GREEN INFRASTRUCTURE BENEFITS AND COSTS

MMSD's 2035 Vision has two key elements: 1) Integrated Watershed Management and, 2) Climate Change Mitigation/Adaptation with an emphasis on Energy Efficiency. A guiding principle is that decisions to proceed with projects be based on the sustainable bottom line. That means MMSD's planning, design, and operational decisions should be made on an approach that considers balanced economic, social, and environmental values. The Plan supports the 2035 Vision and this guiding principle, by assessing the benefits using a triple-bottom-line approach that quantifies the economic, social, and environmental benefits of green infrastructure. For the cost of widespread implementation, green infrastructure provides multiple benefits that matter to us all. It strengthens the region as a great place to live.

TRIPLE-BOTTOM-LINE BENEFITS

The sustainability of any activity can be assessed by three interrelated categories of benefits: economic, social, and environmental. Together, they are referred to as the triple bottom line (TBL).

A TBL analysis is a way to identify and evaluate all of the benefits associated with a program—not just the primary or initial reason for engaging in it (Figure 22). Green infrastructure recommended in this Plan is intended to capture stormwater before it enters the sewer and offsets traditional sewer infrastructure use and costs. Green infrastructure provides many benefits that traditional sewer infrastructure does not, though. For example, it improves quality of life by enhancing neighborhood aesthetics and, in some cases, even reduces crime. Green infrastructure can also reduce pollution to area waterways and improve the air people breathe. Green infrastructure can be less expensive than grey infrastructure, particularly when ancillary economic benefits, such as reduced energy needs, are considered.

To assess the broader economic, social, and environmental benefits of green infrastructure in the region, the 12 factors listed in Table 8 were evaluated. Quantitative analyses were performed for the economic and environmental factors, while social benefits were qualitatively assessed. Green infrastructure strategies that provide social benefits can also impart measurable economic benefits, such as increased property values.

FIGURE 22
TBL Benefits
A TBL analysis was conducted to document the multiple benefits of widespread green infrastructure implementation.

TABLE 8
Triple-Bottom-Line Analysis Factors

Economic Benefits	
1	Green Job Opportunities
2	Reduced Infrastructure Costs
3	Reduced Pumping and Treatment Costs
4	Increased Property Values
Social Benefits	
5	Improved Quality of Life and Aesthetics
6	Improved Green Space
Environmental Benefits	
7	Captured Stormwater Runoff
8	Reduced Pollutant Loadings
9	Increased Groundwater Recharge
10	Reduced Carbon Emissions
11	Reduced Energy Use for Cooling
12	Improved Air Quality

TRIPLE-BOTTOM-LINE SUMMARY

The Plan summarizes the multiple economic, social, and environmental benefits that green infrastructure provides residents, municipalities, and the public. For instance, public works officials can experience improved operations of existing sewers with green infrastructure. Green infrastructure reduces stormwater pollution, helping municipal engineers and developers meet water quality regulatory requirements. The public benefits from green space, reducing crime, and increasing property values. Property owners benefit from energy savings, more naturally beautiful and aesthetically pleasing neighborhoods, and higher property values where green infrastructure is constructed. The summary below is at full build-out.

Economic Benefits

Green infrastructure can save money compared to traditional sewer infrastructure. The most compelling economic benefits of green infrastructure are often related to its ability to help sewers work better. Economic benefits quantified in more detail in the Plan include the following:

+ Infrastructure Savings: Green infrastructure saves $44 million in infrastructure costs in the combined sewer service area compared to constructing more Deep Tunnel storage.
+ Green Job Opportunities: Green infrastructure develops over 500 green maintenance jobs at full implementation and 160 construction jobs on average each year.
+ Property Values: Green infrastructure increases property value by an estimated $667 million throughout the MMSD planning area.

Social Benefits

Numerous studies cited in the Plan have shown that an enhanced connection to the natural environment contributes to the health and safety of residents. Green infrastructure implementation improves existing green space and provides the following:

+ Quality of Life: Green infrastructure improves quality of life and aesthetics.
+ Crime Rates: Green infrastructure lowers crime rates.
+ Reduction of Stress: Green infrastructure reduces stress by providing calming natural areas and green space.
+ Green Spaces: Green infrastructure increases green space with native vegetation and recreational enjoyment.

Environmental Benefits

Green infrastructure captures, retains, and infiltrates stormwater; sequesters carbon; and cools through shading. The processes provide multiple benefits to the environment, including the following:

+ Groundwater Recharge: Green infrastructure recharges up to 4 billion gallons per year.
+ Carbon Emissions: Green infrastructure provides a reduction of 73,000 tons of carbon dioxide (CO_2) per year (equivalent to the emissions from 14,000 vehicles) and an annual social cost benefit (including impacts of climate change on human health, property damages from increased flood risk, and other impacts) of $1.4 million.
+ Energy Conservation: Green infrastructure saves 16,500 megawatt hours per year equating to a cost savings of $1.5 to $2.1 million.
+ Air Quality: Green infrastructure reduces emissions by 8 tons carbon monoxide, 103 tons nitrogen dioxide, 403 tons ozone, 190 tons particulate matter, and 115 tons sulfur dioxide, leading to improved health worth $9.1 million in annual health care savings.
+ Stormwater Regulations: Green infrastructure provides an asset for developers and municipalities to meet stormwater quality and quantity regulations and support reductions in polluted stormwater for anticipated total maximum daily load (TMDL) implementation: 14.8 billion gallons of captured stormwater per year with annual reductions of up to 15 million pounds of total suspended solids (TSS) and 54,000 pounds of total phosphorus (TP).

TRIPLE-BOTTOM-LINE ANALYSIS

Economic Benefits

Installing green infrastructure strategies will require an average of 160 construction jobs per year during project implementation, and over 500 maintenance jobs, once constructed!

Green Job Opportunities

Green infrastructure in the Plan will spur the development of jobs for constructing and maintaining new facilities over the implementation period. On average, there will be 160 new construction jobs per year. Once the new facilities are constructed, there will be over 500 green operations and maintenance jobs.

The construction job estimate assumes a linear implementation of the Plan over 25 years. For this calculation, it is assumed that 33 percent of the annual program cost would be spent on construction labor based on the cost breakdown of similar green infrastructure installation and average construction job labor costs.

The operations and maintenance job calculation assumes that 77 percent of the annual operations and maintenance cost of the Plan would be allocated to labor, based on operations and maintenance experience from the City of Philadelphia, detailed in the *"Inspection and Maintenance Program Development for the City of Philadelphia's Green Stormwater Infrastructure"* (Philadelphia Water Department 2011). The job calculations also take into account landscape maintenance job labor costs. Gallon for gallon, the green infrastructure recommended in this Plan is less expensive than tunnels of comparable volume.

Reduced Infrastructure Costs

Widespread implementation of green infrastructure throughout the region can offset the need to build and maintain conventional grey infrastructure. An investment of $178 million for green infrastructure in the combined sewer service area (just 6 percent of the MMSD planning area) enables the potential capture and storage of 91.6 million gallons of stormwater. Using the cost of the Deep Tunnel construction that would be required to capture this same volume as an indicator of grey infrastructure cost, the investment equates to a $222 million investment in grey infrastructure. This calculation is based on a capital cost of $2.42 per gallon of Deep Tunnel construction, design, and engineering, as described in "Fresh Coast Green Solutions" (MMSD 2009). Gallon for gallon, the green infrastructure recommended in this Plan is less expensive than tunnel storage of comparable volume.

The $178 million of green infrastructure storage in the combined sewer service area is equal to $222 million of Deep Tunnel storage volume.

Capturing stormwater in green infrastructure strategies will also reduce the need for additional grey infrastructure in the separate sewer service area (94 percent of the MMSD planning area). Region-wide implementation of green infrastructure to capture the first 0.5 inch of rainfall from impervious areas from every storm will reduce stress on existing drainage infrastructure and reduce the need for additional storm sewer capacity in areas with existing drainage problems.

Also, coordination between the Plan and MMSD's Private Property Inflow and Infiltration Reduction Program can produce synergies by using green infrastructure to achieve the overarching goals of reducing basement backups and sewer overflows. By capturing the first 0.5 inch of rainfall from impervious areas for every storm, properly implemented green infrastructure strategies should reduce inflow and infiltration to sanitary sewer systems.

In addition, green infrastructure strategies, such as bioretention and rain gardens, filter out pollution in stormwater, such as phosphorus and suspended solids. Green infrastructure strategies will reduce the need for stormwater management facilities to meet TMDL goals now under development in the Milwaukee, Menomonee, and Kinnickinnic River watersheds.

Reduced Pumping and Treatment

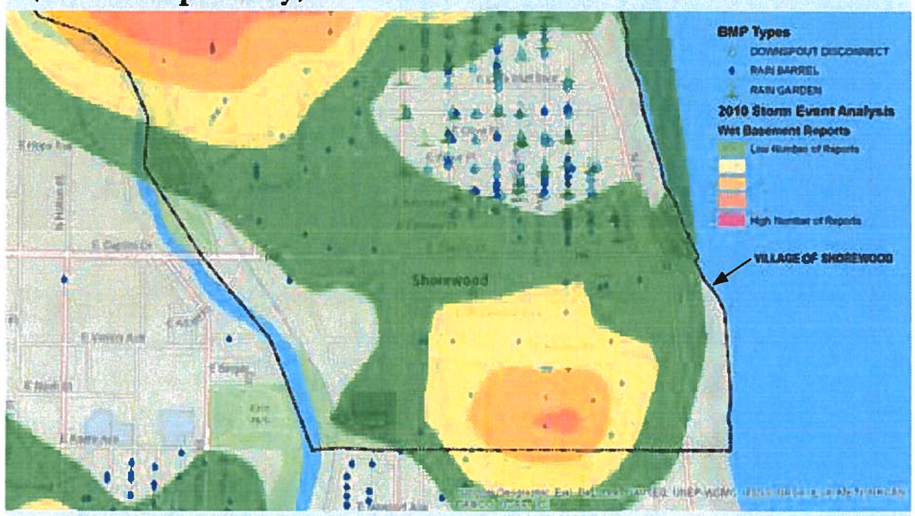
By capturing stormwater that would otherwise enter the Deep Tunnel, green infrastructure reduces the need for tunnel pumping and associated wastewater treatment. Annual reductions in flow to the Deep Tunnel from areas with green infrastructure is estimated at 66 percent based upon typical green infrastructure performance. There may be an estimated reduction of up to 1.31 billion gallons of pumped volume per year and 900 million gallons of reduced treatment per year after Plan strategies are fully implemented.

Increased Property Values

Green infrastructure strategies, such as rain gardens/bioretention and stormwater trees, have the potential to increase property values due to the aesthetic enhancements they provide to a neighborhood.

The triple-bottom-line (TBL) analysis indicates a potential property value increase of $667 million ($409 million in residential areas, $238 million in commercial areas, and $20 million in industrial areas) after Plan strategies are fully implemented. In its analysis, the consultant team applied a 4 percent increase to 2011 average equalized assessed values for the portions of residential, commercial, and industrial areas receiving green infrastructure with the Plan. The one-time factor of a 4 percent increase is based on the median property value increase among nine studies of property value impacts from green infrastructure implementation throughout the United States, as explored in "Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee" (MMSD 2011) and may be conservative based on the study cited below.

Green Infrastructure with Reduced Basement Backups (one example only)



In 2004, MMSD sponsored a downspout disconnection, rain barrel, and rain garden program that effectively managed stormwater. A review of basement backup complaints in 2010 shows that fewer calls occurred in areas where these strategies were implemented.

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A local study conducted by The Center for Economic Development at the University of Wisconsin—Milwaukee called "Center for Economic Development Study on Impact of Green Infrastructure on Property Values within the Milwaukee Metropolitan Sewerage District Planning Area" confirms the link between green infrastructure and increased property values. The study assessed values for residential, commercial, and industrial properties in areas where green infrastructure strategies were implemented in the Milwaukee region. Areas studied included a neighborhood in the Village of Shorewood, the neighborhoods near Lincoln Creek, the Menomonee Valley Redevelopment, and the Pabst City commercial redevelopment. Property value increases were correlated with green infrastructure implementation in the Lincoln Creek, Menomonee Valley, and Pabst City areas. There was no definitive correlation in the Shorewood study area (UWM CED 2012).

A study of local property value data by the University of Wisconsin-Milwaukee Center for Economic Development corroborates the findings of nationwide studies that correlate increased property values with green infrastructure.

Social Benefits

Improved Quality of Life and Aesthetics

Many studies have noted the positive impacts on quality of life in urban areas from improved aesthetics, increased recreational space, and a connection to the natural environment. "Managing Urban and High-Use Recreation Settings" found that office workers who can see nature from their desks report greater job satisfaction and lower rates of sickness than those who cannot see nature from their work areas (Kaplan 1992). "Grow for the Gold: Trees in Business Districts," a study that looked at consumer survey data, concluded that shoppers were willing to pay as much as 11 percent more for goods and services in well-landscaped commercial areas, and also more for parking (Wolf 1999). In addition, "Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue," a study of public housing complexes in an inner city, found a correlation between lower crime rates and nearby vegetation (Kuo 2001). These benefits could be duplicated in the Milwaukee region.

A connection to the natural environment has been shown to increase job satisfaction and lower crime rates in urban areas.

Improved aesthetics have been shown to decrease stress and, when combined with transportation improvements that increase walking and biking, significant health benefits are realized. According to "CDC Recommendations for Improving Health through Transportation Policy," several green infrastructure strategies, such as porous pavement and bioretention, can be placed along roadways and help form Complete Streets—roadways that are planned, designed, and operated to enable safe, attractive, and efficient access and travel for all users (Centers for Disease Control 2010). Complete Streets improve neighborhood connectivity, incorporate stormwater management practices, encourage walking and bicycling, and improve safety.

Improved Green Space

While the Plan does not call for any new green space except as green roofs, opportunities may arise where pavement can be replaced with green space. Opportunities for depaving should be pursued as they become available. The Plan primarily calls for *improved* green space, with aesthetic enhancements and native vegetation that benefits recreation, improves shading, and provides stormwater and pollution management—all of which strengthen neighborhoods and health. Examples of progress at the neighborhood level include the following:

+ In Milwaukee's Walnut Way neighborhood, residents worked together to plant trees and install rain gardens, rain barrels, and other green infrastructure strategies on vacant lots and open spaces. The improvements have not only beautified the neighborhood, but also helped build a sense of community independence, taught valuable skills to both youth and adult residents, and lowered crime in the area. The community's website states that the

Menomonee Valley Redevelopment

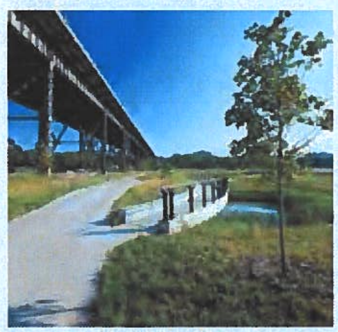
Incorporating green infrastructure in redevelopment project revitalizes community.

Urban redevelopment creates more economically, socially, and environmentally sustainable cities by recycling land. The Menomonee Valley Industrial Center and Community Park project is an excellent example of redevelopment that used regional stormwater best management practices and green infrastructure in its planning to create land ready for development. Individual developers did not have to worry about stormwater requirements. In addition, the redevelopment achieved multiple triple-bottom-line benefits.

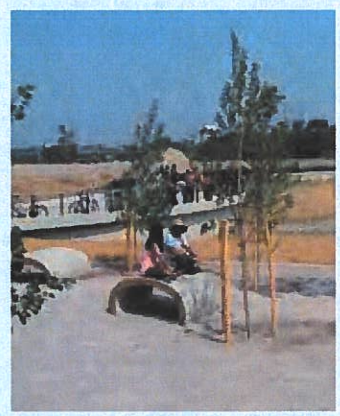
Environmental Benefits. The stormwater reservoir/treatment facilities use natural materials that treat stormwater from 85 acres of the development to a quality that exceeds discharge requirements and removes 80 percent of total suspended solids. Building these facilities as part of the redevelopment removed the issue of stormwater runoff management as a hurdle for potential developers.

Social Benefits. An integrated park space near the stormwater facilities connect with a regional trail system. The recreational green space offers nearby residents and trail users additional amenities and river access for the first time in decades.

Economic Benefits. Increased city tax revenue from the development has resulted in an estimated increase of ecological, recreational, and aesthetic resource site value totaling more than $120 million. Land has sold at prices between $110,000 and $120,000 per acre. Approximately $28.5 million in public investment has resulted in $84 million in private development by eight private businesses since 2006.



State-of-the-art green infrastructure facilities improve water quality. Stormwater trees and native vegetation were planted by volunteers and students

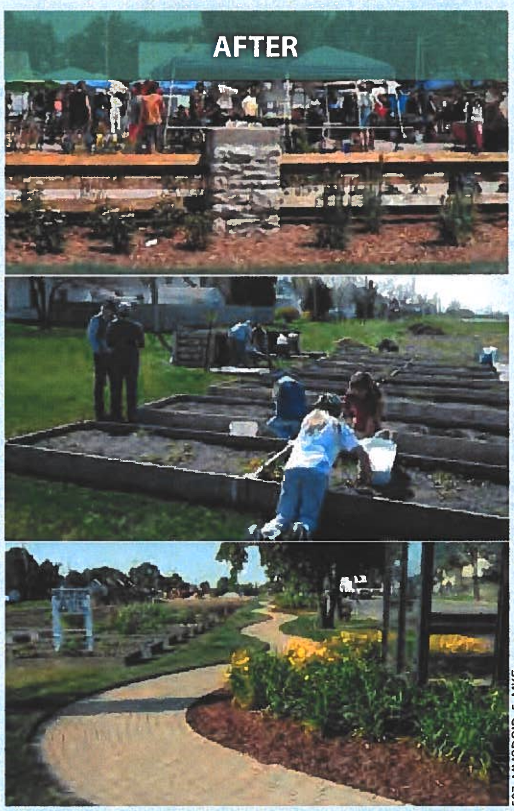


New park-space and trail access helps bring the community together

Eight new businesses since September 2006 anchor the west end of the Menomonee Valley

13th District Green Corridor Improvements

MMSD helped fund improvements spearheaded by the Garden District Neighborhood Association. Green infrastructure strategies included porous pavement, a rainwater harvesting and reuse system using Aquablox®, native plants, bioswales, and cisterns. Below are some before and after shots of the South 6th Street Community Garden and Farmer's Market space. Improvements have also been made to nearby commercial businesses and parking lots to manage stormwater and to spur economic growth.



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Photos courtesy of Garden District Neighborhood Association (GDNA 2012)

A child's wonderment and connection to his natural environment is just one qualitative benefit gained by planting native species across the region.

"gun fire, drug trafficking, and prostitution have virtually disappeared" (Walnut Way Conservation Corp 2010).

- In Milwaukee's 13th District, known as the Garden District, residents encourage one another and area businesses to beautify the neighborhood with trees, gardens, and other plantings. Neighborhood groups, non-profits, businesses, residents, and political leaders created the 3-mile-long green corridor that incorporates porous pavement, bioswales, and planters to help manage stormwater runoff.

Working together—neighborhood groups, non-profits, businesses, residents, and political leaders that implement green infrastructure will transform commercial areas and spur economic growth.

Improved green space in the region can also improve health. The opposite is also true; environmental degradation can harm health. A study conducted by the USFS, titled "The Relationship Between Trees and Human Health: Evidence from the Spread of the Emerald Ash Borer," found an increase in mortality due to cardiovascular and lower-respiratory-tract illness in areas with widespread loss of ash trees from the emerald ash borer. This finding is consistent with other studies that have identified a correlation between the natural environment and health (Donovan et al. 2013). The Plan recommends 738,000 additional trees, 650 acres of bioretention or rain gardens, and 8,600 acres of native landscaping. The considerable environmental benefits from green space improvement are outlined in the next section.

The Grange Avenue green street uses bioswales to capture roadway stormwater runoff. It slows down the stormwater runoff rate and removes pollution, while providing an attractive natural setting to the busy roadway

Environmental Benefits

Captured Stormwater Volumes (Quantity)

At full implementation, green infrastructure may increase stormwater capture up to 740 million gallons per storm event over the MMSD planning area. This volume equates to an average of 14.8 billion gallons per year.

Substantial implementation of green infrastructure strategies to capture a portion of every storm will improve drainage during wet-weather events and increase the level of service of the region's stormwater infrastructure and reduces the risk of sewer overflows and basement backups. In addition, the use of green infrastructure to reduce stormwater volume will be beneficial for municipalities and developers who are responsible for meeting regional or local stormwater management ordinance requirements.

Reduced Pollutant Loadings (Quality)

An additional environmental benefit of green infrastructure is reduced pollutant loadings to area waterways. Reducing stormwater pollution will help municipalities meet water quality regulations. For example, the TMDLs that are currently under development for the Milwaukee River basin (Milwaukee, Menomonee, and Kinnickinnic River watersheds) will establish strict pollution reduction targets. The TMDL implementation Plan will include green infrastructure as one of the methods to improve water quality. The TMDLs will be used by the WDNR to establish permit requirements for municipalities. As a result, the Plan strategies will be useful for municipalities as they establish programs to meet the new requirements.

Green infrastructure strategies can have a positive effect on reducing pollutant loadings. The Plan strategies may remove up to 15 million pounds of TSS and 54,000 pounds of TP per year at full implementation. This level of pollution reduction provides significant progress towards meeting future TMDL phosphorus pollution reduction requirements for each watershed.

How much pollution will be reduced was determined by using baseline loading data from the Source Loading and Management Model (SLAMM) and combined sewer overflow water quality monitoring performed in the planning area. The pollutant reduction method is consistent with "Recommendations of the Expert Panel to Define Removal Rates for

New York State Stormwater Performance Standards," a recent industry guidance study (Chesapeake Stormwater Network 2012). Values are conservative in that they do not account for the effect of infiltration increasing the effective storage of many green infrastructure strategies, or that some treatment is often provided when the green infrastructure capacity is exceeded. Dissolved pollutants are less likely to be removed; however, design standards can include methods to remove dissolved phosphorus, for example, by adding phosphorus-absorbing materials. Using green infrastructure will help municipalities and developers meet water quality requirements in the WDNR's NR 151 stormwater regulations.

Increased Groundwater Recharge

The Plan strategies help stormwater soak into the earth, recharging groundwater supplies. While a portion of the volume that infiltrates is stored in the soil and soaked up by plants, some of the infiltrated volume can seep into deeper parts of the subsurface and recharge groundwater aquifers. Maintaining groundwater supplies is not only important for areas that use groundwater for drinking water and irrigation, it also provides critical baseflow for rivers and helps maintain water levels in lakes and wetlands.

Models of porous pavement and bioretention facilities were developed using a University of Wisconsin-Madison model called RECARGA. The model estimated that the Plan porous pavement and bioretention facilities will infiltrate approximately 4 billion gallons of stormwater per year at full implementation. This represents approximately 25 percent of the annual capture from all green infrastructure strategies.

Carbon Reduction

Green roofs, bioretention/rain gardens, and trees provide carbon reduction benefits by sequestering CO_2 from the air as they grow. In addition, there is carbon reduction because green infrastructure provides energy savings, thereby reducing electricity usage and power plant emissions.

The Plan strategies may sequester approximately 59,000 tons of CO_2 annually. Approximately 14,000 additional tons of CO_2 emissions would be avoided annually due to energy savings related to the reduced need for cooling and reduced stormwater volume entering the Deep Tunnel that would otherwise have to be pumped out.

Through both carbon sequestration and avoided emissions, widespread green infrastructure may reduce CO_2 by a total of 73,000 tons per year. This mass is equivalent to removing the emissions of 14,000 vehicles, based on annual vehicle emission rates from USEPA, as detailed in "Calculations and References for Greenhouse Gas Equivalencies Calculator" (USEPA 2012a). In addition, this reduction has an associated social cost savings of $1.4 million due to the reduction of ill effects on human health and the effects of climate change from the emissions, according to "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" (U.S. Government 2010).

At full implementation, green infrastructure could annually reduce carbon in the atmosphere equivalent to removing emissions from 14,000 vehicles and could save enough energy to power 1,400 homes.

Reduced Energy Use for Cooling

Both tree shading and the insulating properties of green roofs reduce cooling costs during warmer months. At full implementation, green roofs and trees in the Plan are estimated to reduce cooling energy needs by 16,500 MWh per year. This is equivalent to the power consumption of 1,400 homes, based on average annual electricity consumption data from the U.S. Energy Information Administration (USEIA) website's "Frequently Asked Questions" (USEIA 2010a). The reduction in cooling energy needs has an associated cost savings of $1.5 to $2.1 million annually based on a cost range of $0.09 to $0.13 per kWh, according to the "State Energy Profile for Wisconsin" (USEIA 2010b).

Not all trees provide shading benefits—the amount of shading depends upon the tree type and location. In addition, the insulating properties of green roofs vary depending on the depth of the groundcover and type of vegetation. The estimates assume that 30 percent of the stormwater trees in the Plan provide shading. The calculation also assumes that 25 percent of green roofs are intensive green roofs (insulating soil depth of greater than 6 inches) providing 17,000 kWh of energy savings per acre, as described in "Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee" (MMSD 2011). The remaining 75 percent are simpler, tray-type green roofs (insulating soil depth of 3 to 6 inches) with an assumed energy savings equal to one quarter of the intensive green roof, or 4,250 kWh per acre.

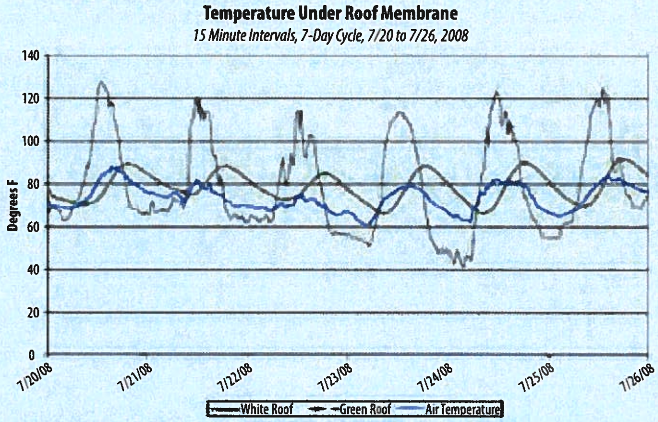
Improved Air Quality

Trees also help to improve air quality by directly removing air pollution. As noted, there is an air quality benefit associated with avoided power plant emissions due to the reduced need for cooling and tunnel pumping. At full implementation of the Plan, trees may remove 8 tons of carbon monoxide, 91 tons of nitrogen dioxide, 403 tons of ozone, 190 tons of particulate matter (particle size less than or equal to 10 microns), and 61 tons of sulfur dioxide per year (USFS 2008).

In terms of avoided emissions, the green infrastructure recommended by the Plan provides a reduction of 12 tons of nitrogen dioxide and 54 tons of sulfur dioxide per year. The human health benefit associated with the reduced and avoided nitrogen dioxide and sulfur dioxide pollution is estimated to be $9.1 million per year. Health effects associated with exposure to air pollution include chronic bronchitis, aggravated asthma, cardiovascular illness, and premature mortality. Green infrastructure provides welcome health benefits by making the air cleaner.

Walmart's Energy Efficient Green Roofs

Green roofs lower roof temperature, thus reducing heating and cooling needs and energy costs. Walmart estimates that a green roof can annually provide stores with 1 to 6 percent in energy savings compared to a highly efficient white roof. Even greater cost savings would be expected compared to a traditional black tar roof.



Source: Walmart, Inc (courtesy of Arup)

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Pollution captured by trees and avoided from reduced fossil fuel emissions may provide $9.1 million in annual health care cost savings in the region.

ACHIEVING THE MMSD 2035 VISION

The MMSD 2035 Vision is to achieve zero sewer overflows, zero basement backups, and improved water quality by the year 2035. As shown by the TBL analysis, green infrastructure can provide an array of benefits to existing infrastructure and the environment. Green infrastructure implementation will complement other ongoing programs and contribute to meeting the 2035 Vision goals in the following ways:

Zero Basement Backups

Basement backups occur for a number of reasons, often when a sanitary sewer system's capacity is exceeded. Basement backups may occur because too much rain becomes groundwater and then enters through cracks and connections to sanitary sewers that are not designed to carry rainwater. In the combined sewer area, this occurs when the rain event exceeds the sewer capacity.

The goal of MMSD's Private Property Inflow and Infiltration Reduction Program is to reduce the risk of basement backups by reducing the amount of excess clear water that enters privately-owned sanitary sewer laterals when they leak, one common source of the problem. Several green infrastructure strategies retain and infiltrate stormwater and, when properly located, they direct stormwater away from sanitary sewers. Green infrastructure complements the program by preventing stormwater from entering into sewers too fast and allows the system to function as designed.

Zero Sewer Overflows

Like basement backups, sewer overflows may occur when a sewer system's capacity is exceeded. In the MMSD system, the Deep Tunnel provides additional capacity and stores wet weather flows until they can be treated. In very large rainfall events, the capacity of the Deep Tunnel is occasionally exceeded triggering sanitary and/or combined sewer overflows to area waterways to minimize the risk of basement backups. By holding back and reducing the amount of stormwater runoff that enters the Deep Tunnel, green infrastructure can free up system capacity later in a storm that would otherwise be filled. The TBL analysis shows green infrastructure complements the grey infrastructure performance by intercepting up to 1.31 billion gallons per year of stormwater that otherwise would have entered the Deep Tunnel system.

Improved Water Quality

As shown in the results of the TBL analysis, green infrastructure can improve water quality by filtering out pollution in stormwater. Through this capability, several green infrastructure strategies will be useful toward achieving water quality requirements. The TBL analysis shows green infrastructure may reduce TSS and TP pollution from stormwater runoff by 15 to 25 percent, which will provide a portion of future TMDL required reductions of these pollutants.

Improved Drainage

Proper stormwater management reduces the quantity and improves the quality of stormwater runoff. MMSD's Integrated Regional Stormwater Management Program aims to develop solutions that minimize flooding caused by stormwater drainage problems. Green infrastructure can supplement grey infrastructure solutions to drainage problems by holding back a portion of the stormwater, thereby increasing the level of service of the infrastructure and improving drainage.

Besides performance, cost is also a consideration. Green infrastructure can often save money for construction projects from the outset. A USEPA report titled "Reducing Stormwater Costs through Low Impact Development Strategies and Practices" summarized several case studies of developments throughout the country that included green infrastructure strategies. It compared the actual project costs to typical costs for conventional development and, of the 12 diverse projects with direct cost comparisons between conventional and green infrastructure approaches, 11 showed cost decreases averaging 36 percent (USEPA 2007).

WHAT WILL IT COST?

The cost of the Plan is well balanced by its benefits. A variety of cost sources and some professional judgment were used to develop the green infrastructure costs shown below. The Plan considers costs in two different ways:

+ Stand-alone costs—The costs associated with stand-alone or retrofit projects (installing a green roof on top of an existing building or replacing conventional pavement with porous pavement, for example). Relatively few projects should be constructed this way.
+ Incremental costs—The incremental costs of green infrastructure represent the cost difference between conventional construction and construction that incorporates green infrastructure (such as the incremental cost of installing a green roof instead of a conventional roof replacement or the cost difference between conventional pavement and porous pavement). As an example, if the total cost of a porous pavement system is $10 per SF and applicable conventional pavement would have cost $3 per SF, then the incremental cost of the porous pavement is $7 per SF. Incremental cost is also sometimes referred to as the additional or marginal cost of green infrastructure. The average incremental cost per gallon is $1.76 in this Plan. It should be noted that this incremental cost does not take credit for the avoided costs of conventional stormwater facilities that new construction or significant reconstruction could realize. Future exploration of these additional savings would help to further the business case for green infrastructure.

Both the stand-alone and incremental costs for most green infrastructure strategies may decrease over time as they become more widespread and become standard practice, to be conservative, this de-escalation cost was not included in the analysis.

Incentive programs may use incremental costs to encourage widespread implementation. For example, grants could fund some of the cost (typically up to the incremental cost) for private entities that voluntarily implement green measures (similar to MMSD's green roof program).

The relationship between the incremental cost and the stand-alone cost used in the Plan is shown in Table 9. Loading ratios—the ratio of drainage area to green infrastructure area—from the Green Infrastructure Performance Capacity Table (see *Summary of Analysis and Results*) were used to convert to per square foot managed costs to facilitate a more meaningful cost comparison among different green infrastructure strategies. The per square foot managed costs provide the information necessary to cost-effectively target green infrastructure implementation for various land uses.

TABLE 9

Stand-alone Costs (per green infrastructure SF and per SF managed) and the Relationship to Incremental Costs

Green Infrastructure Strategy	Stand-alone Cost ($/SF)	Loading Ratio (Ratio of Area Managed to Area of Green Infrastructure)	Stand-alone Cost ($/SF Managed)	Incremental Green Infrastructure Cost Compared to Stand-alone Cost	Sources for Cost Estimates
Green Roofs[1]	$11.50	1.0	$11.50	43%	Median PWD cost ($11.50/SF)
Rain Gardens	$10.00	12.0	$0.83	70%	Middle of FCGS range rounded up to $10/SF
Stormwater Trees[2]	$0.80	0.5	$1.58	50%	FCGS cost
Bioretention/Bioswale	$24.00	12.0	$2.00	70%	Average between PWD[3] and SUSTAIN[4] demonstration project
Native Landscaping/ Soil Amendments	$0.11	1.0	$0.11	60%	Middle of FCGS[5] range, rounded up to nearest $1,000
Porous Pavement	$10.00	4.0	$2.50	70%	$10/ SF, approximately 90 percent of median PWD costs
55-gallon Rain Barrels[6]	$120 (each)	N/A	$0.34	90%	Middle of FCGS range rounded up to nearest $10
1000-gallon Cisterns[7]	$5,000 (each)	N/A	$0.78	90%	$5/gal., middle of FCGS range for 1000-gal cistern

[1] *Incremental cost of green roofs set to 43 percent to match MMSD's $5/SF ($217,800/ acre) green roof incentive program.*

[2] *Trees are assumed to have an average 10-foot canopy radius (314 SF), with 50 percent assumed to be overhanging impervious area.*

[3] *PWD is Philadelphia Water Department.*

[4] *SUSTAIN is from (MMSD 2011) Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee.*

[5] *FCGS is "Fresh Coast Green Solutions" (MMSD 2009).*

[6] *Each rain barrel is assumed to manage 350 SF of rooftop; therefore, 124.5 barrels are required for 1 acre of roof.*

[7] *Each 1000-gallon cistern is assumed to manage 6,500 SF of impervious area; therefore, 6.7 cisterns are required for 1 acre.*

Figure 23 shows the incremental cost per gallon of storage capacity. The cost per gallon of storage capacity provides a comparison of the relative cost of storage by green infrastructure strategy. Native landscaping and soil amendments have the lowest cost per gallon of storage. The remainder of the strategies have an incremental cost between 1 and 5 dollars per gallon. Most of the strategies are estimated to provide storage capacity at a lower unit cost than the $2.42 cost per gallon of Deep Tunnel storage when it was built, as reported in "Fresh Coast Green Solutions" (MMSD 2009). The Plan recommends using each of the strategies, not just the least expensive ones because achieving the 2035 Vision requires a portfolio of green infrastructure strategies that can address unique site conditions for buildings, streets, parking lots, and turf grass areas and that may have high TBL benefits.

The cost per square foot managed (Figure 24) provides a general comparison of incremental cost for treating 1 SF of imperviousness or turf grass, depending upon the green infrastructure strategy. Native landscaping and soil amendments have the lowest cost to manage 1 SF of turf grass. The other green infrastructure strategy costs vary between $0.31 and $1.75 per SF of imperviousness managed, except that green roofs have a much higher cost. Green roofs are significantly higher than other measures in this regard, as they typically only capture rainfall that falls directly on them. The green roof incremental cost is $5 per SF based upon the MMSD Regional Green Roof Initiative incentive plan. Actual costs for green roofs are often 4 or more times higher. However, green roofs will be the only solution on some constrained sites. Differences in relative cost by strategy between per gallon storage costs and per-SF managed cost reflect the storage volume provided by each strategy.

The annual capture volume costs (Figure 25) reflect the efficiency of each green infrastructure strategy to capture stormwater repeatedly throughout the year. The primary goal is the 740 million gallon capacity storage goal; consequently, the analysis assumes consistent performance throughout the seasons when calculating annual performance. The lowest cost per gallon strategies are those targeted towards large turf grass areas and residential properties: native landscaping, soil amendments, rain barrels, and rain gardens. With

The green infrastructure strategies supporting green alleys, streets, and parking lots are included in other strategies. The wetlands Green Infrastructure Strategy is encouraged but not quantified in the Plan.

FIGURE 23
Incremental Cost per Gallon of Storage*

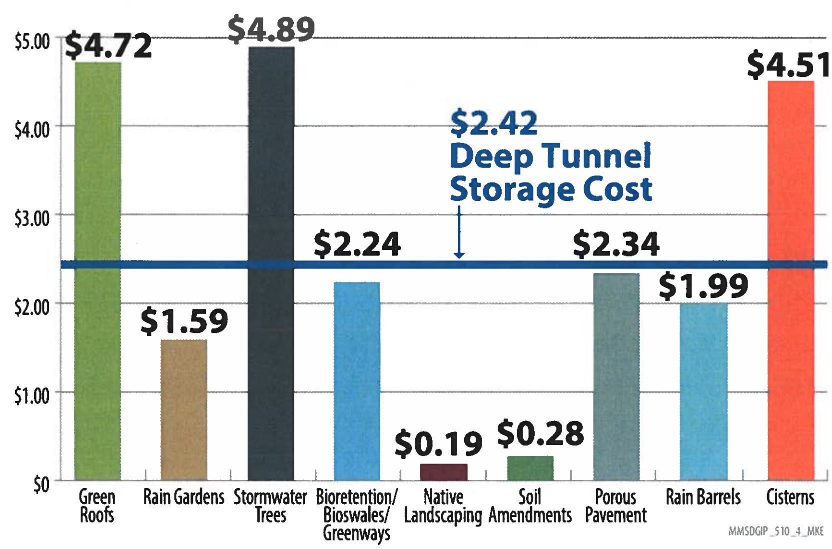


FIGURE 24
Incremental Cost per Square Foot Managed*

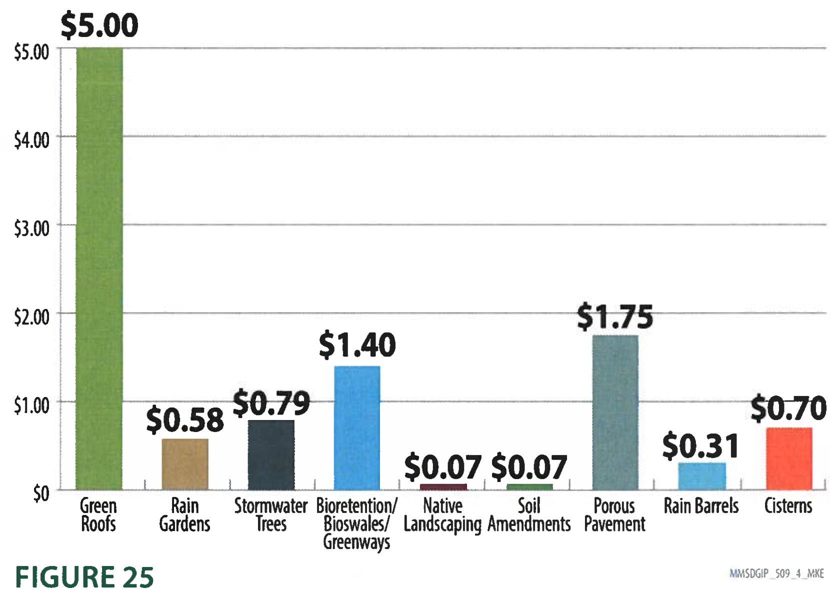
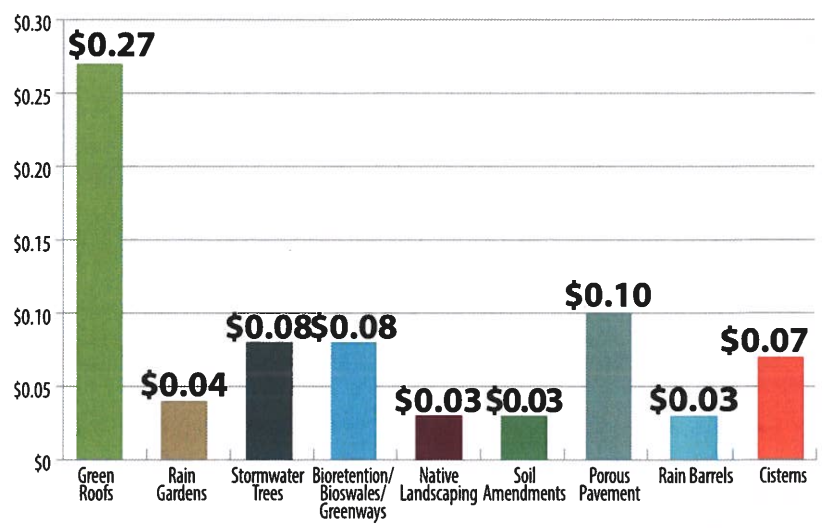


FIGURE 25
Incremental Cost per Annual Gallon Captured*



the exception of green roofs, which have annual efficiency costs 3 to 5 times higher, the remainder of the strategies have similar costs in the range of 7 to 10 cents per annual gallon captured.

These costs are applied to the implementation levels described earlier (*Summary of Analysis and Results*) to estimate the total Plan costs by land use, by green infrastructure strategy to meet the 2035 Vision, and by watershed. A funding amount of $33 million (see Figure 27) is included in the Plan to support rainwater harvesting efforts while work to revise plumbing code regulations proceeds.

Figure 26 shows the Plan cost for green infrastructure applied by land use and Figure 27 shows the Plan cost by green infrastructure strategy. The total Plan cost is $1.3 billion, an average of just over $59 million per year. The Plan cost is roughly split between publicly- and privately-owned property. By planning green infrastructure to coincide with planned capital projects, there is a cost savings of approximately $850 million, or nearly 40 percent compared to green infrastructure constructed as stand-alone projects that would otherwise cost $2.15 billion. This means that significant cost savings can be realized by including green infrastructure in planning and preliminary design discussions, rather than trying to implement after the fact. Other cost savings may be realized with larger economies of scale, in time.

FIGURE 26
Plan Investment by Land Use

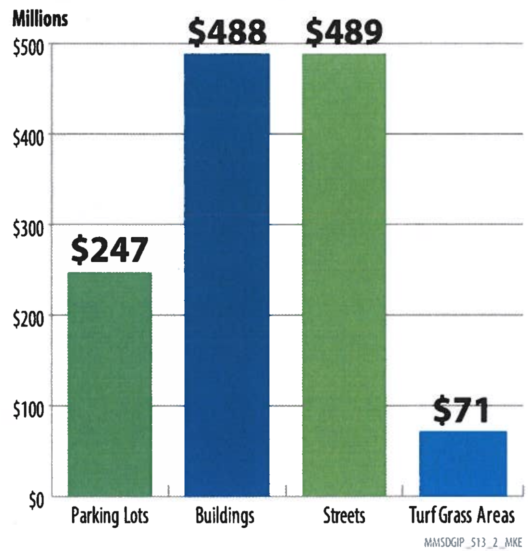
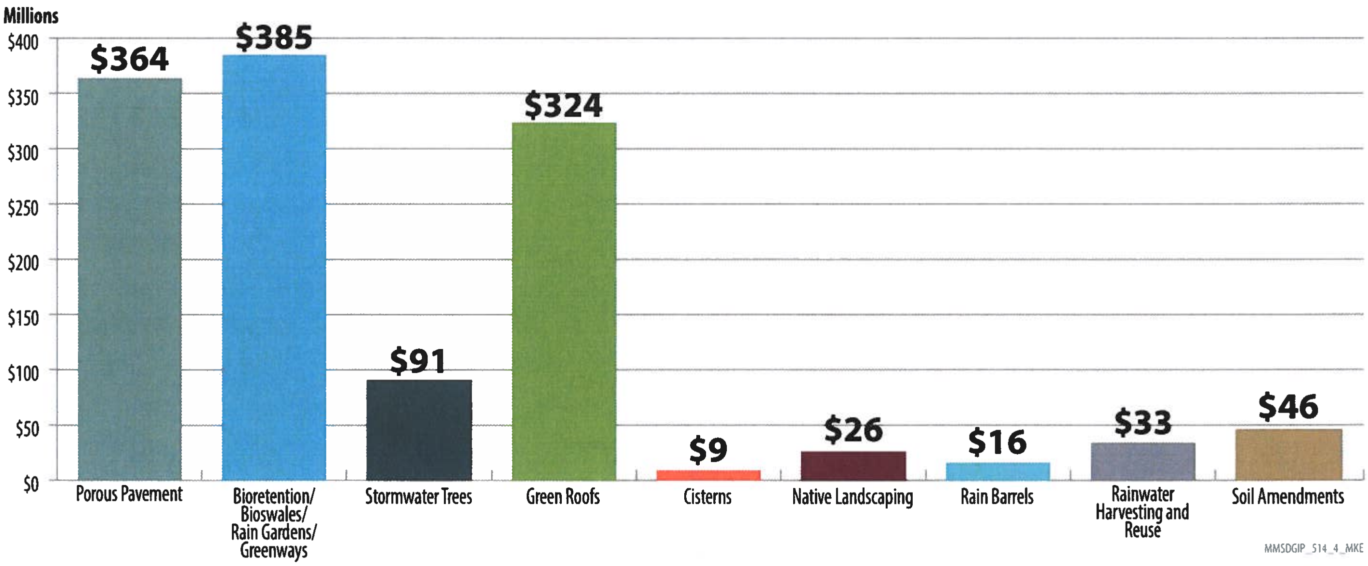


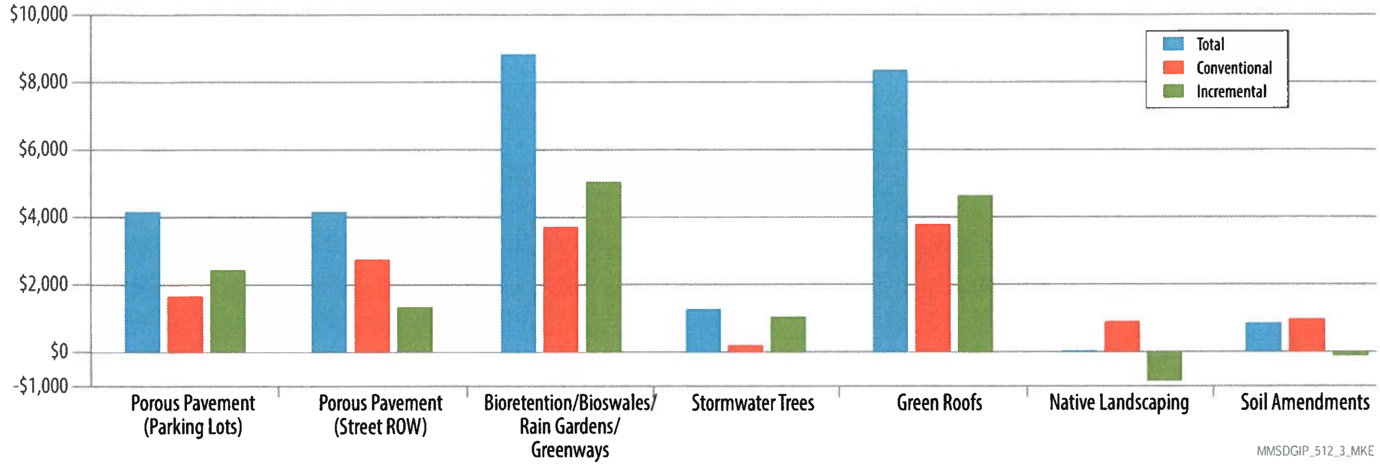
FIGURE 27
Incremental Cost by Green Infrastructure Strategy



Operation and Maintenance Costs

Operation and maintenance costs were considered in two different ways: total and incremental. The total operation and maintenance costs are an estimate of the total annual cost of maintaining the green infrastructure, and the incremental operation and maintenance costs estimate the difference in costs between green infrastructure strategies and their conventional counterparts. A good example of this is the cost difference between maintaining porous and conventional pavements. Just as with the construction cost considerations, to be conservative, the incremental operation and maintenance costs do not reflect the comparable cost of maintaining conventional stormwater facilities. If new or reconstruction projects have fewer conventional stormwater facilities to maintain because of green infrastructure implementation, the

FIGURE 28
Estimated Annual Operation and Maintenance Costs per Acre



incremental operation and maintenance costs would be lower. These potential cost savings could be explored if MMSD's Chapter 13 stormwater rules are revised for green infrastructure.

Figure 28 includes the total, comparable conventional, and incremental operation and maintenance costs for the green infrastructure strategies evaluated in this Plan. Operation and maintenance costs for cisterns and rain barrels are assigned on a per unit basis (e.g., $3 per year per rain barrel) as opposed to a per acre basis and the incremental cost is assumed to be the same as the total cost because there is a not a direct conventional maintenance equivalent. Consequently, rain barrels and cisterns are not included in Figure 28.

Applying these costs to green infrastructure to meet the 2035 Vision capture goal results in an estimated incremental operation and maintenance cost of $10.4 million annually at full implementation. Approximately 64 percent is attributed to publicly-owned lands (the total for private property is lower because more of the savings from native landscaping and soil amendments accrue there). The cost of comparable grey infrastructure and maintenance costs is not known, and is not calculated as an offset.

Plan Cost Summary

The Plan cost reflects the incremental cost representing the efficiency of constructing green infrastructure with planned capital construction projects. To achieve the 2035 Vision goal of providing 740 million new gallons of storage capacity, the Plan estimates a capital cost of $1.3 billion for full implementation, or approximately $59 million per year. This reflects a cost savings of $850 million, or nearly 40 percent, compared to green infrastructure constructed as stand-alone projects that would otherwise cost $2.15 billion. The Plan estimates incremental annual operation and maintenance costs at $10.4 million. Costs are roughly split between the public and private sectors.

Achieving this level of implementation is an ambitious undertaking. There remain real and perceived cost and performance issues, as well as cultural barriers, to greening the region that will need to be addressed with technical solutions, larger economies of scale, and education. The next section, Recommendations, lists strategies to realize the Plan.