industrial demands on electrical grids and generation grow, green infrastructure practices which reduce demand can contribute to a greater community resiliency, mitigating the potential for disruptive black or brownouts and freeing municipal resources for other critical investments. The lessons of Washington, New York and smaller cities around the country are clear—adding green roofs, expanded urban forests, and street trees to our communities will not only provide water quality solutions, but help to reduce our nation's energy costs by billions of dollars.

### Green Infrastructure Solutions Reduce Energy Costs

*Keeping Cool with Green Roofs in Washington, DC*

In 2006, the American Society of Landscape Architects replaced the existing roof on its headquarters in Washington, D.C., with a green roof designed by Michael Van Valkenburgh Associates. The green roof offers a myriad of environmental benefits including providing improved air quality and preventing stormwater runoff from entering the area's already taxed combined sewer system. The ASLA green roof retains about 80 percent of annual rainfall and significantly reduces the amount of nitrogen entering the watershed. Further, the green roof provides an extra layer of insulation for the building, reducing building energy use by as much as 10 percent during the winter months and temperatures on the roof itself measure 59 degrees cooler than a conventional black roof in the neighborhood.

American Society of Landscape Architects

## Increased Energy Efficiency

### *Green Roofs*

Green roofs have a long history of successful implementation in Europe and a growing body of experience in America where they have been particularly favored technologies to address both new stormwater regulations and rising energy costs. While pre-existing structural considerations may constrain green roof installations on older buildings, in many cases they remain a viable and attractive option. Several U.S. municipalities have recognized the value that green roofs can bring to their efforts to reduce stormwater flows into combined sewers and impaired urban waters. Portland, Oregon's Ecoroof Project offers building owners and developers an incentive of up to $5 per square foot to install green roofs.[38] In 2011, there were 288 green roofs covering nearly 14 acres; the City plans to have 43 acres of green roofs by 2013.[39] On the opposite side of the country, Philadelphia emphasizes the role of green roofs in its ambitious plan to reduce the large volumes of stormwater that overwhelm its combined sewer system. The City offers a rebate for 25% of green roof costs up to $100,000.[40] In Syracuse, New York, Washington, DC and Chicago, developers and municipal planners are embracing green roofs for their multiple environmental and economic advantages.

In addition to keeping polluted runoff out of local waterways, green roofs also increase building energy efficiency compared to traditional roofing techniques. Because the vegetation on green roofs lowers absorption of solar radiation and thermal conductance, they can substantially reduce annual energy consumption for interior heating and cooling. Green roofs are on average 60°F cooler than black roofs in summer.[41] A Toronto study found two green roofs with minimal vegetation to both reduce peak summertime roof membrane temperatures by 35°F and summertime heat flow through roofs by 70% and 90% compared with a conventional roof, substantially reducing energy needs for cooling.[42] A study conducted at the University of Central Florida found that the maximum average day temperatures for conventional roof surface was 130°F while the maximum average for green roof was 91°F, which is 39°F lower than the conventional roof. While these reduced temperatures have a value of their own in lowering temperatures in surrounding urban neighborhoods, they also directly translate into lower energy bills for interior heating and cooling.

More detailed research shows considerable potential for benefits at the local level and across the country's climate ranges. Buildings in northern climates, with high temperature extremes and shorter growing seasons, distinctly show the energy advantages of green roofs. One recent study showed savings of $650 in annual heating and cooling costs associated with a typical, commercial-sized green roof.[43] The City of Chicago was an early pioneer in the green roof movement, installing a green roof on its half of the City-County building that is estimated to yield an annual building-level energy savings of $3,600. Following this tradition, the Chicago Department of Aviation has embarked on a sustainability campaign at the area airports that it manages. As part of this effort, by 2011 the Department could count twelve green roof installations at O'Hare and Midway Airports, covering over a quarter of a million square feet.[44] The green roof on FedEx's Main Sorting Facility at O'Hare covers nearly 175,000 square feet, captures close to two million gallons of stormwater annually, and will save the company an estimated $35,000 in energy costs per year.[45]

These energy savings are consistent with modeled results and other experiences. A Canadian model estimated that a green roof could provide savings of 6% in total cooling and 10% of heating energy usage. In the warmer climate of Santa Barbara, California, the same model estimated a 10% increase in savings from avoided cooling costs.[46] Another analysis found that using a green roof on a single story commercial facility translates to a savings of $710 from a green roof, based on energy costs of 2006 dollars, over a conventional roof.[47] The new Mary Catherine Bunting Center at Mercy Medical Center in Baltimore, Maryland installed a 17,500 square foot green roof which is not only expected to reduce energy costs by 15%, but also provides restorative gardens for patients, families, and staff.[48] Similarly, the green roof on the Target Center Arena in Minneapolis encompasses 113,000 square feet and captures nearly 1 million gallons of stormwater annually. The green roof has cut annual energy costs by $300,000.[49] Although heating and cooling needs vary from region to region, the consistent lesson of the green roof experience is that these functional alternatives to traditional roofing can provide considerable energy savings. This direct economic benefit complements the stormwater management and increased lifespan advantages of green roofs, making them an increasingly favorable option for new construction and retrofit onto existing structures.

Energy savings from green roofs can be significant not just at the local level, but on a national scale as well. By 2035 there will be 110 billion square feet of commercial real estate in the United States, an increase of 54% over 2003 levels.[50] Modeling these new roofs using National Oceanic and Atmospheric Agency (NOAA) heating and cooling data shows that if green roofs had been built on all of these new structures since 2003, business and property owners could save a total of approximately $95 billion dollars a year in avoided heating, cooling, and roof replacement costs.[51] In 2006, commercial and industrial energy costs in the United States totaled $202.3 billion, with roughly 50% of due to indoor heating and lighting. While energy consumption in this sector is growing at roughly 1% per year, widespread implementation of green roofs, with their ability to reduce indoor energy consumption by 7–10% per year, could save the American economy $7–$10 billion per year.[52]

### Green Infrastructure Solutions Reduce Energy Costs

#### *Green Roofs and Green Jobs*

Green roofs can also provide economic benefits to communities beyond stormwater management and energy savings. Wide-scale design, construction, and operation of green roofs can result in increased employment opportunities, which can in turn reduce urban unemployment or underemployment. Covering even 1 percent of large buildings in America's medium- to large-sized cities with vegetated roofs could create over 190,000 jobs and provide billions in revenue to suppliers and manufacturers that produce or distribute green-roof related materials. A $10 billion investment in water efficiency projects would produce a total economic output of $25–28 billion and create 150,000 to 220,000 jobs. Through collaborative job training and placement programs, these new jobs could further stimulate the local economy. For example, the New York non-profit Sustainable South Bronx provides training for green infrastructure jobs in landscaping, green roof installation and brownfield remediation. The organization reports that prior to training, nearly all students were on public assistance and half had prison records and afterwards 85% of graduates hold well-paying, steady jobs.

Milwaukee Metropolitan Sewerage District

### *Street Trees*

Street trees, a common green infrastructure practice for urban areas, help to retain runoff from streets, sidewalks, and parking areas. Particularly when planted along with smaller vegetation, these practices can reduce runoff by absorbing precipitation through their foliage and root systems.[53] This benefit can be significant: New York City has calculated an estimated $36 million annual benefit to from street tree runoff reductions alone.[54] As part of a broader urban forestry effort, such as the one supported by the Vibrant Cities, Urban Forests initiative, carefully designed tree plantings next to buildings, along sidewalks, and in rights of way can provide significant runoff reduction and air quality improvements.

Street trees and trees planted along building exteriors can lower surface and air temperatures through shading and evapotranspiration. Shaded surfaces are likely 20–40°F cooler than those that are non-shaded, which reduces electricity demand for cooling in summer.[55] Street and landscaping trees also reduce wind speeds, slowing heat loss in winter. Energy savings in Lisbon, Portugal due to shading and climate effects from the presence of street trees totaled $254,185 or $6.16/tree annually. For every $1 invested in tree management, these trees created a combined benefit of $4.48 in energy savings, cleaner air, increased property values, reduced stormwater runoff and $CO_2$ reduction.[56] A study of five American cities reveals a similar pattern: street trees in Berkeley, California reduced annual energy costs by $15 per tree, while the trees of Cheyenne, Wyoming provided an annual energy benefit of $11.[57] Washington, DC's urban forest, the parks and street trees which cover 28.6% of the district, reduce building energy consumption costs by $2.65 million per year.[58]

There has been considerable research into the direct energy benefits of street and neighborhood trees. In a study of the impacts of street trees in California, Lawrence Berkeley National Laboratory and Sacramento Municipal Utility District found that trees placed around houses to shade windows yielded between 7 and 47% energy savings. Other studies suggest energy savings from properly planted trees may be closer to 5–10%.[59] Given these ranges, a 10% reduction in energy use provides a conservative basis for analysis. At a national level, increasing street and neighborhood trees for cleaner water may save commercial and industrial energy users approximately $10 billion.[60] In temperate U.S. climates, this translates locally to annual savings of $50 to $90 for individual residences and buildings.[61] As demonstrated in communities across the country, comprehensive energy savings benefits are realistically attainable through proper installation of street trees as runoff reduction practices. In many cases, the overall benefits of these installations more than offsets the initial capital cost of design and installation, and continue to provide value to the community for many years.

## Reduced Energy Demand

Green infrastructure practices that capture and infiltrate rainwater where it falls can also save energy by reducing the amount of energy needed to pump and treat drinking water and wastewater. Nationally, water-related energy use (the energy used to heat, treat and pump water supplies) consumes more than 13% of our electrical production at a cost of at least $4 billion.[62] Green infrastructure approaches that capture rainfall on-site and manage it through natural processes can reduce a portion this energy use. For instance, infiltrating stormwater to recharge groundwater supplies to enhance local water supplies will reduce the energy required to transport water from distant sources. Bioretention practices can improve local groundwater recharge, although the time scale for when this water will become available for human use will vary.[63]

This variability combined with inconsistent energy costs makes it difficult to calculate global energy benefits of green infrastructure. However local and regional examples indicate that considerable savings are possible. For example, in the City of Los Angeles, increased use of green infrastructure throughout Los Angeles County could recharge groundwater supplies that would save the city from the costs of importing up to 152,500 acre-feet of water every year by 2030. This would save the city up to 428,000 MWH in energy costs, equivalent to the electricity use of between 20,000 and 64,800 households.[64] At a nominal 5.4 cents/kWh, recharge from green infrastructure could save the City of Los Angeles $23,112,000 annually.[65]

Water harvesting and reuse includes practices such as rain barrels and cisterns that can reduce energy use by saving on the need to use highly treated drinking water for outdoor water and other non-potable uses. A study of an Aurora, Illinois water utility found that the utility requires 1,300 kWh per million gallons of water treated.[66] With a local retail electricity price of 5.8 cents/kWh, this translates to more than $75/ million gallons, or $2752.10 per day for the 36.5 MGD capacity of the city's water treatment works.[67] A community-wide emphasis on rain capture and reuse could cut this financial burden significantly. More dramatically, the energy used for water supply, conveyance, treatment and distribution to Southern California users is 12,700 kWh per million gallons.[68] Cutting down on energy costs for transportation and treatment through green infrastructure could provide significant savings.

Outdoor water use often dominates household water use in the summer, and replacing drinking water quality water with rainwater saves water and energy. Approximately 30% of American water consumption is used for landscaping and other outdoor purposes.[69] In many cases, water used in industrial processes, landscaping, and toilet use can be replaced by harvested rainwater. A feasibility study for the use of rainwater harvesting systems at Texas A & M University revealed a potential $406,000 in savings per year by installing 43 rainwater harvesting systems on 113 buildings on campus.[70] At the Solaire building in New York City, up to 10,000 gallons of stormwater is collected and then re-used for irrigation and cooling.[71] Between its wastewater and stormwater reuse systems that provide water for flushing toilets, irrigation, and cooling, the building has reduced its potable water use by 50% compared to a similarly sized traditional building.[72] By re-using stormwater for non-potable uses like irrigation and groundwater recharge, green infrastructure practices can save communities money in deferred treatment costs and in avoided costs for using potable water for the same needs.

## Conclusions

Stormwater management practices built around natural hydrologic functions, water capture, and increased use of vegetation can dramatically reduce energy consumption. Green roofs, street trees, and increased urban green spaces have the effect of making individual buildings more energy efficient by reducing heating and cooling demands. On a neighborhood or community level, the shading and insulation provided by these techniques reduces urban heat islands, again reducing the energy required to cool indoor spaces during summer months. Additionally, by re-using harvested rainwater, some green infrastructure approaches decrease the need to use potable water for landscaping, toilet flushing, or other industrial uses. In turn, this reduces municipal and utility expenditures to transport, treat, and deliver potable water. As a result, green infrastructure practices not only work to improve water quality and manage stormwater, but also can play a critical role in reducing energy costs from heating and cooling and overall water treatment costs.

# GREEN INFRASTRUCTURE APPROACHES CAN REDUCE FLOODING DAMAGE AND COSTS

Flooding is the most frequent and costly natural hazard in the United States, causing more than 10,000 deaths since 1900 and considerable economic disruption to communities around the country.[73] This disruption has steadily increased in terms of the cost it imposes on residents, businesses and local governments. A 2000 study published in the Journal of Climate found that U.S. annual flood losses increased, adjusting for inflation, from $1 billion in the 1940s to $5 billion in the 1990s.[74] In 2001, there was $7.1 billion worth of flood damage nationally.[75] And while these figures are significant, it is likely that they underestimate actual flood damages since they are not verified by comparison with actual expenditures and do not capture damages from small events that frequently go unreported.[76]

Conventional approaches to stormwater management are intended to move runoff quickly from properties and neighborhoods and into detention facilities that reduce peak flows but not runoff volumes. However, the cumulative downstream impacts of this approach to stormwater control can exacerbate flooding downstream.[77] Cities and towns are beginning to recognize that green infrastructure practices provide a feasible and cost-effective alternative that manages precipitation on-site and reduces loads in local storm sewers and waterways. These solutions can not only reduce localized flooding, but can also significantly reduce negative downstream impacts in a way that traditional grey infrastructure solutions are less able to do. Beyond hydrologic benefits, green infrastructure can be incorporated into highly visible community investment and renewal projects such as greenways and parks, and typically with much lower costs, as discussed previously.

**Flooding can generally be classified as localized, riverine, and coastal:**

***Localized flooding*** is caused by runoff before it enters a storm drain or conveyance system, and is primarily a drainage issue that has been traditionally addressed by increasing the hydraulic capacity of systems to cope with increases in runoff volume and peak flow rates resulting from increasing urbanization and imperviousness.

***Riverine flooding*** occurs when natural stream flow exceeds the carrying capacity of the river or stream's main channel and areas beyond the river banks become inundated.

***Coastal flooding*** occurs when coastal areas are flooded as result of storm surge—ocean waters being driven inland, most commonly by tropical storms, astronomical tides, or less commonly as a result of tsunamis driven by earthquakes.

## Urbanization Contributes to Flooding Losses

Increased urbanization over the past century has resulted in a steady shift from natural landscapes to increasing levels of hardscapes and impervious surfaces such as roads, driveways, parking lots, sidewalks, and rooftops. The impact of impervious cover is directly correlated to an increase in runoff volumes, flow rates, and frequencies in urban and developing watersheds and a substantially increased frequency of moderate flooding. One study estimates that a flood event occurring once in 100 years in a watershed in the Maryland suburbs of Washington, D.C. could occur as frequently as once every five years in the same watershed if impervious area increased to 25%. Similarly, a total impervious cover of 65% in the same watershed could make this flood event occur every year.[78] For example, one researcher noted that the frequency of daily discharge that exceeded 1,000 $ft^3/s$ on the Northeast Branch of the Anacostia River in Maryland increased from once or twice per year in the 1940s and 1950s to as much as six times per year in the 1990s as the area was converted into urban and suburban development.[79] These increases in both peak flows and durations can result from even moderate amounts of watershed development, such as 5 to 10% impervious area. In Southern California, researchers showed 5% increases of the 2-year peak flow at 5% watershed imperviousness, 2-fold increases at 10% imperviousness, and 5-fold increases at 20% imperviousness. Durations of event the largest flows increased by 25% at 5% imperviousness, 60% at 10% imperviousness, and 160% at 20% imperviousness.[80]

Increased runoff as a result of urbanization can lead to more frequent and higher volume floods and dramatically increase stream-channel erosion.[81] The largest relative increases in erosive flows are often the result of smaller storms, which erode stream channels, undermine property and infrastructure, and carry significant amounts of sediment downstream.[82] These small but erosive storm events range between the 0.5-year and the 1.5-year storm in urban areas, and over time, the cumulative impact of these smaller and more frequent storm events that carry enough energy to be erosive is often greater than the onetime damage associated with larger floods.[83,84] The potential for damages caused by smaller storms is one incentive for employing management strategies like green infrastructure that effectively reduce peak runoff volumes in precisely these types of storms.

In fact, the Federal Emergency Management Agency (FEMA) estimates that up to 25% of economic losses resulting from flooding occur in areas not designated as being in a "floodplain," but as a consequence of urban drainage.[85] Since 1978, the National Flood Insurance Program (NFIP) has paid over $2.8 billion in claims, related to localized flooding.[86] Flooding causes extensive and far-reaching damage to public and private property as well as community infrastructure. For instance, flooding in Montana in June 2011 caused an estimated $8.6 million in damage to public infrastructure across the state, and the figure is expected to keep rising. [87] A 1983 flood in Tucson, Arizona resulted in channel widening up to 246 feet, causing land that was designated as outside the 100- and 500-year floodplain to collapse into the channel, with $105 million in total damage.[88] According to a National Cooperative Highway Research Program (NCHRP) report, costs to repair over 2,000 damaged sites on federal aid highways from the flooding along the Mississippi River in 1993 was estimated to be in excess of $158 million.[89] Disruptions to business, loss of income and tax revenues, reductions in property values, and transportation delays can all add additional economic burden to flooded communities. A year after a major flood in Cobb County, Georgia, typical appraisals showed that property values were depressed 6.9% below market value. The county's residential tax digest—the value of real and personal property that governments use to estimate tax revenues and determine budgets—has dropped 10%, or $5 billion, in 2010.[90] Flooding also adversely affects environmental and social aspects of a community through individual and community distress and hardship and can negatively impact public health through the spread of illness.

Many communities across the country experience these impacts regularly and need improved measures to avoid or mitigate these costs. Green infrastructure practices are uniquely suited to addressing the relationship between land use and water resources by attempting to replicate the natural hydrology of the landscape. The infiltration, evapotranspiration, and on-site management advantages of green infrastructure can provide improved rainfall-runoff responses, thus reducing flood hazards and the associated economic losses.

## Role of Green Infrastructure and Flood Control Management

Conventional stormwater management has focused on removing stormwater from a site as quickly as possible to reduce on-site flooding. However, this approach has proven to be devastating to downstream communities by increasing flows and total discharges from storm events and causing scouring of streams which often damages municipal and public infrastructure. In addition, frequent flooding in urban streams increases channel and bank erosion, creating an ongoing threat to roads, bridges, and other public infrastructure.[91] Green infrastructure techniques focus on reducing the excess runoff at the source through infiltration, evapotranspiration, and beneficial use of stormwater. Most commonly, these systems target the capture and infiltration of runoff associated with 90 to 95% of storm events that occur annually in most U.S. communities. These systems have a growing record of reducing runoff from smaller and more frequent rain events, and while they do not target low-frequency high-volume rainfall events, some research suggests green infrastructure may help to manage larger events as well. From rain gardens to restored wetlands, green infrastructure technologies can provide the equivalent, or better, control for small-storm flooding events than detention-based stormwater management approaches as well as providing enhanced water quality treatment while potentially helping to manage events beyond high-frequency storms.

## Green Infrastructure Approaches Can Reduce Flooding Damage and Costs, Role of Green Infrastructure and Flood Control Management

### *Green Infrastructure and Flood Control in Ohio*

The City of Cuyahoga Falls, Ohio used FEMA funds to acquire four flood-damaged residential properties located in a neighborhood which has suffered from repetitive flooding. The City intends to demolish the structures and turn parts of the newly created open-space into a series of rain gardens to mitigate localized flooding in the area. The innovative design measures of this Rain Garden Reserve create an additional 5 five acres of storage for runoff, and enhances outdoor educational and recreational opportunities for the community. (City of Cuayoga Falls, 2008)

City of Cuyoga Falls, Ohio (2008), "Rain Garden Reserve." Accessed December 2011, Available online at <http://planning.co.cuyahoga.oh.us/infrastructure/pdf/raingarden.pdf>.

City of Cuyahoga Falls

## Flood Control Benefits of Green Infrastructure

Green infrastructure practices provide a variety of benefits across the range of flood magnitudes. Common green infrastructure practices used to target flood management include green roofs, bioretention, water quality swales, and infiltration basins and trenches. While most effective at managing localized flooding, runoff volume capture can also significantly reduce the impact of larger scale riverine flooding events. Recent research on the impacts of green infrastructure employed on watershed-scale flooding suggests that green infrastructure can be effective at reducing peak flows for large infrequent storm events as well as provide noticeable volume reduction for more frequent storms. The ability for green infrastructure to address flooding at a variety of scales can lead to significant reductions in flood loss damages on an average annual basis.[92]

***Localized Flooding:*** The advantage of green infrastructure to alleviate local urban flooding in an urban setting by minimizing runoff volume and peak discharges within small urbanized catchments is evident. One such example is the City of San Francisco's Sewer System Master Plan that has incorporated a planned approach to implement green infrastructure (and low impact development (LID) techniques) as a part of their long-term strategy for the management of wastewater and stormwater. This approach includes identifying and prioritizing projects that can integrate green infrastructure into built-out neighborhoods and can harness existing green spaces for stormwater management, thereby resulting in reduced flooding and CSOs. One of the projects underway includes pocket parks, pervious paving, street trees and stormwater retention on a block of Newcomb Avenue, which is located in a flood-prone area of the City.[93]

***Riverine Flooding:*** When communities employ green infrastructure combined with appropriate management requirements, retrofit programs, and riparian preservation that function at a macro or watershed level, they can also reduce riverine flooding impacts. Thomas and Nisbet identified that by reducing the volume of runoff (e.g. by intercepting rain and providing storage areas to hold water in the catchment and on floodplains), promoting water infiltration into the soil, and slowing and reducing runoff to streams, runoff peak flows can be delayed and minimized. The effect of runoff capture on peak flow reduction and delay has been documented in research literature.[94,95] This effect helps to address a consistent problem in urbanized watersheds—the flashy peak flows caused by directly connected impervious surfaces and conveyance systems designed to move runoff as quickly as possible. The infiltration, evapotranspiration, and slow release associated with green infrastructure approaches can control flood flows throughout a watershed, which in turn will reduce flooding in higher order river and stream systems.[96] Another way riverine flooding is being addressed with green infrastructure is with river and floodplain restoration through greenway developments along flood-prone areas. Johnson County, Kansas, which had experienced significant floods along the Chagrin River in the past, opted to spend $600,000 to develop riparian setbacks and a park system rather than $120 million on traditional flood control projects.[97] Restoring a well-connected 'green' floodplain can reduce community flooding by providing flood attenuation and increased transmission storage.[98]

***Coastal Flooding:*** Naturally occurring "green infrastructure" such as dune systems, wetlands (also known as living shorelines), and salt marshes can provide water storage and retention areas, mitigate tidal surges, reduce coastal erosion, and help to alleviate coastal flooding. The South Bay Salt Pond Restoration Project in the San Francisco area is the largest tidal wetland restoration project on the West Coast, and efforts are underway to transform 15,100 acres into a mosaic of tidal wetlands and managed pond habitats. One of the approaches being considered at the San Francisco Estuary, as part of South Bay Salt Ponds restoration project is a "living shoreline" of wetlands, natural stones, and sturdy plants created along shore margins and used as components of a protective strategy.[99]

***Climate Change, Flooding, and Green Infrastructure:*** Global climate change will likely impact all forms of flooding. Over the coming century, climate change experts predict that urban regions will be forced to manage extremes in precipitation and temperature and sea-level rise. It is anticipated that episodic events (e.g., flooding and drought) will increase across the country,[100] which will place a strain on an infrastructure system that is already under great stress. Green infrastructure is a flexible and resilient approach that has an important role to play in the adaptation to and mitigation of climate change by "working with nature's capacity to absorb or control impacts in urban and rural areas than simply focusing on physical infrastructure."[101] By being adaptive, green infrastructure will more readily change with the expected increase in volatile climatic conditions.

### Adapting to Coastal Climate Change Impacts with Green Infrastructure

Community concerns over combined sewer overflows (CSOs) and flooding in low lying neighborhoods drove interest in green infrastructure approaches to address the problem. After significant damage from a flood in 2004, San Francisco began to integrate green infrastructure planning into its Sewer System Master Plan. Relying on an integrated watershed management strategy that blends green and grey solutions, San Francisco has adopted new stormwater ordinances and standards that emphasize on-site management; evaluating the potential flood reduction benefits of daylighting four creeks, and an aggressive "Better Streets" retrofit program. Taken together, these approaches will significantly reduce stormwater volumes, minimize future flooding, and help make the city more resilient to coastal climate change impacts. (San Francisco Public Utilities Commission, 2010)

San Francisco Public Utilities Commission, (2010), "DRAFT San Francisco Sewer System Master Plan (Appendix W – Low Impact Development), June 2010", Accessed December 2011, Available online at <http://www.sfwater.org/modules/showdocument.aspx?documentid=650>

## Economic Benefits

The economic benefits of green infrastructure can be quantified as a combination of the decreased costs of damage resulting from flooding and the reduced cost of constructing stormwater management and drainage infrastructure through the use of low impact development approaches to land development. This approach includes reduced costs associated with higher-density "cluster" development and the limited use of impervious cover onsite, which leads to a decrease in excavated area and volume of runoff generated from the site. Using this approach by itself leads to a reduction in the size and scope of conventional drainage infrastructure and stormwater management practices, such as curb-and-gutter, inlets, catch basins, pipes, and detention or retention ponds. When combining this approach with the use of infiltration-based green infrastructure practices, the need for stormwater infrastructure is further decreased, which can generate significant cost savings over traditional land development and conventional stormwater management approaches.

To cite some specific examples, EPA recently released a report that summarizes 17 case studies of developments that include green infrastructure.[102] In most cases, significant savings were realized for site grading and preparation, stormwater infrastructure, site paving, and landscaping. The study estimates that capital cost savings ranged from 15 to 80% when green infrastructure was used, with a few exceptions in which costs were higher than conventional stormwater management costs. In addition, there are benefits that the study did not monetize but none the less often factor into a project's profit: improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential and faster sales, reductions in long-term operation and maintenance costs, and reductions in the life cycle costs of replacing or rehabilitating infrastructure. To quantify these savings for context, other research has indicated that the cost of a conventional stormwater conveyance system typically ranges between $40–$50 per linear foot, such that eliminating one mile of curb and cutter could save up to approximately $230,000, conservatively.[103] We cannot simply view cost savings through a lens of infrastructure elimination, however, as water quality and quantity treatment is still required after drainage infrastructure is minimized and eliminated, and this treatment comes at cost. Two examples from the University of New Hampshire's Stormwater Center illustrates the types of savings from infrastructure reduction even after progressive water quality and quantity treatment is provided through the implementation of LID and green infrastructure practices. Boulder Hills, a residential development in New Hampshire that was discussed previously, reduced their construction costs by 6% while generating additional resident lots within the same development project while establishing a "zero discharge" site through low impact development techniques and green infrastructure practices. Greenland Meadows, a commercial "big box" site, reduced construction costs by nearly $1 million, which translates to 10% of total construction costs, by using pervious asphalt, which limited the amount of drainage inlets and pipes, and a constructed wetland, which provided enhanced stormwater management over conventional treatment techniques.[104]

### Green Infrastructure to Reduce Flooding in Illinois

The Blackberry Creek Watershed, which is located west of Chicago, Illinois, is an urbanizing area that drains into a 73 square mile watershed in south central Kane County and north-central Kendall County. A study of the area by Johnston, Braden and Price (2006) modeled conventional and green infrastructure approaches using green infrastructure techniques and simulated storm flows in the stream network of the study area. The authors concluded that the green infrastructure approach can increase stormwater runoff volume storage and decrease peak flows for a 50-year flood event by approximately 25% and around 22% for a 100-year event. Green infrastructure technologies can also reduce flood water surface elevations, which means that property values, due to reduced flooding, could increase by as much as 5% and avoided costs in downstream culvert replacement and upgrades could equal over $3 million. (Johnston, et al, 2006)

Johnston, D.M., J.B. Braden and T.H. Price, (2006), "Downstream Economic Benefits of Conservation Development," Journal of Water Resources Planning and Management, American Society of Civil Engineers, 132(1): p 35–43.

Braden, J. and A. Ando, (2011), "Economic Costs, Benefits, and Achievability of Low-Impact Development Based Stormwater Regulations," in Economic Incentives for Stormwater Control, edited by Hale W. Thurston, Boca Raton, FL: Taylor & Francis.


Capitol Region Watershed District

Polluted runoff is a major source of water pollution in the Capitol Region Watershed District (CRWD) in St. Paul, Minnesota. The CWRD incorporated green infrastructure practices like these rain gardens to reduce local flooding and improve water quality.

While flooding impacts are inherently tied to the benefits provided by the use of green infrastructure in the case studies cited above, an example of a situation that is more directly tied to flooding issues is the Arlington-Pascal Stormwater Improvement project in the Capitol Region Watershed District (CRWD) in St. Paul, Minnesota. The CRWD covers an area that is highly urbanized as reflected by 42% impervious cover within the District bounds. Urban stormwater runoff was a major contributor to the localized flooding problems as well as poor water quality found in a significant receiving water body, Como Lake. The Arlington-Pascal Stormwater Improvements project made use of green infrastructure and low impact development techniques (LID), such as infiltration trenches and rain gardens, infiltration trenches, and a perforated parallel pipe system rather than conventional stormwater management approaches that would have provided flood management, but no water quality benefits. The fundamental project goal was to improve the water quality of Como Lake while addressing the localized flooding issues. Although several plans were evaluated, ultimately the green infrastructure-based solution was chosen because it saved $1 million, a 45% reduction compared to the conventional stormwater management option. Monitoring was performed in 2007 and 2008 for Total Phosphorus (TP), Total Suspended Solids (TSS), and runoff volume reduction which showed that flow reduction goals were met, thus alleviating flooding impacts, with the additional benefit of water quality treatment provided by BMPs that exceeded performance expectations.[105]

Another aspect of economic benefits of green infrastructure related to flooding is the avoided flood losses that can result from application of green infrastructure practices and the resulting impacts to properties affected by flooding. For instance, the Center for Neighborhood Technology estimates that marginal flood reduction leads to an increase in the value of floodplain property by up to 5%. To be effective as a flood reduction measure, green infrastructure needs to be deployed on significant portions of a watershed. For example, in a watershed in the Southeastern United States, a study showed that green infrastructure can decrease flood losses by amounts ranging between $9,000 per acre of floodplain for the 100-year event to $21,000 for the 2-year event.[106] These avoided damages are highly dependent on physical and economic factors in a given watersheds and need to be estimated using these site-specific conditions.

## Conclusion

Flooding is a costly phenomenon that affects public and private properties and disrupts economic activity. These events also threaten the public welfare and place an emotional and social burden on impacted communities.

Economic impacts due to flooding of all types and magnitudes are significant; however, the severity of impacts varies depending upon the type, frequency and size of the flood event. Although large flood events impacting riverine systems may lead to catastrophic damages and costs, these events occur relatively infrequently. Smaller events are generally more frequent and widespread, so although the damages tend to be smaller in scale, the higher number of events can create a greater overall economic burden on communities.

The traditional approach to reducing the impacts of flooding has been to capture, convey, and release runoff with an emphasis placed on large storm events. Green infrastructure approaches that employ infiltration, evapotranspiration, rainfall capture, and other site retention techniques, capture of smaller events in an effort to restore the hydrologic function of an area as well as improve and enhance water quality. Because a significant portion of the flood losses is associated with small, frequent storms, green infrastructure is well-suited to manage these flows, and therefore, provides significant flood loss reductions on an average annual basis

The literature illustrates that this type of flood control is cost-effective for small flood events, and also highlights that widespread use of green infrastructure at a watershed scale can also provide measurable flood control benefits for larger, less frequent events. On-the-ground case studies from a variety of locations across the country have also documented the effectiveness of green infrastructure to not only reduce runoff volumes and provide water quality treatment, but also to help address flooding impacts in a cost-effective manner. Add to this the many co-benefits of green infrastructure, which include improved air quality and public health, reduced heat-island effects, greater aesthetic appeal, and an enhanced dimension of flexibility and resiliency. It is clear that green infrastructure is an approach that should be considered when addressing flood impacts for all communities.

# GREEN INFRASTRUCTURE APPROACHES PROTECT PUBLIC AND ENVIRONMENTAL HEALTH: PREVENTING DISEASE AND PROTECTING LOCAL ECONOMIES

Polluted runoff poses a threat to public health by contaminating the rivers, lakes, and coastal waters where we swim, boat, fish, and take our drinking water supplies from. Toxic chemicals such as insecticides and polychlorinated biphenyls (PCBs) as well as heavy metals like copper and lead that make people sick can all be found in polluted runoff. [107,108] Gastrointestinal illness and infection can occur when people swim in or eat shellfish from waters contaminated by bacteria, sewage, or excess nutrients that cause toxic algal blooms. [109,110] When nitrogen, a common pollutant in runoff, contaminates drinking water supplies it can cause methemoglobinemia, where nitrate or nitrite inhibits the blood's ability to deliver oxygen to the body. Babies and young children are particularly susceptible to the effects of high nitrogen in water.[111] From the heavy metals and excess nutrients that get picked up by stormwater to the raw sewage that is discharged directly into our waterways during CSO events, polluted runoff is the primary cause of impairment for almost 40% of water bodies across the country that fail to meet water quality standards.[112]

Green infrastructure practices can reduce pollutant loadings into our waters, which can help to minimize illness from recreational contact or contaminated drinking water. The resulting improvement in local water quality can result in lower health care costs for communities and minimize the economic impacts of beach and shellfish fishery closures. Green infrastructure solutions can also improve air quality which helps to reduce asthma rates, mitigates the urban heat island effect to lower heat stress related fatalities, and improves and increases green space for recreation. As part of a comprehensive stormwater management plan, green infrastructure practices can provide an economic benefit to communities beyond clean water.

## Green Infrastructure Reduces Bacteria and Pollutant Loads

A significant portion of the pollution that contaminates our nation's waters, drives the closure of beaches and shellfish harvest areas, and makes water unsafe for drinking, comes from stormwater runoff. Urban runoff was the primary source of impairment for 13% of rivers, 18% of lakes, 32% of estuaries, and 55% of ocean shorelines across the country under EPA's regularly updated list of the nation's impaired waters.[113] To put this into perspective, urban areas cover only 3% of the land mass of the United States.[114] This demonstrates the significant impact that runoff from urbanized areas can have on water quality.

Incorporating green infrastructure into stormwater management plans helps to protect public health by reducing the amount of polluted runoff entering surface waters used for recreation and drinking water supplies. Often, outbreaks of waterborne disease are correlated with heavy rainfall when combined sewers systems are most likely to be overloaded and send high volumes of polluted runoff and raw sewage into our waters.[115] Water pollution associated with stormwater runoff imposes costs to community health and economic viability from increased hospital visits and missed work days to reduced revenues for the tourism industry when beaches are closed. Updating stormwater infrastructure can minimize these costs by integrating forward-thinking management practices to capture rainwater where it falls, keeping it out of sewer systems and reducing the pollutants that enter rivers and lakes that make people ill.

### *Minimizing Costs from Illnesses Related to Recreational Contact with Polluted Runoff*

In the EPA's 2006 *Report to Congress*, the Agency found that CSOs and SSOs caused at least 5,576 illnesses every year from exposure at recognized recreational beaches across the country. The number of illnesses is likely much higher because EPA's analysis was limited to gastrointestinal illness alone and did not evaluate illness at inland or unrecognized beaches.[116] In a 1998 study of bathers and non-bathers, 34.5% of gastroenteritis infections and 65.8% of ear infections that were reported were linked to swimming in ocean waters that were contaminated by sewage, resulting in at least one lost day of normal activity due to the illness from between 7% and 26% of participants who became ill.[117] A study of over 13,000 swimmers in Santa Monica Bay found that those swimmers who swam within 100 yards of a storm drain experienced increased incidences of gastrointestinal illness with rates highest for those who swam nearest the storm drain outlet.[118]

Illnesses attributable to water contaminated by urban runoff can have a significant economic impact. Every year, up to 3.5 million people become sick from contact with water contaminated by sewage.[119] A 2004 study of Huntington Beach State Beach and Newport Beach in California determined that the cost of illness from water-borne gastrointestinal illness was $36.58 per person in lost work days and medical costs, not including lost recreational values or willingness-to-pay of individuals to avoid getting sick.[120] Another study of 28 popular yet polluted beaches in Southern California calculated that swimmers suffered an estimated 1.5 million gastrointestinal illnesses, resulting in an economic loss of between $21 million and $51 million every year.[121] For two beaches in California, illness associated with swimming in water contaminated by polluted runoff at those beaches cost the public over $3 million every year.[122]

Incorporating green infrastructure practices into stormwater management and combined sewer mitigation plans can reduce the downstream transport of pollutants, minimizing the impacts on receiving waters used for recreation. This can help to make communities healthier as well as save money in avoided medical costs. For instance, the City of Philadelphia's 'Green City, Clean Waters' plan proposes to use green infrastructure to reduce runoff into combined sewers by 80 to 90% and provide residents of the city with additional benefits that residents would not receive with traditional grey infrastructure solutions.[123] Philadelphia projects that after 45 years, the program's benefits will generate more value in benefits than its costs to the City.[124] Reducing polluted runoff that flows into rivers, streams, and coastal waters is a cost-effective strategy to ensure that these waters are safe for swimming, boating, and fishing.

**Reducing Pollutants in Local Waters in Washington, DC**

A 2007 study of Washington, DC found that the use of urban trees and green roofs for stormwater management would keep 1.2 billion gallons of runoff out of the water infrastructure system. This equals a 10% reduction in untreated discharge entering local rivers and would reduce the frequency of combined sewer overflows by almost 7%. At the minimum, this would keep an estimated 120 pounds of copper, 180 pounds of lead, 340 pounds of phosphorous, and 530,000 pounds of total solids among other pollutants out of local waterways every year.

'The Green Build-Out Model,' Casey Trees, 2007, p. 4–3, 4–6.

U.S. Environmental Protection Agency

## *Mitigating Economic Losses to Communities from Closed Beaches and Fisheries*

Poor water quality as a result of polluted runoff and combined sewer overflows has a negative impact on local economies that depend upon fisheries. The National Oceanic and Atmospheric Administration (NOAA) reported that CSOs are a significant source of pollution for shellfish beds and fisheries. In fact, NOAA estimated that CSOs were linked to harvest restrictions on nearly 600,000 acres of shellfish beds in 1997.[125] Shellfish harvesting is prohibited or highly limited in 40% of existing harvest areas because of high bacteria levels primarily due to the presence of urban runoff discharges.[126] In the Puget Sound, one harvest area alone lost $3 million in shellfish sales due to forced closures.[127] An EPA study found the contamination and loss of aquatic species and habitats from polluted stormwater runoff costs the commercial fish and shellfish industry up to $30 million every year.[128] Illness and death caused by eating contaminated seafood is estimated to cost local economies an average of $22 million per year from missed work days, medical expenses, and investigation of the contamination.[129]

Beach closures put in place to protect the public from contaminated waters can have a significant economic impact as well. In the travel and tourism industry beaches are the top destination spot for travelers. Tourism associated with coastal states comprise 85% of total US tourism revenues, with the average American spending 10 recreational days along the coast every year.[130,131] Across the country, coastal and marine waters support 28.3 million jobs which depend upon safe, clean water.[132] According to the National Research Council, in 2011, 36% of beach closures across the country were due to "polluted runoff and stormwater."[133] Pollution-related beach closures result in job loss and threats to local economies. A study of Zuma Beach and Huntington State Beach in Southern California estimated the economic losses if Zuma Beach was downgraded from a "Grade A" beach to a "Grade F" to be $1,284,157 annually, and it would cost the local community $864,438 if Huntington State Beach were closed for a month.[134]

### Portland, Oregon Reducing Pollution into Willamette River Using Green Infrastructure

Combined sewer overflows from the City of Portland contribute over 40% of the bacteria loading in the Willamette River. This poses a public health risk to swimmers and boaters when the river fails to meet water quality standards and contaminates fish with PCBs, dioxins, and pesticides that can make them hazardous to eat. In 2008, the City initiated its 5-year Grey to Green Initiative (G2G) to improve water quality, air quality, and community livability in addition to its existing CSO reduction plan. Under the G2G plan, the City intends to build 43 acres of green roofs which are estimated to reduce peak flow of runoff flow by 93% and reduce total suspended solids (TSS) by 80% from 92 acres across the city. As of August 2010, 4.7 acres of green roofs have been built and 325 green streets have been put in place which put the City on track to expand its green infrastructure and improve water quality by reducing pollutant loadings into the Willamette River.

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http://www.deq.state.or.us/wq/pubs/factsheets/willamette/bacteria.pdf

http://www.portlandonline.com/bes/index.cfm?a=298042&c=52055

In Pittsburgh, Pennsylvania and the surrounding Allegheny County, as little as one-tenth of an inch of rain can cause combined sewer overflows to send raw sewage into Pittsburgh's three rivers. CSO events that make the rivers unsafe for recreational contact occur for as many as 70 days during boating season. Not only are the Ohio River and its principle tributaries, the Allegheny, Monongahela and Youghiogheny, important rivers for recreation, they supply drinking water to 90% of Allegheny County residents.[135] Green infrastructure projects like the green roof on the McGowan Institute for Regenerative Medicine that will capture and reuse 168,000 gallons of stormwater every year and the restoration of Nine Mile Run and Frick Park that will restore wetlands work to reduce pollutant loadings in local waters. By capturing and treating rainwater where it falls, green infrastructure practices can reduce the pollution in rivers, lakes, and coastal waters that can make people sick.

## Green Infrastructure Creates Healthier Cities

Land cover in many urban areas is dominated by impervious cover. Studies show that water quality becomes degraded when total impervious surface exceeds 10%, and in some cases at even lower levels.[136] This indicates that a close relationship exists between urbanization and water quality. However, the effects of impervious surface aren't limited to water quality alone. Significant levels of impervious surface play a role in decreased air quality and exacerbating the urban heat island effect. Buildings, pavements, and rooftops absorb heat from the sun which raises the temperature of stormwater runoff flowing over these hard surfaces and increases the surrounding air temperature. [137,138] Higher air temperatures worsen the impacts of heat waves which may lead to heat stroke and even death in vulnerable populations and accelerate the chemical reactions that cause smog and ozone to form which can trigger asthma and reduce lung function.[139,140] Green infrastructure practices offer a cost-effective way for communities to manage polluted runoff while at the same time increasing vegetated and natural areas, or green space, in their communities that provides significant public health benefits.

### *Mitigating the Urban Heat Island Effect*

Many cities across the country are plagued by summertime urban heat islands which detract from local quality of life and create health problems for local residents. This is a direct effect of urbanization where hard surfaces like parking lots and rooftops can be 50–90°F hotter than the surrounding air, causing higher temperatures in urban areas compared to more rural areas.[141] Characterized by higher temperatures, even at night, and increased air pollution levels, the urban heat island effect can exacerbate the impact of heat waves particularly for sensitive populations. The Centers for Disease Control and Prevention calculated that the premature deaths in the US that occur as a result of exposure to extreme heat outnumber total deaths from hurricanes, lightning, tornadoes, flooding, and earthquakes combined.[142] Not only do higher temperatures put the elderly and those with poor access to public transportation and air conditioning at risk, but they also increase the formation of ground level ozone. A study in Los Angeles found that every increase in 1°F above 70°F results in a 3% increase in ozone levels, which have been shown to trigger asthma attacks and may even lead to the development of asthma in children.[143] Increasing green space through green infrastructure practices such as building green roofs or planting rain gardens and trees can mitigate the urban heat island effect and the negative public health and economic consequences that result.

Even small reductions in temperature can have significant benefits to public health. Green roofs in particular not only capture rainwater onsite but provide shade for roof surfaces that lowers temperatures within buildings and decreases the heat that is re-emitted back into the atmosphere. Plants growing on the green roof cool the surrounding air through evapotranspiration by absorbing water through their roots (transpiration) and releasing it back into the air (evaporation). Multiple studies have demonstrated the cooling power of green roofs. One study in Florida found that the average surface temperature on a green roof was 86°F compared to the adjacent traditional roof which had an average surface temperature of 134°F.[144] An analysis of green roof implementation in New York City estimated that by covering 50% of the city's flat rooftops with green roofs would result in a city-wide decrease in temperature of 1.4°F.[145] Even pervious pavements have been found to store less heat and have higher cooling rates than traditional pavement.[146] A 2006 study in the City of Philadelphia found that 196 heat-related fatalities could be avoided over a forty year period through the use of green infrastructure to manage polluted runoff and reduce combined sewer overflows. Based on the EPA's value of a statistical life (VSL) in 2006, reductions in urban heat island related fatalities in Philadelphia could save the public over $1.45 billion.[147] Green infrastructure practices not only capture water onsite to keep it out of the system, but they provide benefits to public health by reducing temperatures to mitigate the urban heat island effect, which in turn can reduce economic costs caused by heat-related illness and fatalities.

### *Improving Air Quality*

Increasing green space through green infrastructure practices like green roofs can improve air quality, particularly in urban areas, because the trees and plants that are critical components of these technologies are able to remove common air pollutants like nitrogen dioxide, ozone, sulfur dioxide, and some particulate matter.[148] These pollutants can trigger asthma attacks as well as worsen bronchitis, emphysema, and other respiratory diseases.[149] A 2008 study of green roofs in the City of Portland, Oregon found that each square foot of green roof removed 0.04 pounds of dust and particulate matter out of the air. Their analysis found that one 40,000 square foot green roof would remove 1,600 pounds of particulate matter from the air every year and would yield $3,024 annually in avoided healthcare costs.[150] The City of Chicago estimated the economic benefits of greening 10%of the City's rooftops with green roofs could remove 17,400 Mg of nitrogen dioxide every year which would result in avoided public health costs of $29.2 million to $111 million annually.[151] The Urban Ecosystem Analysis of Washington, DC demonstrated that tree cover in the city not only saved $4.7 billion in avoided stormwater storage costs, but also created $49.8 million in annual air quality savings by removing 20 million pounds of pollutants from the air every year.[152]

Green infrastructure practices provide tangible and economic public health benefits to local communities that extend beyond their more obvious role in protecting water quality. By increasing the amount of green space, from parks to urban forests, these stormwater management practices can prevent or reduce the economic and human losses associated with poor air and water quality.

**Avoiding Public Health Costs with Green Infrastructure in Philadelphia, PA**

The City of Philadelphia found that in comparing a plan using significant investments in green infrastructure practices versus building large tunnels to address its combined sewer overflows, the green infrastructure option not only saved them money, but also provided benefits to public health. Across the City, health effects avoided using the green infrastructure option included 1 to 2.4 premature fatalities avoided every year and over 700 cases of respiratory illness days avoided per year. Avoided healthcare costs were estimated to be $130 million over 40 years.

'A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds,' Stratus Consulting, 2009, p. 4–7.

Abby Hall, Nancy Arazan, U.S. Environmental Protection Agency

### *Increasing Recreational Space*

With nearly 80% of Americans residing in urban areas, many communities face problems associated with poor public health, economic decline, and a lack of access to green space and recreational opportunities.[153] Increased vegetated cover through the implementation of green infrastructure practices not only helps to keep temperatures cooler and improve air quality, but it also can improve recreational opportunities in urban and ex-urban sprawl areas. Lenexa, Kansas has embarked on an ambitious "Rain to Recreation" program that implements and maintains water quality protection and flood control projects "that protect the natural and developed environment, while providing public education, involvement and recreational opportunities."[154] The city's regional detention basins, stream and pond restoration projects create recreational opportunities while using natural functions to manage runoff.[155] By making it easier and safer for people to get outside and stay active, green infrastructure can yield cost savings by helping to keep medical expenses low. Studies have demonstrated that people with access to parks and green space are less stressed and prone to anxiety, have lower blood pressure and cholesterol, have faster recovery from surgery and heart attacks, and show more improvement managing attention and behavioral disorders.[156,157] One study found that inactive adults who began regularly exercising could save $865 in annual mean medical costs.[158] In a study of Philadelphia's park system looking at the economic benefits of water and air pollution reduction, the cost savings in avoided medical expenses due to park use in 2007 was estimated to be $69,419,000.[159] Incorporating green space into urban areas through green infrastructure practices enhances community livability and also provides opportunities for recreation for adults and children to be, and stay, healthier leading to reduced medical costs.

**Linking Land Use and Water Quality in Los Angeles County, CA**


In Los Angeles County, the Emerald Necklace is a regional plan encompassing 62 cities and 2.5 million residents that incorporates green infrastructure to improve water quality within the Rio Hondo and San Gabriel Watersheds while also increasing access to green space and recreational opportunities. For instance, in the City of El Monte, the 1.8 acre Lashbrook Nature Park was built along an existing bike trail that includes native plantings and a vegetated bio-swale. This network of over 447 existing parks focuses on linking green space to enhance livability, providing safe areas for children and families to get outside and interact with nature, protecting clean water through green infrastructure, and improving air quality. Photo: Amigos de los Rios

"Emerald Necklace Green Infrastructure Los Angeles County," Amigos de los Rios, 2005.

## Conclusions

The pollutants transported in stormwater runoff and related combined sewer overflows are a major source of contamination of drinking water supplies, recreational waters, and productive fish and shell fishing areas. Reducing the amount of pollutants being delivered to rivers, lakes, and streams can lead to reduced medical and lost productivity costs associated with water-borne illnesses and negative economic impacts to local businesses and fishing industries can also be mitigated. Clean waters are essential to the vibrancy and success of local businesses that depend on beachgoers and other recreational water users. Commercial and recreational fisheries bring millions of dollars to local economies. Threats to, or closures of, these resources are disastrous to impacted communities. Green infrastructure practices reduce the amount of polluted runoff delivered to local waters leading to corresponding reductions of the economic impact associated with polluted waterways.

## FINAL CONCLUSION

The history of urban drainage and stormwater management in the United States has been written in the countless miles of buried pipes, sewers and tunnels that rush rainwaters out of sight and out mind. This impression lasts only as long as it takes for runoff and its pollutants to burden our waters, back up into our basements, and flood our streets. While effective in its original purpose, these grey infrastructure approaches often create new problems, and provide only limited benefits to the communities they serve. As Milwaukee Mayor Tom Barrett quipped, "You can't have a picnic or tailgate party in a deep tunnel."[160] Planning infrastructure solutions to current and future stormwater challenges will require us to think differently about how we manage runoff. Additionally, ratepayers and taxpayers will likely insist on greater benefits and efficiencies for the investments they're asked to fund. Green infrastructure promises cost-effective runoff management strategies that reduce or prevent flows of runoff into over-stressed sewer systems and waters, while providing tangible benefits to neighborhoods and communities. The benefits described in this report are but four examples, though fundamental ones, to local policies that encourage or require green infrastructure. Green infrastructure practices can be less expensive and more cost-effective than traditional infrastructure approaches. These practices can also increase energy efficiency and reduce energy costs, mitigate flooding, and improve public health. Building on the success of green infrastructure practices in cities and towns across the country, local leaders, utility managers and engineers can create healthier, more energy efficient and less flood-prone communities for the future.

# ENDNOTES

[i] US EPA at http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

[ii] US EPA at http://cfpub.epa.gov/npdes/home.cfm?program_id=5

[iii] Ibid

[iv] US EPA at http://cfpub.epa.gov/npdes/home.cfm?program_id=4

[v] Green Roofs for Healthy Cities, at http://greenroofs.org/index.php/about-green-roofs

[vi] See, Charles River Watershed Association, Stormwater Tree Pit Fact Sheet, at www.crwa.org/projects/bmpfactsheets/crwa_treepit.pdf

vii See, Charles River Watershed Association, Green Street Fact Sheet, at http://www.crwa.org/projects/ESUD/GreenStreet.pdf

viii Arlington Echo Outdoor Education Center, at http://www.arlingtonecho.org/restoration-projects/rain-gardens.html

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