

## CHAPTER 3

# Economics and LID Practices

**L**ow Impact Development (LID) represents one of the most progressive trends in the area of stormwater management and water quality. This approach involves utilizing strategies to control precipitation as close to its source as possible in order to reduce runoff volumes, promote infiltration, and protect water quality. While better known for its capacity to reduce pollution and manage stormwater more sustainably, LID designs are also economically beneficial and more cost-effective as compared to conventional stormwater controls.

In the vast majority of cases, the U.S. Environmental Protection Agency (EPA) has found that implementing well-chosen LID practices saves money for developers, property owners, and communities while also protecting and restoring water quality (USEPA, 2007). Specifically, utilizing LID designs can result in project cost savings by decreasing the amount of expensive below ground drainage infrastructure required, as well as reducing or eliminating the need for other stormwater management-related facilities including curbs, erosion control measures, catch basins, and outlet control structures.

LID designs also have space-saving advantages and can reduce the amount of land disturbance required during construction, saving money on site preparation expenses. In northern Frederick County, Maryland, a number of cost saving benefits were realized by redesigning a conventional subdivision with LID designs. This included eliminating two stormwater ponds representing a reduction in infrastructure costs of roughly \$200,000; increasing the number of buildable lots from 68 to 70, which added roughly \$90,000 in value; and allowing the site design to preserve approximately 50 percent of the site in undisturbed wooded condition, which reduced clearing and grubbing costs by \$160,000 (Clar, 2003). Also, an infill site in northern Virginia was able to save over 50 percent in cost for infrastructure by minimizing impervious surfaces, protecting sensitive areas, reducing setback requirements, and treating stormwater at the source (CWP et al., 2001).

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Additional economic benefits of LID include reduced flooding costs as well as lower home cooling expenses. For example, natural vegetation and reduced pavement area in the Village Homes LID development in Davis, CA helped lower home energy bills by 33 to 50 percent as compared to surrounding neighborhoods (MacMullan, 2007). Further economic incentives to developers for LID inclusion

include the potential for higher property values as well as a reduction in permitting fees; in Dane County, WI, permit fees for development are calculated based on the amount of impervious area in a site, providing an incentive for developers to use LID. In another example, an analysis of 184 lots in one community found that conservation subdivisions were more profitable than conventional subdivisions. Lots in the conservation subdivisions cost an average of \$7,000 less to produce, resulted in a 50 percent decrease in selling time, and had a value of 12 to 16 percent more as compared to lots in conventional subdivisions (Mohamed, 2006).

Additionally, incentives encouraging the implementation of LID may include the means to support new construction. This may include a range of incentives such as an increase in floor to area ratio (FAR), rebates, and tax credits. The City of Portland, OR has a Green Roof bonus

that provides an additional three square feet of floor area for every one square foot of green roof, provided the roof is covered by at least 60 percent. Some cities offer builders a cost-share and/or rebates when they install green infrastructure such as in the case of King County, WA that pays 50 percent of the costs, up to \$20,000. Similarly Austin, Chicago and Santa Monica provide discounts for homes that employ LID. Reducing taxes is another strategy employed to encourage implementation. In New York City a project can earn a one year tax credit up to \$100,000 for inclusion of a green roof on 50 percent of the structure, and in Maryland green building credits are being used to offset property taxes and can be carried forward for ten years (MacMullan, 2010).

Traditionally, land planning and development projects are often based upon on fundamental economic decisions: costs versus benefits. The costs are the real and documented costs of mobilizing, constructing, landscaping, compliance, and marketing. The benefits are the real project income. However, there are other costs that exist and these burdens are either born by the landowner, known as lost opportunity costs or the public as natural and social capital. Lost opportunity costs are associated with other options for the land rather than what was built. For example, a land development project may have generated benefits greater than economic costs, whereas alternative options might have generated more net benefits. Since opportunity costs are primarily borne by the landowner, it is certainly within the landowner's right to develop the parcel to their desire, as

long as it complies with State and local codes and regulations. However, the expenditure of natural and social capital is usually borne by the public: in essence the land developer passes off costs to the public. Natural capital represents the ecological value of the goods and services provided by the environment. In the case of stormwater, if streams are degraded because of poor stormwater management, that is an expenditure of natural capital. If the degraded stream is in need of restoration, often this is done by the expenditure of public funds. Just as water quality and water quantity affect the health of an ecosystem, the built environment affects and reflects the community. Healthy environments,

foster stronger community connections: whether through community groups, recreational activities, or social gatherings. Societies that have demonstrated stronger community connections (social capital) reduce community costs, such as crime, emergency response, transportation, etc (Knack and Keefer, 1997). Better stormwater management at the site level ultimately minimizes the expenditures of natural and social capital which translates to less long term adverse impacts to community budgets.

While these additional benefits are recognized, the focus of this section is to clearly articulate, through case studies and detailed examples, the hard cost benefits of implementing LID.

## CASE STUDIES

### ECONOMIC BENEFITS OF LID PRACTICES

The following case studies show how utilizing an LID approach to site drainage engineering, specifically with porous asphalt installation, led to more cost-effective site and stormwater management designs.

#### **BOULDER HILLS**

In addition to more effective stormwater management, an economic benefit was gained by utilizing an LID approach that featured porous asphalt for a residential development.

FIGURE 3-1  
Boulder Hills



Boulder Hills is a 24-unit active adult condominium community in Pelham, New Hampshire that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land

and includes a total of 5 buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and



**FIGURE 3-2**  
Comparison of Two  
Designs, LID Design  
(top) and Conventional  
(bottom) for Boulder  
Hills, Pelham, NH

(SFC, 2009)

the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage. The University of New Hampshire (UNH) Stormwater Center advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure

for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and

flood zone areas. Over time, the porous asphalt placements are also anticipated to require less salt application for winter de-icing, resulting in additional economic and environmental benefits. By the end of the first winter 2009-2010, the project owners reported using substantially less salt for winter ice management.

## DESIGN PROCESS

Initially, SFC Engineering Partnership began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., L.L.S., manager of SFC's Civil Engineering Department, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas while the upland areas were fragmented and limited," Jordan said. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations. We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and specifically, porous asphalt, emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive.

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Stickville was aware of the advantages of LID and porous pavement and was interested in utilizing these measures as a possible marketing tool which could help differentiate them as green-oriented developers. SFC advised Stickville LLC to pursue this option. Jordan had attended a seminar on porous pavement presented by The UNH Stormwater Center which covered the multiple benefits of utilizing this material, including its effectiveness for being able to meet stormwater quantity and quality requirements.

“Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel,” Jordan said. “In addition to controlling runoff, stormwater mitigation measures also had to be adequate in terms of treatment. Porous pavement allows us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage.”

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. “The planning board was on board from the very beginning,” he said. “They were very supportive of utilizing porous asphalt and recognized the many benefits of this option.”

## ECONOMIC COMPARISONS

SFC Engineering Partnership designed two development options for the project. One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional

asphalt in the roadway and driveways with porous asphalt and using sub-surface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly as compared to traditional asphalt, the engineers found that by utilizing this material, cost savings in other areas could be realized. For one, installing porous asphalt significantly lowered the amount of drainage piping and infrastructure required. Using porous asphalt also reduced the quantity of temporary and permanent erosion control measures needed while cutting in half the amount of rip-rap, and lowering the number of catch basins from 11 to 3. Additionally, the LID option completely eliminated the need to install curbing, outlet control structures, as well as two large stormwater detention ponds. Another benefit was a 1.3 acre reduction in the amount of land that would need to be disturbed, resulting in less site preparation costs.

Table 3-1 shows the construction estimate cost comparisons between the conventional and the low impact development options. As shown, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most

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TABLE 3-1  
Comparison of Unit Costs for Materials for Boulder Hills LID Subdivision  
(SFC, 2009)

ITEM	CONVENTIONAL	LID	DIFFERENCE
Site Preparation	\$23,200.00	\$18,000.00	-\$5,200.00
Temp. Erosion Control	\$5,800.00	\$3,800.00	-\$2,000.00
Drainage	\$92,400.00	\$20,100.00	-\$72,300.00
Roadway	\$82,000.00	\$128,000.00	\$46,000.00
Driveways	\$19,700.00	\$30,100.00	\$10,400.00
Curbing	\$6,500.00	\$0.00	-\$6,500.00
Perm. Erosion Control	\$70,000.00	\$50,600.00	-\$19,400.00
Additional Items	\$489,700.00	\$489,700.00	\$0.00
Buildings	\$3,600,000.00	\$3,600,000.00	\$0.00
<b>PROJECT TOTAL</b>	<b>\$4,389,300.00</b>	<b>\$4,340,300.00</b>	<b>-\$49,000.00</b>

noticeably, drainage. Overall, the LID option was calculated to save the developers \$49,128 (\$789,500 vs. LID cost of \$740,300) or nearly 6 percent of the stormwater management costs as compared to the conventional option.

**CONCLUSIONS**

Beyond its effectiveness at reducing stormwater runoff, facilitating more groundwater infiltration, and promoting water quality benefits, porous asphalt was shown in

this case study to be capable of bringing positive economic results. Primarily, cost savings were achieved in the Boulder Hills site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized. Compared to a conventional development plan, an option utilizing LID featuring porous asphalt was shown in this example to be more economically feasible.

Overall, the LID option was calculated to save the developers \$49,128 or nearly 6 percent of the stormwater management costs as compared to the conventional option.



## GREENLAND MEADOWS

Utilizing an LID approach which featured porous asphalt, a cost-competitive drainage system was designed for a large retail development.



FIGURE 3-3  
Greenland Meadows

### OVERVIEW

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based Packard Development in Greenland, New Hampshire that features the largest porous asphalt installation in the Northeast. The development is located on a 55.95-acre parcel and includes three, one-story retail buildings (Lowe's Home Improvement, Target, and a future supermarket), paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, as well as advanced stormwater management facilities. The total impervious area of the development – mainly from rooftops and non-porous parking

areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to development, the project site contained an abandoned light bulb factory with a majority of the property vegetated with grass and trees.

Framingham, Mass.-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, sub-surface crushed stone reservoir, sand filter, and underground piping and catch basins. Dr. Rosen of the UNH Stormwater Center provided guidance and oversight with

the porous asphalt installations and supporting designs.

This case study will show how a combination porous asphalt and standard

pavement design with a sub-surface gravel reservoir management system was more economically feasible as compared to a standard pavement design with a conventional sub-surface stormwater management detention system. Additionally, this analysis will cover some of the site-specific challenges, as well as the environmental issues with this development that mandated the installation of an advanced LID-based stormwater management design.

“Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging. We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources.”

interested in the project’s approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, CLF feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. “Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging,” Turner said. “We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources. The CLF wanted this project to have the gold standard in terms of discharge.”

In order to ensure a high level of stormwater treatment as well as gain project approval, Tetra Tech Rizzo worked closely with Packard Development, the UNH Stormwater Center, the New Hampshire Department of Environmental Services, and CLF on the design of an innovative stormwater management system with LID designs.

### ENVIRONMENTAL CONCERNS

During the initial planning stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff as compared to existing conditions. These concerns were especially heightened given the fact that the development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay. One group that was particularly

### HYDROLOGIC CONSTRAINTS

Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, said one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. “The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration,” Potvin said. “Water did not infiltrate well during site testing and the soils were determined to not be adequate for

receiving runoff.” As such, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

**ECONOMIC COMPARISONS**

Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

**1. Conventional**

This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel sub-base and stone backfill, stormwater wetland, and supporting infrastructure.

**2. LID**

This option included the use of porous asphalt and standard paving in addition to a sub-surface crushed stone reservoir, sand filter beneath the porous asphalt, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site’s stormwater prior to discharge into

Pickering Brook. Table 3-2 compares the total construction cost estimates for the conventional and the LID option.

As shown, paving costs were estimated to be considerably more expensive (by \$884,000) for the LID option because of the inclusion of the porous asphalt, sand filter, and porous asphalt crushed stone reservoir layer. However, the LID option was also estimated to save \$71,000 in earthwork costs as well as \$1,743,000 in total stormwater management costs, primarily due to piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of \$930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management.

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Item	Conventional Option	LID Option	Cost Difference
Mobilization / Demolition	\$555,500	\$555,500	\$0
Site Preparation	\$167,000	\$167,000	\$0
Sediment / Erosion Control	\$378,000	\$378,000	\$0
Earthwork	\$2,174,500	\$2,103,500	-\$71,000
Paving	\$1,843,500	\$2,727,500	\$884,000
Stormwater Management	\$2,751,800	\$1,008,800	-\$1,743,000
Addtl Work-Related Activity (Utilities, Lighting, Water & Sanitary Sewer Service, Fencing, Landscaping, Etc.)	\$2,720,000	\$2,720,000	\$0
<b>Project Total</b>	<b>\$10,590,300</b>	<b>\$9,660,300</b>	<b>-\$930,000</b>

**TABLE 3-2**  
Comparison of Unit Costs for Materials for Greenland Meadows Commercial Development

\* Costs are engineering estimates and do not represent actual contractor bids.

Tables 3-3 and 3-4 further break down the differences in stormwater management costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by \$159,440,

The LID option completely removed the need to use large diameter piping for subsurface stormwater detention, which amounted to a savings of \$1,356,800. “The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative,” Potvin said.

the LID option also completely removed the need to use large diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of \$1,356,800. “The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative,” Potvin said. “Utilizing void spaces in the porous asphalt sub-surface crushed stone reservoir to detain stormwater

allowed us to design a system using significantly less large diameter pipe. This represented the most significant area of savings between each option.”

**CONSERVATIVE LID DESIGN**

Although the developers were familiar with the benefits of porous asphalt, Potvin said they were still concerned about the possibility of the systems clogging or failing. “The developers didn’t have similar projects they could reference,” he said. “For this reason, they were tentative on relying on porous asphalt alone.”

In order to resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs: additional stormwater infrastructure including leaching catch basins. “This was a conservative ‘belt and suspenders’ approach to the porous asphalt design,” Potvin said. “Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration.”

To further alleviate concerns, a combination paving approach was utilized. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was

TABLE 3-3		TYPE	QUANTITY	COST
Conventional Option Piping	Distribution	6 to 30-inch piping	9,680 linear feet	\$298,340
	Detention	36 and 48-inch piping	20,800 linear feet	\$1,356,800

TABLE 3-4		TYPE	QUANTITY	COST
LID Option Piping	Distribution	4 to 36-inch piping	19,970 linear feet	\$457,780
	Detention*	—	0	\$0

\*Costs associated with detention in the LID option were accounted for under “earthwork” in Table 3-2.

put in near the front and more visible sections of the retail center and for the loop roads, delivery areas expected to receive truck traffic. “This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores,” Potvin said.

### LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the side parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage. The aggregate reservoirs are underlain by sand filters which provide an additional means of stormwater treatment. Runoff from the sand filters flows through perforated underdrain pipes that converge to a large header pipe. Peak flow attenuation is attained by controlling the rate at which runoff exits the header pipe with an outlet control structure.

After being collected in catch basins, a majority of the stormwater runoff from rooftops and nonporous pavement areas flow to particle separator units, which treat stormwater prior to discharging into the crushed stone reservoir layers below the porous asphalt.

Outlet from the smaller aggregate reservoir, located underneath the side parking area, flows to an existing wetland on the east side of the site, while outlet from the larger aggregate

reservoir flows to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater.

### CONCLUSIONS

Although the use of porous asphalt in large-scale commercial and residential development is still a relatively new application, this case study showed how porous asphalt systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits. With Greenland Meadows, an advanced LID-based stormwater design was implemented given the proximity of the development to the impaired Pickering Brook waterway. But in addition to helping alleviate water quality concerns, the LID option featuring porous asphalt systems eliminated the need to install large diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

Although the use of porous asphalt in large-scale commercial and residential development is still a relatively new application, this case study showed how porous asphalt systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits.

## LID RETROFIT: UNH PARKING LOT BIORETENTION

A bioretention retrofit was performed at the University of New Hampshire (UNH) for a site consisting of a landscaped area with existing stormwater infrastructure. Existing infrastructure consisted of curbing, catch-basins, and a drainage network that directed stormwater runoff offsite. The system was designed by UNH Stormwater Center in conjunction with the Maine Department of Environmental Protection (MEDEP). The system is a conversion of an existing landscape island into a bioretention and used as a source control measure to manage water quantity and improve water quality for parking lot run-off.

**FIGURE 3-4**  
Bioretention retrofit installation at the University of New Hampshire, 2008

(UNHSC, 2008)



### OVERVIEW

Retrofitting of stormwater infrastructure is commonly considered to be very costly compared to new construction. However, in certain instances using existing resources, simple retrofits can be performed at minimal expense. Typically Gray Infrastructure represents the largest expense for construction of stormwater controls, and in combination with labor and equipment, may represent the bulk of project costs. Institutions such as municipalities that have a Public Works can provide both labor and equipment

for retrofitting existing infrastructure. In these instances retrofit expenses are limited to design and materials costs only, while installation expenses for labor, equipment, and some infrastructure can be avoided provided the labor is idle and/or municipal operations are already engaged in infrastructure updates or replacements. Public Works Department personnel training for construction of many LID structural controls such as bioretention can be simple. Training often consists of simply having qualified installation oversight to instruct

and train personnel at system construction. The following example details the process and expenses associated with the installation of a bioretention system for an existing parking area on the University of New Hampshire campus.

### PROJECT LOCATION

The bioretention system is installed in an existing commuter parking lot located on-campus in Durham, New Hampshire with routine commuter and bus traffic. The parking lot is a standard design consisting of parking stalls and landscaped islands that are raised, curbed, and vegetated. These islands are approximately 500 feet long, 9 feet wide, and are designed to shed rainwater onto the adjacent impervious surface while the curbing directs runoff to storm drains. Existing stormwater management consists of a conventional catch basin and pipe network draining to a swale. Two catch basins are located near the center of the island, one on each side, draining approximately one acre each with a 12 inch concrete pipe running under the island.

### PROJECT DESCRIPTION

The bioretention was designed to treat runoff from a one-inch rainfall on 0.8 acres of pavement over a 24 hour period, and includes a filter area that is 30 feet long and 9 feet wide. The cross-sectional layout of the system from the bottom up consists of native soil; 10 inches of crushed stone; three inches of ¾-inch pea gravel; 24 inches of an engineered bioretention soil mix (BSM); and a 2-inch layer of hardwood mulch.

The top layer was planted with several varieties of native perennial wild flowers. The BSM mix was based upon a design developed to meet the State of Maine regulatory requirements for bioretention areas. The system was underdrained and includes an infiltration reservoir, and high-flow bypass. All drainage was connected to the existing drainage infrastructure by coring into the adjacent catch-basin underneath the retrofit. The sides of the system were fitted with an impermeable liner to prevent runoff from migrating under the existing pavement as well as to prevent migration of adjacent soils into the system. Bioretention construction took three working days and included a construction team consisting of two skilled contractors in addition to an engineering staff which provided oversight.

### PROJECT COST

Total project cost per acre was \$14,000. With labor and install provided, costs are limited to materials and plantings at \$5,500 (see Table 3-5). Costs could be further reduced with onsite preparation of the BSM saving additional materials and trucking expenses.

In addition to this example, numerous municipal projects have been implemented utilizing bioretention, dry well, tree filter, and porous pavement retrofit installations. In these instances

Institutions such as municipalities that have a Public Works can provide both labor and equipment for retrofitting existing infrastructure. In these instances retrofit expenses are limited to design and materials costs only.

# THE ECONOMICS OF LOW IMPACT DEVELOPMENT: CASE STUDIES

TABLE 3-5	ITEM	COST PER ACRE
Project Cost per Acre	Labor and Installation	\$8,500
	Materials	\$4,675
	Plantings	\$825
	Total	\$14,000

minimal expenses were incurred by the municipal partner beyond contribution of labor and equipment. Expenses were typically limited to materials, design, and installation oversight (which doubled as training of municipal personnel and is not expected to be a

recurring expense for future installs). In all instances, community partners (such as university cooperative extensions and watershed groups) contributed both expertise in plant selection and installation, and often donated materials as well.

**FIGURE 3-5**  
Completed  
Bioretention Retrofit  
Installation 2008

(UNHSC, 2008)





## CASE STUDIES

## LID PRACTICES FOR CSO MANAGEMENT

Combined sewer overflows (CSOs) represent major water quality threats to hundreds of cities and communities in the U.S. that are served by a combined sewer system (CSS). CSO events cause the release of untreated stormwater and wastewater into receiving rivers, lakes, and estuaries, causing a host of environmental and economic-related problems. Costs associated with CSO management are expensive. The U.S. Environmental Protection Agency (EPA) estimates the costs of controlling CSOs throughout the U.S. are approximately \$56 billion (MacMullan, 2007).

The traditional approach to CSO management involves the development of a separate drainage system to convey stormwater flows or the use of gray infrastructure and conventional stormwater controls for enhancing the storage and conveyance capacity of combined systems. These approaches can include the construction of large underground storage tunnels that store sewage overflows during rain events for later treatment, as well as necessary improvements and upgrades to municipal treatment facilities in order to handle increasing volumes. Both approaches, while effective for CSO controls, are very expensive.

Integrating Green Infrastructure strategies and LID designs into a CSO mitigation plan can help communities achieve CSO management requirements at lower costs. In addition to

many benefits including groundwater recharge, water quality improvements, and reduced treatment costs, the use of LID can help minimize the number of CSO events and the volume of contaminated flows by managing more stormwater on site and keeping volumes of runoff out of combined sewers (MacMullan, 2007).

Utilizing a combination approach of gray and Green Infrastructure strategies can be a considerably more cost-effective method for CSO management as compared to a traditional gray infrastructure approach alone. Indeed, LID methods can cost less to install, can have lower operations and maintenance (O&M) costs, and can provide more cost-effective stormwater management and water quality services than conventional stormwater controls (MacMullan, 2007). Some LID alternatives are also being initiated by the private sector. While municipalities may provide oversight and consultation, as is the case with the City of Portland, OR, these projects are not controlled by municipalities in regards to implementation, operation, and maintenance. The purpose of this study is to show the cost-benefits of integrating Green Infrastructure strategies with traditional gray infrastructure.

Integrating Green Infrastructure strategies and LID designs into a CSO mitigation plan can help communities achieve CSO management requirements at lower costs.

Although communities rarely attempt to quantify and monetize the avoided treatment costs from the use of LID designs, the benefits of these practices for decreasing the need for CSO storage and conveyance systems should be factored into any economic analyses (EPA, 2007).

The following case studies are presented to develop an economic context

for the use of Green Infrastructure and LID designs as a strategy for CSO compliance. The case studies will also identify and contrast historical gray infrastructure approaches to CSO management using store, pump, and treat with approaches using Green Infrastructure/LID designs that focus on reduced stormwater runoff volumes.

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## NARRAGANSETT BAY COMMISSION

### A Baseline Gray Infrastructure Approach to CSO Management

**FIGURE 3-6**  
Narragansett Bay



The Narragansett Bay Commission (NBC) in Providence, Rhode Island, oversees the operation and maintenance of approximately 89 miles of combined sewer interceptors, including two wastewater treatment facilities. These systems serve a total of 10 different communities, including 360,000 residents, 8,000 businesses, and 160 major industrial users. According to the NBC, approximately 66 CSO events occur each year in the NBC service area, accounting

for an estimated 2.2 billion gallons of untreated combined sewage released into Narragansett Bay and its tributaries.

In order to mitigate these CSOs and protect the Narragansett Bay and the region's urban rivers from sewage overflows, the NBC initiated a three-phase CSO Abatement Plan. Phase I of the project, which began in 2001, was completed and went on-line in November 2008. The chief component of Phase I includes a three-mile long, 30-foot



**FIGURE 3-7**  
Phase I  
Tunnel System

diameter deep rock tunnel 250 feet below the surface. The Phase I tunnel system has a 62 million gallon capacity and is anticipated to effectively reduce overflow volumes by approximately 40 percent.

**ECONOMIC CONTEXT**

The total capital costs for Phase I of the NBC’s CSO Abatement plan were \$365 million. The associated operational and maintenance costs of Phase I, the bulk of which are attributed to electrical costs for pumping, are \$1 million per every one billion gallons of stormwater and sewage flow, or \$1 for every 1000 gallons (Brueckner, 2009). Phase II of the CSO abatement plan, which will begin in 2011, includes two near-surface interceptors that will convey additional flow to the Phase I tunnel. The estimated capital costs for the Phase II project are \$250 million.

The NBC’s regulations regarding stormwater management require developers to execute stormwater mitigation plans if required by the

NBC. These plans encourage the use of LID strategies, BMPs, and other methods to eliminate or reduce storm flows. Between 2003 and 2008, a total of 67 stormwater mitigation plans were approved and implemented which accounted for 8.9 million gallons of stormwater diverted from the combined system (Zuba, 2009). Calculating in 2009 dollars, the 67 LID projects can save approximately \$9,000/yr in operating costs for CSO abatement. Over time, as electricity costs increase, the avoided cost of the 67 projects also increases. With increased implementation of LID projects, we can expect those cost savings to be realized in the same manner.

Between 2003 and 2008, a total of 67 stormwater mitigation plans were approved and implemented which accounted for 8.9 million gallons of stormwater diverted from the combined system. Calculating in 2009 dollars, the 67 LID projects can save approximately \$9,000/year in operating costs for CSO abatement.

## PORTLAND, OREGON

### Economic Benefits of Utilizing Green Infrastructure Programs for CSO Management

**FIGURE 3-8**

Portland, Oregon street scene; inset: CSO Tunnel system



#### BACKGROUND

The City of Portland, Oregon is considered a national leader in the implementation of innovative stormwater management strategies and designs. Included among the city's Sustainable Stormwater Management Programs is the Innovative Wet Weather Program, the Green Street Program, the Portland Eco-Roof Program, and individual case studies and projects that include commercial and multifamily stormwater retrofits and porous pavement placements.

With Portland receiving an average of 37 inches of precipitation annually, creating roughly 10 billion gallons of stormwater runoff per year, these programs are very important for helping reduce flooding and erosion as well as minimizing CSO events.

#### Innovative Wet Weather Program

This city-wide program encourages the implementation of stormwater projects that improve water quality and watershed health, reduce CSO events and stormwater pollution, and control stormwater runoff peaks and volumes. The program goals include:

- Capturing and detaining stormwater runoff as close to the source as possible;
- Reducing the volume of stormwater entering the combined sewer system;
- Filtering stormwater to remove pollutants before the runoff enters groundwater, streams, or wetlands;
- Using and promoting methods that provide multiple environmental benefits; and
- Using techniques that are less costly than traditional piped solutions.

## Green Streets Program

Portland's Green Street Program promotes the use of natural above-ground and vegetated stormwater controls in public and private development in order to reduce the amount of untreated stormwater entering Portland's rivers, streams, and sewers. The program is geared towards diverting stormwater from the city's overworked combined system and decreasing the amount of impervious surface so that stormwater can infiltrate and recharge groundwater systems.

The program takes a sustainable and blended approach to finding the most optimal solution for storm and sanitary sewer management. This includes overlaying and integrating green and sustainable stormwater strategies with traditional gray infrastructure to maintain or improve the city's sewer capacity (Dobson, 2008).

Green streets have been demonstrated to be effective tools for inflow control of stormwater to Portland's CSO system. Two such green street designs, the Glencoe Rain Garden and the Siskiyou Curb Extension facilities, were shown to reduce peak flows that cause basement sewer backups and aid compliance with CSO regulations by reducing runoff volumes sent to the CSO Tunnel system (Portland, 2007). The City of Portland also conducted simulated storm event modeling for basement sewer back-ups and determined that two green street project designs would reduce peak flows from their drainage areas to the combined sewer by at least 80 to 85 percent. The City of Portland also

ran a simulation of a CSO design storm and found that the same two green street project designs retained at least 60 percent of the storm volume, which is believed to be a conservative estimate.

## ECONOMIC BENEFIT

The following sections of this case study communicate the economic context for both the application of LID strategies in Portland, as well as the city's programs that promote the use of Green Infrastructure designs for stormwater management.

## Green Streets Program

For the City of Portland, utilizing green streets is the preferred strategy

for helping relieve sewer overflow conditions because it is the most cost-effective and eliminates the need for expensive below-ground repairs, which often involve replacing infrastructure (Dobson, 2008). As an example, a basement flooding relief project that was under design was projected to cost 60 percent less than what would have been

the cost of a traditional pipe upsize and replacement project. This is because the solution, a mix of green streets and private system disconnects, intercepts and infiltrates the water before it enters the public storm system thereby reducing the need to dig up and upsize the existing piped infrastructure (Portland, 2007).

For the City of Portland, utilizing green streets is the preferred strategy for helping relieve sewer overflow conditions because it is the most cost-effective and eliminates the need for expensive below-ground repairs.

**COST COMPARISONS  
BETWEEN GRAY AND GREEN  
INFRASTRUCTURE STRATEGIES**

**Tabor to the River:  
The Brooklyn Creek Basin Program**

In June of 2000, prior to implementation of the Green Street Program, the City of Portland was faced with the need to upgrade an undersized sewer pipe system in the Brooklyn Creek Basin, which extends from the Willamette River to Mt. Tabor between SE Hawthorne and SE Powell boulevards, and covers approximately 2.3 square miles. Upgrades were needed in order to improve the sewer system reliability, contain street flooding, stop sewer backups from occurring in basements, and help control CSOs to the Willamette River.

At that time, the city considered constructing a new separated stormwater collection system to support the existing undersize pipes in this basin. The

original cost estimate for constructing this new system using traditional gray infrastructure was \$144 million (2009 dollars). However, following this proposal, a second plan was developed that included a basin redesign using a combined gray and Green Infrastructure approach. Including a total of \$11 million allocated for green solutions, the cost estimate for this integrated approach was \$81 million, a savings of \$63 million for the city (Portland, 2009).

The combined gray and green approach was chosen as the 2006 Recommended Plan for the Brooklyn Creek Basin, and includes project objectives of reducing CSO events, improving surface and groundwater hydrology, protecting and improving sewer infrastructure, optimizing cost-effectiveness, boosting water quality, and enhancing community livability.

The approved basin improvement plan consists of 35 public and private sector projects over the next 10-20

**FIGURE 3-9**  
Tabor raingarden  
planting



PROJECT	TOTAL CAPITAL COSTS	ANNUAL O&M COSTS	TABLE 3-6 CSO Infrastructure Costs for City of Portland, Oregon
East Side CSO Tunnel	\$624,892,000	\$22,700	
Swan Island CSO Pump Station – Phase 2	\$7,500,000	\$3,100,000	
Portsmouth Force Main	\$55,306,000	\$12,000	
Balch Consolidated Conduit	\$22,052,000	\$3,900	

years. Gray infrastructure upgrades include repairing or replacing 81,000 feet of combined sewer pipes, while the Green Infrastructure strategies include building green roofs, retrofitting parking lots with sustainable stormwater controls, planting nearly 4,000 street trees, and adding more than 500 green streets with vegetated curb extensions and stormwater planters.

**GREEN INFRASTRUCTURE FOR CSO COMPLIANCE: COST COMPARISONS**

Portland’s combined sewer system covers 26,000 acres and contains 4,548,000 linear feet (861 miles) of gravity drained, combined sewer

pipe. The city’s combined system also includes 42 separate basins connected via three major interceptor systems and served by three major pump stations.

The City of Portland, under federal and state requirements as well as stipulations from the Clean Water Act to comply with regulations regarding CSO management, initiated the construction of a new pump station and two CSO tunnels (West Side and East Side CSO Tunnels) which would serve as the primary means to protect the city’s receiving waters from future CSO events. However, in addition to these initiatives, more projects and programs were needed for providing additional CSO mitigation.

In December of 2005, the City of Portland’s Bureau of Environmental Services prepared a report (Portland, 2005) charged with sizing of the East Side CSO Tunnel and providing recommendations for long-term operations and flow management of the Willamette CSO system. The city’s final recommendations included the following for the Willamette CSO tunnels and supporting infrastructure:

**East Side CSO Tunnel** This storage facility will be constructed with a 22-foot diameter and will have a capacity of 83 MG. Total length is 29,145 linear feet; annual O&M costs are \$0.78 per linear foot. Design life is 50 years.

**Swan Island CSO Pump Station** This facility pumps approximately 500 MG per year with an annual O&M cost of \$0.0002 per gallon for pump station operations and \$0.006 per gallon for Columbia Boulevard Wastewater Treatment Plant treatment. Design life is 50 years.

**Portsmouth Force Main** This infrastructure is 66 inches in diameter and 15,000 feet in length. Annual O&M costs are \$0.80 per linear foot. Design life is 50 years.

**Balch Consolidated Conduit** This infrastructure is 84 inches in diameter and 4,900 linear feet. Annual O&M costs are \$0.80 per linear foot. Design life is 50 years.

Along with determining the final recommendations for the East Side CSO Tunnel and supporting infrastructure, the city considered a range of possible alternatives for additional CSO mitigation. This included 12 different stormwater separation projects as well as a number of watershed health initiatives, some of which involved Green Infrastructure strategies including:

**Eastside Curb Extensions**

Involves the use of vegetated swales at a cost of \$50,000 per acre and O&M costs of \$2,000/year/acre.

**Eastside Roof & Parking Inflow Control**

Parking retrofits use vegetated infiltration basins at a cost of \$90,000 per acre and O&M costs of \$1,100/year/acre. Rooftop stormwater controls use either stormwater planters (\$40,000 per acre; O&M costs of \$600/year/acre), or vegetated infiltration basins.

**Green Roof Legacy Project**

Retrofit 20 acres of rooftop in an industrial district with eco-roofs. Project costs include \$285,000/acre/year for design/construction and \$935/acre/year for O&M activities.

**Extended Downspout**

**Disconnection Program (DDP)**

Continues the city’s successful existing DDP at the cost of \$22,300 per acre and O&M costs of \$7/year/downspout. Depending on site conditions, this can include the use of LID strategies including rain gardens and soakage trenches built by private citizens with City of Portland consultation.

The City’s goal was to determine which project/program alternatives would be the most cost-effective for long-term CSO management. The basic metric common to the projects identified for CSO control was the amount of stormwater volume that could be removed from the CSO tunnel system. The city’s final evaluation was based on the relationship between project capital costs and stormwater volume that could be removed from the system. This analysis took into account cumulative capital costs, marginal costs for gallons removed, and cumulative volume removed from the system.

Table 3-6 shows all stormwater separation and watershed health projects/programs considered by the City of Portland. The projects/programs are sorted by dollars per gallons of stormwater that can be removed (marginal cost). Project staff agreed that cost-effectiveness was determined by an inflection point, or knee-of-the-curve point, on a graph that compared costs to stormwater volume that could be diverted from the CSO system. This inflection point was determined to be approximately \$4 per gallon removed the system.

Projects/programs costing at or below \$4 per gallon were the ones recommended for further design and eventual implementation for long-term CSO control. These projects/programs are the first seven listed in Table 3-7.

The projects/programs chosen on the basis of cost-effectiveness included the Eastside curb extension projects (vegetated swales), the Eastside roof and



## THE ECONOMICS OF LOW IMPACT DEVELOPMENT: CASE STUDIES

**TABLE 3-7 CSO Control Alternatives Costing for Portland, Oregon.**

Project/Program	Effective Imp. Acres Controlled	Est. 3-year Volume Removed (MG)	Capital Cost	Marginal Cost (\$/Gallon)	Cumulative Volume Removed (MG)	Cumulative Capital Cost
Extended Downspout Disconnection Program (can include LID)	284	7.45	\$6,633,000	\$0.89	7.45	\$6,633,000
School Disconnection*	68	1.77	\$1,954,000	\$1.10	9.22	\$8,587,000
Church Disconnection*	32	0.96	\$2,031,000	\$2.12	10.18	\$10,618,000
Beech-Essex Sewer Separation	37	1.40	\$3,889,000	\$2.78	11.58	\$14,507,000
ES Curb Extensions (LID)	349	4.29	\$12,323,000	\$2.87	15.87	\$26,830,000
Tanner Phase 3 Sewer Separation	85	3.10	\$10,767,616	\$3.47	18.97	\$37,598,000
ES Roof & Parking IC (LID)	475	17.64	\$72,047,000	\$4.08	36.61	\$109,645,000
NWN Pre-design – Tanner North Sewer Separation	14	0.22	\$1,127,000	\$5.12	36.83	\$110,772,000
Carolina Stream & Storm Separation	93	1.02	\$5,319,000	\$5.21	37.85	\$116,091,000
NWN Pre-design – Tanner South Sewer Separation	13	0.26	\$1,602,000	\$6.16	38.11	\$117,693,000
NWN Pre-design – Tanner Central Sewer Separation	2	0.04	\$269,000	\$7.60	38.14	\$117,962,000
NWN Pre-design – Nicolai/Outfall Sewer Separation	34	0.54	\$6,321,000	\$11.76	38.68	\$124,283,000
NWN Pre-design – Nicolai/Outfall 13 Sewer Separation	52	0.68	\$8,217,000	\$12.04	39.36	\$132,500,000
Green Roof Legacy Project (LID)	20	1.04	\$14,179,000	\$13.65	40.40	\$146,679,000
NWN Pre-design – Nicolai/Outfall 15 Sewer Separation	24	0.36	\$6,546,000	\$17.98	40.77	\$153,225,000
Holladay Sewer Separation	125	0.69	\$14,360,000	\$20.94	41.45	\$167,585,000
NWN Pre-design – Balch Neighborhood Sewer Separation	8	0.14	\$7,664,000	\$55.06	41.59	\$175,249,000
NWN Pre-design – Balch/Forest Park Storm Separation	5	0.13	\$12,026,000	\$93.82	41.72	\$187,275,000

\* Church and School Disconnection programs assumed downspout disconnection and drywells would remove this stormwater volume. The former is an LID method.

parking inflow control projects (vegetated infiltration basins & stormwater planters), three disconnection programs (which can include LID strategies) and two stormwater separation projects.

### LID AVOIDANCE COSTS

The City of Portland recognizes two avoidance costs for incorporating LID strategies with combined sewer systems.

One of these avoidance costs is annual O&M costs to pump and convey stormwater through the existing combined sewer system. The city measures this by applying a rate of \$0.0001 per gallon treated and \$0.0001 per gallon pumped. This equates to an annual O&M avoidance cost of \$0.0002 per gallon.

Secondly, the City of Portland recognizes an avoidance cost that benefits the CSO system. This is based on the relationship between project capital costs and stormwater volume removed from the CSO system, which was described above. The cost-effectiveness point for projects/programs that remove stormwater volume from the CSO system (\$4 per gallon) is also considered as the avoidance cost of constructing a larger CSO tunnel. In life-cycle cost analyses, this “savings” can reduce the capital costs of other LID facilities that the city builds for objectives other than CSO control (e.g. water quality improvements, basement flooding relief), but still removes stormwater from entering the CSO tunnels (Owen, 2009).

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## KANSAS CITY, MISSOURI

### ECONOMIC BENEFITS OF INTEGRATING GREEN SOLUTIONS WITH GRAY INFRASTRUCTURE FOR CSO COMPLIANCE

**FIGURE 3-10**  
Raingarden,  
Kansas City,  
Missouri



## BACKGROUND

The City of Kansas City, Missouri has committed to implementing a green design initiative that will be considered a community amenity and will work to reduce the amount of water entering the city's combined system.

Under a USEPA mandate, the City of Kansas City, Missouri is required to update its network of aging sewer infrastructure in order to address overflows from its combined and separate sewer systems. Kansas City's 318-square mile sewer system includes 58 square miles of a combined system and 260 miles of a separated system. The overall system serves 668,000 people and includes 7 wastewater treatment plants with a total capacity of 153 million gallons per day (MGD).

Overflows in the combined system amount to 6.4 billion gallons in a typical year, and on average, 12 rain events per year are responsible for 67 percent of this total overflow. This contributes to the poor water quality of Kansas City's streams, urban lakes and rivers.

The original planned improvements associated with upgrading the city's combined system include 310 MGD of additional treatment capacity, 25 million gallons (MG) of in-line storage, 10 separation areas, neighborhood sewer rehabilitations, as well as pump station and treatment plant modifications. Three storage tunnels from 16 to 26 feet in diameter are also proposed which would run between 1.4 and 3.4 miles in length and would be capable of storing 78 MG of overflow. The goals of the

improvements in the combined sewer system are to capture 88 percent of flows, reduce the frequency of overflow events by 65 percent, and lower the 6.4 billion gallons of overflow per year down to 1.4 billion gallons (KCWSD(a), 2009).

The original estimated capital costs associated with overhauling Kansas City's total sewer system is \$2.4 billion dollars, of which \$1.4 billion would go towards the combined system. The yearly operations and maintenance costs (O&M) of this total upgrade are estimated at \$33 million per year.

## GREEN SOLUTIONS

In developing a plan for the combined sewer system upgrade, Kansas City began exploring the possibility of incorporating Green Infrastructure strategies in combination with gray infrastructure improvements. The city formed a green solutions subcommittee and later developed a green solutions position paper, which eventually resulted in a city council resolution directing city staff to develop a plan to implement Green Infrastructure strategies.

## GREEN OVERFLOW CONTROL PLAN

In May of 2008 the Kansas City Water Services Department proposed \$30 million in green solutions during the first five years of the proposed \$1.4 billion overflow control plan. This plan included

Under a USEPA mandate, the City of Kansas City, Missouri is required to update its network of aging sewer infrastructure in order to address overflows from its combined and separate sewer systems.

language to allow green solutions to replace gray infrastructure. Upon review, however, the city council determined that additional Green Infrastructure strategies were needed in the overflow control plan and directed the water services department to request a 6-month

The city estimated that it should be possible to completely replace two CSO storage tanks with distributed green solutions without increasing costs or reducing CSO control performance.

extension for submittal of the plan. The extension was granted by the Missouri Department of Natural Resources and EPA Region 7.

The city moved ahead in developing a more green-orientated overflow control plan and conducted reviews of basins located within the combined system in order to identify areas

where green solutions could replace gray infrastructure in whole or in-part. High altitude desktop analyses were performed in order to assess the potential for shifting from gray storage to green solutions for storage in three major basins. The types of green solutions considered included catch basin retrofits, curb extension swales, pervious pavement, street trees, green roofs and stormwater planters.

Two principal assumptions were included with these considerations. Firstly, storage volume in green solutions would replace an equal volume in conventional storage facilities; and secondly, each 1-MG of green storage would result in 0.5 MGD reduction in capacity of downstream pumping stations and treatment facilities due to infiltration and

evaporation (KCWSD, 2009). Following revisions, the city's submitted a new plan that proposed a total of \$80 million in green solutions programs.

### ECONOMIC BENEFIT

Based on city analyses, it was determined that replacing gray infrastructure with green solutions would be cost-effective in portions of the Middle Blue River Basin (MBRB), a 744-acre region with 34 percent impervious surface. Based on calculations, the city estimated that it should be possible to completely replace two CSO storage tanks with distributed green solutions without increasing costs or reducing CSO control performance (Leeds, 2009).

The original MBRB Plan was based on a traditional gray infrastructure design with controls capable of providing 3 MG of storage. The capital costs associated with these upgrades were estimated at \$54 million, an average of \$18 per gallon, and would be capable of reducing overflows in the MBRB to less than 6 per year, on average.

The revised MBRB Plan is a non-traditional design that includes gray infrastructure projects as well as Green Infrastructure strategies and will provide distributed storage of at least 3.5 MG. The revised plan would also eliminate the need for storage tanks while still achieving the goal of reducing the amount of overflows to less than 6 per year. The projected costs associated with this revised plan are \$35 million, potentially \$19 million less than the original gray infrastructure plan. However, because of uncertainties, the green solutions project

budget has been set at \$46 million. Note: Construction uncertainties are a routine consideration in the planning of any construction budget. The uncertainties will be reduced overtime as developers, contractors, and practitioners become more familiar with these practices.

**MIDDLE BLUE RIVER BASIN GREEN SOLUTIONS PILOT PROJECT**

A large-scale study was needed to test the city’s key assumptions regarding the performance of green solutions. As such, the city initiated a pilot project within a 100-acre area of the MBRB. The MBRB Green Solutions Pilot Project will help determine the effects of widespread implementation of distributed storage utilizing green solutions, infiltration, and inflow rehabilitation on combined sewer overflows and is potentially the largest green solutions-based CSO control project in the nation (KCWSD(b) 2009).

Green-based strategies in the pilot area will be installed on both residential and commercial areas and will need to provide at least 0.5 MG of distributed storage, replacing an equal amount of stormwater stored in conventional

concrete tanks. Following implementation, post-construction monitoring will be conducted to determine functionality and performance.

**GREEN SOLUTIONS UNIT COSTS**

In developing unit costs for green solutions, the city used a number of assumptions including:

- Green roofs have incremental costs above normal roof replacements with 3 to 4 inches of growth media providing 1 inch of storage. Incremental capital costs associated with green roofs are \$14 per square foot.
- Deciduous street trees have interception storage of 0.032 inches, 20-foot crown radius, with 25 gallons per tree.
- Porous pavements would provide effective storage for an area approximately 3 times its surface area.

Table 3-8 presents unit costs, in dollars per gallon, used by the city for each type of green solution.

The results of the pilot project will be used to guide work in the remaining 644 acres as well as other future green solutions projects.

GREEN SOLUTION	UNIT COST (\$/GAL)
Catch Basin Retrofits in Road and Street ROW	\$2.28-\$7.13 (avg \$5.00)
Porous Pavement	\$4.62
Street Trees (Residential)	\$10.80
Street Trees (Commercial)	\$23.36
Curb Extension Swales	\$10.86
Replacement of Sidewalks in ROW with porous pavement	\$11.62
Conversion of Roof Areas to Green Roofs	\$22.68
Stormwater Planters	\$26.83

TABLE 3-8  
Unit Costs for  
Green Solutions

Presentation at the Midwest AWMA Annual Technical Conference (January 2009) by Terry Leeds, Overflow Control Program Manager, Kansas City Water Services Department.

## CHICAGO, ILLINOIS

### UTILIZING GREEN INFRASTRUCTURE FOR REDUCING CSS VOLUMES

Figure 3-11  
City Hall,  
Chicago, Illinois



#### BACKGROUND

The City of Chicago has implemented a number of innovative plans geared towards building community resiliency toward climate change, while promoting sustainability and conservation and is recognized as a worldwide leader in terms of its environmental initiatives. In addition to green building and energy efficiency, Chicago has implemented advanced city-wide programs that address water quality, water efficiency, and stormwater management.

As part of the Chicago Water Agenda, the city is committed to managing stormwater more sustainably and encourages the use of BMPs that include a range of Green Infrastructure designs such as green roofs, permeable paving, filter strips, rain gardens, drainage swales, naturalized detention basins,

as well as the use of rain barrels and natural landscaping. These measures are important strategies for facilitating infiltration, improving water quality and minimizing the potential for basement flooding. BMP strategies which divert water away from the combined sewer system also reduce the energy demands associated with pumping and treating the combined sewage.

Chicago's gravity based combined collection system includes 4,400 miles of sewer main lines that flow to interceptor sewers that are owned and operated by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). The interceptor sewers are a pumped system which conveys dry weather flow to the MWRDGC's treatment plants. During storm events, excess flows are diverted to the MWRDGC's Tunnel and

Reservoir Plan system for storage, which is intended to prevent combined sewer overflows to the city’s waterways. This tunnel reservoir system is the largest in the world and includes 109 miles of 30-foot diameter pipes that is generally located 200 feet below the Chicago River system.

CSO events occur with regular frequency each year, causing untreated wastewater and stormwater to be released into the city’s river systems as well as Lake Michigan. Green Infrastructure controls and other BMP measures are needed in order to limit inflow stormwater volumes to the system, thus reducing the frequency and intensity of CSO events.

**Chicago Green Alley Program**

One of the city’s more progressive Green Infrastructure initiatives is the Chicago Green Alley Program, which has been developed to alleviate flooding in the city’s extensive alley network, which consists of approximately 1,900 miles of public alleys and roughly 3,500 acres of impervious surface. The program encourages the use of porous pavements in order to reduce the city’s quantity

of impervious surface, as well as filter runoff, and recharge groundwater.

In addition to facilitating infiltration and diverting stormwater from Chicago’s combined system, the Green Alley Program brings environmental benefits such as heat reduction, material recycling, energy conservation, and glare reduction.

**ECONOMIC BENEFIT**

The City of Chicago actively records the ongoing number or coverage area of various green BMP designs that are added within city limits. This includes the year-to-date number of rain gardens and rain barrels added / downspouts disconnected, as well as the effective square footage of green roofs, green paving, turf to native grass, and Stormwater Management Ordinance (SMO) permits. Each of these BMP designs has been assigned an equivalence factor by the City of Chicago, which, when multiplied by the actual number or amount of square footage of each BMP, will calculate a more accurate shed of capture for each representative design.

Table 3-9 presents data that shows estimated year-to-date numbers or

BMP	Actual SF or number	Annual volume (gals) diverted from combined system	TABLE 3-9 City of Chicago Volume Reductions and Square Footage for CSO Controls
Green Paving (SF)	182,000	4,832,000	
Green Roofs (SF)	100,000	1,907,000	City of Chicago draft Stormwater Carbon Calculator
Rain Gardens (#)	5	53,000	
Rain Barrels/Downspout Disconnections (#)	2,220	8,281,000	
Turf to Native Grass (SF)	1,701,000	23,426,000	
SMO Permits (SF) 1	1,869,000	31,684,000	

\* SMO permits can include any number of BMP designs. SMO permit data does not overlap with data from individual BMPs.

square footage totals (as of November, 2009) for each type of BMP measure that has been implemented.

In order to calculate the volume of stormwater that is diverted from the combined system, the City of Chicago uses a conversion factor of 21.19 that is

multiplied by the SF equivalence of each corresponding BMP design. Based on the above BMPs, equivalent factors, and calculations, a total of 70,182,236 gallons of stormwater is estimated to have been diverted from Chicago's combined system in 2009 through November, 2009.

## NEW YORK CITY, NEW YORK

### IMPLEMENTING A GREEN INFRASTRUCTURE PLAN FOR CSO REDUCTION

**FIGURE 3-12**  
The Brooklyn Bridge  
spanning the East River.



#### BACKGROUND

The City of New York, facing the need to improve the water quality of New York City's waterways and coastal waters, has developed a multi-tiered, long-term plan that will draw upon green infrastructure strategies towards managing stormwater more sustainably. The NYC Green Infrastructure Plan, an extension of the City's *Sustainable Stormwater Management Plan* and Mayor Bloomberg's PlaNYC initiative

towards a cleaner, greener city, will employ a hybrid approach towards controlling Combined Sewer Overflows (CSO) and improving water quality. The NYC Green Infrastructure Plan will employ such practices as porous pavements, green streets, green and blue roofs, swales, rain gardens, street trees, constructed wetlands, and other strategies. The City of New York has already built or planned to build over \$2.9B in grey infrastructure specifically to reduce CSO volumes. In the NYC Green



Infrastructure Plan, these are referred to as the Cost-Effective Grey Infrastructure Investments and are the most cost beneficial practices to achieve their goal. In addition, the City will also implement measures to optimize the performance of the existing system reduce CSO events and reduce stormwater runoff volumes.

According to analyses by the New York City Department of Environmental Protection (DEP), which examined areas of the New York Harbor where water quality standards have not been met, the biggest remaining challenge is to further reduce CSOs. Since 2005, the City has spent over \$1.5 billion towards CSO reduction including infrastructure improvements and CSO storage facility upgrades. A conventional approach for CSO reduction would include the construction of large piping networks to store or separate stormwater and wastewater. However, according to the September 2010 NYC Green Infrastructure Plan report, these types of CSO reduction projects are very expensive and do not provide the sustainability benefits that New Yorkers have come to expect from multi-billion dollar public fund investments. Furthermore, officials feel that while meeting water quality goals is the primary consideration for future DEP investments, the long-range alternatives it considers should also be consistent with the City's sustainability goals. CSO reduction strategies, according to the report, would be more valuable if they incorporated a sustainable approach, managing stormwater at its source through the creation of vegetated

filtration (i.e. rain gardens, street trees, constructed wetlands) and green infrastructure.

Conclusions formulated in the City's *Sustainable Stormwater Management Plan* found that green infrastructure could be more cost-effective than certain large infrastructure projects such as CSO storage tunnels. DEP modeling efforts demonstrated that the use of green infrastructure in combination with other strategies would be more effective at controlling CSOs as compared to grey strategies alone, but would also provide the additional benefits of cooling the city, reducing energy costs, and increasing property values. Moreover, green-based strategies would provide further economic benefits in terms of lower operations and maintenance (O&M) costs, a greater distribution of O&M costs towards jobs potentially resulting in job creation, improved air quality, and reducing CO<sub>2</sub> emissions.

### **PERFORMANCE COMPARISONS BETWEEN GREEN AND GREY STRATEGIES**

DEP evaluated and compared two different infrastructure investment plans for long-term CSO management and reduction. These two plans included a Green Strategy and a Grey Strategy. The main components of each respective strategy include:

#### **Green Strategy**

- Green Infrastructure
- Cost-Effective Grey Infrastructure Investments
- System Optimization and Reduced Flow

**Grey Strategy**

- Cost-Effective Grey Infrastructure Investments
- Potential Tanks, Tunnels, and Expansions

Utilizing an InfoWorks computer model to estimate future City CSO flows, DEP modeled CSO volume projections under both strategies in order to access and compare future CSO control performances for each alternative.

One of the assumptions made by DEP in reference to modeling of Green Infrastructure – which would be implemented as a combination of infiltration and detention technologies – included the capture and infiltration

of the first inch of rainfall on 10 percent of existing impervious surfaces in each combined sewer watershed in the city.

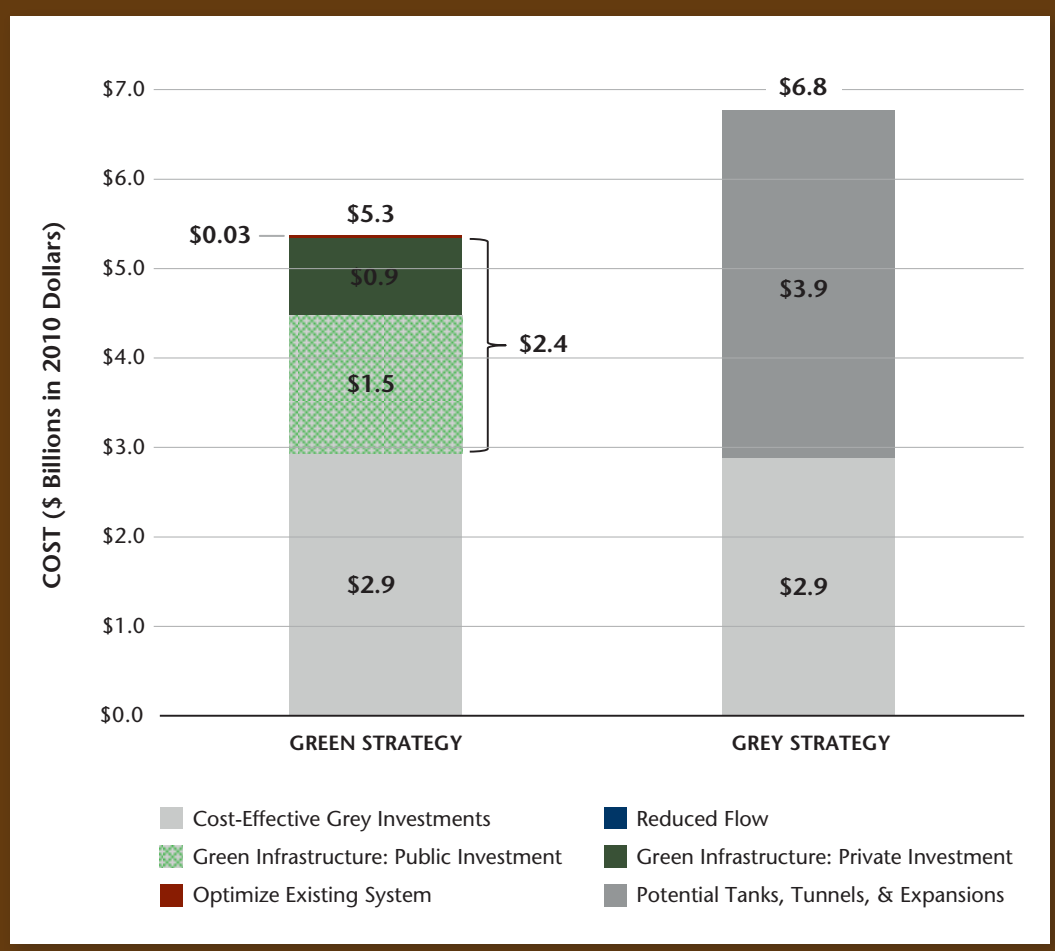
According to predictions by DEP, implementation of the Green Strategy over a 20-year time frame will reduce CSO volumes from approximately 30 billion gallons per year (bgp) to approximately 17.9 bgp. This is nearly 2 bgp more of CSO reduction as compared to the Grey Strategy, which was estimated to reduce CSO volumes down to 19.8 bgp.

**ECONOMIC BENEFIT**

In addition to significant citywide CSO reductions every year, DEP also predicted considerable economic

**FIGURE 3-13**  
Citywide Costs of CSO Control Scenarios (after 20 years)

(NYC Green Infrastructure Plan, 2010)



benefits in several areas that would result from implementation of a Green Strategy as compared to a Grey Strategy.

**Total Citywide Costs**

According to DEP estimates compiled in the Green Infrastructure report, costs associated with full implementation of the Green Strategy are anticipated to be considerably less as compared to costs for the Grey Strategy. Figure 3-13, taken directly from the Green Infrastructure Plan report, depicts the estimated total citywide costs after 20 years under both the Green and Grey Strategy scenarios.

As shown, the total cost of the Grey Strategy is approximately \$6.8 billion (2010 dollars), which includes

\$3.9 billion for the potential tanks, tunnels, and expansions component of the plan. The cost for the city-wide Green Strategy, however, is estimated at approximately \$5.3 billion, of which \$2.4 billion would be allocated towards green infrastructure programs for capturing 10 percent of the combined sewer watersheds’ impervious areas. In total, the Green Strategy is forecasted by DEP to save the City \$1.5 billion over the next 20 years.

The costs for each strategy were also broken down for comparison on a unit cost basis. This is shown in Figure 3-14, borrowed from the Green Infrastructure Plan. Examining the cost per gallon of CSO reduction for each



**FIGURE 3-14**  
Estimated Citywide Costs per Gallon of CSO Reduced

(NYC Green Infrastructure Plan, 2010)

respective alternative, the Grey Strategy is estimated to be the more expensive option (**\$0.62** per gallon for Grey Strategy vs. **\$0.45** per gallon for Green Strategy).

Figure 3-14 also further breaks down the cost per gallon of CSO reduction for each component of both strategies. These unit costs include:

**Green Strategy (\$0.45)**

- Cost-Effective Grey Investments
- Reduced Flow
- Green Infrastructure
- Optimize Existing System

**Grey Strategy (\$0.62)**

- Cost-Effective Grey Investments
- Potential Tanks, Tunnels and Expansions

As displayed, the cost per gallon of CSO reduced for the Green Infrastructure component is estimated to be considerably less than the cost per gallon of CSO reduced for the potential tanks, tunnels, and expansions of the Grey Strategy. Also, as discussed in the report, the overall Green Strategy is more of an affordable alternative as compared to the Grey Strategy in part because optimizing the existing system – a part of the Green Strategy – is the most cost-effective component-strategy.

**Operations and Maintenance**

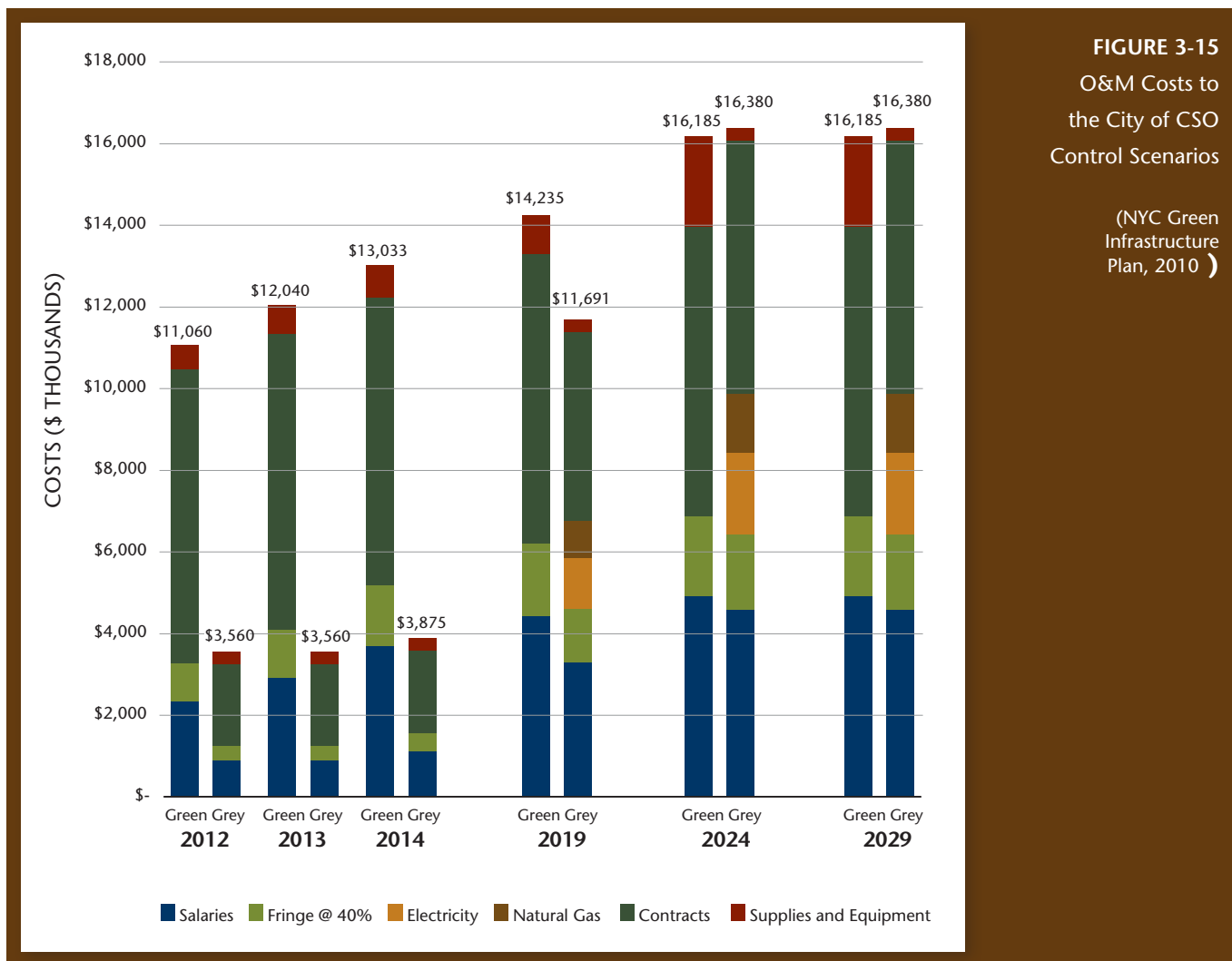
**Cost Estimates**

DEP also estimated and compared long-term operations and maintenance (O&M) costs to the City under both Green and Grey Strategy scenarios. O&M expenses evaluated included

salaries, electricity and natural gas, contracts, supplies and equipment, as well as fringe costs. As shown in Figure 3-15, borrowed from the Green Infrastructure report, O&M costs for the Green Strategy would be higher in the initial years as green infrastructure controls are implemented relatively quickly. However, according to the estimates, O&M costs for the Grey Strategy would eventually outrun those of the Green Strategy as tanks, tunnels and expansions are completed and come online. Another factor contributing to this cost difference is energy costs, including electricity and natural gas expenses, which are not needed for green infrastructure but would weigh in much heavier under a Grey Strategy scenario.

**Economic Sustainability Benefits**

Further value-added advantages predicted by DEP as a result of implementation of the Green Infrastructure Plan include benefits related to a reduced urban heat island effect, greater recreational opportunities, energy savings, improved air quality, and higher property values. In addition, the Green Infrastructure Plan shows a greater distribution of funds to support maintenance-related activities in the form of salaries and benefits. For every year scenario, there is a greater distribution of monies to support jobs rather than to pay for utilities (electric and gas). This is an important finding as job creation is one element of sustainability that is often overlooked.



In order to estimate these dollar-based benefits, DEP first generated a working model to anticipate the amount of land that would be converted from impervious surfaces to planted areas. DEP’s modeling efforts forecasted that the amount of total city-wide vegetated surface area by 2030 would range from 1,085 acres up to 3,255 acres. Of this range, DEP assumed that half of all planted green infrastructure would be fully vegetated (such as green roofs), with the other half partially vegetated (to account for a lower ratio of surface area in order to

drain impervious surfaces in the right-of-way).

Next, DEP estimated a dollar per acre benefit for both fully and partially vegetated infrastructure controls. For this process, DEP used the economic values for street trees located in the *New York Municipal Forest Resource Analysis* (MFRA) as well as the energy benefit assumptions for green roofs in *Green Roofs in the New York Metropolitan Region*, as cited in the Green Infrastructure Plan. Utilizing these data, DEP estimated the annual economic benefits resulting from fully and partially

	Fully Vegetated	Partially Vegetated
<b>Energy</b>	8,522	2,504
<b>CO<sub>2</sub></b>	166	68
<b>Air Quality</b>	1,044	474
<b>Property Value</b>	4,725	4,725
<b>Total</b>	14,457	7,771

**TABLE 3-10**  
New York City Annual Benefits of Vegetated Source Controls in 2030 (\$/acre)

vegetated infrastructure controls on a dollar per acre basis in the year 2030.

The results of DEP’s analysis are displayed in Table 3-10, which is taken directly from the Green Infrastructure Plan report. As displayed in the table, DEP estimates that in the year 2030, every fully vegetated acre will result in a total annual benefit of \$14,457, with partially-vegetated acres \$7,771 per year. This includes annual economic benefits from reduced energy demand, reduced CO<sub>2</sub> emissions, improved air quality, and increased property values.

DEP also estimated a range of accumulated economic benefits from new green infrastructure controls over a 20-year implementation time frame. According to DEP’s modeling efforts, the total accumulated sustainability benefits (through lower energy costs, reduced CO<sub>2</sub>, better air quality and increased property values) will range from

\$139 to \$418 million, depending on the amount of vegetation used in the source controls.

## CONCLUSIONS

The previous examples show how incorporating a green infrastructure strategy with LID can help cities and municipalities reduce stormwater runoff volumes entering combined systems, lowering treatment costs. Also, as shown, utilizing a combination of grey and green infrastructure strategies for CSO management can be considerably more economically viable than using grey infrastructure alone.

This was clearly demonstrated in the City of Portland’s Tabor to the River plan, which showed a cost benefit of \$63 million to the city by the inclusion of green strategies in combination with a grey infrastructure approach for upgrading an undersized sewer pipe system in order to help control CSOs and improve sewer system reliability. An economic benefit potentially as much as \$19 million was also estimated by the City of Kansas City for incorporating green infrastructure strategies along with a traditional grey infrastructure approach for the Middle Blue River Basin Plan, a part of Kansas City’s city-wide Overflow Control Program.

An economic context for the use of LID was also established for the

Utilizing a combination of grey and green infrastructure strategies for CSO management can be considerably more economically viable than using grey infrastructure alone.

City of Portland’s overall approach for CSO management. The City of Portland determined that watershed health initiatives, which included LID and green infrastructure strategies, were cost-effective project alternatives for the city to implement as part of its approach for long-term CSO management.

Chicago’s initiatives demonstrate the city’s commitment to using green infrastructure for the purpose of CSO control. Although economically-based information depicting the future cost of construction for CSO separation was not available, the City of Chicago has shown a major reduction of stormwater volume to its combined system as a result of LID.

Additionally, New York City forecasted long-term performance and economic benefits by incorporating a CSO reduction plan that includes green infrastructure in combination with cost-effective grey infrastructure investments. New York City’s estimates also included future economic sustainability benefits in the form of lower energy costs, reduced emissions, improved air quality, increased property values, as well as a greater distribution of operations and maintenance costs leading to the potential for more employment opportunities.

The projects and plans presented in this article establish an economical and performance-based benefit for LID and green infrastructure. Shown in the context of actual project designs, incorporating these strategies alongside grey infrastructure improvements can

result in significant cost savings for cities pursuing and implementing CSO management. This article demonstrates the beneficial economic context for the implementation of green infrastructure and LID design for future CSO compliance projects.

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