Green Infrastructure Feasibility Scan

for Bridgeport and New Haven, CT

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Evaluation of Green Technologies to Manage Wet Weather Flows

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Executive Summary

Within the cities of Bridgeport and New Haven, Connecticut, combined sewer systems manage both sanitary and stormwater flows, and are subject to combined sewer overflows (CSOs) during storm events. CSOs occur when the capacity of the system is exceeded due to stormwater inflow, and untreated overflows are discharged into surrounding surface waters. Since CSOs present public health and environmental concerns, management efforts to control these overflows are essential. Historically, management efforts have relied upon sewer separation, underground storage, and increased treatment plant capacity, all of which are collectively known as grey infrastructure. In contrast, green infrastructure, an alternative and increasingly popular wet weather management approach, utilizes predominantly natural processes such as infiltration and evapotranspiration, as well as rainwater reuse, to manage storm flows.

A feasibility scan was conducted for Bridgeport and New Haven to evaluate opportunities to incorporate green infrastructure into ongoing wet weather management efforts. Specifically, the study was intended to address green infrastructure source controls available for implementation, an implementation framework, small-scale and neighborhood demonstration projects, green infrastructure costs and benefits, funding mechanisms, and opportunities for job creation. In total, this report is intended to serve as a foundation for future detailed planning and design efforts.

Results of the feasibility scan indicate that green infrastructure can serve as an effective approach to managing CSOs within Bridgeport and New Haven. Opportunities available for implementation include blue roofs and green roofs on commercial and industrial buildings; bioretention installed within parking lots and roadway medians, along streets, within tree pits and planter boxes, and within courtyards; rainwater harvesting systems used to irrigate lawns and athletic fields; and permeable pavement installed along sidewalks and parking areas. Implementing these concepts through a pilot program, particularly at a neighborhood scale, will reduce stormwater flow to the combined sewer, and more importantly provide invaluable experience to guide and facilitate future management efforts. The experience will especially help to address the logistical challenges associated with design, implementation, maintenance, and public perception, as well as provide a real world indication of realized stormwater management benefits. Such a pilot program can also provide support for development and implementation of future financing mechanisms.

Although green infrastructure costs are highly variable, there are instances where implementation costs are lower than grey infrastructure approaches. When implementation costs are comparable, green infrastructure feasibility is aided by the additional benefits these source controls can provide. Additionally, green infrastructure presents opportunities for phased and distributed implementation in areas where grey infrastructure approaches may be difficult. In considering a combination of grey and green infrastructure to manage wet weather flows, as many other CSO communities have done, Bridgeport and New Haven can expect to develop an effective framework for managing CSOs while providing a myriad of additional benefits.

Introduction

Within the cities of Bridgeport and New Haven, as in many other older cities, combined sewer systems are utilized to collect both sanitary and storm flows and then convey those flows to wastewater treatment facilities, where water quality is improved before the flow is discharged into the natural environment. During rain events, or wet weather, the capacity of the conveyance system and treatment facility can be exceeded, resulting in the direct discharge of these combined sewer flows into receiving water bodies in what is known as a combined sewer overflow (CSO). During these overflows, combined sanitary and runoff flows, which contain pathogens, metals, nutrients, and other anthropogenic contaminants, are discharged into receiving waters with little or no treatment, ultimately contributing to contamination of the Long Island Sound. These contaminants have the potential to harm aquatic life, degrade aesthetics, pose public health concerns, and overall diminish the functionality of these water bodies. These impacts can be particularly evident in coastal communities such as Bridgeport and New Haven. Due to the degradation of surface water quality and other environmental concerns to which these overflows contribute, many cities are currently undertaking efforts to reduce CSOs. Historically, wet weather management in combined sewer areas has been addressed through a combination of increased treatment plant capacity, implementation of storage tunnels and tanks, or separation of storm and sanitary flows into separate pipe networks. Collectively, these practices are referred to as grey infrastructure, as they generally involve concrete, steel, and other engineered infrastructure.

A wet weather management technique that is gaining increased national prominence utilizes predominantly natural processes such as infiltration and evapotranspiration, as well as rainwater reuse, to manage storm flows in what is known as green infrastructure. By reducing the rate and volume of runoff entering the combined sewer system, these practices, which are often widely distributed on a small scale, alleviate pressure on the sewer system during storm events and consequently can play a role in reduction of CSOs. Reduction of CSOs can contribute towards a substantial decrease in pollutant loads discharged to surrounding water bodies from the urban environment. Due to the nature of these practices, they are often able to help mimic predevelopment hydrology by reducing surface runoff and encouraging infiltration and evapotranspiration, which further aids in alleviating CSOs and other capacity concerns with the sewer system. Additionally, green infrastructure source controls have the potential to provide a variety of other benefits, including improved aesthetics, reduction of localized flooding, increased wildlife habitat, reduction of soil erosion, urban greening, carbon sequestration, increased groundwater recharge, improved air quality, and reduction of the urban heat island effect. A green infrastructure feasibility scan was conducted for the cities of Bridgeport and New Haven to not only evaluate the overall feasibility of green infrastructure implementation, but also guide future efforts by considering implementation opportunities, job creation potential, costs, and benefits.

The green infrastructure feasibility scan presented herein was prepared by Hazen and Sawyer for Save the Sound, a program of the Connecticut Fund for the Environment. Hazen and Sawyer, a national environmental engineering firm founded in 1951, has specific experience with managing stormwater and green infrastructure implementation, developing green infrastructure designs, evaluating stormwater system performance, developing watershed plans, and leading public outreach efforts. During the course of this feasibility study, Hazen and Sawyer received input from a variety of stakeholders including the Cities of Bridgeport and New Haven, the Bridgeport Water Pollution Control Authority (WPCA), Greater New Haven WPCA, and others who are listed in the acknowledgements section of this report. This collaborative effort was intended to provide not only valuable information on the feasibility of green infrastructure implementation within these cities, but also a sensible framework for future implementation efforts.

Nationally, there is increasing interest in green infrastructure as municipalities seek to identify and implement innovative management strategies to address the stormwater management challenges they face. Cities such as New York, Philadelphia, Syracuse, and Nashville are actively incorporating green infrastructure elements into their management plans. In many cases, the approach to implementation has relied upon pairing green infrastructure with cost effective grey infrastructure implementation and identifying opportunities to incorporate green infrastructure elements into other ongoing city projects. Incorporation of green infrastructure into city projects has not only provided direct stormwater management benefits, but also encouraged private developers and others within these cities to implement green infrastructure throughout their own development projects.

EPA has specifically recognized green infrastructure as a stormwater management approach that can be cost effective and environmentally preferable when used to support or replace grey infrastructure practices[1]. Within Bridgeport and New Haven sustainability initiatives that share elements with green infrastructure implementation are already underway, including Bridgeport's BGreen 2020 Sustainability Plan, and New Haven's tree planting program. A specific example of these ongoing efforts is the Seaside Village project in Bridgeport, where residential rain gardens and other green infrastructure elements are proposed throughout the community. This feasibility scan is intended in part to build upon efforts already in progress within these cities, while also providing local context to national trends in green infrastructure implementation.

Existing Conditions

Combined sewer systems are utilized to manage storm and sanitary flows through a substantial portion of both Bridgeport and New Haven (Figure 1). Combined sewer overflow outfalls are distributed along surface waters throughout these cities and can even discharge during small and frequent storm events. In both cities, sewer separation has served as a major component of previous and planned efforts to address CSOs; however, combined sewers are still prevalent in some of the mostly intensely developed areas. This is likely attributed to the difficulties and expense associated with retrofitting separated sewer systems in ultra-urbanized areas, particularly when there are not other reasons for major infrastructure repairs or replacement. Factors such as utility conflicts, traffic disruption, property ownership, and limited open space all contribute towards the difficulty of retrofitting separated sewer systems in these dense areas. In addition to separation efforts, tunnels and tanks that store combined sewage until there is available capacity at the treatment plant have been utilized and planned for future efforts. While these storage components can be effective at reducing CSOs, they often carry substantial costs and represent a public investment that is hidden and does not generally provide additional benefits beyond wet weather control. Ultimately, the occurrence of combined sewer overflows within Bridgeport and New Haven results in an environmental and public health concern that requires investments in infrastructure to address. With the complexities and challenges of comprehensively addressing these issues with grey infrastructure alone evident, there is a need to consider alternative wet weather management approaches to supplement these efforts.

1. Grumbles, B. H. (2007). "Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source, and other Water Programs." < http://www.epa.gov/npdes/pubs/greeninfrastructure_h2oprograms_07.pdf> (Jan. 2012).

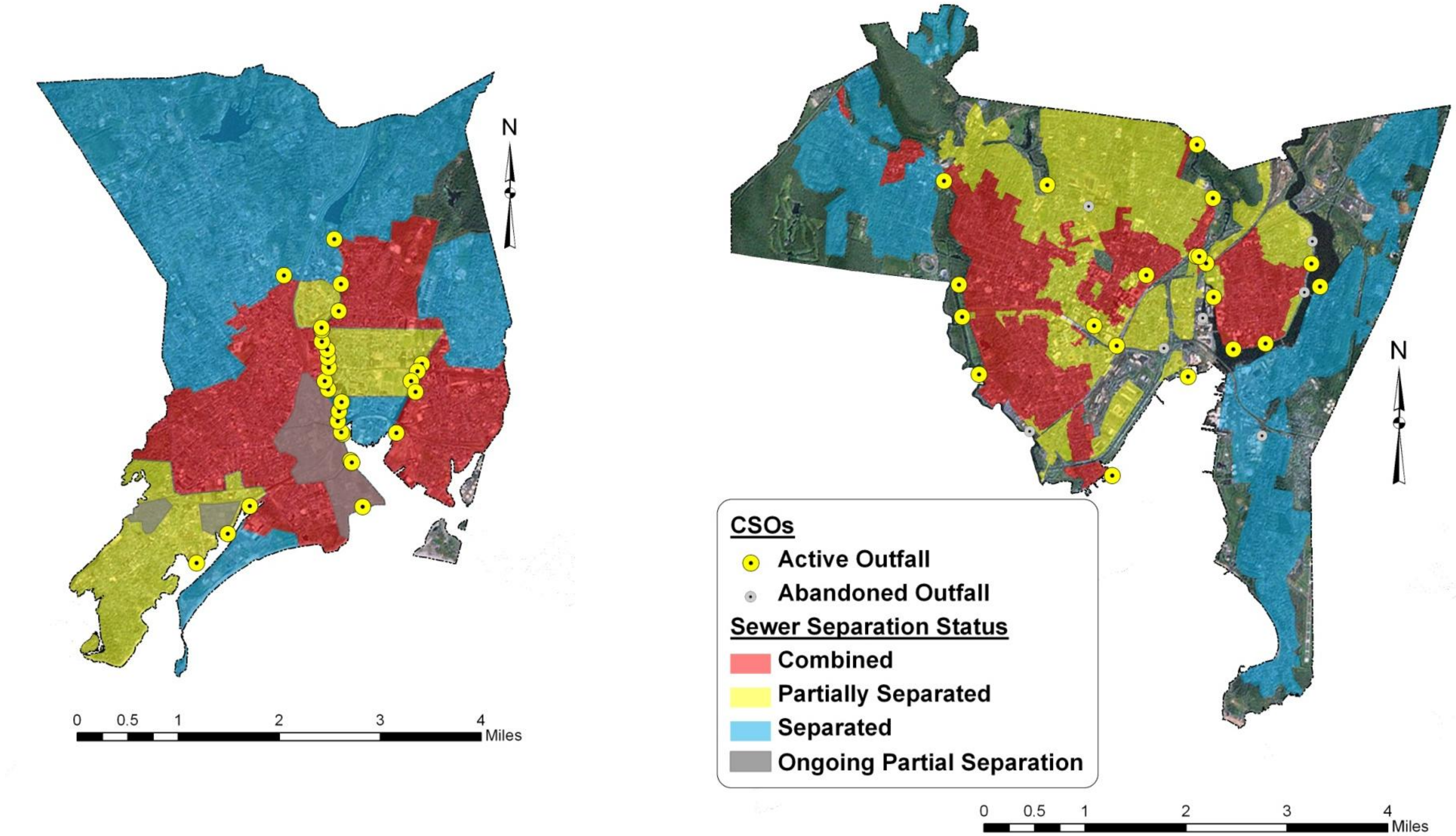


Figure 1: Approximate regions of combined, separated, and partially separated sewers in Bridgeport (left) and New Haven (right)

Green Infrastructure Approaches

Green infrastructure collectively refers to a wet weather management strategy that relies predominantly upon natural processes. There are a wide variety of stormwater source controls that fit within the green infrastructure management framework. Unlike some grey infrastructure approaches that focus on consolidating runoff management into large storage systems, green infrastructure source controls are typically widely distributed throughout an area, managing runoff from the immediately surrounding surfaces. These source controls affect storm hydrology, often restoring a more natural balance of runoff, infiltration, and evapotranspiration. Some of the more common green infrastructure source controls include bioretention, subsurface infiltration, blue roofs, green roofs, permeable pavement, and rainwater harvesting, all of which have been utilized within cities in the Northeastern United States.

Bioretention

Bioretention is a prevalent green infrastructure technology that consists of a shallow vegetated basin filled with an engineered sandy soil mixture that is generally underlain by a stone drainage layer and underdrain system. Bioretention functions by storing water on the surface and allowing that water to infiltrate through the engineered soil. Because the bottom of these systems is generally in contact with the in-situ soil, there are opportunities for runoff to seep into shallow groundwater. In addition, soil retention and vegetative uptake can further reduce the volume of water ultimately discharged from the system. There are a variety of green infrastructure source controls that consist of variations on bioretention design, including enhanced tree pits, engineered planter boxes, rain gardens, and bio-swales. The flexibility, effectiveness, and aesthetics of bioretention are reasons why it has become a popular green infrastructure technology.

Figure 2: A bioretention area constructed to capture sidewalk runoff

Subsurface Infiltration

Subsurface infiltration systems can take a variety of forms; however, the main objective of all these systems is to detain water in voids underground such that it can seep into the underlying soil. Common variations of subsurface infiltration systems include gravel beds, perforated pipe systems, and chamber systems. Subsurface infiltration systems can be utilized in a variety of site configurations, since they do not occupy space on the surface, and are often installed under parking lots.

Figure 3: Subsurface chamber (top) and perforated pipe (bottom) infiltration systems under construction

Blue Roof

A blue roof system detains rainwater directly on a rooftop and slowly releases that water to the sewer system, allowing for some depression storage and evaporation losses. A blue roof can be created with a control structure installed over or within the roof drain, detention berms or check dams installed on the rooftop, or a series of detention trays laid on the rooftop. Blue roofs can be paired with other green infrastructure practices downstream to infiltrate runoff released from the rooftop. Blue roofs are most effective and practical when installed on relatively flat surfaces, which are often associated with commercial or industrial buildings. In some cases, special structural considerations are necessary to ensure that adequate support is provided for the detained water and blue roof materials themselves.

Green Roof

A green roof system utilizes an engineered drainage layer and soil media in combination with specially selected vegetation to manage rooftop runoff. Due to the nature of the soil media and presence of vegetation, green roofs can combine the detention elements of blue roofs with enhanced retention and evapotranspiration. When installed in areas with direct roof access or higher adjacent buildings, green roofs can also provide aesthetic benefits. Similar to blue roofs, these systems are best suited for relatively flat rooftop surfaces, although some low slope roofs can be accommodated. Structural evaluations are also necessary to ensure that there is adequate support for the green roof materials and captured rainwater.

Figure 4: A blue roof consisting of engineered trays with stone ballast (left) and a green roof tray system installed on a sloped roof (right)

Permeable Pavement

Permeable pavement consists of a pavement structure that supports stormwater infiltration, underlain by a stone drainage layer and typically some type of underdrain system. Common types of permeable pavement include pervious concrete, porous asphalt, concrete grid pavers, and permeable interlocking concrete pavers. Permeable pavements are generally best suited for locations that do not experience high traffic loads, such as sidewalks, parking areas, and driveways.

Rainwater Harvesting

Rainwater harvesting is the practice of capturing rainwater, often from a rooftop, and storing it for subsequent use. Rainwater harvesting systems are often used to satisfy non-potable demands, since these uses of water can be substantial and treating captured water to potable standards can increase the complexity and cost of a system. The main system component is a cistern, which can be installed above or below ground. These cisterns may be constructed from plastic, concrete, metal, or fiberglass. Establishing a consistent and substantial use for the water captured by the rainwater harvesting system is important in order for stormwater management benefits to be realized.

Figure 5: Perimeter of a permeable pavement walkway (left) and a rainwater harvesting system installed at a nature education center (right)

Implementation Framework

Green infrastructure represents an emerging and rapidly evolving approach to CSO management that encompasses many unique elements when compared with conventional grey infrastructure approaches. While this approach can provide a multitude of benefits, implementation, particularly during early stages, is not without challenges. Consequently, it is beneficial to have a framework to guide implementation efforts, ensuring that green infrastructure can provide optimal benefits while minimizing costs, and can be understood and supported by the variety of stakeholders involved. As part of this feasibility scan, a framework was developed to serve as a roadmap for implementation and address issues such as identification and implementation of demonstration projects, opportunities to offset implementation costs, and mechanisms to collaborate with other agencies impacted by green infrastructure.

General Implementation

Unlike many grey infrastructure stormwater controls, which are often hidden underground or within facilities not accessible to the general public, green infrastructure source controls are inherently distributed throughout communities and are often highly visible. The distributed and visible nature of green infrastructure offers a variety of both challenges and benefits. One of the greatest challenges imposed by the distributed nature of these practices is facility maintenance. Like any grey or green infrastructure control, maintenance is important to ensure that these systems are able to provide long-term benefits. While the requirement for maintenance is not unique to green infrastructure, the types of activities involved and locations where maintenance is conducted differs from typical grey infrastructure approaches. Common grey infrastructure maintenance activities may include pump and valve repairs or replacement and removal of sediment and trash from sumps or storage tanks, as well as a multitude of activities associated with the operation of the treatment plant. Green infrastructure controls are more likely to require activities associated with landscaping, erosion repair, soil replacement, and collection of debris and sediment from surface features. While these activities are not inherently more difficult or costly than those associated with grey infrastructure, they may be less familiar and are likely to be distributed over a wider area. This distribution requires careful coordination to ensure that maintenance efforts are executed in an effective manner. Opportunities to help facilitate these activities include the designation of easements for inspection and maintenance, or agreements with property owners to share responsibility of system maintenance. Identifying opportunities to consolidate green infrastructure maintenance with other operations within the city can also facilitate effective implementation and is an important element of detailed planning and design efforts.

The visibility of green infrastructure source controls can also pose maintenance challenges by presenting opportunities for vandalism or littering, which can negatively impact performance. By developing an implementation framework that engenders public support for green infrastructure, these issues can be minimized by encouraging the public to protect these facilities. An effective way to garner this support is to utilize one of the key benefits of green infrastructure, its ability to serve as an aesthetic amenity through the use of landscaping and other surface features, which are often integral components of these systems. Similarly, source controls such as rainwater harvesting, which provide a valuable commodity in the form of captured runoff for reuse, can help stimulate public support.

A major advantage of green infrastructure is that implementation can occur in a phased and distributed approach. Since individual source controls are generally implemented at a site specific scale, the challenges associated with funding, design, stakeholder coordination, and construction of large scale grey infrastructure projects can generally be overcome in a shorter period of time and with less difficulty. This distributed nature also allows stormwater management efforts to progress as funds are available. The visibility of green infrastructure source controls also provides a recognizable demonstration of the city's efforts to manage stormwater runoff and improve water quality.

Pilot Program

One of the most effective mechanisms to educate the general public on green infrastructure, garner their support for this strategy, and gain a true understanding of the challenges and benefits associated with implementation is through the development of demonstration projects or a pilot program. Demonstration projects present an opportunity for a wide range of stakeholders to become familiar with the concepts of green infrastructure, as well as the real world issues associated with implementation. At a basic level, the general public can view examples of source controls, understand how they work, and see what they look like. Additionally, planners, engineers, regulators, and public officials can gain real world experience with the design, construction, maintenance, and the functionality of these systems. This education can facilitate implementation of projects that require inter-agency coordination, as well as encourage professionals and officials to incorporate elements of green infrastructure into other projects.

There are several factors that contribute towards the effective identification and selection of green infrastructure demonstration sites. Publically owned locations often serve as good demonstration sites because the complexities and expense of planning, construction, and maintenance are often reduced. Furthermore, these sites are more likely to be accessible to the public for demonstration and educational purposes.

While green infrastructure source controls can provide water quantity and quality benefits in separated and partially separated areas, green infrastructure controls in these areas will have little impact on the city's ongoing CSO management efforts, making separated areas less desirable for pilot implementation. Instead, green infrastructure controls are best suited within combined sewer areas, where CSOs are of greatest concern. Within combined sewer areas, there are a variety of factors that affect the contribution of runoff from a specific area to CSOs, making it difficult to identify specific areas where additional retention and detention provided by source controls would yield the greatest benefits. This is evidenced by the fact that operators of combined sewer systems often maintain complex models to describe these systems, accounting for differences in storm characteristics, hydrograph timing, conveyance system characteristics, and control devices such as regulators. However, source controls can be implemented where there are historical problems with CSOs or logistical challenges making other management strategies difficult within a given area.

Potential pilot sites should also be given high priority based on the presence of public attractions, recreation areas, and general opportunities for public visibility and outreach. Increasing the visibility of demonstration sites not only illustrates the city's efforts to improve water quality, but may also encourage implementation of green infrastructure by the public on their own properties. Because green infrastructure incorporates a variety of natural processes that are not as well defined as conventional grey infrastructure approaches to stormwater management, uncertainty regarding the design, construction, and functionality of these systems can serve as a substantial hurdle to implementation. Providing visible demonstration projects can help to overcome these barriers by providing physical evidence of how the systems perform and the benefits they can provide.

With retrofits of existing development, generally the most expensive type of green infrastructure implementation, identifying opportunities to reduce costs is paramount. This can be accomplished in several ways within Bridgeport and New Haven. One of the most effective ways to implement green infrastructure is through synergistic efforts with other renovation and repair activities conducted by the city. For example, both Bridgeport and New Haven have plans to plant numerous street trees over the coming years. Instead of implementing basic tree pits, there may be opportunities to incorporate basic bioretention elements into tree pit designs. While these elements would increase costs beyond those of a standard tree pit, they would result in both aesthetic and stormwater management benefits. Such synergistic efforts are not only more likely to ease the logistics of implementation, but would be expected to cost less than tree pits and stormwater management features that were constructed separately. Similar opportunities to synergistically incorporate green infrastructure concepts presented later in this report also exist with the street and sidewalk re-surfacing activities ongoing within both cities.

Utility conflicts, configuration of existing drainage patterns, and grading requirements also present significant costs when implementing modifications to divert runoff to source controls. Consequently, green infrastructure can be most effectively implemented in locations where simple modifications can be utilized to divert runoff to source controls. Examples include installation of basic curb cuts to divert runoff to source controls such as bioretention, and installation of permeable pavement in areas that receive not only direct rainfall, but runoff from adjacent areas. Identifying these types of cost saving and cost sharing measures has the potential to facilitate overall green infrastructure implementation and reduce stormwater management costs.

Demonstration Concepts

A series of site and neighborhood scale green infrastructure concepts were developed to illustrate the potential for source control implementation within Bridgeport and New Haven. While these concepts reference specific locations within these cities, they demonstrate concepts that could be adapted and applied at numerous locations. There were a variety of factors that influenced the selection of these concept locations, many of which were outlined in the previous section. As the concept locations were developed in coordination with Bridgeport and New Haven city and WPCA staffs, they are intended to address areas where CSOs are a concern and there are needs for ongoing management efforts. These controls will address those concerns by providing improved stormwater retention and detention, alleviating pressure on downstream sewer infrastructure and CSOs. With the exception of the Church St. housing concepts in Bridgeport, which could be implemented within many residential areas, these sites were all located in areas where sewer separation efforts have not been undertaken.

Some of the concepts within this report are proposed for areas where future sewer separation efforts are planned. The concepts in these areas illustrate how grey and green infrastructure can be utilized in tandem to maximize stormwater management effectiveness. For example, it may be possible to minimize the extent of sewer separation efforts or reduce the size of newly installed separated sewers in areas where green infrastructure source controls can effectively manage runoff. This can be particularly beneficial where utility conflicts or other site constraints may complicate separation efforts. Green infrastructure may also improve stormwater control in partially separated areas where roadway runoff has been routed to a separated sewer by managing rooftop and other on-site sources of runoff that were not addressed in separation efforts. Beyond CSO management benefits, green infrastructure implementation in separated or partially separated areas can improve water quality and reduce localized flooding, which has been noted as a problem within some separated sewer areas in Bridgeport and New Haven.

In addition to individual site concepts, a neighborhood scale implementation concept is presented for Bridgeport and New Haven. These neighborhood concepts were intended to address several aspects of overall implementation. First, these concepts illustrate the potential for green infrastructure implementation using a variety of locations and source control types. Implementation of these or similar neighborhood concepts can also yield valuable experience for future management efforts. During planning and design, experience can be gained from interaction with the wide variety of stakeholders involved in green infrastructure implementation, including property owners, maintenance personnel, and the general public. Specifically, it would be beneficial to understand how to design and spatially locate source controls to make effective use of maintenance staff, equipment, and existing protocols. During the construction phase, experience can not only be gained from individual sites, but also from the overall coordination and potential cost savings associated with the larger neighborhood scale of implementation efforts. Finally, after construction, experience can be gained from coordinating maintenance activities among the various sites, as well as quantifying the net effect the combination of practices can have on the sewer system.

For each proposed source control concept, several approximations are provided regarding the basic cost of the systems and benefits they may provide in order to facilitate the overall feasibility assessment. It is important to note that the estimates are intended to provide a basic context and do not account for the multitude of factors affecting specific project costs and benefits that should be addressed during detailed planning and design efforts. The quantity of annual runoff managed for each concept is based upon typical sizing ratios in conjunction with a historical precipitation analysis and the assumption that source controls are designed to capture runoff from one inch of rainfall. The annualized 25-yr total cost presented with the neighborhood concepts reflects the design, construction, and maintenance costs that would be incurred over an assumed 25 year source control lifespan in combination with the volume of runoff captured by the source control over that same period. Adjustments were made to cost estimates for several of the smaller pilots to account for some of the contingencies and complexities associated with individual, small scale pilot implementation. Anticipated rainwater harvesting system costs were excluded from the presentation of these concepts as they are highly variable depending upon the nature of the system. Their costs depend on factors such as contributing area, water demands, usage patterns, system materials, and distribution and control components that are dictated by a combination of site conditions and user preferences. A wide range of potential maintenance costs is included to account for variability in the availability of existing staff and equipment, accessibility and distribution of source controls, sediment and debris removal needs, and the appearance and level of performance that is to be maintained. More information on these estimates and their associated methodology can be found within the cost and benefit analysis section of this report.

While the concepts presented within this report are basic in nature, they may serve as a basis for future detailed design efforts. Design tasks associated with the proposed concepts may include detailed site selection, surveys, property owner and stakeholder coordination, source control sizing, hydraulic and hydrologic analyses, preparation of design drawings, specifications, maintenance plans, and permitting activities. The time required to complete these tasks is highly variable and may range from as little as several months for basic, small-scale projects, to one or two years for projects requiring extensive evaluations, designs, and stakeholder coordination. In general, design timelines are expected to shorten over time as designers and stakeholders become more familiar with green infrastructure implementation. The development of standard designs based on prior implementation experience can also assist in shortening the duration of design activities.

New Haven Demonstration Concepts

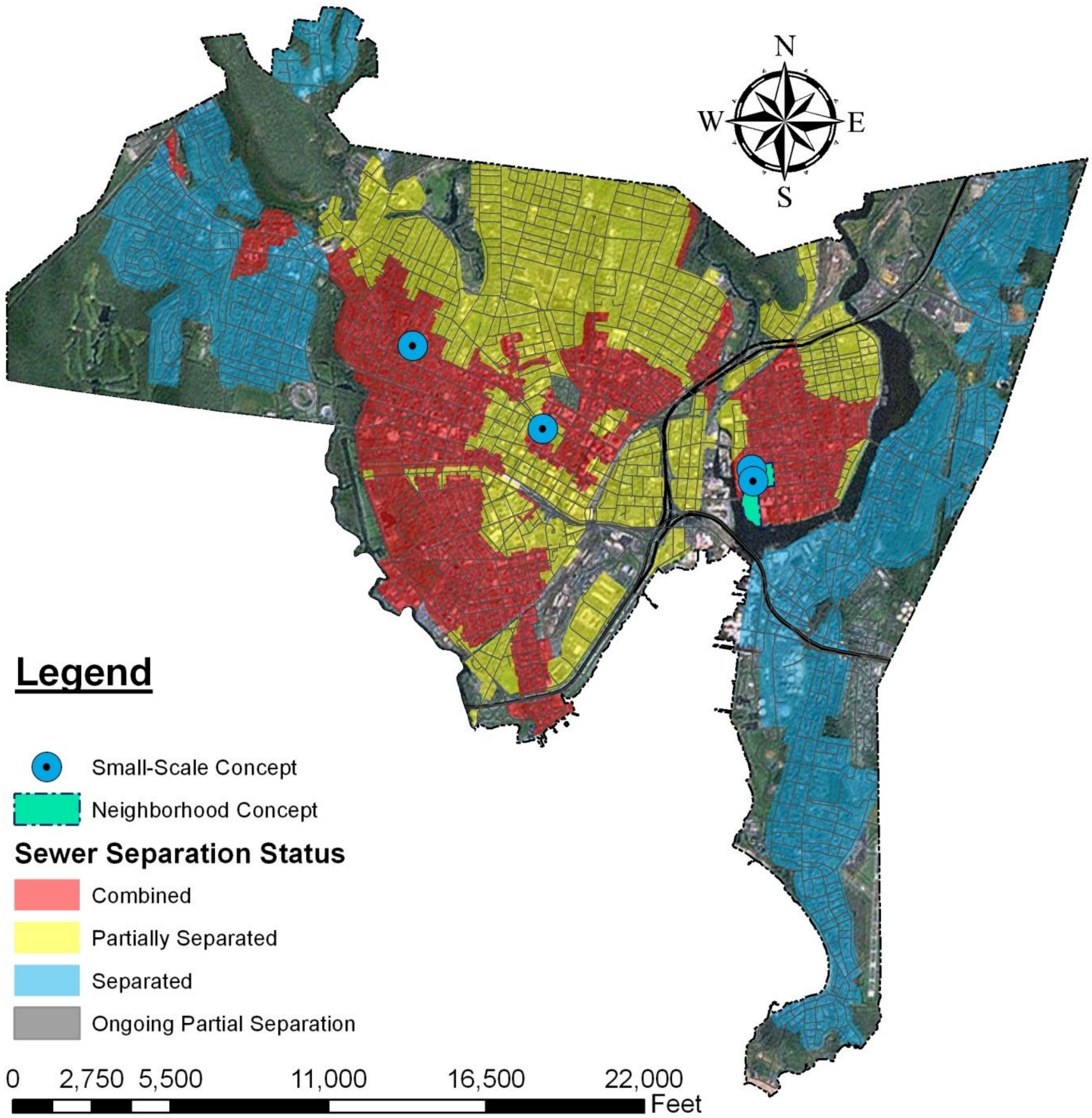
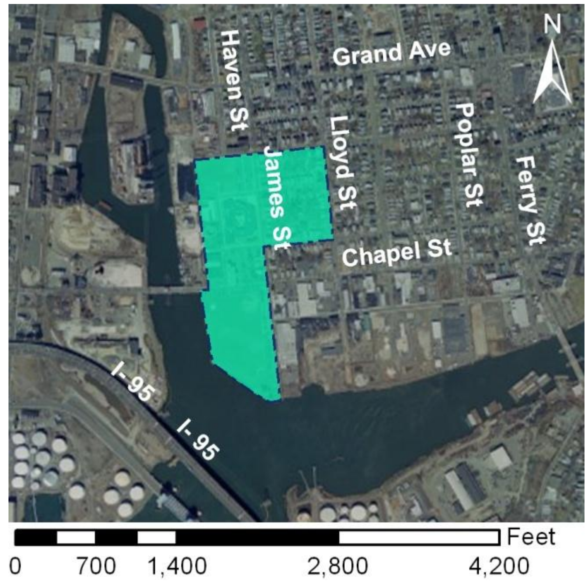


Figure 6: Overview of small-scale and neighborhood demonstration concept locations within New Haven

New Haven: Quinnipiac Neighborhood

Location	Quinnipiac Park Vicinity New Haven, CT
Approx. Runoff Managed	3 MG/yr
Approx. Design & Construction Cost	$1,500,000
Approx. Annual Maintenance Cost	$20,000-200,000
Annualized 25-yr Total Cost	$0.07/gal



The Fair Haven area of New Haven contains predominantly combined sewers and could benefit from additional stormwater management efforts. In the vicinity of Quinnipiac Park, the presence of a school, residential areas, and the park itself all present opportunities for green infrastructure implementation on a neighborhood scale. There are several small-scale concepts presented later in this report which are located within the neighborhood concept area, including bioretention installed within the median of a parking lot and a blue roof combined in series with a rainwater harvesting system. Within Quinnipiac Park itself, there are opportunities to incorporate permeable pavement into the adjacent parking lots, as well as bioretention along the outer park edges to manage runoff from the impervious perimeter of the park. As the source controls constructed within the park will be located on public property, their implementation will be simplified and they can serve as highly visible demonstrations of green infrastructure. Although there is limited available open space in the residential areas near Quinnipiac Park, there are still opportunities for green infrastructure implementation. Examples include permeable pavement sidewalks and street-side parking, bioretention between the sidewalk and street, and external roof drains directing stormwater into bioretention planter boxes. Implementation of permeable pavement sidewalks would be most efficient in areas where the existing sidewalk is in need of repairs or replacement. Incorporating permeable pavement into street-side parking encourages infiltration of stormwater without subjecting the permeable pavement to roadway traffic loads, while also providing potential opportunities to direct runoff from the roadway to these parking areas for treatment. Bioretention planter boxes present an opportunity to manage runoff within a small footprint by maintaining the bioretention soil and drainage layer above the ground surface within a wooden, brick, or concrete structure. An impermeable layer could be installed at the base of the system to address concerns regarding infiltration immediately adjacent to building foundations, while still providing the detention and retention benefits of the bioretention system itself.

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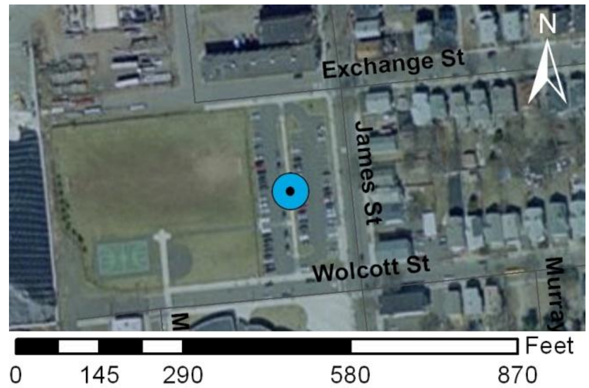
Green Infrastructrure Plans for the **City of New Haven**

Parking Lot Median Bioretention

Location	John S. Martinez School James St. & Walcott St. New Haven, CT
Approx. Runoff Managed	36,000 gal/yr
Approx. Design & Construction Cost	$15,000
Approx. Annual Maintenance Cost	$500-1,500



*Estimate applies to each individual bioretention area

In areas where substantial changes or replacement of site infrastructure is not needed or justified, basic modifications can be used to divert runoff to source controls where stormwater can be detained and infiltrated. This approach was utilized in the development of a bioretention concept for a relatively new parking lot near the John S. Martinez School in New Haven, located within the concept neighborhood. Under existing conditions, runoff from the parking lot flows along the curb into storm grates (Figure 8, top). Curb cuts could be installed along the length of the parking lot to divert runoff into the vegetated median area where runoff would be stored and infiltrated (Figure 8, bottom). These curb cuts could serve a dual function as an inlet and overflow, with storm flows continuing along their existing pattern to the catch basin during periods when the bioretention capacity is exceeded without the need for additional structures and piping. If existing soils have relatively high infiltration rates, a shallow basin may be excavated to receive this runoff and amended to improve infiltration. If infiltration rates of the existing soils are limited, a 2-3 ft layer of engineered soil may be added below the shallow basin in conjunction with an underdrain layer and piping to drain the system within a reasonable timeframe. The details of the drainage configuration are best addressed during detailed planning and design efforts, such that the benefits of maximizing detention and retention are balanced with the need to drain the system in a reasonable time to avoid creating a nuisance and make capacity available for future storm events.

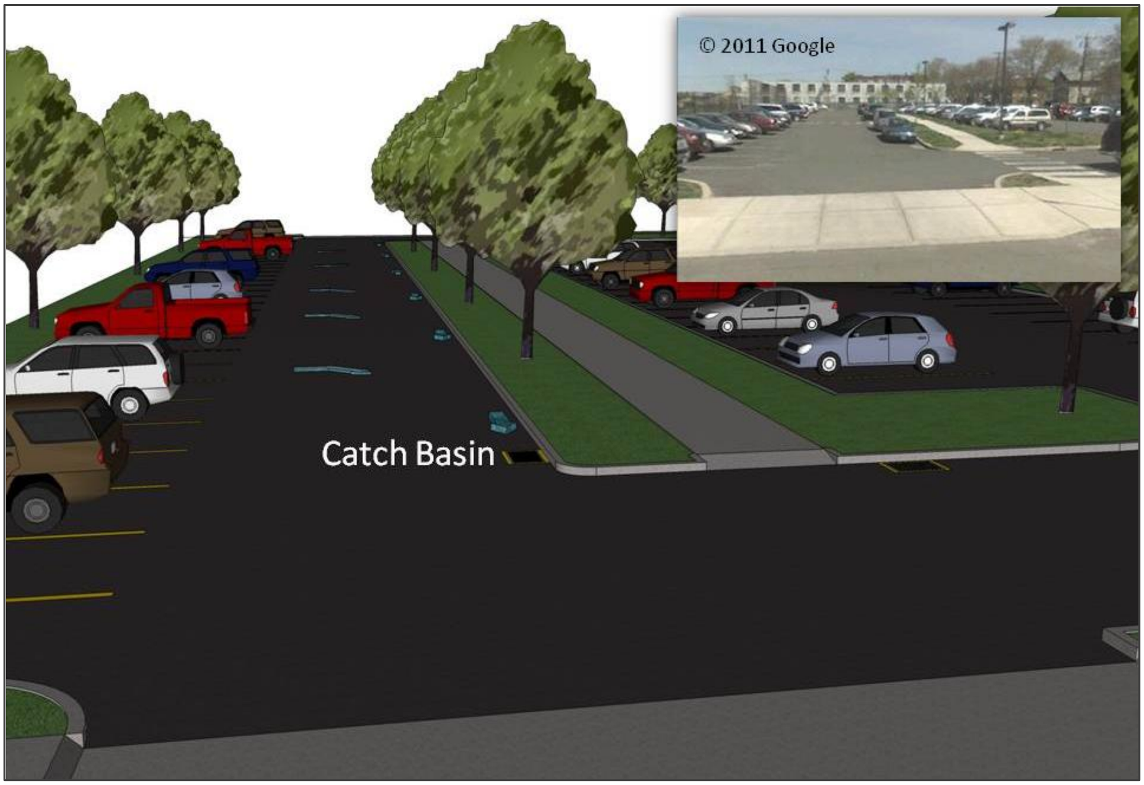


Figure 8: Existing parking lot configuration (top) and proposed bioretention concept within parking lot median (bottom).

Blue Roof with Rainwater Harvesting

Location	John S. Martinez School James St. & Walcott St. New Haven, CT
Approx. Runoff Managed	700,000 gal/yr
Approx. Design & Construction Cost	$100,000
Approx. Annual Maintenance Cost	$3,500-7,000

* Estimates exclude rainwater harvesting

Rainwater harvesting presents an opportunity to manage stormwater runoff while providing a valuable resource in the form of non-potable water for irrigation. In some areas, rainwater harvesting alone may not provide reliable stormwater management, since consistent and substantial water uses are essential for stormwater benefits to be realized. For example, non-potable demands may be seasonal or may not always be large enough to utilize the rainfall received by the system. Seasonal usage can be addressed by detaining water within the storage system and slowly releasing it to the combined sewer. Seasonal concerns, as well as limited usage can also be addressed by pairing a rainwater harvesting system with a rooftop source control. For the Martinez School, there is a large rooftop area to manage, but somewhat limited opportunities for irrigation in the immediate vicinity; therefore, a rainwater harvesting system paired with a blue roof is proposed (Figure 9). The rainwater harvesting system would capture water from the rooftop for use on the nearby athletic fields, while the blue roof would provide additional detention capacity directly at the runoff source. This extra capacity would be particularly beneficial at times when the capacity of the cistern has been exceeded and would result in direct overflow to the sewer system or in situations where it is not feasible to pipe certain sections of the rooftop runoff to the cistern. Due to the scale of the contributing rooftop and water demand, the rainwater harvesting system could rely upon a subsurface chamber system to store runoff for later use. This combination provides an economical means of storing large volumes of runoff without occupying valuable surface space. On the rooftop, runoff could be detained through the use of check dams which would restrict the ability of water to quickly flow to the roof drain during smaller storms by distributing storage across the roof surface.

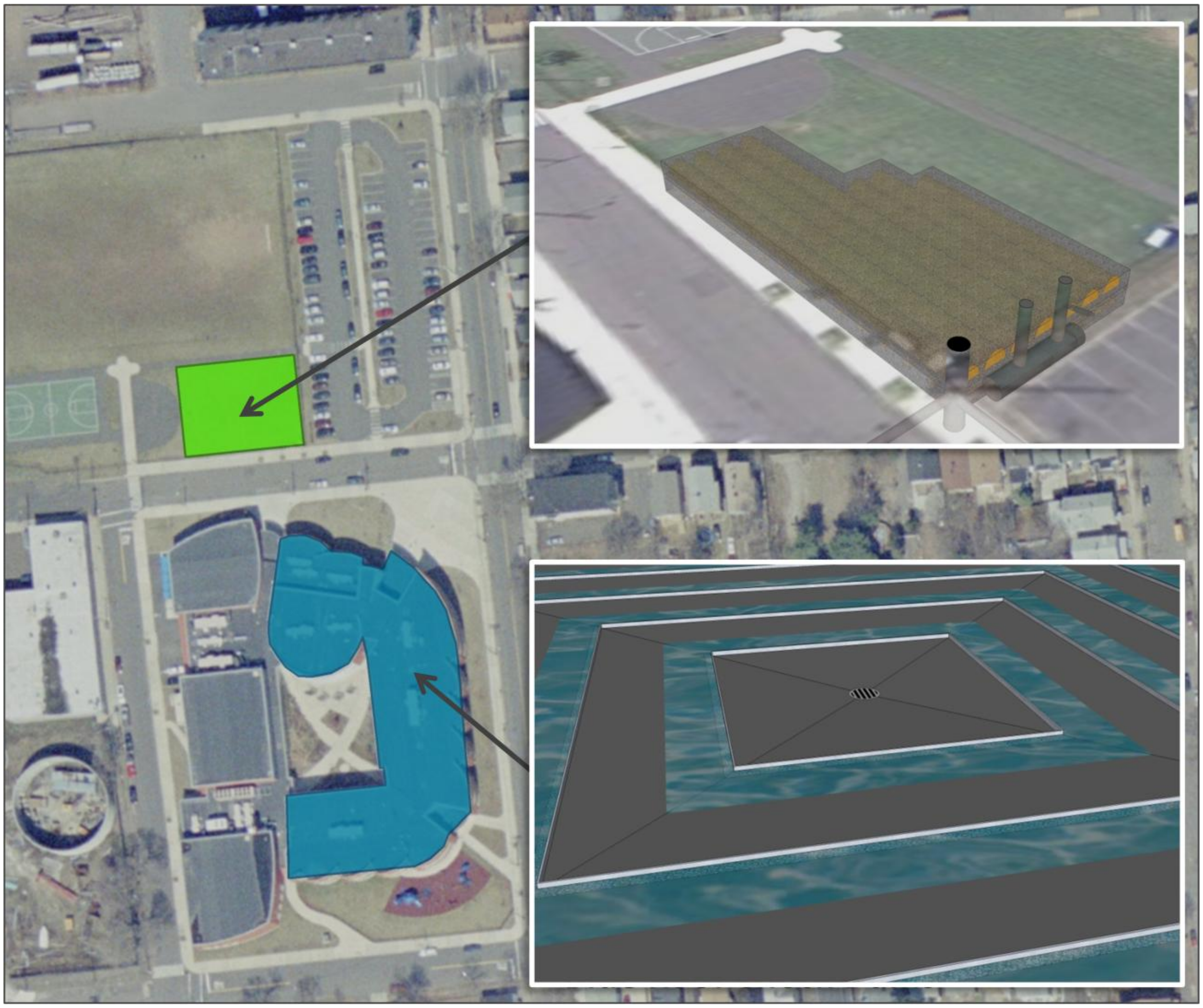
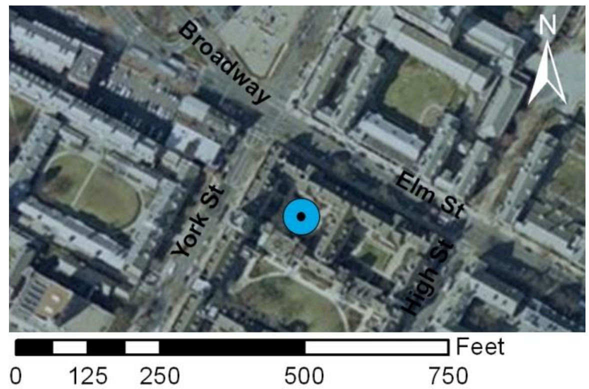


Figure 9: Subsurface rainwater harvesting storage (top) and blue roof check dam system (bottom)

Yale University Courtyard Bioretention

Location	Yale University Campus York St. & Elm St. New Haven, CT
Approx. Runoff Managed	100,000 gal/yr
Approx. Design & Construction Cost	$30,000
Approx. Annual Maintenance Cost	$1,000-3,000



Within areas with high pedestrian traffic, such as a university campus, impermeable sidewalks can cover substantial areas. In some cases, vegetated open areas are in immediate proximity to these sidewalks, presenting opportunities to enhance stormwater infiltration through the use of bioretention (Figure 10). In locations such as the courtyard adjacent to York and Elm Streets, where open spaces may be used for walking, studying, or recreation, it is important to understand how green infrastructure may impact future uses of these spaces in order to ensure the acceptance of the source controls. At this location, there may be additional opportunities to direct rooftop runoff to the bioretention area. Implementation of green infrastructure source controls on a college campus not only provides direct stormwater management benefits, but can also provide valuable research and educational elements. In fact, there is apparent interest among several departments and groups associated with Yale University in the implementation and evaluation of green infrastructure, which could be further integrated during future green infrastructure planning efforts.

Figure 10: Courtyard bioretention concept

Street-Side Bioretention Bump-Outs

Location	Whalley Ave. & Norton Parkway New Haven, CT
Approx. Runoff Managed	55,000 gal/yr
Approx. Design & Construction Cost	$22,000
Approx. Annual Maintenance Cost	$600-2,000

*Estimate applies to each individual bump-out

In areas where streets are relatively wide, due to large shoulders or unused street-side parking, bioretention bump-outs present an opportunity to intercept and manage roadside runoff before it reaches a catch basin. Although there are numerous opportunities within both Bridgeport and New Haven, one specific example is along Whalley Avenue in New Haven, along which future road work may be planned. Openings within the curb around the proposed bioretention areas would allow for inflow by intercepting the existing drainage pattern along the curb and would discharge any overflow along the downstream curb to continue to the existing catch basin (Figure 11). These bioretention bump-outs could also be combined with permeable pavement along the sidewalk to improve stormwater management. Depending upon existing soils and configuration, an underdrain may be connected into the existing catch basin. These source controls also present an opportunity to manage runoff for isolated catch basins in areas that could not be addressed during previous sewer separation projects. Among the many elements that must be considered during detailed planning design efforts are the impacts of these controls on traffic flow, parking, and street maintenance. Both Bridgeport and New Haven have undertaken initiatives to employ green-streets programs, suggesting that these elements do not present insurmountable obstacles to implementation.

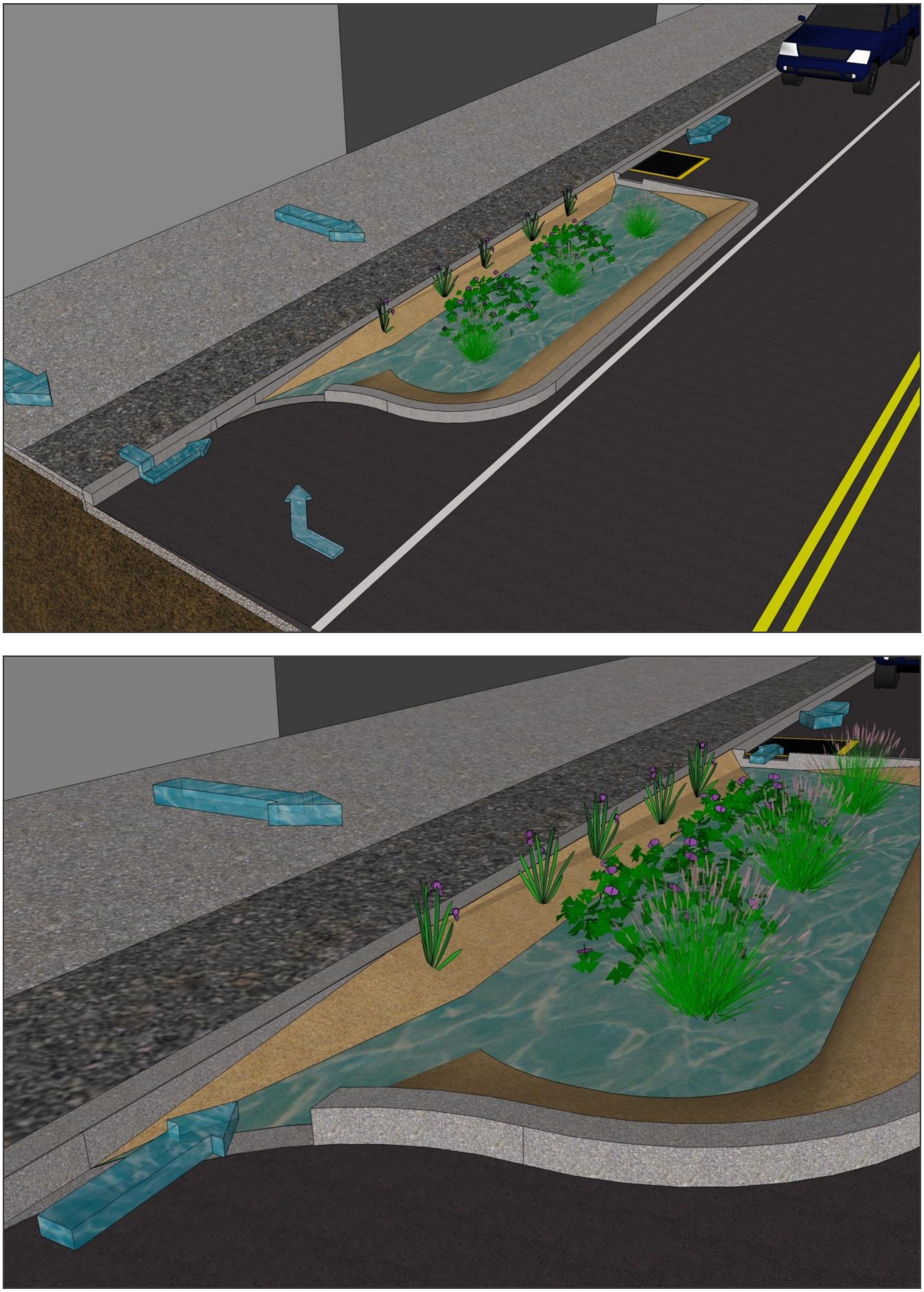


Figure 11: Street-side bioretention bump-out

Bridgeport Demonstration Concepts

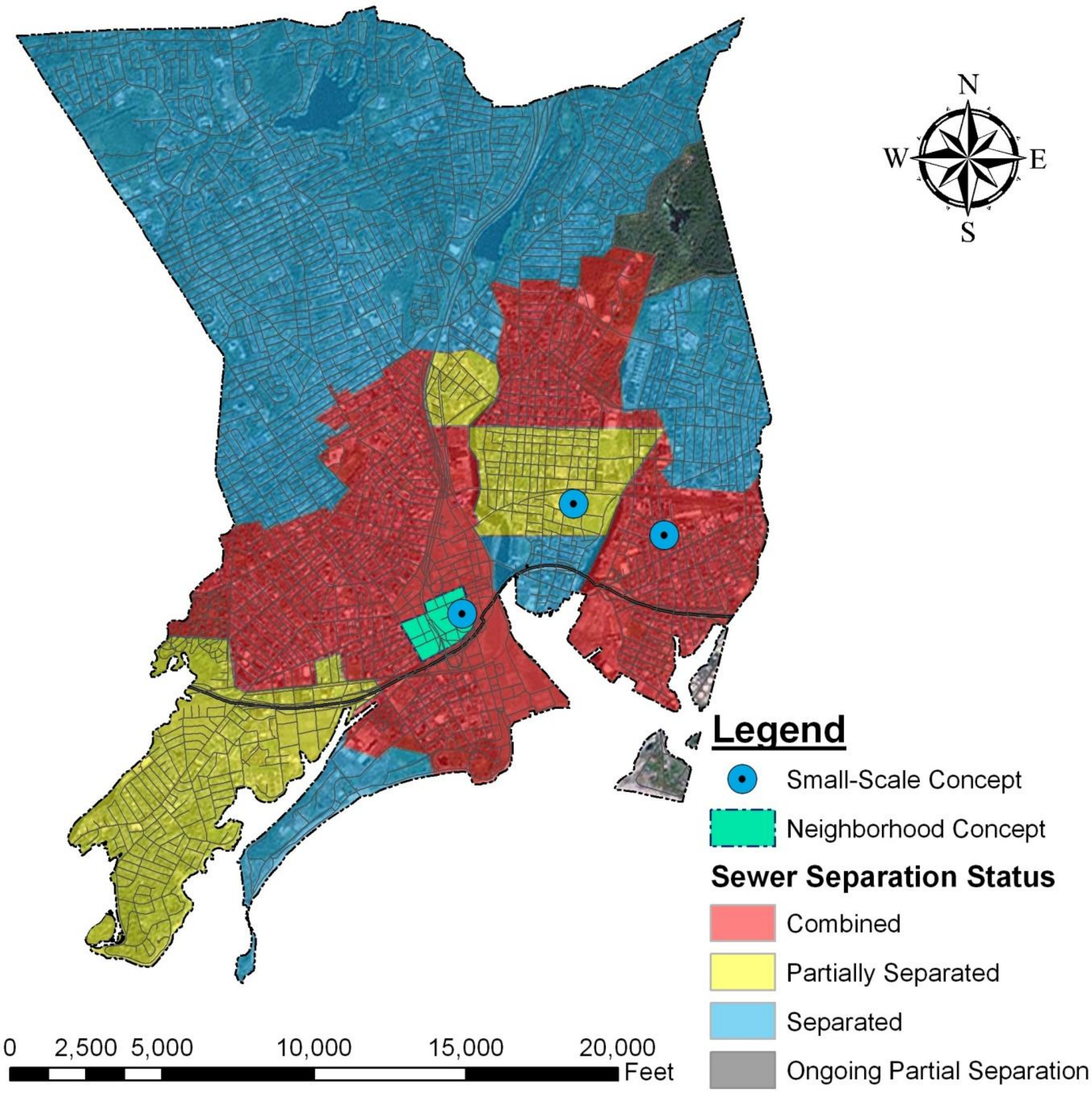
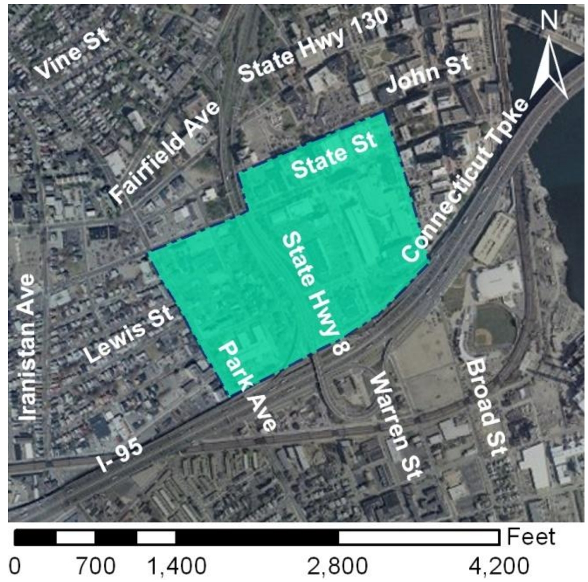


Figure 12: Overview of small-scale and neighborhood demonstration concept locations within Bridgeport

Bridgeport: Downtown Neighborhood

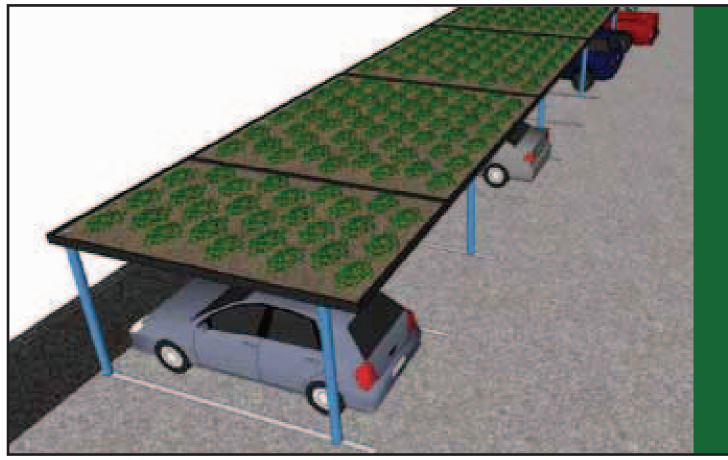
Location	Downtown Area Bridgeport, CT
Approx. Runoff Managed	8 MG/yr
Approx. Design & Construction Cost	$4,200,000
Approx. Annual Maintenance Cost	$60,000-600,000
Annualized 25-yr Total Cost	$0.09/gal



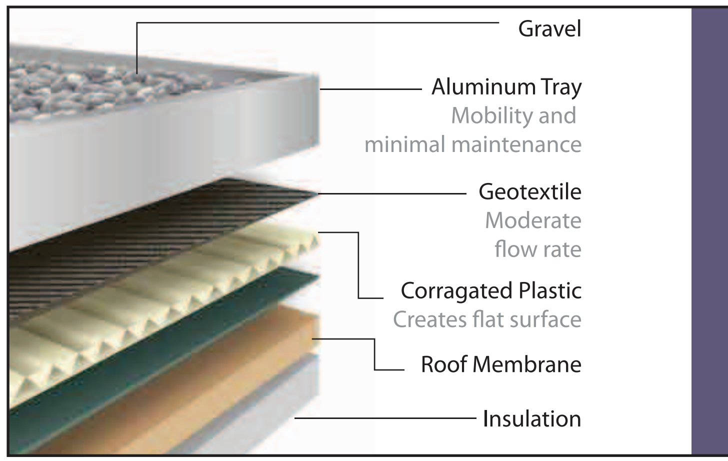
The dense downtown area of Bridgeport, which is serviced by a combined sewer system, presents many obstacles to large scale grey infrastructure implementation, making green infrastructure alternatives desirable. There are a variety of opportunities for green infrastructure implementation within the downtown area of Bridgeport, specifically within the H-4 area bound by Park Avenue, John Street, Broad Street, and Interstate 95. With future sewer separation efforts planned for this area, this neighborhood concept presents an opportunity to implement green infrastructure in advance or in tandem with separation efforts. This would allow city planners to better understand how green infrastructure implementation and sewer separation efforts interact, potentially allowing for more effective integration in future control plans. There are also several projects already planned or currently underway in this vicinity that facilitates the development of this area as a green infrastructure neighborhood. These projects include existing plans for source controls and renovations with opportunities to incorporate green infrastructure. Of note are a bioswale at the Roosevelt School, and opportunities to incorporate green infrastructure with the renovation of the public library roof, renovation of the City Hall Annex roof, and a complete street design for Park Avenue. Additionally, a substantial portion of the proposed neighborhood concept area is owned by either the city or state, facilitating the logistics of pilot implementation.

Impervious areas within the concept boundary consist of large rooftops, parking lots and garages, roadways, and some residential areas. The large rooftops in this area present opportunities for blue and green roofs, much like those proposed for the Housatonic Art Museum later in this report. Blue roofs in particular can be an economical management option on large and flat rooftops, as the low slopes require fewer modifications to store larger runoff volumes. Permeable pavement incorporated into the parking lots within the concept boundary could be designed to capture not only direct rainfall, but runoff from contributing areas as well. Management of runoff from the parking decks within this area presents challenges, since any controls installed directly on the rooftop would affect parking availability. One potential management option is the incorporation of blue or green roof canopies over the parking surface. Such an installation would not only improve stormwater management, but would provide shade for vehicles parked on the top levels of these garages. Throughout the commercial and residential areas, there are opportunities for street-side bioretention, permeable pavement, and residential rain gardens. Specifically, these practices could be directly incorporated into the street work planned for Park Avenue. Opportunities also exist within vegetated islands on several parking lots in this neighborhood to implement bioretention.

There are a number of additional opportunities for green infrastructure implementation in the vicinity of the proposed neighborhood concept, some of which could be executed in conjunction with other city efforts. South of Interstate 95, there may be opportunities to incorporate bioretention or permeable pavement to manage runoff from the large parking areas surrounding the arena and baseball park. Some of the same types of practices illustrated in the proposed neighborhood concept could also be applied east of the proposed neighborhood, where future downtown enhancement activities may be underway.

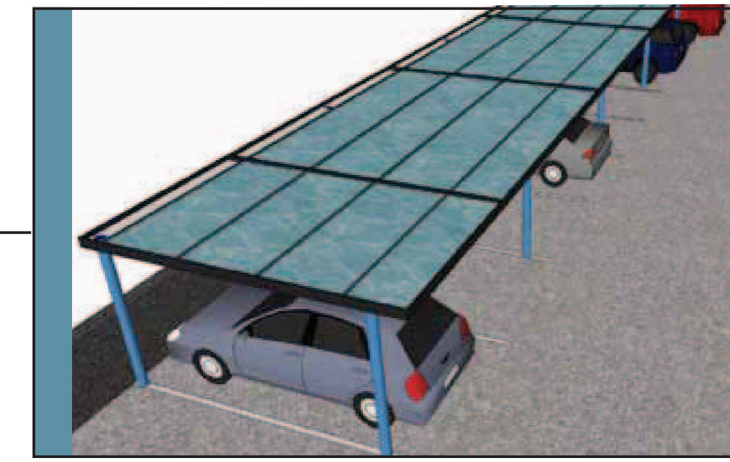


Green Roof Canopy

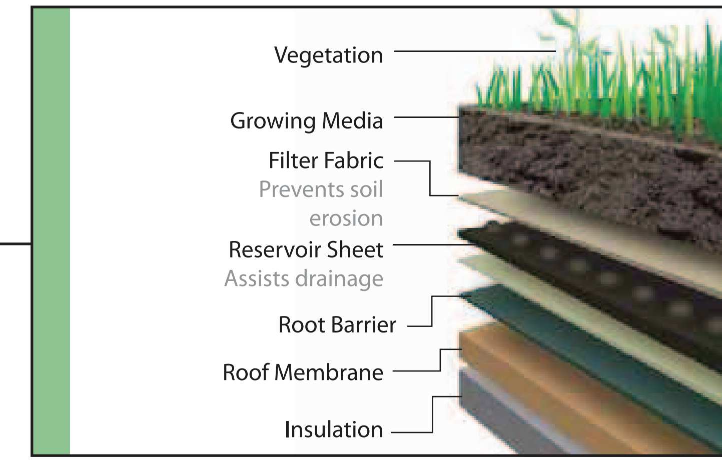


Blue Roof

Bioretention



Blue Roof Canopy



Green Roof

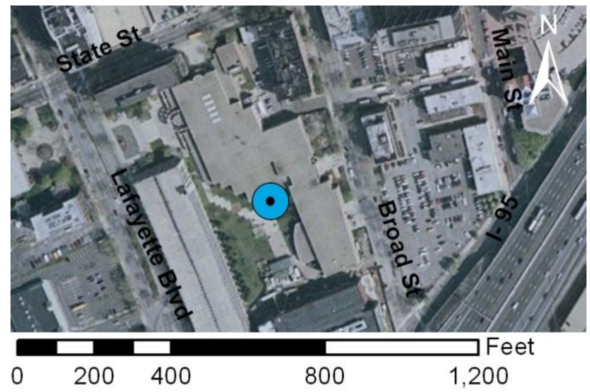
Permeable Pavement

Green Infrastructure Neighborhood for the **City of Bridgeport**

Figure 13

Housatonic Museum of Art Blue and Green Roof

Location	Broad St. & Caesar Batalla Way Bridgeport, CT
Approx. Runoff Managed	1,800,000 gal/yr
Approx. Design & Construction Cost	$1,700,000
Approx. Annual Maintenance Cost	$15,000-150,000



*Estimates assume complete roof coverage

The large, relatively flat rooftop at the Housatonic Museum of Art presents an opportunity for a combined blue and green roof system (Figure 14). Such a system combines the aesthetic and rainwater retention benefits of a green roof with the reduced cost and detention benefits of a blue roof. The lower roof near the center of the facility, where the green roof is proposed, is visible from the upper floors of the museum itself, as well as the adjacent community college, providing valuable aesthetic and educational benefits. A tray type system for both the blue and green roof systems could be utilized to facilitate construction and maintenance, while also providing flexibility in the shape, size, and placement of the systems. Flow out of the green and blue roof trays would travel through a drainage layer between the bottom of the trays and the roof surface to the existing roof drains.

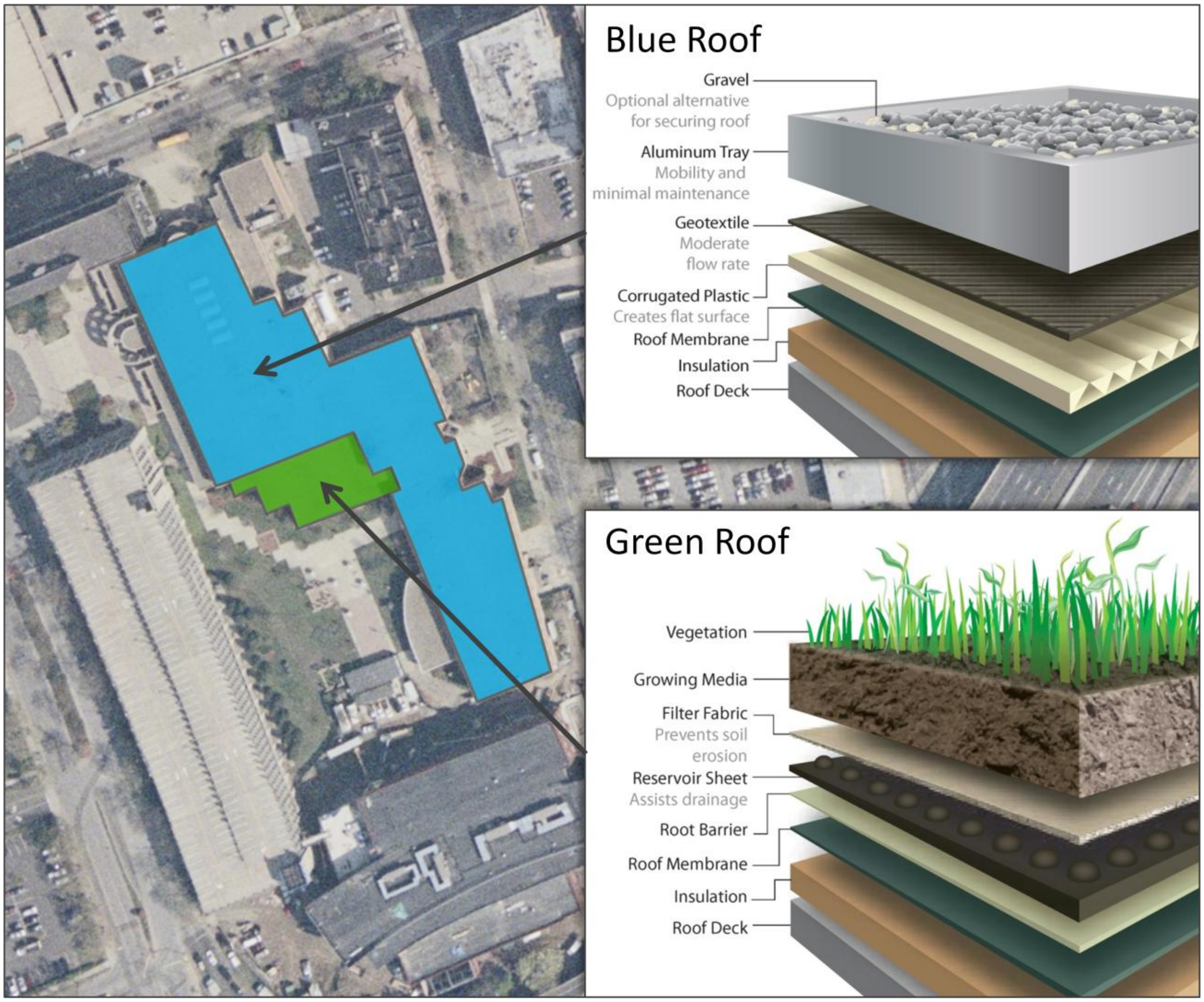
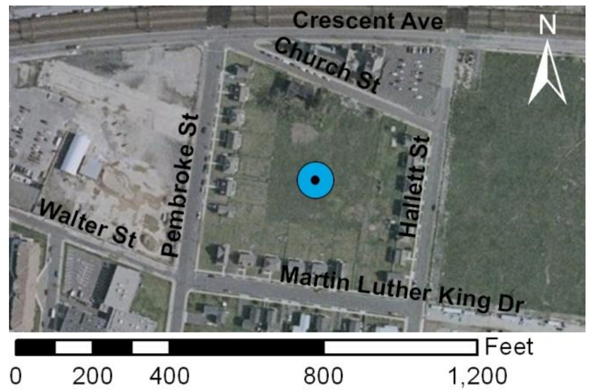


Figure 14: Blue and green roof concept at the Housatonic Museum of Art

Church St. Public Housing

Location	Pembroke St. & Church St. Bridgeport, CT
Approx. Runoff Managed	50,000 gal/yr
Approx. Design & Construction Cost	$20,000
Approx. Annual Maintenance Cost	$500-2,000



* Estimate applies to an individual house and excludes rainwater harvesting

The implementation of green infrastructure source controls at public housing properties adjacent to Church Street was evaluated, since there were a number of these publicly owned homes in close proximity. Although the direct benefit of implementation at this location is diminished because the sewer has been partially separated, these properties represent opportunities for a wide variety of green infrastructure source controls that could be implemented at similar public and private residential properties throughout both Bridgeport and New Haven at a range of scales.

Green infrastructure source control options at these homes include rain gardens, rainwater harvesting, and street-side bioretention. Due to the sloped roofs of these homes, green roofs and blue roofs are not feasible options. However, due to the significant presence of grassed landscaping, rainwater harvesting could be incorporated to reduce runoff flows and water demands for irrigation. These rainwater harvesting systems can consist of above or below ground cisterns connected to an automated irrigation system (Figure 15). Although rain barrels are a popular green option for household stormwater management, they generally do not provide adequate storage to manage runoff from an entire rooftop or provide a water supply for any substantial demands. Cistern sizing is determined by a number of factors including contributing rooftop area and water usage patterns. As such, cisterns capable of holding at least several hundred gallons are expected for sites such as the public houses near Church Street in order for substantial stormwater benefits to be realized. An automated irrigation system that utilizes captured runoff when it is available is a key component of rainwater harvesting systems distributed throughout residential properties. In order for a rainwater harvesting system to provide stormwater management benefits, the captured water must be utilized to make storage capacity available for future storms. An automated system can provide consistent water usage without direct human intervention, maximizing stormwater benefits.

Rain gardens are another green infrastructure option that can be implemented at many homes or housing complexes throughout Bridgeport and New Haven. Rain gardens could be installed on open space within the front yards of these houses and treat runoff from rooftops, sidewalks, and driveways (Figure 16). Simple drainage modifications such as constructing shallow swales and redirecting downspouts can increase the amount of runoff conveyed to a rain garden. Rain gardens often lack the engineered drainage layers associated with most bioretention areas. Consequently, they carry less substantial costs than some other surface green infrastructure features, but are limited in the amount of runoff they can treat. Rain gardens can also serve as attractive landscaped areas while simultaneously managing stormwater runoff.

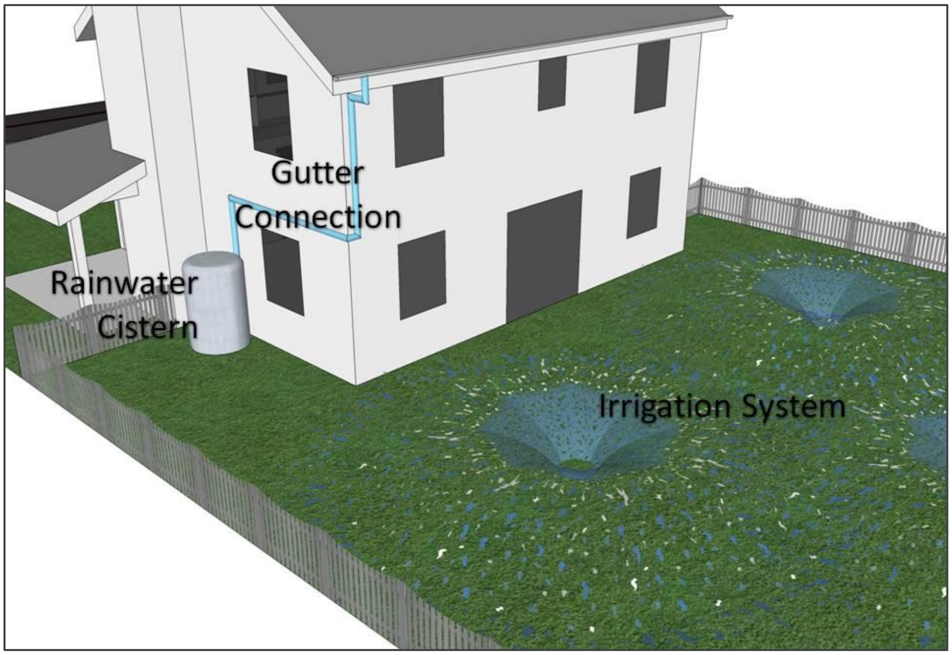


Figure 15: Rainwater harvesting cistern installed behind a house

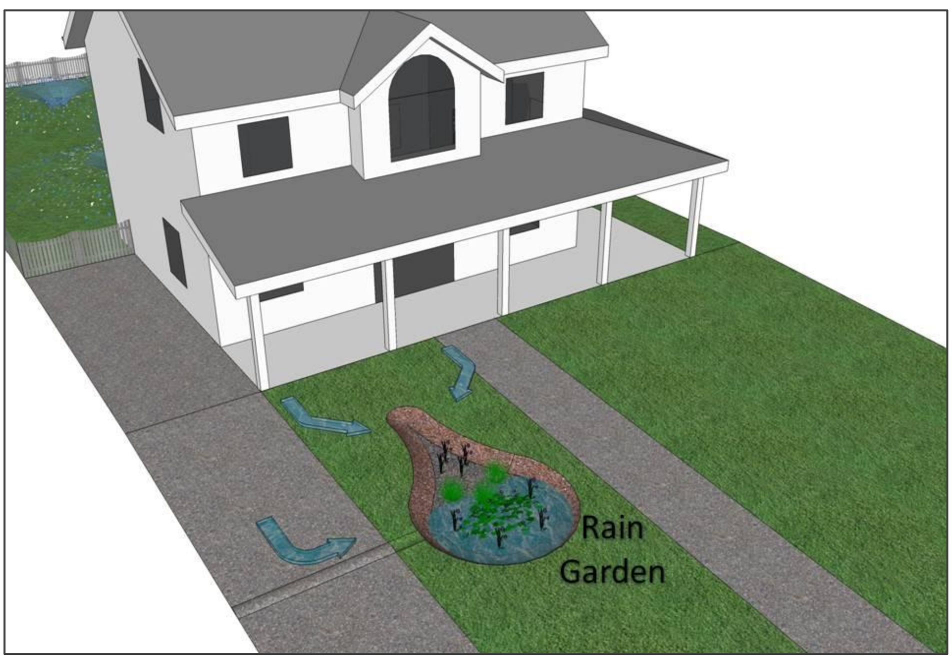


Figure 16: Rain garden constructed on a front yard capturing runoff from the rooftop, driveway, and sidewalk

Finally, runoff from yards, driveways, sidewalks, and the street can be managed through street-side bioretention areas constructed between the sidewalk and street (Figure 17). Unlike the rain gardens proposed for front yards, the street-side bioretention areas require substantial engineered soil media and drainage layers to increase subsurface storage for the increased runoff volumes they will receive. Depending upon the infiltration rates of underlying soils, these bioretention areas may require underdrain layers that tie into existing sewer infrastructure. Curb cuts along the street can serve as points of both inflow and overflow.

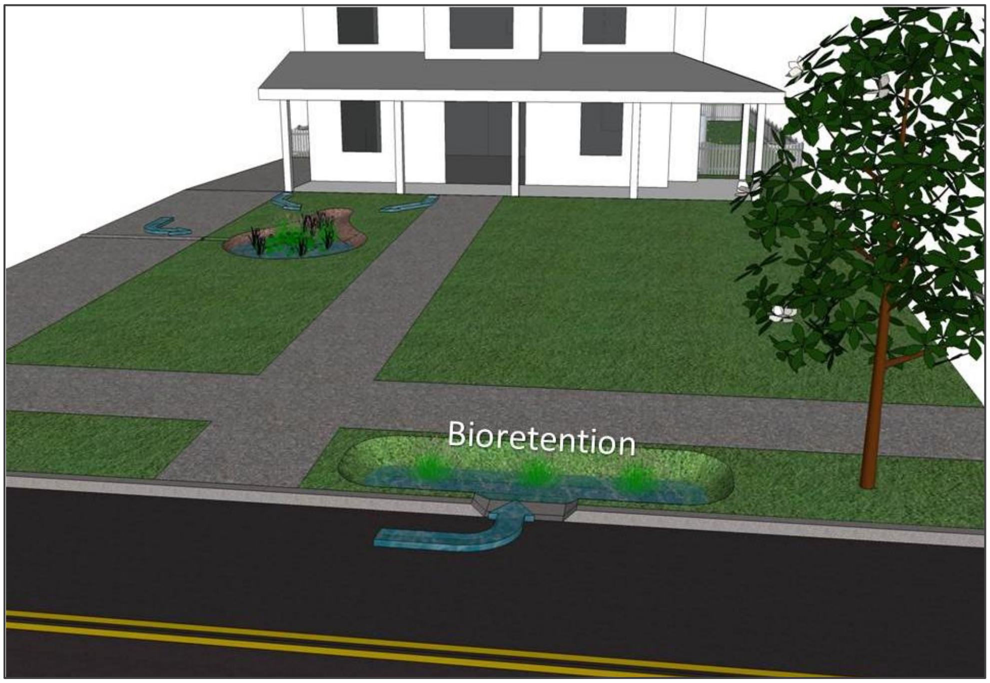


Figure 17: Street-side bioretention capturing runoff from the yard, sidewalk, driveway, and street

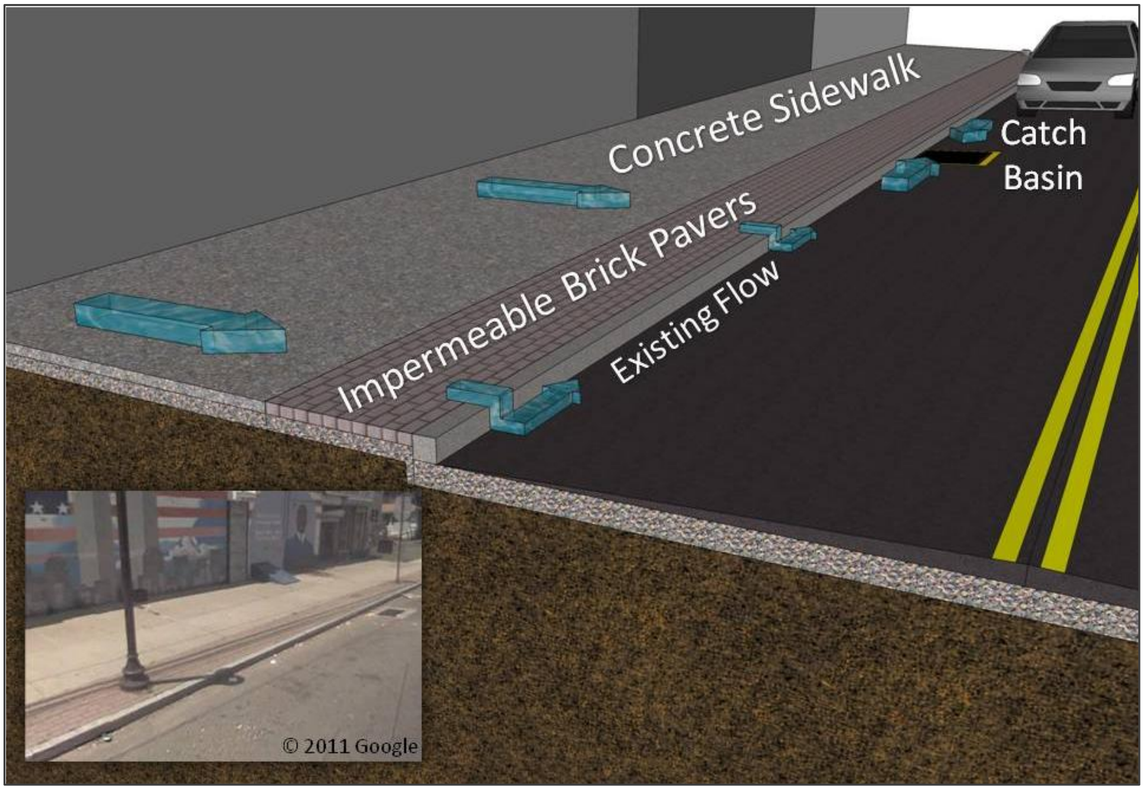
Permeable Pavement Sidewalk

Location	Central Ave. & Connecticut Ave. Bridgeport, CT
Approx. Runoff Managed	5,000 gal/yr
Approx. Design & Construction Cost	$15,000
Approx. Annual Maintenance Cost	$800-2,000

*Estimate is per 200 ft² sidewalk area

Along Central Avenue in Bridgeport, as well as many similar streets in Bridgeport and New Haven, there are opportunities to utilize simple drainage modifications to maximize runoff management while also implementing source controls in conjunction with other infrastructure improvements. This concept location currently consists of a concrete and brick paver sidewalk, which slopes towards the street and is entirely impervious (Figure 18, top). Retrofitting the brick pavers with permeable pavement provides an opportunity to intercept runoff from the sidewalk and detain or infiltrate that water within a subsurface gravel layer. The proposed concept occupies the existing footprint of the brick pavers and utilizes a permeable interlocking concrete paver to maintain a similar appearance; however, pervious concrete or other types of permeable pavement could also be used. Additionally, the concept includes screened curb cuts that are hydraulically connected with the subsurface gravel layer (Figure 18, bottom). These curb cuts not only allow runoff from the street to be diverted to the gravel storage layer for detention or infiltration, but also serve as an overflow if the storage capacity of the gravel storage layer is exceeded. The incorporation of these types of curb cuts in conjunction with permeable pavement can be especially beneficial near isolated catch basins that could not be connected to a separate storm sewer during prior separation efforts, providing an alternative means to manage runoff in those areas.

Permeable pavement is generally designed to store one inch of runoff from the contributing drainage area and can infiltrate substantial volumes depending upon the permeability of the underlying soil. An underdrain system would likely be needed to prevent water from remaining in the gravel storage layer for an excessive amount of time, reducing freezing or structural concerns. However, the underdrain can be configured to maximize infiltration and reduce discharge rates to the receiving sewer. This concept can be utilized throughout both Bridgeport and New Haven in conjunction with sidewalk repair and replacement activities, as well as supplement separation efforts in areas such as Trumbull Street in New Haven.



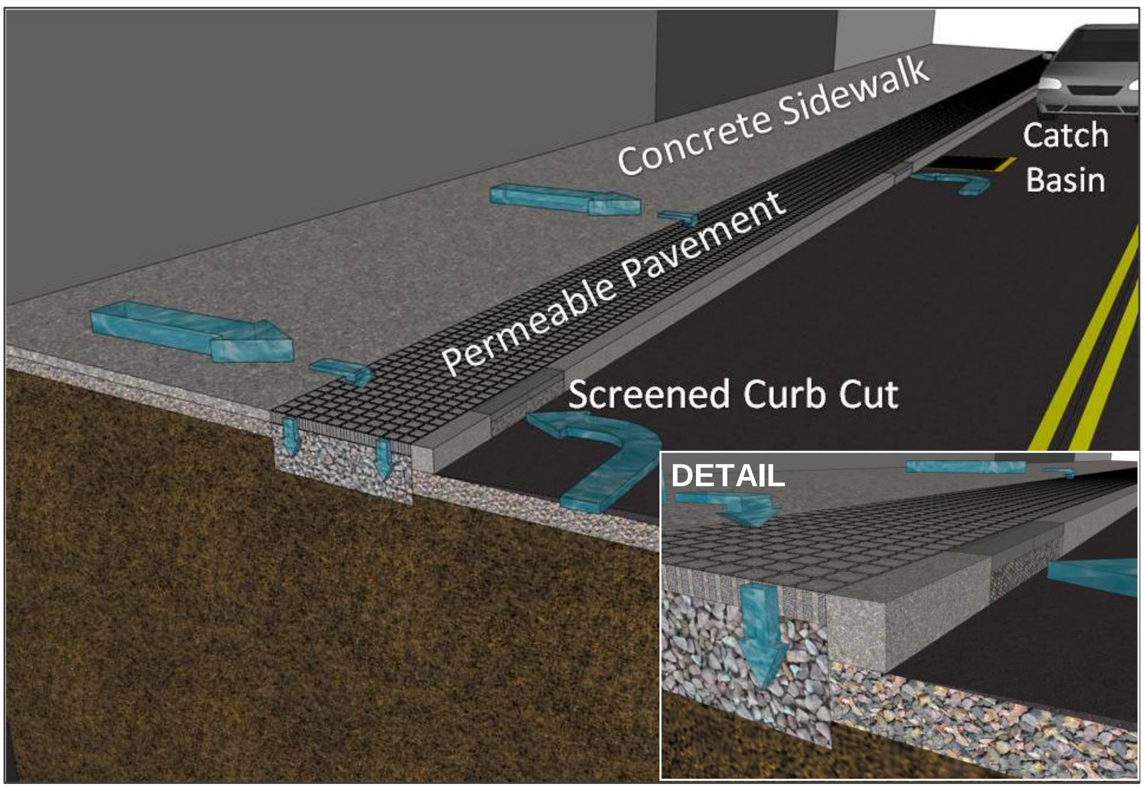


Figure 18: Existing sidewalk configuration (top) and proposed permeable pavement retrofit (bottom)

Financing Mechanisms

There are a variety of options available for financing the short and long-term implementation of green infrastructure. During the initiation of a green infrastructure program and implementation of demonstration projects, grants may serve as a major source of short-term funding. Both public and private green infrastructure grant programs are becoming more prevalent as more people become familiar and interested in this wet weather management strategy. The existence of an implementation plan and green infrastructure source control concepts can facilitate the compilation of successful grant applications by illustrating directed implementation efforts.

Historically, the Connecticut Clean Water Fund program, administered by the Connecticut Department of Energy and Environmental Protection (DEEP), has served as a valuable funding source for the design and construction of projects intended to reduce CSOs. Under this program, approved projects can have 50% of project costs covered by a grant, with the remainder funded through low interest loans. Funded projects have generally been closely related to management efforts which are incorporated into the city's long term control plan, which contain sewer separation and other grey infrastructure strategies. If green infrastructure can be proven as a valuable component of CSO management efforts within Bridgeport and New Haven through pilot projects and other efforts, program approval and funding support from DEEP for this management approach could increase and greatly facilitate implementation.

While grant programs can play an important role in initial implementation, they are not always feasible as a long-term funding source. Opportunities exist to directly or indirectly fund green infrastructure implementation though new development and redevelopment activities. It is possible for direct green infrastructure implementation to be required or recommended on-site through either a regulatory requirement or incentive-based programs. Doing so defers direct implementation costs from municipalities to developers. Already, stormwater management requirements are in place for new development and redevelopment within Bridgeport and New Haven, with the potential to incorporate additional incentives specifically for green infrastructure. Additionally, user fees collected from these development activities could be utilized to implement community-based green infrastructure projects.

In some rapidly developing areas, it may be feasible to directly require developers to implement green infrastructure or fund the majority of green infrastructure implementation through fees and assessments on new development and redevelopment. In areas that are approaching built-out conditions, such as many combined sewer areas within Bridgeport and New Haven, the feasibility of utilizing these funding mechanisms for widespread green infrastructure implementation may be limited. A stormwater utility is generally considered to be a viable, long-term funding option for stormwater management in communities with substantial existing development. The concept of a stormwater utility or user fee is becoming increasingly prevalent within the United States as the need for increased funding to maintain and improve stormwater infrastructure and address water quality issues becomes more evident. These programs have been implemented in combined sewer communities such as Philadelphia, Cincinnati, and Louisville. Unlike a property tax, which is based on the value of a property, or a sewer bill that is based on potable water usage, stormwater utilities are generally based on the amount of runoff generated by a property. Consequently, this framework is generally considered to serve as a more equitable funding mechanism. For example, a large shopping center parking lot could generate much more runoff than a multistory building with a much smaller footprint, but similar property value. Incentives can also be incorporated into the utility framework to provide discounts and other benefits for property owners who implement and maintain green infrastructure source controls to reduce their impact to the sewer system. It may be possible to incorporate similar incentives into WPCA rate structures. Providing these incentives may serve as a cost effective means of implementation, with property owners taking a greater role in stormwater management activities.

While stormwater utilities can serve as valuable funding mechanisms, their implementation must follow careful study and be accompanied by educational efforts to ensure that these programs are implemented in an effective and understandable manner. Without fully understanding the challenges at hand or benefits improved management efforts provide, the public may view stormwater utilities as additional fees for existing or unnecessary services. Due to the multiple benefits and high visibility green infrastructure can provide, implementation of source control demonstration projects may be a way to promote public acceptance of a stormwater utility program, as the benefits of such a program can be more recognizable.

When evaluating green infrastructure funding options, it is important to recognize that increased investment in infrastructure may be unavoidable in order to maintain a level of service or address existing sewer capacity and CSO concerns due to regulatory requirements, environmental health and safety issues, and public demands. Because these issues must be addressed in some fashion, green infrastructure implementation does not necessarily represent an extra expense a municipality would not otherwise incur, but rather one of several approaches which could address stormwater issues which require resolution.

Job Creation

Through increased investment in stormwater infrastructure, specifically green infrastructure, it is possible to foster new jobs. Due to the multifaceted nature of green infrastructure made evident within the framework and concepts presented in this report, effective implementation of green infrastructure requires involvement from a diverse workforce. Tasks associated with green infrastructure implementation can generally be categorized as design, construction, and maintenance. Design tasks will generally involve the work of planners, landscape architects, and engineers. Construction and maintenance tasks may involve the work of laborers, equipment operators, construction administrators, and landscapers.

While the design, construction, and maintenance of green infrastructure can be accomplished through the involvement of professionals and contractors from varying backgrounds, it is beneficial to have a workforce educated in green infrastructure to address the wide variety of unique elements associated with these practices. For example, engineers who may be more familiar with engineering concrete detention tanks and other grey infrastructure approaches must understand the importance of utilizing natural processes like infiltration and vegetation in effective green infrastructure implementation. Similarly, a contractor who may be accustomed to thoroughly compacting soils at a site to maximize stability must understand the need to minimize compaction and maximize infiltration with many green infrastructure practices. To address these unique aspects, various training efforts and conferences have been developed throughout the country in conjunction with EPA's efforts to support the implementation of green infrastructure. These efforts are intended to educate people who have interests in green infrastructure implementation, yet have little background in related areas, as well as provide training for professionals and contractors already working in related fields on the unique aspects of green infrastructure implementation. Green infrastructure training efforts not only facilitate effective implementation by providing a skilled workforce, but also provide job seekers with marketable skills in a developing field.

Job Creation Estimate Assumptions

Increased investment in green infrastructure is likely to create jobs as workers are needed to design, construct, and maintain new source controls. By making a number of simplifying assumptions, it is possible to estimate the number of jobs which might be created to support this implementation based upon the level of investment in green infrastructure. Although green infrastructure investment can indirectly create jobs associated with design, production, and marketing of materials, as well as induce jobs by making more money available for businesses and employees to spend, these types of jobs were not considered in these initial analyses due to the myriad of contributing factors and complexities associated with them. A key assumption of these estimates is that implementation of green infrastructure will be driven by new infrastructure investments, possibly drawing upon new funding sources and mechanisms, recognizing that without new investment, jobs created from the implementation of green infrastructure may be re-allocated from other sectors.

Costs associated with most construction projects can be categorized into material and equipment costs, construction labor costs, and design labor costs. The distribution of funds among these categories is dependent upon the specific nature of the construction project; however, it is reasonable to develop basic partitions for planning purposes (Table 1). As implementation of green infrastructure within a localized area increases, the relative proportion of total capital costs allocated to construction and design labor may be reduced as workers become more familiar with green infrastructure and consequently more productive and efficient. Material and equipment costs were assumed to result in indirect job creation and were consequently excluded from these initial analyses.

Table 1: Percentage of total capital costs from implementation allocated to each sector

Scenario	Material and Equipment	Construction Labor	Design Labor
High Labor Estimate	40%	45%	15%
Mid Labor Estimate	50%	35%	15%
Low Labor Estimate	60%	25%	15%

Job Creation Estimate Based on Federal Government Approach

One method of estimating jobs created from increased green infrastructure implementation spending is based upon an approach utilized by the federal government to estimate job creation from the American Recovery and Reinvestment Act of 2009[1]. In this approach, it is assumed that $92,000 of direct government spending creates one job for one year. This estimate accounts for the fact that increased government spending does not directly translate into increased wages, as there is a need to cover rent, profits, and other non-compensation costs associated with job creation. This approach also serves as a very basic estimate as it does not account for differences in job creation costs across varying regions and professions. In general, labor costs within the Northeast United States, including Bridgeport and New Haven, are higher than other parts of the country. Consequently, this approach is expected to overestimate the number of direct jobs created from increased green infrastructure implementation. Utilizing this approach, an annual green infrastructure capital investment of $10 million is expected to support approximately 15 direct jobs in the design field and 25-50 direct jobs in the construction field, not including indirect and induced jobs (Figure 19).

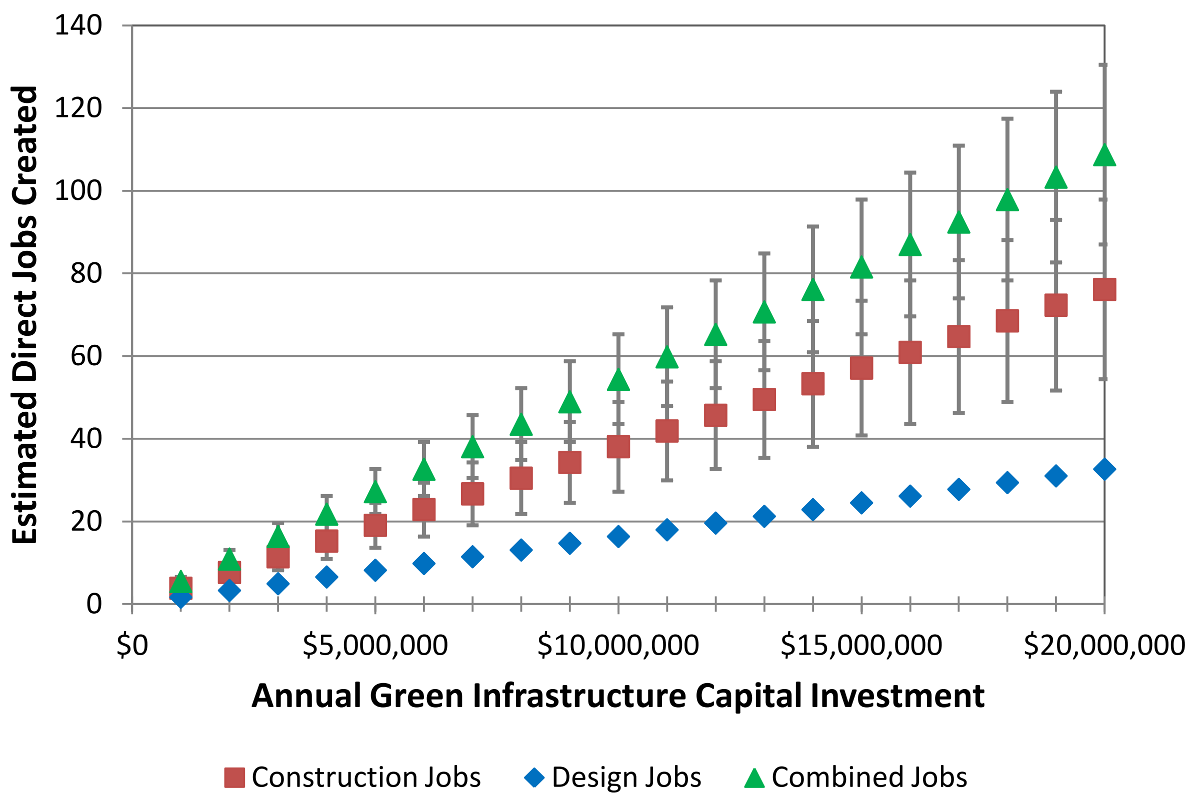


Figure 19: Estimate of direct jobs created in the construction and design fields based upon increased annual capital investment in green infrastructure, utilizing a similar approach as the federal government for the American Recovery and Reinvestment Act

1. Executive Office of the President, Council of Economic Advisers. (2009). "Estimates of Job Creation from the American Recovery and Reinvestment Act of 2009."

Job Creation Estimate Based on Assumed Labor Rates

An alternative to the previous approach is to utilize assumed labor billing rates in the Long Island Sound region. This approach is expected to provide an estimate of job creation that is more relevant based upon the region and type of labor involved. At the same time, labor billing rates not only support jobs for those directly involved in the design and construction tasks, but also non-billable personnel associated with the work conducted by a firm or contractor. Due to variations in corporate policies and financial structures, it is impractical to estimate the number of non-billable personnel supported by labor billing rates; consequently, this approach may underestimate the number of direct jobs created by increased capital investment in green infrastructure. Utilizing this approach, an annual green infrastructure capital investment of $10 million is expected to support approximately 5-6 direct jobs in the design field and 9-17 direct jobs in the construction field, again excluding indirect and induced jobs (Figure 20).

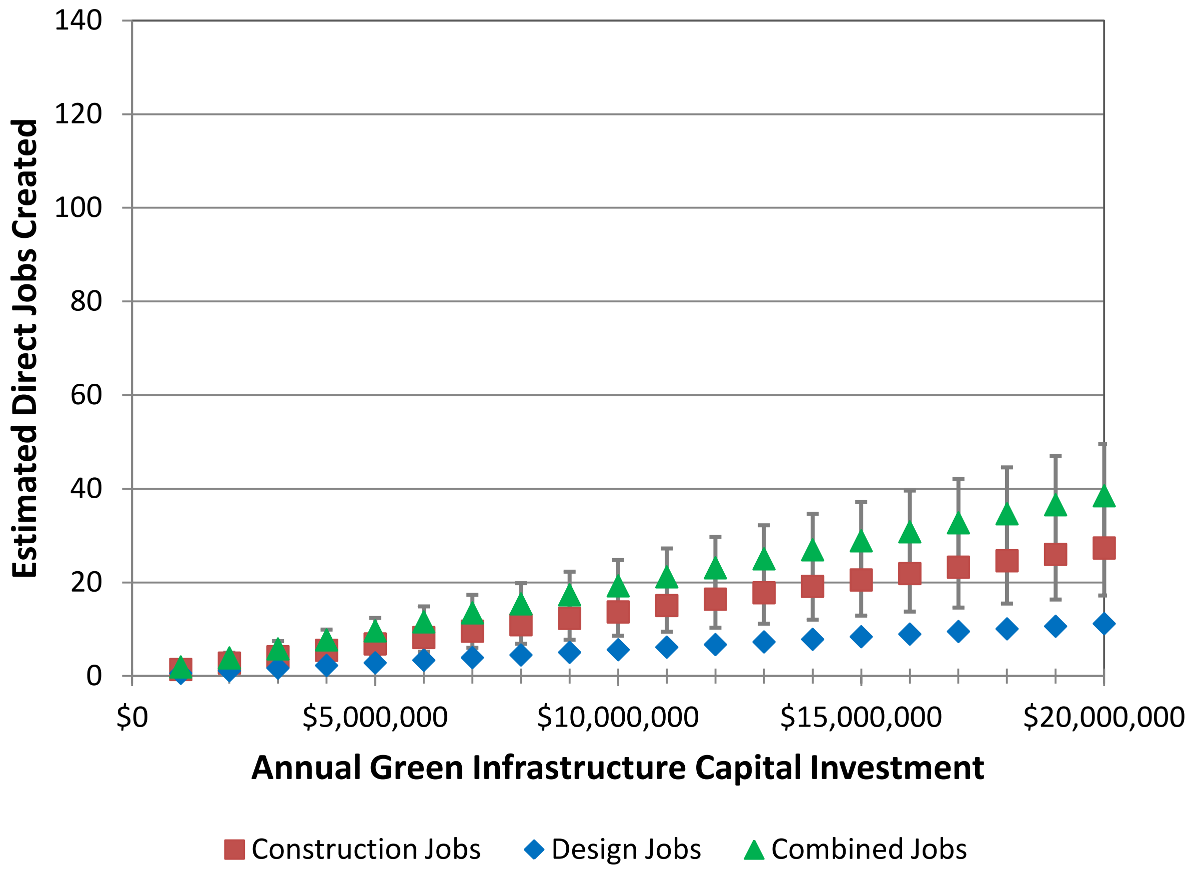


Figure 20: Estimate of direct jobs created in the construction and design fields based upon increased annual capital investment in green infrastructure, utilizing an approach based on assumed labor billing rates

Direct, Indirect, and Induced Jobs Estimate

In order to understand the full effect of increased green infrastructure investment on job creation, it is helpful to estimate not only the quantity of jobs created directly in the design and construction fields, but also the number of indirect and induced jobs that could be created. Accounting for these aspects results in higher job creation estimates, but is dependent on the assumption that these jobs can be provided and retained within the local area in order for local benefits to be realized. Due to the combination of these factors and other complexities, accounting for indirect and induced jobs results in less conservative estimates than the previous approaches. For example, equipment and materials utilized in green infrastructure construction may be procured from remote areas, which may still support job creation, but not directly within Bridgeport and New Haven. At the same time, companies and workers within Bridgeport and New Haven directly or indirectly involved in green infrastructure implementation may have opportunities to export their goods and services to other localities, benefitting from green infrastructure investments outside these cities. To illustrate this potential, it is estimated that the majority of green roof plants currently produced within Connecticut are exported from the state (Kevin Sullivan, Connecticut Nursery and Landscape Association, personal communication, January 2012). The Connecticut Office of Policy and Management estimates that 21 total jobs are created for every $1 million in new investment (Figure 21). This estimate is similar to those developed from a policy and economic analysis conducted by the Alliance for American Manufacturing and Political Economy Research Institute, which provides a general basis for estimating direct, indirect, and induced jobs created from increased investment in infrastructure[1].

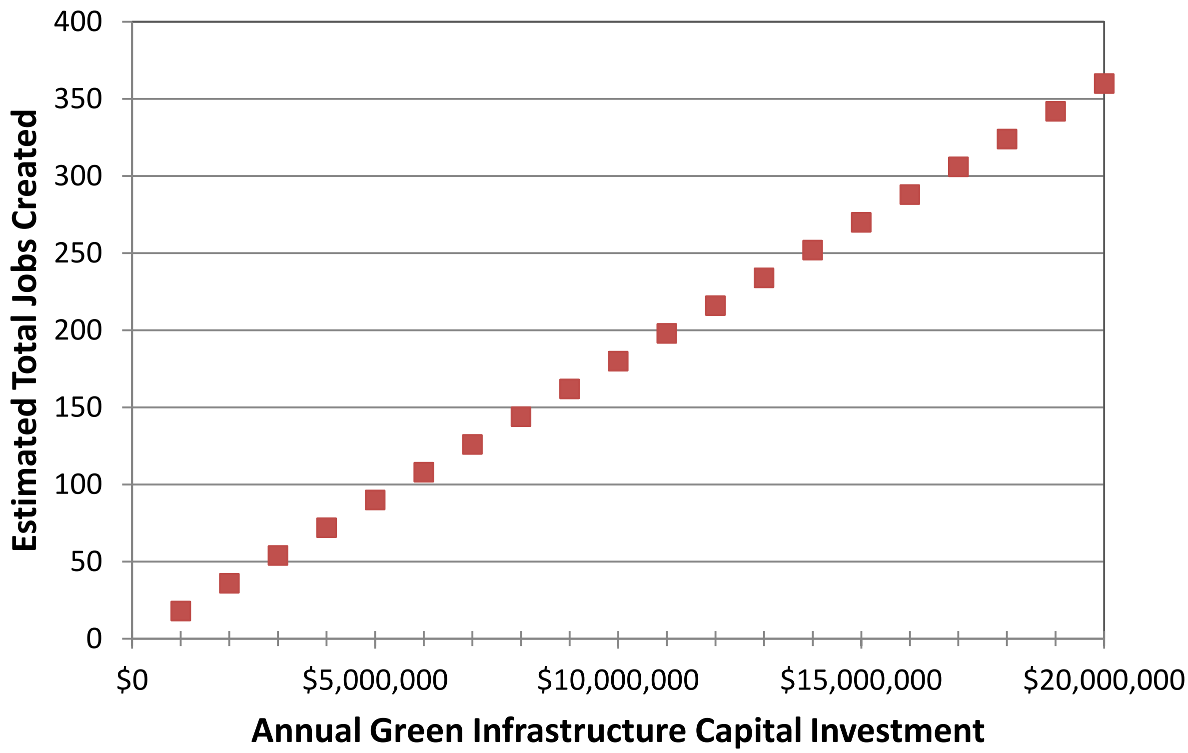


Figure 21: Estimate of total direct, indirect, and induced jobs created based upon increased annual capital investment in green infrastructure

1. Heintz, J., Pollin, R., and Garrett-Peltier, H. (2009). "How Infrastructure Investments Support the U.S. Economy: Employment, Productivity and Growth." Alliance for American Manufacturing, Washington, DC, and Political Economy Research Institute, Amherst, MA.

Job Creation Conclusions

Due to the many complexities and contributing factors involved, there is clearly a large amount of variability in estimating the number of jobs which may be created from increased green infrastructure investment. Despite this variability and uncertainty, it is reasonable to conclude that green infrastructure implementation has the potential to create jobs and foster the local economy, in addition to the many other benefits it can provide. Furthermore, as an emerging trend nationwide in stormwater management, local experience with green infrastructure can result in a workforce that is capable of providing valuable goods and services not only to Bridgeport and New Haven, but other communities throughout the country.

Cost-Benefit Analysis

The costs and benefits of green infrastructure implementation have a major influence on the overall feasibility of this wet weather management strategy. An important element to consider when evaluating costs and benefits is that green infrastructure implementation is inarguably more costly than doing nothing to manage stormwater runoff; however, in Bridgeport and New Haven, as well as many other urban areas, some form of stormwater management is required due to environmental concerns, regulatory requirements, and public demands. When comparing the implementation of green infrastructure source controls to conventional grey infrastructure strategies, the potential for green infrastructure implementation becomes much more feasible due to the comparative costs and wide variety of benefits these practices can provide.

Implementation Extent and Quantitative Runoff Management

Often, green infrastructure source controls are progressively implemented within a sewershed until a certain implementation extent is achieved. The extent to which these source controls are implemented and the effectiveness of each individual control has a major impact on the overall runoff management benefits realized. Due to cost considerations and other practical constraints, it generally is not feasible to install green infrastructure source controls to manage 100% of the runoff within a sewershed. While specific goals are dependent upon a variety of factors, including the characteristics of the combined sewer system, several cities in the Northeastern United States have adopted goals to manage from 10% to more than 30% of total impervious areas with green infrastructure. Remaining runoff may be managed through a variety of existing or proposed grey infrastructure elements. Development of a relevant impervious area management goal for Bridgeport and New Haven requires detailed analyses of existing sewer capacities and hydraulic and hydrologic modeling; however, it is anticipated that such a goal would fall within the range of other cities in the Northeast.

An evaluation of the land cover within Bridgeport and New Haven provides insight into the scale of potential green infrastructure implementation. GIS analyses indicate that combined sewer areas within New Haven are comprised of approximately 20% buildings and 30% pavement, resulting in roughly 50% of the total land area covered by impervious surfaces. Within Bridgeport, 20% of the combined sewer area is covered by buildings. Although geospatial information on pavement areas within Bridgeport was not available, inspections suggest relative proportions are similar to those in New

Haven. While pavement is the predominant impervious surface, it is evident that management of rooftop runoff, either directly through practices such as blue and green roofs, or indirectly through downstream practices, such as downspouts directed to bioretention, is an important element of overall management strategies. Table 2 presents the relative areas requiring runoff management under various implementation targets.

Table 2: Overview of combined sewer coverage and potential impervious area extents managed by green infrastructure

	Bridgeport	New Haven
Combined Sewer Area	2,800 ac	2,300 ac
Impervious Area	1,500 ac*	1,200 ac
Rooftop Area	555 ac	490 ac
Paved Area	900 ac*	740 ac
10% Management	150 ac	120 ac
20% Management	290 ac	240 ac
30% Management	440 ac	360 ac

* Area estimates based on relative proportion of rooftop to total impervious area

The ability of a source control to capture and manage runoff that is directed towards it also has a substantial impact on the ultimate benefits green infrastructure source controls can provide. In most cases, it is not economically feasible to design a source control to capture 100% of the runoff it would receive, since doing so would result in increased costs from storage capacities and other components that would only be necessary during rare and extreme events. A general design guideline used for many green infrastructure, low impact development, and stormwater control measures in general, is to capture runoff from the first inch of rainfall, since these smaller storms represent the majority of annual runoff volumes. Although less relevant to CSO control, this runoff also contains the highest levels of stormwater pollutants. An analysis of historical rainfall data collected at LaGuardia Airport from 1970-2006 revealed that designing source controls to capture runoff from storms with one inch of rainfall or less would result in approximately 75% of annual rainfall being managed by green infrastructure (Figure 22). For perspective, combined sewer overflows occur in some locations within Bridgeport and New Haven for storm events with less than half an inch of rainfall, suggesting that the existing system in those areas manages approximately half of total annual rainfall. It is worth noting that some source controls may be able to manage more than one inch of rainfall depending on how they are designed, as well as the characteristics of individual storm events. Assuming the green infrastructure proposed in this study captures runoff from an inch of rainfall on the impervious areas with the extents previously outlined, it is possible to approximate the annual rainfall volume that could be managed by green infrastructure if implemented throughout Bridgeport and New Haven (Table 3).

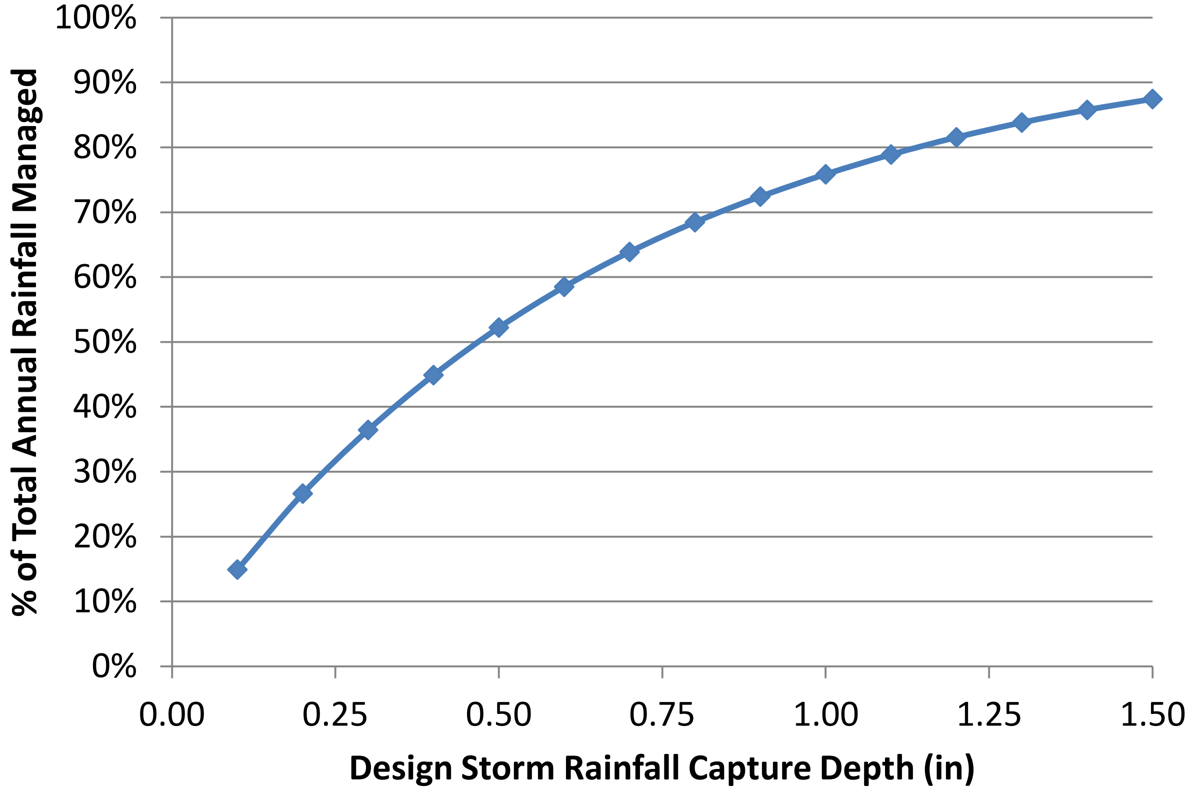


Figure 22: Portion of total annual rainfall managed by green infrastructure designed to capture specified individual storm depths

Table 3: Potential annual rainfall volumes captured and managed by green infrastructure

Bridgeport				
Implementation Extent	0%	10%	20%	30%
Managed Rainfall Volume	0 MG/yr	130 MG/yr	250 MG/yr	380 MG/yr
Unmanaged Rainfall Volume	1,700 MG/yr	1,500 MG/yr	1,400 MG/yr	1,300 MG/yr
New Haven				
Implementation Extent	0%	10%	20%	30%
Managed Rainfall Volume	0 MG/yr	110 MG/yr	210 MG/yr	320 MG/yr
Unmanaged Rainfall Volume	1,400 MG/yr	1,300 MG/yr	1,200 MG/yr	1,100 MG/yr

Flows managed by green infrastructure provide several direct benefits regarding runoff quantity management. Most green infrastructure source controls provide direct detention of storm flows, holding runoff and releasing flows at a slower rate that can be better handled by downstream infrastructure and the treatment plant. Due to the natural elements of green infrastructure source controls, these practices often reduce the volume of stormwater that is discharged to the combined sewer through seepage into the underlying soil and evapotranspiration losses. Although highly site specific, it may be possible in some locations to manage captured runoff through retention, seepage, and other losses that result in substantial reductions or elimination of discharges to the combined sewer system.

The combination of detention and retention provided by these systems may make it possible to reduce the size of downstream grey infrastructure. In the case of retention, runoff is managed by the source control directly and withheld from the downstream grey infrastructure control. When runoff is detained, there is an opportunity for runoff stored in downstream grey infrastructure controls to be managed by the treatment plant, making storage capacity available for water released by contributing green infrastructure controls. Although specific volume reductions are dependent on the characteristics of individual source controls and the downstream drainage infrastructure, reducing required grey infrastructure detention volumes by a volume equivalent to the runoff retained or detained by green infrastructure source controls may be feasible in some cases. This pairing of green and grey infrastructure also makes it possible to manage more than the 75% of annual rainfall volumes that green infrastructure controls would provide by themselves, possibly approaching full control depending upon the extent of implementation. It is important to note that if runoff can be effectively managed by source controls and the combined sewer system without generating overflows, the overall pollutant loads discharged to surface waters can be substantially lower than they would be if storm flows were conveyed via separated sewers to surface waters without any direct treatment.

Additional Benefits

In addition to controlling wet weather flows for CSO management, green infrastructure controls can provide a variety of additional benefits. By reducing downstream runoff flow rates and volumes, it may be possible to reduce the size and extent of conventional drainage infrastructure. Flow reductions may reduce the size and extent of gutters, catch basins, pipes, and other detention structures. While the cost savings associated with these reductions are less likely to be immediately realized in retrofit scenarios, since much of the conventional drainage infrastructure is existing, there could be substantial savings with new development or future infrastructure repair and renovation requirements. The flow reductions induced by green infrastructure controls could also have direct benefits when implemented in conjunction with sewer separation projects by potentially reducing the size of the newly separated sewer pipes, depending upon specific site and source control characteristics. The flow and volume reductions provided by green infrastructure may also alleviate localized flooding.

Perhaps one of the greatest benefits of green infrastructure when compared to grey infrastructure is its ability to garner public support for stormwater management by providing stormwater management features that can also serve as aesthetic amenities. Although their costs are comparable, grey infrastructure controls are generally underground and otherwise hidden from the general public. In contrast, green infrastructure source controls are often distributed widely throughout communities and incorporate vegetative or architectural elements that improve aesthetics, provide valuable habitat within the urban landscape, and provide an array of additional potential benefits, including urban greening, carbon sequestration, and urban heat island reduction.

Source Control Construction Costs

Costs associated with green infrastructure implementation can be categorized as design costs, construction costs, and operation and maintenance costs. Due to the site specific nature of green infrastructure source controls, construction costs can be highly variable. Some of the greatest variability can be associated with the infrastructure requirements to convey runoff to the source control itself. For example, some sites may allow an existing drainage pattern to be intercepted with simple curb cuts or similar features, thereby minimizing costs. At the same time, sites involving utility conflicts, complicated grading, substantial removal of existing materials, or major drainage infrastructure modifications may have increased project costs. In a retrofit scenario, the cost of site modifications and drainage infrastructure can exceed the construction costs of the source control itself.

Costs are likely to be highly variable and generally higher during the initial phases of implementation as well. As green infrastructure incorporates many unique elements, it is likely that many contractors will utilize higher prices in their bids for these projects in order to account for any unforeseen issues associated with the construction. These construction costs will likely decrease and become more consistent as the construction community becomes more familiar with these practices.

There are a wide variety of additional factors that can affect green infrastructure construction costs, including project scale, location, contractor experience, equipment requirements, material requirements, and overall nature of the retrofit. The analyses contained herein are intended to capture some of this variability by referencing an array of construction costs; however, it is imperative to perform detailed site analyses when developing project specific cost estimates, as well as track local costs during the overall implementation of green infrastructure.

Planning and Design Costs

Planning and design costs for green infrastructure source controls can differ somewhat from other civil engineering projects due to the unique elements of these systems. For the purposes of this study, design costs were assumed to constitute 15% of construction costs. This proportion could be substantially higher for green infrastructure designs involving highly detailed site specific work. It could also be lower for projects that utilize basic modifications of standard designs. In addition, the ratio of design costs to construction costs will vary based on the scale of the project, generally with a higher overall percentage allocated for design of smaller projects. Like construction costs, variability and overall design costs are expected to reduce as the local design and regulatory community becomes more familiar with these practices.

Maintenance Costs

All stormwater management facilities, whether grey or green, require some form of routine maintenance in order to sustain their functionality. For grey infrastructure, common maintenance tasks may include removal of sediment and debris from detention structures, repair and replacement of valves and pumps, and all varieties of routine maintenance associated with operations at the wastewater treatment plant. For green infrastructure, maintenance may include sediment and debris removal from soil or rooftop surfaces, pruning, mulching, and soil replacement. Concerns over maintenance requirements and associated costs can serve as a substantial hurdle to garnering stakeholder support for green infrastructure. A variety of factors influence maintenance costs including the availability of existing staff and equipment, location and accessibility of source controls, nature of source control design, and the level of performance that is maintained, resulting in large potential variability in costs. Lower maintenance costs could be achieved when source control maintenance can be consolidated with existing city activities, inputs of sediment and debris are minimal, and there is not a need to maintain a high aesthetic or performance standard. High maintenance costs are associated with source controls that are widely distributed, difficult to access, receive high loads of sediment and debris, and are maintained in a condition similar to how they were installed. Particularly in these high level maintenance scenarios, it is possible for maintenance costs to exceed construction costs over the lifetime of the facility.

Many aspects of source control maintenance do not necessarily involve new maintenance demands, but may instead require maintenance at new locations. For example, collection of litter and other gross solids is a routine source control maintenance activity. Depending upon the nature of the source control, litter collection may take place across the surface of a vegetated practice, within a pretreatment basin or forebay, or within some subsurface pretreatment device. Installation of green infrastructure does not increase the production of litter. Instead, it requires litter removal from wherever it is captured within the source control, rather than removal from gutters, catch basins, pipes, subsurface tanks, or screens at the treatment plant. While maintenance activities at these grey infrastructure locations may be more consolidated, they are also more likely to require special equipment and have higher associated costs. Additionally, because green infrastructure source controls utilize natural and passive treatment mechanisms, they do not require the ongoing operational costs of many grey infrastructure approaches, such as pumping and treatment plant costs. A major benefit of a pilot program is to gain better perspective on the details of how maintenance activities can be conducted within these cities and what the associated costs and opportunities for cost savings would be, as well as what level of source control performance needs to be maintained over the long term.

Grey vs. Green Infrastructure Costs

In order to compare the cost of grey and green infrastructure implementation, the cost of managing a gallon of stormwater runoff per year was calculated for an array of green infrastructure source controls and a large detention tank. For the green infrastructure source controls, assumptions were made regarding typical sizing ratios, ratios of construction costs to annual maintenance costs, anticipated source control lifespan, and construction costs per unit area of the source control. Results of the precipitation frequency analysis mentioned earlier in conjunction with source control sizing ratios were used to determine the annual volume captured per unit area of the source control. Construction and maintenance costs were evenly distributed over the lifespan of the source control and combined with the annual capture volume to determine stormwater management costs for each source control (Table 4).

Table 4: Summary of general cost estimates for green infrastructure implementation

Source Control (SC)	SC Area / Contributing Area	Construction Cost / ft² SC	Annual Maint. Cost / Construction Cost	Annual Vol. Captured	Annual Runoff Management Cost
Bioretention (High)	10%	$45/ft²	10%	199 gal/ft² SC	$0.03 /gal treated/yr
Bioretention (Low)	7%	$10/ft²	3%	284 gal/ft² SC	$0.003 /gal treated/yr
Permeable Pavement (High)	100%	$40/ft²	15%	20 gal/ft² SC	$0.39 /gal treated/yr
Permeable Pavement (Low)	75%	$10/ft²	5%	27 gal/ft² SC	$0.04 /gal treated/yr
Blue Roof (High)	100%	$25/ft²	10%	20 gal/ft² SC	$0.19 /gal treated/yr
Blue Roof (Low)	100%	$3/ft²	3%	20 gal/ft² SC	$0.01 /gal treated/yr
Green Roof (High)	100%	$30/ft²	12%	20 gal/ft² SC	$0.23 /gal treated/yr
Green Roof (Low)	100%	$10/ft²	5%	20 gal/ft² SC	$0.05 /gal treated/yr

Assumptions

- Construction costs incorporate a 15% increase to account for design costs
- A 25 year lifespan was assumed for all source controls
- All source controls were assumed to manage runoff from storm depths up to 1”
- Average annual precipitation was specified as 41.92”

A similar grey infrastructure cost estimate was developed based on information provided by the Greater New Haven Water Pollution Control Authority (GNHWPCA) for the Truman Tank, a 5 MG tank designed to store combined sewage during storm events until adequate capacity becomes available at the treatment plant (Table 5).

Table 5: Summary of grey infrastructure implementation example costs

Transport and Treatment Cost	$0.0031/gal
Annual Vol. Captured	125,000,000 gal
Construction Cost	$21,000,000
15% Design Cost	$3,000,000
Tank Lifespan	25 yrs
Annual O&M Cost	$52,000/yr
Annual Runoff Management Cost	$0.01 /gal treated/yr

Extrapolation to City-Wide Scale and Analysis Conclusions

In order to provide a basic context regarding what a large-scale implementation of green infrastructure might cost, it is possible to extrapolate the management costs estimated within this analysis to meet a city-wide implementation target (Table 6). The annualized costs presented distribute design and construction costs evenly over a 25 year source control lifespan and incorporate estimated annual maintenance costs. Ultimate implementation costs are subject to substantial variation due to the types of source controls implemented, as well as the variable costs of individual controls.

Table 6: General extrapolation of implementation costs to city-wide scale

Bridgeport			
Implementation Extent	10%	20%	30%
Managed Rainfall Volume	130 MG/yr	250 MG/yr	380 MG/yr
High Estimate of Annualized 25-yr Total Cost	$27,000,000/yr	$52,000,000/yr	$79,000,000/yr
Low Estimate of Annualized 25-yr Total Cost	$4,000,000/yr	$7,000,000/yr	$10,000,000/yr
Potential Total Job Creation	80-550	140-1,100	210-1,700
New Haven			
Implementation Extent	10%	20%	30%
Managed Rainfall Volume	110 MG/yr	210 MG/yr	320 MG/yr
High Estimate of Annualized 25-yr Total Cost	$23,000,000/yr	$44,000,000/yr	$67,000,000/yr
Low Estimate of Annualized 25-yr Total Cost	$3,000,000/yr	$6,000,000/yr	$9,000,000/yr
Potential Total Job Creation	60-480	120-920	190-1,400

The results of this cost-benefit analysis indicate that in some cases green infrastructure can be directly cost competitive with grey infrastructure, or even less expensive, while in others, implementation costs can be substantially higher (Figure 23). Although a specific example of grey infrastructure implementation costs is included within this report, these costs are also subject to variation. Specifically in areas where grey infrastructure implementation may be more difficult than the example included within this report, green infrastructure may be a more cost competitive option. The cost effectiveness of green infrastructure implementation has become evident in other cities where options for cost-effective grey infrastructure installations have been exhausted. As has been previously noted, green infrastructure can provide a variety of additional benefits not generally associated with grey infrastructure, increasing its feasibility when costs are comparable. Additionally, due to factors such as utility conflicts, there are a number of scenarios where green infrastructure implementation may be feasible while grey infrastructure controls are not, making certain direct cost comparisons irrelevant. The overall results of this cost-benefit analysis and feasibility study as a whole support the need to consider a combination of grey and green infrastructure in efforts to reduce CSOs, as many other CSO communities have done. Doing so allows each of these wet weather management strategies to be utilized in areas where they are best suited and can provide optimal benefits, while minimizing costs.

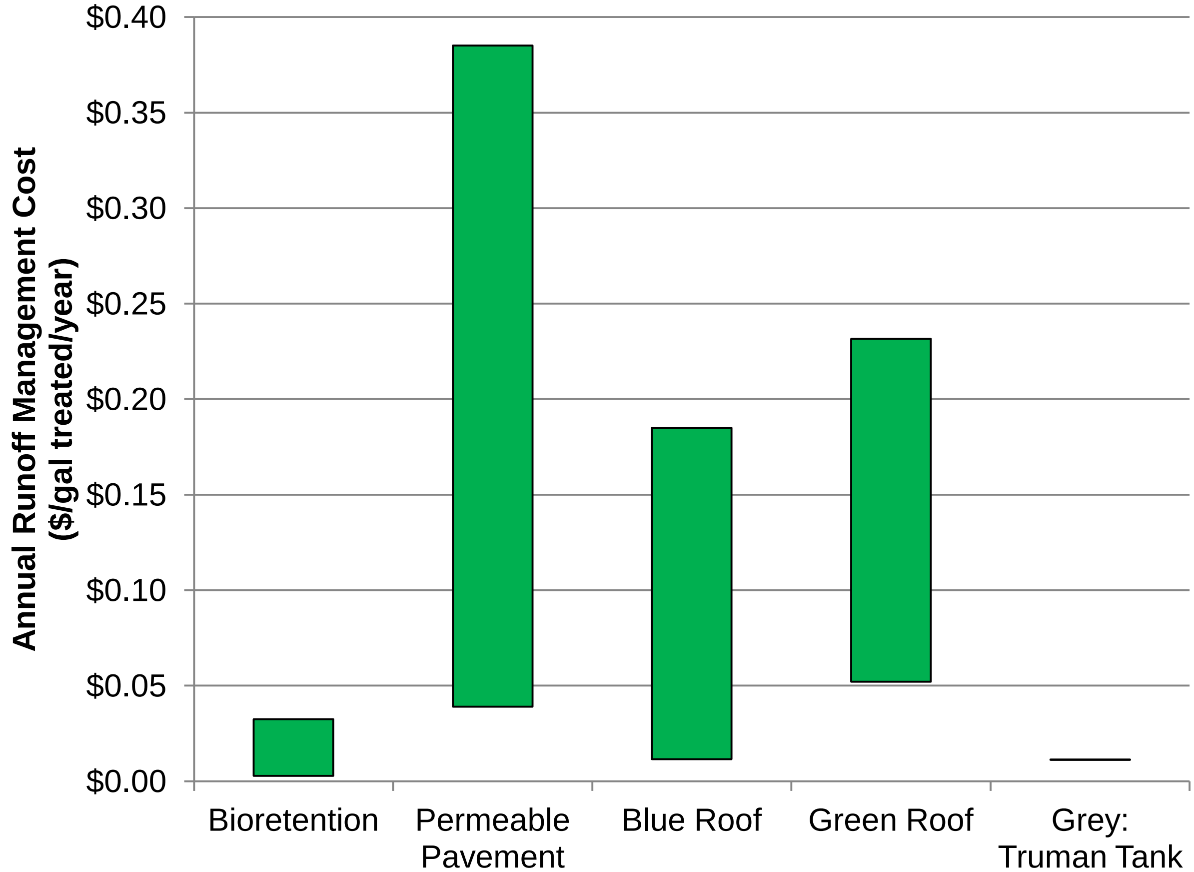


Figure 23: Summary of general cost estimates for green and grey infrastructure implementation

Conclusions

In developing a detailed plan to implement green infrastructure, it is desirable to know the direct impact of green infrastructure implementation on CSO reduction and the corresponding role of green infrastructure in meeting goals specified within long term control plans. Unfortunately, as has been discussed throughout this report, there are a multitude of complexities that make presentation of specific impacts at a basic level infeasible. These complexities are not entirely unique to green infrastructure, as detailed evaluation of the existing sewer system, site design considerations, sizing calculations, and modeling efforts are frequently incorporated into assessments of grey infrastructure benefits. Green infrastructure evaluations can involve additional complexities due to the distributed nature of source controls, variety of stormwater management mechanisms, and variability of natural elements.

Because grey infrastructure approaches often involve complete removal of certain flows from the combined sewer system, as is the case with sewer separation, or large scale detention associated with tanks or tunnels, a design storm approach is sometimes used to quantify the impact of grey infrastructure on CSOs. Design storm evaluations are the basis for much of the Bridgeport and New Haven long term control plans and management goals are stated in terms of eliminating overflows for a specified design storm. In this approach, the response of the combined sewer system to a single, relatively large storm event is analyzed. Because design storms are based on statistical frequencies, they can be utilized to design around a single storm event that has a certain probability of occurring.

While a design storm approach provides a standardized mechanism to evaluate CSO reduction under a relative worst-case scenario, it does not provide an indication of total CSO discharges or effectively consider the impact of interim or distributed management efforts for smaller, more frequent storm events. Because these smaller events occur with greater regularity, they may present a large portion of overall annual CSO discharges. This aspect of CSO evaluations has important implications for the assessment of the benefits green infrastructure implementation can provide for CSO control, since green infrastructure controls are designed to manage these smaller, more frequent storms. By managing a portion of overall design storm flows, green infrastructure can contribute towards meeting design storm management goals by alleviating the demand on other CSO management efforts; however, the ability of green infrastructure to contribute towards overall design storm control is dependent upon specific characteristics of the sewer infrastructure, as well as characteristics of individual source controls.

One way to account for the benefits green infrastructure and similar controls provide is to perform continuous simulations of the combined sewer system using rainfall records for a typical year or multiple years. This approach has been utilized to evaluate the combined sewer system within Bridgeport's long term control plan. While more complex than a design storm approach, this analysis method provides a better indication of the effect of management efforts on total CSO discharges throughout a year. Doing so not only provides a better indication of the total impact of CSOs to surrounding water bodies, but also provides a mechanism to gauge the effect of interim control measures or green infrastructure controls that do not manage a full design storm by themselves. These benefits are evidenced by EPA's incorporation of annual evaluations into the national CSO Control Policy. Consequently, expressing CSO management goals in terms of annual CSO discharge volumes within the long term control plans for Bridgeport and New Haven may be worth considering in order to better evaluate the effect of future CSO management approaches, particularly green infrastructure controls.

With the substantial challenges of managing combined sewer overflows within Bridgeport and New Haven evident, it is important to consider the full toolbox of available options for managing stormwater runoff. The results of this feasibility scan suggest that green infrastructure can play a vital role in future wet weather management efforts in these cities, while providing a myriad of additional benefits. At the same time, effective green infrastructure implementation is not without challenges.

A pilot program can provide invaluable experience regarding how these challenges may be overcome and what benefits may be realized within Bridgeport and New Haven. For example, a pilot program can help planning officials and involved stakeholders understand the array of site specific issues which must be considered during green infrastructure planning and implementation. Some of these elements, such as identifying who will be responsible for maintenance, can be considered in advance of the pilot implementation, while other unforeseen elements will undoubtedly arise during the course of pilot implementation. A pilot program can also provide real information on local costs and benefits, perspectives on the logistics of implementation, education of stakeholders, and support for future efforts. Such a program can also provide information on the long-term performance of source controls, accounting for elements such as the effects of maintenance activities or the lack thereof. This type of information can be essential in incorporating green infrastructure into long term control plans, as a true indication of system performance is needed to ensure that stormwater management efforts can achieve specified goals for the combined sewer system.

Although valuable insights can be gained from implementation of small-scale concepts, conducting a neighborhood scale pilot program can provide additional benefits. When aligned with sewershed boundaries, implementation at the neighborhood scale can provide essential information on the effect green infrastructure incorporation within combined sewer areas can have on the sewer system. Demonstration of these concepts and quantifying the actual benefits they provide on the ground should assist with their overall implementation moving forward, including participation from funding sources such as DEEP. All of these elements combined provide valuable experience that can guide future wet weather management efforts.

A neighborhood pilot program could be based on the concepts presented within this study. The feasibility of these concepts should be further evaluated and designs advanced by engaging in detailed planning and design efforts, accounting for the variety of site specific factors affecting these source controls. Stakeholder education and coordination would be an important component of planning and design efforts, ensuring that all relevant parties support the proposed source controls and identifying opportunities for synergistic efforts to reduce costs.

Upon implementation of a pilot program, further steps to incorporate green infrastructure on a larger scale can be pursued. Namely, results from a pilot implementation and monitoring program, in conjunction with detailed modeling efforts, could aid city officials in Bridgeport and New Haven in evaluating the impact of green infrastructure implementation on CSO reduction and the potential roles of green infrastructure within the long term control plans of these cities. A detailed, long-term green infrastructure plan for Bridgeport, New Haven, and their respective water pollution control authorities could be developed to define CSO reduction objectives and the measurable role of green infrastructure in achieving those goals, while greening the city.

Other cities pursuing green infrastructure, such as New York, Philadelphia, Syracuse, and Nashville, are aiming to implement green infrastructure on 10-30% of their existing impervious area. A pilot program in Bridgeport and New Haven could better indicate whether these goals could provide similar levels of benefits for Bridgeport and New Haven or whether they should be altered or adapted. Additionally, results of the pilot program and future planning efforts could build upon frameworks already established within Bridgeport's and New Haven's long term control plans, stormwater regulations, and sustainability plans. Further guidance can be found in this report and in the control plans developed by the other cities listed above which are incorporating green infrastructure. Ideally, the green infrastructure plan would ultimately become incorporated within Bridgeport and New Haven's long term control plans as part of a comprehensive management strategy.

With a detailed plan in place, and proven outcomes from a pilot program, the ability to secure long-term funding for green infrastructure implementation becomes much more feasible. Such funding sources could include the Connecticut Clean Water Fund, other state and federal grant programs, a stormwater utility program, user fees from new development and redevelopment, and other sources outlined within this report. The existence of a pilot program and detailed implementation plan can not only maximize the effective use of program funds, but also encourage public support of such a program.

With a plan and funding mechanisms in place, implementation of green infrastructure can be sustained by further educating the public and incentivizing construction of source controls. This educational support could be in the form of demonstration projects, educational websites, publications, training workshops, and seminars. Implementation incentives could include public recognition for implementation efforts, streamlined permitting, tax credits, and sewer rate reductions, as well as partnerships between the cities and private property owners to share maintenance responsibilities.

While not without challenges, it is evident that green infrastructure can play a valuable role within ongoing efforts in Bridgeport and New Haven to reduce CSOs and improve water quality. This report is expected to advance existing interests in green infrastructure within these cities, providing a foundation for future pilot programs and detailed planning efforts. Utilizing the practices and strategies outlined within this study, it should be possible to improve wet weather management within Bridgeport and New Haven, thereby reducing CSOs while improving the environment within the Long Island Sound, other surrounding water bodies, and these cities themselves.

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