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EXECUTIVE SUMMARY

Green infrastructure, which utilizes natural processes to treat stormwater, potentially offers a number of benefits over the equivalent gray infrastructure. In this report, we investigate the types of benefits, and where possible, quantify and value the benefits green infrastructure provides for two case studies in the Great Lakes watershed. We describe green infrastructure projects and their benefits in Milwaukee, Wisconsin and Ann Arbor, Michigan.

The Milwaukee Metropolitan Sewer District (MMSD) incentivizes the implementation of green infrastructure projects through various funding mechanisms. Recently, Milwaukee’s City Council has taken additional steps toward promoting green infrastructure by designating a three-mile section along South 6th Street as the city’s first green corridor where, as the city hopes, green infrastructure will be used to reduce impervious surfaces in the heavily developed industrial area. MMSD has compiled a detailed inventory of completed green infrastructure projects, on private and public property, over the past several years. Of identified projects, tens of millions of gallons of stormwater are retained each year, while providing energy savings, air and water quality improvements, carbon absorption, and habitat, all with quantifiable benefits. MMSD ran a simulation model on three of its sewersheds, which we used to extrapolate the extent of existing green infrastructure into the area’s potential. In addition to the quantifiable benefits listed above, green infrastructure improves community livability, heat island reduction, education and flood prevention in the Milwaukee area, but the amounts cannot be quantified with available data at this time.

Ann Arbor provides some small-scale incentives for residential and commercial property owners to implement green infrastructure on their properties. The city itself has invested in several large green infrastructure projects including two green streets, a park renovation including a 12-acre wetland, and over 50 rain gardens. These projects manage millions of gallons of stormwater each year, while improving air and water quality, and reducing carbon emissions, and providing habitat. Based on these existing projects, the net present value of quantifiable services provided by green infrastructure in Ann Arbor would be nearly $100 million. In addition to the quantifiable benefits listed above, green infrastructure improves community livability, heat island reduction, education opportunities, and flood prevention in the Ann Arbor area, but the value of these benefits cannot be quantified with available data at this time.

The projects across these two areas provide benefits at multiple scales, and the majority of quantifiable benefits accrue to the community as a whole or are even more widespread. Efficient green infrastructure implementation requires coordination as near to the geographical scale of benefit as possible. Community-wide benefits require community-wide coordination. Public incentives, financing, and regulation all appear to facilitate this process. By themselves, however, onsite benefits likely are not sufficient in motivating home and business owners to provide green infrastructure to the level that makes economic sense. Communities in the Great Lakes region have found ways to implement green infrastructure, and there is potential to greatly expand the role of green infrastructure in these areas over the coming years.
I. INTRODUCTION

Clean water is one of the most important and vital resources for communities, and it is crucial that we are able to protect it. We rely on it directly or indirectly in nearly every aspect of our day, from drinking, cooking and bathing to industry operations and on to recreation, views, and supporting wildlife and ecosystems. The Clean Water Act and Safe Drinking Water Act as well as other federal laws combined with state and local regulations attempt to address our water quality goals across channels, often relying upon large-scale infrastructure to capture, convey, and treat contaminated water and pollutants to protect our water resources. There is growing recognition, however, that harnessing natural processes may, in some cases, offer a preferred set of benefits.

Vegetation, soils, topography, and organisms (combined through green infrastructure) can provide services that, under appropriate circumstances, are similar to services provided by traditional gray infrastructure. Green infrastructure is “management approaches and technologies that utilize, enhance and/or mimic the natural hydrologic cycle processes of infiltration, evapotranspiration, and reuse.”¹ In addition to the stormwater-related services green infrastructure projects provide, they also provide habitat, air quality, recreational, visual, and other benefits that traditional gray infrastructure cannot. Furthermore, green infrastructure is adaptive and can regenerate and grow on its own rather than degrade over time. Considering construction and operation and maintenance costs, green infrastructure can be less expensive than gray infrastructure and function at scales, from the landscape down to the individual private parcel, which are not efficient for gray infrastructure technologies.

As more communities look to implement green infrastructure solutions, an in-depth analysis of areas that undertook early adoption is an important step in designing and understanding the appropriate role for green infrastructure in our communities. In this report, we consider the experience of select communities in the Great Lakes region (see Figure 1). These communities, Milwaukee, Wisconsin and Ann Arbor, Michigan, have implemented green infrastructure to meet multiple community goals, and provide lessons for other areas. We identify the effects, the services provided by their green infrastructure, and quantify these services in order to consider the economic value they provide. We also evaluate the potential scale of economic benefits these communities might expect with even greater use of green infrastructure in their areas.

We find a range of benefits with real and substantial economic value to broad geographical scales. This evidence can help these communities and others better understand the reasonable and potential benefits they might achieve from undertaking green infrastructure projects of their own. It can also help them to identify financing and implementation mechanisms that lead to efficient community-level outcomes.


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**Figure 1. Great Lakes Watershed**

Source: US EPA.
II. STRUCTURE AND METHODS

A. Structure of Report

This report contains two case studies based in the Great Lakes region: Milwaukee, Wisconsin and Ann Arbor, Michigan. Figure 2 shows a map of the region and each of the case study locations. Each case study has a similar structure. We begin by providing background regarding stormwater management in each case study area. Some of the things we discuss include:

• Watershed conditions (e.g., major waterways, EPA-approved TMDL)
• Management agencies and other parties responsible for stormwater
• Major permits (e.g., MS4, NPDES) applicable to the area
• Regulations and restrictions regarding stormwater management in the area
• Existing components of stormwater management (e.g., combined/separate sewer systems)

Next, we describe existing green infrastructure projects and programs supporting the adoption of green infrastructure techniques. For each project and program, we identify the number of different types of techniques used, and estimate the volume of stormwater reductions associated with each. In the Milwaukee case study, we extrapolate from the existing inventory to estimate the potential future extent of green
infrastructure in the area. In the Ann Arbor case study, there are insufficient data to make this extrapolation, but we provide short narratives of each project and project in the area. Finally, in both case studies, we estimate the economic value of the different types of benefits associated with green infrastructure today and in the future.

### B. Methods for Estimating Economic Value of Benefits from Green Infrastructure

The main part of our analysis involves the estimation of economic values associated with existing and potential green infrastructure in each of the case study areas. We provide full details on our assumptions and calculations in the appendices to the report. In general, we applied the methods described in the Center for Neighborhood Technology’s 2010 report entitled, *The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental, and Social Benefits* (hereafter referred to as the 2010 CNT Report). In this section, we provide a brief overview of our approach to estimating the economic value of different benefit categories provided by green infrastructure. The different benefit types accrue at differing geographical scales, from the individual site owner, to the community, and broader.

#### 1. Water-Related Benefits

Green infrastructure reduces the volume of stormwater runoff entering sewers and/or nearby waterways. Consequently there are two primary categories of water-related economic benefits: (1) avoided costs associated with reduced stormwater runoff, and (2) reduced flooding. These benefits can accrue from onsite to downstream, with general diffusion of benefits with increasing distance.

**Avoided costs associated with reduced stormwater runoff and water quality benefits**

Decreasing the volume of stormwater runoff decreases costs, incurred by residents and government agencies, associated with managing and treating stormwater. In this report, we estimate these avoided costs using the most relevant data available in each case study. We describe, in detail, each method in the appropriate sections of each case study. Some of these approaches include:

- Estimating avoided costs by applying stormwater rates (which households in each of the case study areas pay) to the decreased volume of stormwater runoff.
- Estimating avoided costs related to water quality benefits by applying sediment-related values to the quantity of reduced sediment accumulating in waterways.
- Estimating avoided costs associated with potential future increases in gray infrastructure capacity.
- Estimating avoided costs associated with operations and maintenance of treating water entering combined sewer systems.

These categories are not additive for any one site nor are they perfect substitutes for each other. So consideration of all is necessary to understand the types and values of benefits, without summing their full value. We present the values for each and provide the range of values they hold.
Reduced flooding

To the extent that it reduces the volume of stormwater runoff and the speed with which stormwater enters nearby waterways, green infrastructure can decrease the severity of flooding events. Research suggests that the improved water quality and reduced flood risk resulting from green infrastructure development could increase residential property values by 0–5 percent, depending on the respective changes in relative quality and risk. In a follow-up case study, researchers examined the potential flood benefits outside Chicago. Applying the 0–5 percent impact on property values to properties in the case study, the researchers estimated an economic benefit of $0 to $7,800 per acre of increased property value attributed to reduced flooding. They also calculated the economic benefit of reduced flooding based on the avoided flood damage to structures and contents for properties in the floodplain. This analytical method included data compiled by the U.S. Army Corps of Engineers on the relationship between flooding and damages to properties in floodplains. Their approach yields an economic benefit of avoided flooding of $6,700 to $9,700 per acre for properties in the floodplain.

Given the absence of concrete data in other regions, these economic benefits are not readily transferable to the case studies in this report. The level of benefit is dependent on the reduction in flood risk stemming from existing and potential green infrastructure, as well as the existing and potential market value of developments in the area. Nonetheless, these estimates are useful in understanding the existence of flood-related benefits from green infrastructure and shed light on the potential magnitude of the benefit’s value. This value is directly proportional to the differential between the rate of flooding and the potential for green infrastructure in a given area. In the case studies, we briefly describe historical incidents of flooding for perspective of the potential for this type of benefits from green infrastructure.

2. Energy-Related Benefits

Green infrastructure projects provide both direct and indirect energy-related benefits. They decrease energy consumption, which, in turn, decreases the amount of money households, commercial and public entities, and other building owners and operators spend on energy. Our calculation of energy-related benefits is based on the associated energy and cost savings for buildings with green roofs and buildings with nearby trees. These benefits generally accrue onsite as well as immediately adjacent areas.

Green roofs provide buildings with extra insulation. All else equal, this extra layer of insulation can increase the efficiency of a building’s temperature-regulation system. By increasing the efficiency of heating and cooling units, the owner/operator of a property can expect decreased energy costs. Trees provide shade and act as wind breaks to surrounding dwellings. All else equal, trees can reduce indoor temperatures in the summer and increase them in the winter. This impact on indoor temperature can lead to

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decreased demand for energy consumption related to indoor cooling and heating, which can result in decreased energy costs for nearby building owners/operators.

Here, we use several variables to calculate the economic benefit associated with this reduction in energy use. The list of variables includes:

- **Cooling and heating degree days** – these are metrics that estimate how high above or how low below outdoor temperatures are relative to preferred indoor temperatures, in a specific area, over the course of an average year.
- **Thermal resistance value** – this is a metric that estimates how resistant a material is to heat flow (a green roof, for example, is more resistant to heat flow than a conventional roof, so it has a higher thermal resistance value).
- **Average energy prices** – we use average annual electricity prices and natural gas prices for all energy users in the area.
- **Average annual energy savings** – these metrics estimate the annual amount of electricity and natural gas savings associated with small, medium, and large trees on private and public lands.

We calculate the actual savings by applying the methods outlined in the 2010 CNT Report to quantitative estimates of completed and potential future green infrastructure projects in each case study areas. In many instances, these estimates rely on assumptions regarding the effectiveness of green infrastructure and other conversion ratios in the ecosystem. Where possible, we substitute local data to the calculations to provide results more specific to individual case studies.

### 3. Air Quality-Related Benefits

Green infrastructure, particularly the vegetation provided by green roofs and trees, provides air quality-related benefits in two ways: (1) by decreasing the emission of harmful pollutants by decreasing energy demand, and (2) removing harmful pollutants already in the air. Improvements in air quality have economic value insofar as they reduce the costs associated with air pollution (e.g., health-related costs from respiratory illness and habitat destruction).

We calculate the actual savings by applying the methods outlined in a 2010 CNT Report to quantitative estimates of completed and potential future green infrastructure projects in the case study areas. In many instances, these estimates rely on assumptions regarding the effectiveness of green infrastructure and other conversion ratios in the ecosystem. Where possible, we substitute local data to the calculations to provide results more specific to individual case studies. These benefits generally accrue to the community and more broadly, with diffusion of benefit as distance increases.

**Decreased emissions of pollutants from reduced energy production**

Green infrastructure directly reduces the demand for energy providing additional building insulation and, in turn, decreases energy consumption. Lower rates of energy use have two economic benefits: increased consumer savings, as discussed in the previous section, and decreased costs associated with the treatment of air pollution and its associated externalities.
By reducing energy consumption, green infrastructure will result in a comparable decline in energy production and, consequently, air pollution emissions. As with other mechanisms for improving air quality, the economic benefit from this mechanism is primarily derived through decreased health-related costs and air quality compliance costs associated with NO₂ and SO₂. The list of variables includes:

- **Average emissions rates** – these metrics estimate the amount of emissions generated from electricity and natural gas use.
- **Average economic value air quality improvements** – these values are derived from the literature that estimates the marginal value of economic benefits derived from removal of the two pollutants.

**Improved air quality from vegetation on green roofs and trees**

Newly planted trees and vegetation on green roofs provide air quality benefits that are not derived under the status quo. Trees and vegetation remove pollutants and impurities from the air such as NO₂, O₃, SO₂, and PM-10 (the four pollutants we consider in our calculations). Removing these pollutants has a number of economic benefits including decreased health costs related to respiratory illness and lower costs from complying with air quality standards. Unfortunately, the relationship between different vegetation species and their capacity to filter these pollutants is very complex. For our analysis, we assume a range of filtration rates from the literature, which likely include the filtration rates of trees and vegetation on green roofs in the Midwest region. The list of variables includes:

- **Average filtration rates** – these metrics estimate the amount of each of the four pollutants that trees and typical vegetation on green roofs removes from the air.
- **Average economic value air quality improvements** – these values are derived from the literature that estimates the marginal value of economic benefits derived from removal of the four pollutants.

**4. Climate Change-Related Benefits**

Research shows that Wisconsin, Michigan, and other states in the Midwest are already experiencing noticeable changes in climate and suggests that more impacts will occur in the future. Research has identified several types of anthropogenic greenhouse gas emissions that contribute to climate change; chief among them is the emission of CO₂. Since 1850, the concentration of CO₂ in the atmosphere has increased from 280 to 379 parts per million, and has grown by an average of 1.9 parts per million per year since 1995. In general, green infrastructure provides climate change-related benefits by removing CO₂ from the atmosphere as well as by decreasing the volume of CO₂ emissions in the first place, which could mitigate some of the potential costs associated with climate change. More specifically, green infrastructure reduces atmospheric CO₂ in two ways:

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5 See, for example, the assessments of climate science and other reports prepared by the U.S. Climate Science Program: http://www.climatescience.gov, and the reports of the Intergovernmental Panel on Climate Change: http://www.ipcc.ch.

• Reduced energy demand and production decreases CO₂ emissions.
• Increased carbon sequestration by more tree coverage and green roof vegetation.

To quantify these economic benefits, we apply the calculation methods outlined in the 2010 CNT Report in conjunction with quantitative estimates of completed green infrastructure projects and potential green infrastructure projects in the case study regions. In many instances, these estimates rely on several general assumptions regarding the effectiveness of green infrastructure and other conversion ratios in the ecosystem. Where possible, we substitute local data to the calculations to provide results more specific to individual case studies. These benefits accrue at the global scale.

**Carbon sequestration by trees and vegetation on green roofs**

Trees and vegetation on green roofs provide climate change-related benefits by capturing carbon from the atmosphere. Decreasing atmospheric carbon is one way to mitigate some of the potential costs associated with climate change. Unfortunately, the relationship between different vegetation species and their capacity to capture carbon from the atmosphere is very complex. For our analysis, we assume a range of carbon absorption rates from the literature that likely include the absorption rates in the Midwest. The list of variables includes:

- **Range of carbon absorption rates** – these metrics estimate the amount of carbon absorbed by typical trees and vegetation on green roofs in the region.
- **Range of carbon values** – these values are derived from the literature that estimates the marginal value of economic benefits derived from removal of carbon from the atmosphere (our range is based on the value of carbon in the European Union’s carbon market and social cost of carbon from the Stern Review).

**Reduced carbon emissions from decreased energy production**

By reducing energy consumption, green infrastructure will result in a comparable decline in energy production and, consequently, air pollution emissions. As with other climate change-related benefits, the economic value associated with this mechanism is primarily derived through mitigation of the potential future costs of climate change. The list of variables includes:

- **Total energy savings** – these metrics estimate the total amount of energy savings associated with green infrastructure.
- **Average emissions rates** – these metrics estimate the amount of CO₂ emissions generated per unit of energy production.
- **Range of carbon values** – these values are derived from the literature that estimates the marginal value of economic benefits derived from removal of carbon from the atmosphere (our range is based on the value of carbon in the European Union’s carbon market and social cost of carbon from the Stern Review).

5. **Heat Island Effect**

According to the EPA, “heat island” is a term used to describe an urban area that is hotter than nearby rural, less developed areas. A city of one million people, for example, can have average annual temperatures 1.8–5.4 degrees warmer than surrounding areas
with evening temperatures as high as 22 degrees above temperatures in surrounding areas. Some of the negative impacts associated with the heat island effect include:

- Increased energy consumption for cooling due to increased local temperatures.
- Elevated emission of air pollutants and greenhouse gases from increased energy production and increased ground-level ozone formation.
- Compromised human health and comfort due to heat-related illnesses and injuries, especially among sensitive populations (e.g., children, older adults, and people with existing medical conditions).
- Impaired water quality from high-temperature stormwater entering waterways.

Green infrastructure reduces the impacts of the heat island effect by decreasing the amount of heat-attracting infrastructure (e.g., impermeable pavement), increasing the amount of shade, and increasing the amount of water vapor. The decreased energy consumption and emissions associated with green roofs, for example, are two parts of this benefit. What’s not included, however, is the benefit to the overall community from changes in average temperatures across the entire urban area.

Data and research are insufficient to estimate the benefits derived from existing green infrastructure or the future benefits from potential green infrastructure projects. This fact does not, however, mean that the value of the benefits is $0. The benefits could, in fact, be quite large. For example, a study describing the potential benefits of reducing Philadelphia’s stormwater runoff by 50 percent using green infrastructure found that over the first 40 years of a proposed plan, 196 premature fatalities would be avoided. Using the EPA’s value of a statistical life, this reduction in premature fatalities would have an NPV of about $1.1 billion. These benefits accrue at the community scale.

6. Community Livability

The 2010 CNT Report lists several ways in which green infrastructure can improve community livability. There are insufficient data to estimate the values of these benefits for the counties analyzed in the three case studies, but existing research suggests that these values are positive. Below, we briefly describe some of these benefits, all of which generally accrue to the immediate community:

- **Increasing home values by improving aesthetics.** Several studies have shown that trees and other vegetation increase property values in urban areas. While there are insufficient data to estimate this value for the three case studies, research suggests that trees planted on private property could increase property values by $5-$28 per tree. A study based on data in Philadelphia found that homes within 1,000 feet of street trees planted through the Fairmont Park Commission’s tree planting program

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sold for about 2.4 percent more than homes more than 1,000 feet from a street tree (controlling for other variables).11

- **Improving health and well-being by increasing the quantity and improving the quality of recreation opportunities nearby.** Research suggests that increasing the amount of green space and decreasing development near residential areas increases the quantity of and improves the quality of recreation opportunities. While there are insufficient data to estimate the value of this benefit, research from Philadelphia suggests that each additional acre of vegetation could translate to a benefit worth about $950 per year.12

- **Improving well-being by reducing noise pollution.** Several studies have found that green infrastructure such as porous pavement and vegetated surfaces decrease noise pollution, by absorbing more noise than gray infrastructure.13 While there are insufficient data to estimate the value of these noise-reduction benefits, the value likely is positive insofar as noise reduction decreases stress, improves well-being, and could potentially increase property values.

### 7. Habitat-Related Benefits

Research suggests that communities and individuals derive several different types of benefits from nearby habitat. Wetlands, for example, provide flood protection, improve water quality, regulate the flow of water, provide recreational and commercial fishing opportunities, provide bird watching opportunities, and increase amenity value on nearby property.14 Where natural wetland habitat is not available, such as in urban areas where urban development has decreased habitat provisions, green infrastructure may be used to provide similar benefits.15 Green roofs and rain gardens, for example, often provide habitat for native bird and insect species. The return of wildlife to an area can, in turn, offer some of the same recreational opportunities and property value benefits that wetland habitats offer. The following subsections provide a deeper analysis of the habitat benefits associated with wetlands and green infrastructure. These benefits accrue locally as well as more broadly.

**Wetlands**

Wetlands generate a number of different types of benefits. Table 1 provides several estimated values for the ecosystem services they provide. The first set of rows estimates

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the values associated with several different wetlands that researchers assumed provide only a single type of service. In many cases, however, a wetland may provide multiple services. The range of values associated with single-service wetlands is about $18–$9,200 per acre per year. Another estimate, based on the net primary productivity suggests that the value of services wetlands across the country provide may be about $2,400–$12,400 per acre per year. These estimates come from meta-analyses of many individual site-specific studies.\textsuperscript{16}

<table>
<thead>
<tr>
<th>Single Service Wetland Type</th>
<th>Mean Value</th>
<th>Range of Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>$645</td>
<td>$146–$2,865</td>
</tr>
<tr>
<td>Water quality</td>
<td>$684</td>
<td>$207–$2,260</td>
</tr>
<tr>
<td>Water quantity</td>
<td>$208</td>
<td>$10–$4,216</td>
</tr>
<tr>
<td>Recreational fishing</td>
<td>$585</td>
<td>$156–$2,201</td>
</tr>
<tr>
<td>Commercial fishing</td>
<td>$1,276</td>
<td>$177–$9,214</td>
</tr>
<tr>
<td>Bird watching</td>
<td>$1,988</td>
<td>$866–$4,562</td>
</tr>
<tr>
<td>Amenity</td>
<td>$5</td>
<td>$2–$23</td>
</tr>
<tr>
<td>Habitat</td>
<td>$502</td>
<td>$156–$1,609</td>
</tr>
<tr>
<td>Storm</td>
<td>$389</td>
<td>$18–$8,433</td>
</tr>
</tbody>
</table>


**Small-Scale Habitat**

Different types of habitat provide different sets of services from which individuals derive benefits. Most green infrastructure projects cover too little land to provide quantifiable habitat value. Some projects, however, cover more land and thus generate benefits related to reduced stormwater runoff, increased shaded area, and habitat provision for wildlife.

Research from the United Kingdom shows that, if green roofs are intended to provided habitat-related benefits, in addition to other benefits described elsewhere in this report, their design must consider habitat demands from local wildlife. When designers in the UK addressed wildlife demands in their green infrastructure projects, researchers observed the return of increasingly rare species in some areas. Brown roofs provided habitat benefits for several local bird species, thus prompting a renewed growth in their local population. In the case of green roofs in London, researchers noticed a similar regeneration of rare spider and insect populations.\textsuperscript{17} Rain gardens provide similar

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habitat-related benefits. Research shows that they attract birds, butterflies, and insects while improving the habitat quality of downstream waterways for aquatic organisms.

To date, there is little literature describing the economic value of habitat provided by green infrastructure projects. There is, however, a large set of literature describing the economic value of benefits derived from other habitat types. Wetland-related benefits have drawn much of the attention. The habitat-related benefits provided by green infrastructure likely are less valuable than those provided by wetlands, so the estimates in Table 1 serve as illustrative upper-bounds of currently known and identifiable benefits.

8. Public Education Benefits

We do not quantify the economic value of public education opportunities and benefits provided by green infrastructure in the three case studies, but it is important to recognize that they can play an important role. Not only do the green infrastructure sites provide locations for learning about natural processes, water quality, and ecology, but they also help demonstrate the effects that people can have on other members of their community, both positive and negative. Green infrastructure projects provide opportunities at home and at school to learn about biophysical cycles, processes, society’s impact, and the consequences of these impacts. These benefits accrue to the community.

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III. CASE STUDY – MILWAUKEE, WISCONSIN

Milwaukee, Wisconsin is in Milwaukee County, on the southwestern shore of Lake Michigan. According to the 2009 American Community Survey (5-year estimate), the City of Milwaukee has a population of about 603,000 and a median household income of $37,089 (in 2009 dollars), and the county has a population of about 948,000 with a median household income of $43,848 (in 2009 dollars). In this section, we describe the watershed conditions and the agencies, regulations, and components associated with stormwater management in the Milwaukee area. Then we describe the existing stock of green infrastructure from some of the area’s projects and initiatives and the potential green infrastructure in the future based on a projection of potential green infrastructure from three sewersheds (we extrapolate from these projections to estimate potential across the area). For both existing and potential green infrastructure we estimate the economic benefits across quantifiable categories.

A. Management Agencies and Responsible Parties

The City of Milwaukee’s Department of Public Works, Infrastructure Division is tasked with managing stormwater at the local level. They have taken the lead in ensuring that the city reduces the amount of total suspended solids entering its waterways by 40 percent by 2013, as required by the Wisconsin Department of Natural Resources. In 2004, Mayor Tom Barrett created the City of Milwaukee Office of Environmental Sustainability. Since its inception, the Office has promoted the adoption of cost effective green infrastructure projects to solve the city’s stormwater management challenges and to meet stormwater goals.

The Milwaukee Metropolitan Sewerage District (MMSD) is tasked with handling several regional issues including water quality research, household hazardous waste collection, pharmaceutical collection, industrial waste monitoring, laboratory services, planning and engineering services, and flood management services for 1.1 million customers in 28 communities across 411 square miles. The City of Milwaukee covers about 25 percent of MMSD’s service area and contains about 50 percent of its households. A map of MMSD’s service area is shown in Figure 3. MMSD has been a proponent of green infrastructure throughout the watershed and has produced several publications outlining past projects and the potential benefits of different techniques.

In the summer of 2011, Milwaukee’s City Council designated South 6th Street as the city’s first green corridor. The corridor runs along three miles of South 6th Street from Howard Avenue to College Avenue, several miles south of the City Center, near General Mitchel International Airport. This industrial area is heavily developed with about 80 percent of the land covered by impervious development. The City of Milwaukee is

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working with MMSD, Energy Exchange, American Rivers, Milwaukee Public Works, and The Gateway to Milwaukee to identify funding sources and implement green infrastructure projects in the green corridor.

**Figure 3. Map of MMSD’s Service Area**

B. District-wide Watershed Conditions

The area MMSD serves contains six major watersheds: Kinnickinnic River, Lake Michigan, Menomonee River, Milwaukee River, Oak Creek, and Root River. MMSD has received $1.35 million in funding (about $0.9 million of which came from the Great Lakes Restoration Initiative) to complete third party TMDL analyses in the area. The analyses will examine pathogens, phosphorous, and sediments in the Kinnickinnic, Menomonee, and Milwaukee Rivers, and the Milwaukee River Estuary. MMSD expects the work to be completed by fall 2013.23

In April of 2010, Wisconsin’s Department of Natural Resources submitted its Impaired Waters List to the EPA for approval.24 Each of the six main watersheds in MMSD’s service area has stretches of waterways identified in the list. Some of the pollutants found in these waterways include: phosphorus, fecal coliform, PCBs, E. coli, and unspecified metals. Most of the impaired sections of these waterways are listed as low or medium priorities.

C. Regulations

The City of Milwaukee regulates stormwater practices primarily through stormwater management plans (SMPs). Table 2 describes the City of Milwaukee’s SMP requirements. Aside from these development and redevelopment scenarios, current property owners are not responsible to take any actions minimizing their impact on the stormwater system.

<table>
<thead>
<tr>
<th>Require a Stormwater Management Plan</th>
<th>Plan Must Address Water Quality</th>
<th>Plan Must Address Water Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Activities cause a land disturbing activity of one acre or more</td>
<td>• Removal of total suspended solids in stormwater from the development</td>
<td>• Activities that increase impervious area by 0.5 acres or more must limit discharge to 0.15 cfs/acre for 2-year storm event and 0.5 cfs/acre for 100-year storm event</td>
</tr>
<tr>
<td>• Activities cause the cumulative area of land disturbing activities to be one acre or more over three years</td>
<td>• General housekeeping and pollution prevention measures</td>
<td>• Activities that increase impervious area by less than 0.5 acres must limit post-development peak runoff rates to at least 10% less than pre-development peak for 2-year and 100-year storm events.</td>
</tr>
<tr>
<td>• Activities cause an increase of half an acre or more of impervious area</td>
<td>• Industry-specific pollution prevention measures</td>
<td></td>
</tr>
</tbody>
</table>


At the regional level, MMMSD regulates stormwater practices primarily through language in Chapter 13 of their Rules. Specifically, Chapter 13.11 describes MMMSD’s runoff management requirements. Some of these requirements include:

---


24 The full list of impaired waters is available at http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html.
• Governments must manage volume, timing, and peak flow rate of runoff from development and redevelopment.
• Governments must reduce runoff release rates where development and redevelopment disturb areas larger than two acres.
• Governments can manage stormwater with watershed or sub-watershed stormwater management plans, or with site-specific plans.
• Governments should preserve natural features and minimize impervious area when selecting management techniques.25

D. Current Components of Stormwater Management

About 95 percent of MMSD’s service area uses separate sewers for stormwater and wastewater. The other 5 percent uses combined sewers.26 In total, MMSD’s service area contains about 300 miles of MMSD sewer pipes, 3,000 miles of municipal pipes, and 3,000 miles of private laterals. MMSD also operates a 28.5-mile long deep tunnel system, buried 300 feet below ground, as part of its combined sewer system. The deep tunnel system is 17–32 feet in diameter and has a capacity of 521 million gallons.27 Construction on the deep tunnel system has recently completed and MMSD is currently using the extra storage capacity. Initial motivation for the project stemmed from historically frequent CSO events (50-80 events a year in the 1980s and early 1990s). Since completion of the project, the annual number of CSOs has dropped to about 3.1. According to MMSD, “too much unwanted stormwater gets into the system . . . resulting in sanitary and CSOs.”28 Their goal is to completely eliminate sewer overflows by integrating both green and gray infrastructure components.

E. Green Infrastructure Programs and Projects in the Milwaukee Area

In addition to the gray infrastructure described above, MMSD and other agencies, groups, and individuals have invested in implementing green infrastructure techniques to manage stormwater. Here we describe several of the green infrastructure programs, incentives, and projects in the Milwaukee area along with quantitative estimates describing the extent of their implementation.

1. MMSD’s BMP Program

Since 2002, MMSD has funded (sometimes partially, sometimes fully) over 150 green infrastructure projects in its service area through the BMP Program. In 2009, MMSD decentralized the program. Now, funding is administered at the community level. Each year, interested individuals, groups, or communities, submit proposals describing the green infrastructure projects for which they want funding. MMSD collects and scores the

proposals and awards funding to the projects promising the most benefits in terms of stormwater management and water quality. To date, MMSD has provided about $20.5 million in funding through the program. MMSD has a running inventory of all the green infrastructure projects it funds through this program.29

2. Utility Incentives for Commercial Property Owners

The City of Milwaukee’s stormwater utility provides price breaks for commercial and other non-residential property owners that implement green infrastructure techniques. The utility does not provide incentives to residential households promoting green infrastructure. The program is administered by the City of Milwaukee’s Department of Public Works.30

3. Rain Barrel Program

MMSD initiated its Rain Barrel Program in 2004. Since then, it has sold over 17,000 rain barrels in the Milwaukee area.31 Each 55-gallon barrel is made using recycled materials and comes with a 3-inch adapter to connect the downspout to the rain barrel. The program works closely with the Milwaukee Community Service Corps, which provides job and skills training to at-risk youth that build the barrels.32

4. Rain Garden Program

MMSD initiated its Rain Garden Program in 2006. The program allows all groups, government entities, businesses, and homeowners to apply for grants providing plants at a reduced price (typically about 50 percent of their retail price) for rain gardens. Since it started, the program has sold over 15,000 plants.33

5. Greenseams Property Acquisitions Program

MMSD is influencing future stormwater management through its Greenseams Program. The program provides funding to purchase privately owned, undeveloped land near streams, shorelines, and wetlands across the district where future development is likely. The program serves to prevent development in areas currently useful for stormwater management, ensuring the areas will continue providing stormwater management services in the future. To date, the program has purchased 75 properties on over 2,200 acres of undeveloped land.34

6. Green Streets

The Village of Greendale in MMSD’s service area recently completed a bio-retention swale along the median of Grange Avenue. The impervious pavement on the street is designed to push water toward the median. The water flows along the curb and is forced into the median through a series of 41 openings in the curb line. The median itself is covered with native wildflowers. The stormwater drains through layers of soils, crushed stone, and sand engineered specifically to remove pollutants harmful to the watershed before it collects and drains at the end of the swale into Dale Creek. Modeling suggests the project removes 700 pounds of stormwater pollutants each year.\(^{35}\) The swale runs along about a quarter mile of roadway and covers about 3 acres.\(^{36}\)

7. Summary of Existing Green Infrastructure and Potential Future Green Infrastructure in the Milwaukee Area

Most of the programs, projects, and incentives described in this section were, at least partially, funded through MMSD. As part of their own efforts to organize green infrastructure-related data, MMSD has compiled an inventory of the types and quantities of green infrastructure projects they’ve been involved with over the years. Table 3 summarizes these projects.

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Quantity</th>
<th>Units</th>
<th>Recharge Obtained (gallons/year)</th>
<th>TSS Removed (lbs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetlands</td>
<td>0.03–0.04</td>
<td>acres</td>
<td>22,500–30,000</td>
<td>32–43</td>
</tr>
<tr>
<td>Porous pavement</td>
<td>4–4.8</td>
<td>acres</td>
<td>2.8–3.4 million</td>
<td>3,794–4,553</td>
</tr>
<tr>
<td>Rain barrels</td>
<td>17,000–20,400</td>
<td>55-gallon barrels</td>
<td>20.1–24.1 million</td>
<td>14,478–17,374</td>
</tr>
<tr>
<td>Cisterns</td>
<td>13–16</td>
<td>6,350-gallon cisterns</td>
<td>1.8–2.2 million</td>
<td>1,278–1,573</td>
</tr>
<tr>
<td>Green alley/street</td>
<td>1.4–1.7</td>
<td>acres</td>
<td>1.0–1.2 million</td>
<td>1,327–1,612</td>
</tr>
<tr>
<td>Bioswale</td>
<td>202,605–243,125</td>
<td>square feet</td>
<td>2.6–3.1 million</td>
<td>2,823–3,388</td>
</tr>
<tr>
<td>Rain gardens</td>
<td>25,163–30,195</td>
<td>square feet</td>
<td>0.4–0.5 million</td>
<td>477–570</td>
</tr>
<tr>
<td>Green roof</td>
<td>309,695–371,635</td>
<td>square feet</td>
<td>4.0–4.8 million</td>
<td>4,316–5,179</td>
</tr>
<tr>
<td>Totals</td>
<td>N/A</td>
<td>N/A</td>
<td>32.7–39.3 million</td>
<td>28,500–34,300</td>
</tr>
</tbody>
</table>


Notes: Given the limited scope of projects and programs in our discussion, the lower bound quantities likely underrepresent the total amount of green infrastructure in the area. Assuming the data under-represent existing projects, we have generated a range of values; the upper limit is calculated by multiplying the lower value by 1.2.

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The first column in Table 3 lists several different types of green infrastructure projects. The second and third columns describe the amount of each type of project (e.g., number of acres, number of barrels, number of square feet). The fourth column shows the estimated volume of recharge obtained from these projects (gallons per year) and the amount of total suspended solids removed (pounds per year) as calculated using MMSD’s H2OCapture tool.

**Potential green infrastructure in the Milwaukee Area**

In addition to these existing projects, MMSD anticipates participating in the implementation of additional green infrastructure projects in the future. MMSD recently conducted a modeling exercise using the SUSTAIN model to project the potential impacts of different green infrastructure implementation scenarios. They modeled these scenarios on three sewersheds covering about 600 acres in the services area (about 0.2 percent of all the land in the service area). Table 4 shows the breakdown of the original scenario, as well as extrapolations from that scenario to the rest of the service area. The first column lists the different types of projects considered in the simulation. The second column shows the quantity of each type of project under the simulation. The third and fourth columns extrapolate the simulation parameters across the combined sewer area and the entire sewer area MMSD manages.

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Simulation (600 acres)</th>
<th>Combined Sewer (13,000 acres)</th>
<th>Total Sewer Area (263,000 acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous pavement (acres)</td>
<td>1.1</td>
<td>24.0</td>
<td>480</td>
</tr>
<tr>
<td>Green alley (acres)</td>
<td>3.8</td>
<td>83.0</td>
<td>1,660</td>
</tr>
<tr>
<td>Block bioretention (acres)</td>
<td>4.5</td>
<td>98.0</td>
<td>1,970</td>
</tr>
<tr>
<td>Rain garden (gardens)</td>
<td>850</td>
<td>18,580</td>
<td>371,590</td>
</tr>
<tr>
<td>Regional bioretention (acres)</td>
<td>2.8</td>
<td>61.0</td>
<td>1,220</td>
</tr>
<tr>
<td>Rain barrels (barrels)</td>
<td>1,300</td>
<td>28,400</td>
<td>568,300</td>
</tr>
<tr>
<td>Roadside porous pavement (acres)</td>
<td>8.5</td>
<td>186</td>
<td>3,716</td>
</tr>
<tr>
<td>Green street - roadside porous pavement (acres)</td>
<td>2.6</td>
<td>57</td>
<td>1,137</td>
</tr>
<tr>
<td>Green street – rain garden (acres)</td>
<td>0.6</td>
<td>13</td>
<td>262</td>
</tr>
</tbody>
</table>


As we did with MMSD’s existing green infrastructure projects, we ran the quantities of potential projects through MMSD’s H2OCapture tool. Table 5 summarizes the results. The first column shows five different scenarios. The first row reflects the characteristics of the 3-sewershed simulation MMSD ran using SUSTAIN modeling. The second row assumes a linear relationship between the simulation area and the area across the combined sewer portion of MMSD’s service area. The third, fourth, and fifth rows...
assume that same green infrastructure mix across varying portions of MMSD’s entire service area (25, 50, and 75 percent). For each of these scenarios, the table summarizes the volume of water recharged and the total suspended solids removed, per year.

<table>
<thead>
<tr>
<th>Projected Green Infrastructure Scenario</th>
<th>Recharge Obtained (gallons/year)</th>
<th>TSS Removed (lbs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation (600 acres)</td>
<td>21.5 million</td>
<td>2.5 million</td>
</tr>
<tr>
<td>Combined sewer area (13,000 acres)</td>
<td>469.0 million</td>
<td>54.4 million</td>
</tr>
<tr>
<td>Total sewer area 25% (65,750 acres)</td>
<td>2.3 billion</td>
<td>272.2 million</td>
</tr>
<tr>
<td>Total sewer area 50% (131,500 acres)</td>
<td>4.7 billion</td>
<td>544.3 million</td>
</tr>
<tr>
<td>Total sewer area 75% (197,250 acres)</td>
<td>7.0 billion</td>
<td>816.5 million</td>
</tr>
</tbody>
</table>


### Green roofs and trees

There are currently about 0.3–0.4 million square feet of green roofs operating in MMSD’s service area. MMSD has not emphasized tree planting in its green infrastructure efforts. Green infrastructure projections described above did not consider using green roofs and trees as a means of managing stormwater. Here, we assume that the projected reduction in stormwater runoff (described in the previous section) remains the same, but that the types of projects implemented to achieve that reduction is different (incorporating green roofs and trees). Table 6 summarizes our estimates of existing and potential trees and green roofs in MMSD’s service area.

<table>
<thead>
<tr>
<th>Green Infrastructure Scenario</th>
<th>Existing</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trees</td>
<td>0</td>
<td>0.2–0.3 million</td>
</tr>
<tr>
<td>Green roofs (square feet)</td>
<td>0.3–0.4 million</td>
<td>1.9–2.2 million</td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous tables and discussion.

Note: We assume that none of the City’s existing trees were planted for the stormwater management purposes and that all future trees are planted with management in mind.

Current estimates suggest there are about 3.4 million trees in the City of Milwaukee, which provide cover on about 22 percent of the area.\(^{37}\) Here, we assume that none of these existing trees provide stormwater benefits. Greening Milwaukee, a non-profit organization in the area that promotes tree planting, hopes to increase the city’s canopy

coverage to 40 percent.\textsuperscript{38} Assuming linear relationships between the number of trees and canopy cover, increasing canopy cover to 40 percent would mean planting about 2.5–2.8 million trees in the city. Here, we assume 8–10 percent of those trees are planted with stormwater management in mind for a total of about 0.2–0.3 million trees.

To date, MMSD estimates that about 0.3–0.4 million square feet of green roofs have been installed in its service area over the past 10 years. Here, we assume the same rate of green roof installation will continue into the future. At that rate, there could be a total of about 1.9–2.2 million square feet of green roofs in MMSD’s service area in 50 years.

\begin{table}
\begin{center}
\begin{tabular}{|l|}
\hline
\textbf{Milwaukee’s Green Corridor} \\
\hline
During the summer of 2011, Milwaukee’s City Council designated South 6\textsuperscript{th} Street as the city’s first green corridor. The green corridor runs along three miles of South 6\textsuperscript{th} Street from Howard Avenue to College Avenue, several miles south of the city center near General Mitchel International Airport. This industrial area is heavily developed with about 80 percent of the land covered by impervious development. The City of Milwaukee is working with MMSD, Energy Exchange, American Rivers, Milwaukee Public Works, and The Gateway to Milwaukee to identify funding sources and implement green infrastructure projects in the green corridor. To date, the Greater Milwaukee Foundation Fund for Lake Michigan and the Joyce Foundation have provided funding for the implementation of several projects. Some of these completed projects were included in our discussion of existing green infrastructure in the Milwaukee area.

\textbf{Historical Conditions} \\
The green corridor is about three miles long and, assuming an average width of 0.4 miles, covers about 768 acres in a mostly industrial part of the city. Most of the land in the corridor (about 80 percent) is covered by impervious materials that send water to the city’s separate sewer system where it is treated before being released to nearby waterways, including Lake Michigan and the Kinnickinnic River. With so much impervious area, the corridor has few green features, such as trees and other vegetation, that often provide several types of benefits.

\textbf{Projects Completed and Projects Underway} \\
The city and its partners have started planning and implementing green infrastructure projects in the green corridor. These projects include:

\begin{itemize}
\item A green street, designed by three engineering students at Marquette University, may run along five blocks of the corridor. The project will replace existing pavement with permeable pavement capable of retaining about 116,000 gallons of stormwater per inch of rainfall. This reduction in stormwater runoff will have many types of benefits, some of which we quantify and monetize. The most notable unquantifiable benefit is flood prevention. Stormwater from this street typically drains to Wilson Park Creek and then into the Kinnickinnic River. Wilson Creek is prone to flash floods during heavy rain events, so reductions in stormwater runoff into the creek likely will decrease the intensity of flooding in the area.

\item 4707 S. 13th St. – A 4,875 square foot green roof system capable of absorbing over 5,000 gallons of water per 1-inch rain event has been installed.
\end{itemize}
\end{tabular}
\end{center}
\end{table}

• 815 W. Layton- Bioswale catchments with native plantings and engineered soil act as a dry detention of the parking lot. The bioswales were excavated to a depth of 6 feet, and a stone storage underlay was topped with the engineered soil. The bioswales are just under an acre in size. This 12-acre site contributes over 313,632 gallons of rainwater to the sewers per 1-inch rain event that is contained onsite.

• General Mills at 4625 S. 6th – The company’s parking lot was retro-fitted with porous pavers. The sub-base contains a mix of gravel and sand to a depth of two feet. This system is designed to infiltrate stormwater runoff instead of shedding it off the surface, while providing maximum hardness, porosity and abrasion resistance. Runoff is stored in the stone storage layer, and allowed to infiltrate into the surrounding soil. This one-acre parking lot infiltrates over 31,000 gallons of rainwater per 1-inch rain event.

• American Rivers, MMSD, and the Energy Exchange have partnered with multiple stakeholders to create a center for education and implementation of BMPs. The center is located at 4121 S. 6th Street in the Kinnickinnic Watershed. The completed facility maintains over 7,500 square feet of permeable pavement, 4,000 square feet of green roofs, 1,100 square feet of bioswales/rain gardens, two 1,000-gallon rain harvesters, and rain barrels.

The stakeholders have been successful at eliminating stormwater runoff on site barring any 100-year storm events, by the use of green infrastructure. The partners have also successfully petitioned the City of Milwaukee to reduce the properties Stormwater Management Charge from 24 ERUs (Estimated Residential Units) to 5 ERUs saving the property owner $1,300 in charges over the course of a year. By using this credit, an average business parcel of 10 acres could save up to $15,000 in stormwater charges a year by retrofitting their impervious surfaces.

The table below summarizes the ways in which these projects provide benefits.

<table>
<thead>
<tr>
<th>Summary of Existing and Potential Projects in Milwaukee’s Green Corridor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Green Street</strong></td>
</tr>
<tr>
<td>Permeable Pavement</td>
</tr>
<tr>
<td><strong>4707 S. 13th St.</strong></td>
</tr>
<tr>
<td>Green Roofs</td>
</tr>
<tr>
<td><strong>815 W. Layton</strong></td>
</tr>
<tr>
<td>Bioswales</td>
</tr>
<tr>
<td>General Mills</td>
</tr>
<tr>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Education Center</td>
</tr>
<tr>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Green Roofs</td>
</tr>
<tr>
<td>Bioswales</td>
</tr>
<tr>
<td>Water Harvesting</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
</tr>
</tbody>
</table>

F. Economic Benefits of Green Infrastructure in the Milwaukee Area

In this section, we estimate the economic benefits derived from existing and potential green infrastructure in the Milwaukee area. We assume benefits derived from Milwaukee’s green corridor are realized within our benefit estimates. This section is divided into eight parts, each of which estimates the values associated with different benefit categories. The benefit categories we discuss in this section are:

- Water-related benefits
- Energy-related benefits
- Air quality-related benefits
- Climate change-related benefits
- Urban heat island-related benefits
- Community livability-related benefits
- Habitat-related benefits
- Public education-related benefits

1. Water-Related Benefits

In this section, we describe and quantify the economic values associated with four categories of water-related benefits:

- Reduced gray infrastructure costs
- Reduced water treatment costs
- Improved water quality
- Reduced flooding

To help guide our analysis, we used estimated changes in stormwater flow and total suspended solids associated with existing and potential future green infrastructure projects. Table 7 summarizes the data we use to quantify the economic value of water-related benefits. The first row shows the impacts of MMSD’s existing green infrastructure projects. The second and third rows show the potential impacts of future MMSD green infrastructure projects in the combined sewer area and the total sewer area.

<table>
<thead>
<tr>
<th>Green Infrastructure Scenario</th>
<th>Recharge Obtained (gallons/year)</th>
<th>TSS Removed (lbs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing green infrastructure</td>
<td>32.7–39.3 million</td>
<td>28,500–34,300</td>
</tr>
<tr>
<td>Combined sewer area (13,000 acres)</td>
<td>469.0 million</td>
<td>54.4 million</td>
</tr>
<tr>
<td>Total sewer area 25–75% (65,750 - 197,250 acres)</td>
<td>2.3–7.0 billion</td>
<td>272.2-816.5 million</td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous tables.

Reduced gray infrastructure costs

As described earlier in this report, MMSD has completed construction of a deep tunnel system that manages the flow of stormwater and wastewater across the service area. The deep tunnel system provides about 521 million gallons of capacity. The system is used to
manage stormwater and wastewater in MMSD’s combined and separate sewer systems. To the extent that green infrastructure decreases the need for future expansion of the deep tunnel system, it may provide avoided costs to MMSD and residents in its service area. Some of the marginal capital investments associated with the system could include:

- $15 per cubic foot – Increase volume
- $5 million per 45 cfs pump – Increase pumping capacity
- $1 million per cfs – Increase treatment capacity
- $12 million to upgrade siphoning capacity

MMSD has estimated that the average capital cost for additional gray infrastructure capacity is about $2.42 per gallon. In other words, it would cost about $2,420 to increase the deep tunnel system’s maximum daily capacity by 1,000 gallons. Table 8 shows the avoided costs associated with existing green infrastructure, and potential future green infrastructure in the combined sewer and total sewer areas. To calculate this value, we first distributed annual changes in stormwater flow to daily rates. At the low end of the range, we assume that annual flow is distributed evenly throughout the year; in other words, we assume it rains the same amount every day. At the high end of the range, we assume that annual flow is distributed evenly over a fourth of the year; in other words, we assume it rains the same amount every fourth day.

Table 8. Estimated Value of Avoided Infrastructure Costs Associated with MMSD’s Existing and Potential Green Infrastructure

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Potential – Combined Sewer Area</th>
<th>Potential – Total Sewer Area 25–75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge obtained (gallons/day)</td>
<td>89,600-430,700</td>
<td>1.3–5.1 million</td>
<td>6.3–76.7 million</td>
</tr>
<tr>
<td>$/year</td>
<td></td>
<td>50-year NPV</td>
<td>50-year NPV</td>
</tr>
<tr>
<td>Avoided gray infrastructure cost</td>
<td>$0.2–$1.0 million</td>
<td>$1.6–$6.1 million</td>
<td>$8.0–$97.9 million</td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous tables and MMSD. 2009. *Fresh Coast Fresh Solutions: Weaving Milwaukee’s Green & Gray Infrastructure into a Sustainable Future.*

The top section shows the estimated recharge obtained, per day, by existing and potential future green infrastructure. In the bottom section, we estimate the value of the avoided gray infrastructure costs associated with each scenario. Existing green infrastructure is associated with an avoided gray infrastructure cost of about $0.2–$1.0 million. Assuming our projections for potential green infrastructure in the combined sewer area are realized over the next 50 years, the NPV of the avoided gray infrastructure costs is about $1.6–$6.1 million. Similarly, if the potential green infrastructure in the total sewer area is realized over the next 50 years, the NPV of the avoided gray infrastructure costs is about $8.0–$97.9 million. These NPV estimates do not include the avoided costs associated with existing green infrastructure.


40 MMSD. 2009. *Fresh Coast Fresh Solutions: Weaving Milwaukee’s Green & Gray Infrastructure into a Sustainable Future.*
Reduced water treatment costs

In addition to the infrastructure costs discussed above, some stormwater management activities require operations and maintenance expenses for water treatment. As previously noted, about five percent of MMSD’s service area is connected to a combined sewer system. Stormwater collected from this area is mixed with wastewater and conveyed to facilities where the water is treated. Data from MMSD suggests that operations costs for treating this water is about $1.04 per 1,000 gallons.41 Since only the stormwater in the combined sewer system is treated, we consider only the impact of existing and potential future green infrastructure on stormwater in the combined sewer area.

Table 9 summarizes our results. Assuming all reductions in stormwater runoff from existing green infrastructure are in the combined sewer portion of the service area, the value of avoided treatment costs is about $34,000–$40,900 per year. Assuming MMSD achieves their potential green infrastructure capacity within the next 50 years, the NPV of avoided water treatment costs from reduced stormwater runoff in the combined sewer area would be about $5.6 billion.

Table 9. Estimated Value of Water Treatment Costs Associated with MMSD’s Existing and Potential Green Infrastructure

<table>
<thead>
<tr>
<th></th>
<th>Existing – Combined Sewer Area</th>
<th>Potential - Combined Sewer Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge obtained (gallons)</td>
<td>32.7–39.3 million</td>
<td>469.0 million</td>
</tr>
<tr>
<td>Avoided treatment cost</td>
<td>$34,000–$40,900</td>
<td>$5.6 billion</td>
</tr>
</tbody>
</table>


Improved water quality

Green infrastructure has been shown to improve water quality through several different mechanisms. Researchers have linked green infrastructure projects with quantifiable reductions in the concentrations of pollutants such as ammonia, nitrate, total nitrogen, suspended solids, copper, iron, lead, manganese, and zinc.42 The interactions between green infrastructure and changes in water quality, however, are complex. Without primary data collection from the area we cannot estimate the benefits of existing and potential future green infrastructure derived from changes in pollutant concentrations. That is not to say, however, that there are no water quality benefits from green infrastructure.


Improvements in water quality are associated with several different sources of economic value based upon the types of demand for clean water. Figure 4 shows some of those relationships. A river that is safe to swim in, for example, derives use value from households as well as passive use value based on feelings of altruism for future generations. A river that provides fish safe to eat, on the other hand, derives use value from households as well as markets along with the passive use values attributable to altruism for future generations.

One way to estimate the value of improved water quality is to estimate the public’s willingness to pay for it. Typically, waterways are split into four categories depending on their water quality: non-boatable, boatable, fishable, and swimmable. A 1993 study found that households would be willing to pay about $160 per year to maintain boatable water quality. These households would be willing to pay an additional $120 per year to improve the water quality to fishable conditions, and another $135 per year to improve the fishable waters to swimmable status. Other studies have found comparable values for improvements in water quality. Individuals traveling to the area for recreation would also benefit from improvements in water quality. Research from the East coast found that a new policy that promised to improve water quality and increase fish catch increased consumer surplus (value beyond prices paid) associated with water-based recreation by about $30 from $73 to $103 per trip.

### Figure 4. Water Quality Categories and Economic Value Types

<table>
<thead>
<tr>
<th>Water Quality Services</th>
<th>Economic Value for Water Quality Improvements</th>
<th>Passive-Use Services</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use Services</td>
<td>Public Sector Production</td>
</tr>
<tr>
<td></td>
<td>Market Production</td>
<td>Household Production</td>
</tr>
<tr>
<td>Primary contact recreation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Secondary contact recreation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Agricultural water supply</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Industrial water supply</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Public water supply</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fish consumption</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aquatic life</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>


---


One study found that households are willing to pay about $28 per year for a 1 percent improvement in water quality in nearby waterways. Assuming all households in the Milwaukee area are willing to pay for improvements in water quality, green infrastructure’s impact on water quality could be worth about $12.3 million per year per percent improvement.

Unlike other pollutants, MMSD provides an estimate of the potential reduction in suspended solids associated with green infrastructure. By reducing the amount of suspended solids, or sediment, flowing to receiving water bodies, green infrastructure generates benefits for downstream users, including fisheries, agriculturalists, municipal and industrial users, steam power plants, and shippers. A study conducted by the U.S. Department of Agriculture identified 13 types of benefits associated with decreasing sediment. For each benefit, the researchers modeled the potential value associated with reducing sediment, per ton, for each 8-digit watershed across the country. For our analysis, we apply the average value for the 8-digit HUC codes for watersheds in the Milwaukee area, $12.31 per ton, to estimate the benefits derived from the prevention of sediment deposition. Table 10 summarizes the results.

We estimate the value of water quality-related benefits associated with MMSD’s existing green infrastructure is about $175–$211 per year. We estimate the NPV of water quality-related benefits associated with MMSD’s potential future green infrastructure in the combined sewer area is about $564 million. If future green infrastructure is spread across a broader area (25–75 percent of the service area), we estimate water quality-related benefits could have an NPV of $2.8–$8.5 billion.

| Table 10. Estimated Value of Improved Water Quality Associated with MMSD’s Existing and Potential Green Infrastructure |
|-------------------------------------------------|-----------------|-----------------|-----------------|
| TSS (lbs./year)                                | Existing        | Potential – Combined Sewer Area | Potential – Total Sewer Area 25–75% |
|                                                | 28,500–34,300   | 54.4 million     | 272.2–816.5 million |
| Value of water quality benefits                | $175–$211      | $564 million     | $2.8–$8.5 billion |


---


47 MMSD’s service area has about 1.1 million people. Assuming an average household size of 2.5, this equates to a total of 440,000 households. If each household is willing to pay $28 for each percent improvement in water quality, they would, as a whole, be willing to pay $12.3 million per year.

48 These benefits include: water-based recreation, irrigation ditches and channels, road drainage ditches, municipal water treatment, flood damage, marine fisheries, marine recreational fishing, municipal and industrial water use, steam power plants, soil productivity, dust cleaning, reservoir services, and navigation.

**Reduced flooding**

In 2010, two episodes of severe flooding caused by heavy rainfall occurred in Milwaukee. In July of 2010, the first of these flood events shut down the local airport and many downtown streets.\(^{50}\) Heavy rainfall again shut down the city in September, causing Wisconsin Governor, Jim Doyle to declare a state of emergency in Milwaukee County after severe storms and flash floods hit most of the county.\(^{51}\) The September flood caused one death (the body of a 19-year old man was found in Lincoln Creek, several blocks away from the car he was driving during the storm) and flood damage to nearly 10,000 homes costing an estimated $37.5 million.\(^{52}\)

In response to increased public demand for flood prevention, the Milwaukee’s Mayor formed the Milwaukee Flood Task Force in 2010. The task force focused on potential infrastructure improvements, specifically major improvements to the sewer systems.\(^{53}\) In July of 2011, the Task Force published 18 recommendations for the City of Milwaukee to adopt in hopes of reducing the impacts of future flood events. While many of the Task Force’s recommendations emphasized the importance of improving the capacity of the city’s gray infrastructure to handle flood events, some of the recommendations focused on green infrastructure:

- Develop stormwater standards for new development and redevelopment.
- Prioritize green infrastructure in development and road improvement projects in flood-prone areas.
- Continue monitoring effectiveness of green infrastructure projects to understand their effectiveness.
- Implement a mandatory downspout disconnection program in targeted areas within the combined sewer area.\(^{54}\)

To the extent that it reduces the volume of stormwater runoff and the speed with which stormwater enters nearby waterways, green infrastructure can decrease the severity of flooding events incurred by these residents.\(^{55}\) Data are unavailable to estimate the potential impact of existing and potential green infrastructure on future flooding events in the county.

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2. Energy-Related Benefits

In this section, we estimate the value of energy-related benefits associated with existing and potential green infrastructure in the Milwaukee area. Green infrastructure projects provide energy-related benefits insofar as they decrease energy consumption, which in turn decreases the amount of money households, commercial and public entities, and other building owners and operators spend on energy. These benefits include:

- Reduced energy use in buildings with green roofs.
- Reduced energy use in buildings with nearby trees.

Table 11 summarizes the results of our analysis of energy-related benefits from green roofs. MMSD has participated in the construction of about 0.3–0.4 million square feet of green roofs. We assume the area covered by green roofs will increase to 1.9–2.2 million square feet over the next 50 years. Furthermore, we assume that while MMSD has not planted trees for stormwater management yet, they will plant 0.2–0.3 million trees over the next 50 years. The annual value of reduced energy costs stemming from these existing green roofs is about $17,000–$20,500 per year. Assuming the potential area of green roofs and number of trees are incorporated over the next 50 years, they could provide energy-related benefits with an NPV of about $37.6–$47.0 million.

### Table 11. Reduced Energy Use from Green Roofs and Trees

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green roofs (square feet)</td>
<td>0.3–0.4 million</td>
<td>1.9–2.2 million</td>
</tr>
<tr>
<td>Number of trees</td>
<td>0</td>
<td>0.2–0.3 million</td>
</tr>
<tr>
<td>Total energy savings (per year)</td>
<td>61,000–73,000 kWh</td>
<td>15.2–19.0 million kWh</td>
</tr>
<tr>
<td></td>
<td>2.4–2.9 billion Btu</td>
<td>478–597 billion Btu</td>
</tr>
<tr>
<td><strong>Total value of energy savings from green roofs and trees</strong></td>
<td>$17,100–$20,500</td>
<td>$37.6–$47.0 million</td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous tables and Center for Neighborhood Technology. 2010. The Value of Green Infrastructure.

Notes: For details on our assumptions and calculations, see Appendix A.
3. Air Quality-Related Benefits

In this section, we analyze two types of air quality-related benefits associated with green infrastructure. In general, green infrastructure provides air quality-related benefits by removing harmful pollutants from the air as well as decreasing the emissions of those pollutants in the first place. Improvements in air quality have economic value insofar as they reduce the costs associated with air pollution (e.g., health-related costs from respiratory illness and habitat destruction). In this section, we discuss:

- Improved air quality from vegetation on green roofs and from trees.
- Reduced emissions of pollutants from energy production.

Table 12 summarizes the results of our analysis of the value of air quality-related benefits from vegetation on green roofs and from trees. As of 2011, MMSD has participated in the construction of about 0.3–0.4 million square feet of green roofs. This existing stock of green roofs removes an estimated 0.2–0.4 tons of pollutants (NO$_2$, O$_3$, SO$_2$, and PM-10) from the air, per year. The value of this pollutant reduction is about $1,200–$2,200 per year. Over the next 50 years, we assume green roof installation will increase, covering an area of 1.9–2.2 million square feet, and that about 0.2–0.3 million trees will be planted.$^{56}$ This potential stock of green roofs and trees would remove an estimated 168–211 tons of the four pollutants per year, when fully implemented. The NPV of the improved air benefits from these potential projects is $9.8–$12.3 million.

<table>
<thead>
<tr>
<th>Table 12. Air Quality-Related Benefits from Vegetation on Green Roofs and Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing</strong></td>
</tr>
<tr>
<td>Green roofs (square feet)</td>
</tr>
<tr>
<td>Number of trees</td>
</tr>
<tr>
<td>Annual pollutant reduction (tons of all four pollutants per year)</td>
</tr>
<tr>
<td>Value of air-quality benefits from vegetation on green roofs and trees</td>
</tr>
</tbody>
</table>


Notes: A description of our methods for calculating these estimates is in Appendix A.

Table 13 summarizes the results of our analysis of the value of air quality-related benefits from reduced emissions. Using the avoided energy calculated in previous sections, and the avoided energy from the reduction in stormwater treatment, we can estimate the weight of avoided emissions of NO$_2$ and SO$_2$. Existing green infrastructure in MMSD’s service area decreases the total weight of airborne pollutants associated with energy production by about 1.5–1.8 tons per year, worth about $8,500–$10,200 in air.

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$^{56}$ As described earlier in this report, we base these potential quantities of green roofs and trees on existing conditions, programmatic goals for tree planting, and the recent rate of green roof expansion.
quality benefits. Potential future green infrastructure could reduce energy consumption by much more, removing about 296–380 tons of pollutants from the atmosphere when fully implemented. The NPV of the air quality benefits from reduced emission, over the next 50 years, is about $17.8–$22.7 million.

<table>
<thead>
<tr>
<th>Table 13. Air Quality-Related Benefits from Reduced Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing</strong></td>
</tr>
<tr>
<td>Total energy savings (per year)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Annual emissions reduction (tons of both pollutants per year)</td>
</tr>
<tr>
<td><strong>Existing</strong></td>
</tr>
<tr>
<td>Total value of improved air quality from emissions reduction</td>
</tr>
</tbody>
</table>


Notes: A description of our methods for calculating these estimates is in Appendix A.

4. Climate Change-Related Benefits

In this section, we analyze two types of climate change-related benefits associated with green infrastructure. In general, green infrastructure provides climate change-related benefits by removing CO$_2$ from the atmosphere as well as by decreasing the volume of CO$_2$ emissions in the first place, which could mitigate some of the potential costs associated with climate change. More specifically, green infrastructure reduces atmospheric CO$_2$ in two ways:

- Carbon sequestration by trees and vegetation on green roofs.
- Reduced carbon emissions from energy production.

Table 14 summarizes the results of our analysis of the value of climate change-related benefits from trees and vegetation on green roofs.

As of 2010, MMSD has participated in the construction of about 0.3–0.4 million square feet of green roofs. This *existing stock* of green roofs removes about 19–23 tons of CO$_2$ from the air, per year. The value of this reduction in atmospheric carbon is about $300–$1,800 per year. Over the next 50 years, we assume green roof installation will increase, covering an area of about 1.9–2.2 million square feet, and that about 0.2–0.3 million trees will be planted. This *potential stock* of green roofs and trees would remove an estimated 49,200–61,500 tons of CO$_2$ from the air, per year, when fully implemented. The NPV of the climate change-related benefits from potential green roofs and trees is $7.7–$103.4 million.
Table 14. Climate Change-Related Benefits from Trees and Vegetation on Green Roofs

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green roofs (square feet)</td>
<td>0.3–0.4 million</td>
<td>1.9–2.2 million</td>
</tr>
<tr>
<td>Number of trees</td>
<td>0</td>
<td>0.2–0.3 million</td>
</tr>
<tr>
<td>Carbon absorption (tons per year)</td>
<td>19–23</td>
<td>49,200–61,500</td>
</tr>
</tbody>
</table>

| Total value of climate change-related benefits from trees and green roofs | $300–$1,800 | $7.7–$103.4 million |


Notes: A description of our methods for calculating these estimates is in Appendix A.

Table 15 summarizes the results of our analysis of the value of climate change-related benefits from reduced energy production. Using the avoided energy calculated in previous sections, and the avoided energy from the reduction in water treatment, we can estimate the weight of avoided CO₂ emissions associated with existing and potential future green infrastructure projects. Existing green infrastructure in MMSD’s service area decreases the total weight of airborne CO₂ associated with energy production by about 194–233 tons per year, worth about $2,900–$18,000 in climate change-related benefits per year. The area’s potential future green infrastructure projects could reduce energy consumption by much more, preventing 39,000–50,900 tons of CO₂ from entering the atmosphere per year, when fully implemented. The climate change-related benefit associated with decreased energy production has an NPV of about $6.2–$86.0 million, over the next 50 years.

Table 15. Climate Change-Related Benefits from Reduced Energy Production

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Potential – Total Sewer Area 25–75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy savings (per year)</td>
<td>80,600–96,700 kWh</td>
<td>16.7–23.7 million kWh</td>
</tr>
<tr>
<td></td>
<td>2.4–2.9 billion Btu</td>
<td>478–597 billion Btu</td>
</tr>
<tr>
<td>CO₂ emissions reduction (tons)</td>
<td>194–233</td>
<td>39,000–50,900</td>
</tr>
</tbody>
</table>

| Total value of climate change-related benefits from reduction in energy production | $2,900–$18,000 | $6.2–$86.0 million |


Notes: A description of our methods for calculating these estimates is in Appendix A.
5. Heat Island Effect

Green infrastructure can decrease the intensity of the negative impacts associated with the heat island effect. In its most severe sense, the heat island effect can increase urban temperatures to levels that pose dangers to human health and well-being. As of mid-2011, there had been one heat related death in the City of Milwaukee.\(^{57}\) In 1995, during one of the area’s worst heat waves on record, there were 95 heat-related deaths and 95 heat-related paramedic emergency medical service runs in Milwaukee County. In 1999, during another heat wave, there were 11 heat-related deaths and 28 heat-related paramedic emergency medical service runs in the county.\(^{58}\) There are insufficient data to estimate the number of heat-related injuries associated with the heat island effect or their economic value. That is not to say, however, that green infrastructure provides no economic benefits related to the heat island effect in Milwaukee.

6. Community Livability

In Section II of this report, we list several ways in which green infrastructure can improve community livability. There are insufficient data to estimate the values of these benefits derived from existing or potential future green infrastructure in the Milwaukee area, but existing research suggests that these values are positive. Below are some examples of the types of community livability benefits associated with green infrastructure projects:

- Increasing home values by improving aesthetics.
- Improving health and well-being by increasing the quantity and improving the quality of recreation opportunities nearby.
- Improving well-being by reducing noise pollution.

7. Habitat-Related Benefits

Different types of habitat provide different sets of services from which individuals derive benefits. Most green infrastructure projects cover too little land to provide quantifiable habitat benefits. Some projects, however, cover more land and provide benefits described in previous sections (e.g. benefits related to reduced stormwater runoff and increased shaded area) as well as benefits such as habitat provision for wildlife. Above, we described the Greenseams program, which has purchased over 2,200 acres of land much of which borders shoreline or contains wetlands. Assuming an average value of $4,000 derived from wetland-related benefits, and that 25 percent of this area is covered by wetlands, the land the Greenseams program has purchased provides about $2.2 million in benefits per year. There are insufficient data to estimate the potential extent of wetland construction, conservation, or restoration in the Milwaukee area. But, following the assumptions above, the Greenseams wetlands continue to function over the next 50 years, the NPV of the services these wetlands provide is about $58.3 million.


8. Public Education Benefits

We do not quantifiy the economic value of public education opportunities and benefits provided by green infrastructure in the Milwaukee area, but it is important to recognize that it can play an important role. Not only do the green infrastructure sites provide locations for learning about natural processes, water quality, and ecology, but they also help to demonstrate the effects that people can have on other members of their community, for both positive and negative.

G. Summary of Economic Benefits in the Milwaukee Area

| Table 16. Summary of Benefits from Existing and Potential Green Infrastructure Projects in the Milwaukee Area |
|--------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------------|
| | Existing ($/year) | Potential (50-year NPV) |
| Value of avoided infrastructure costs | $0.2–$1.0 million | $8.0–$97.9 million |
| Value of avoided water treatment costs | $34,000–$40,900 | $5.6 billion |
| Value of improved water quality | $175–$211 | $2.8–$8.5 billion |
| Reduced flooding | Not Quantified | Not Quantified |
| Total value of energy savings | $17,100–$20,500 | $37.6–$47.0 million |
| Total value of improved air quality from trees and green roofs | $1,200–$2,200 | $9.8–$12.3 million |
| Total value of improved air quality from emissions reduction | $8,500–$10,200 | $17.8–$22.7 million |
| Total value of carbon absorption | $300–$1,800 | $7.7–$103.4 million |
| Total value of reduced carbon emissions | $2,900–$18,000 | $6.2–$86.0 million |
| Heat island effect | Not Quantified | Not Quantified |
| Community livability | Not Quantified | Not Quantified |
| Value derived from wetland habitat | $2.2 million | $58.3 million |
| Public education benefits | Not Quantified | Not Quantified |
| Total | $2.2–$2.3 million | $5.7–$8.8 billion |

Source: ECONW with data from previous tables.

Notes: To sum the benefits, we did not combine the three quantified water-related benefits in the first three rows of the table. Rather, we used the full range of potential benefits across the three benefit categories.

Our estimates of economic benefits for the Milwaukee area suggest that water-related benefits have the highest economic value and that climate change-related benefits from carbon absorption and emissions reduction are also high, as we show in Table 16. When considering the potential benefits over 50 years, stormwater benefits and carbon benefits stand out, as well as energy savings. Several categories of benefits cannot be quantified though, and some of these unquantified categories such as community livability and...
public education can play important roles for local success in implementation support and long-term maintenance. Overall, green infrastructure in the Milwaukee area provides the primary categories of quantifiable and unquantifiable benefits not at the individual site level, but at the regional scale and larger. This suggests that private benefits to the individual alone without government or community support or mandate are unlikely to be sufficient to generate an efficiently high level of installation and maintenance.
IV. CASE STUDY – ANN ARBOR, MICHIGAN

The City of Ann Arbor, Michigan is about 45 miles west of Detroit, in Washtenaw County. According to the 2009 American Community Survey (five-year estimate), Ann Arbor has a population of about 114,000 and a median household income of $51,001 (in 2009 dollars), which is 4.5 percent higher than the state average.\(^{59}\) In this section, we describe the watershed conditions and the agencies, regulations, and components associated with stormwater management in the Ann Arbor area. Then we describe the existing stock of green infrastructure from some of the area’s programs and initiatives. For each of the city’s existing green infrastructure projects and programs we estimate the economic benefits across quantifiable categories in present terms and their 50-year NPV.

A. Management Agencies and Responsible Parties

The City of Ann Arbor Systems Planning Unit is tasked with managing stormwater at the local level. The city has regulations for stormwater related to construction activities, post-construction runoff, and illicit discharge, as well as incentive programs promoting the reduction of stormwater runoff. The city’s regulations are based on requirements outlined in its MS4 permit.

- In 1994, the Huron River Watershed Council developed the *Middle Huron River Watershed Management Plan* (updated in 2000 and 2008) in which it describes strategies to protect natural areas, mitigate impacts of existing pollution, and restore degraded areas.
- In 2009, the Huron River Watershed Council developed the *Public Participation Plan for the Middle Huron River Subwatershed* in which it describes how the public will participate in efforts to develop and implement the stormwater program.
- The Huron River Watershed Council also developed the Stormwater Pollution Prevention Initiative, which outlines six specific actions watershed partners must implement: TMDL, public education program, illicit discharge elimination program, post construction stormwater management, construction stormwater controls, and pollution prevention and good housekeeping practices for municipal operations.\(^{60}\)

The Office of the Washtenaw County Water Resources Commissioner manages stormwater at the county level. The Office designs, constructs, operates, and maintains all the county’s stormwater drains, responds to floods, maintains lake levels, finances drain projects, and manages drain financial accounts. The Office is also responsible for developing design standards for stormwater systems, and has emphasized its preference for non-structural (source) controls over structural (site) controls in its standards.\(^{61}\)

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At the watershed level, the Washtenaw County Drain Commissioner along with the Huron River Watershed Council developed the *Watershed Management Plan for the Huron River in the Ann Arbor – Ypsilanti Metropolitan Area*. The Plan describes the existing conditions of the watershed, outlines a watershed action plan, and puts forth implementation and evaluation strategies. In terms of stormwater management, the Plan describes several best management practices, and outlines strategies for authorities within the watershed to reduce stormwater runoff and improve water quality and quantity.

**B. Area-Wide Watershed Conditions**

The City of Ann Arbor is part of seven tributary creeksheds: Traver, Malletts, Miller, Honey, Swift Run, and Flemming. Together, these creeksheds comprise part of the Huron River Watershed. The watershed provides critical services to the city including opportunities for recreational enjoyment, wildlife habitat, and hydropower. The Huron River Watershed Council is responsible for monitoring, maintaining, and, when appropriate, improving the quality of the watershed. According to the Council, significant portions of the Watershed are not suitable for their primary uses and have been deemed ‘impaired.’ As detailed in Table 17, EPA has approved TMDLs for five main waterbodies in the watershed.

<table>
<thead>
<tr>
<th>Table 17. Huron River Watershed TMDLs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waterbody</strong></td>
</tr>
<tr>
<td>Ford Lake/ Belleville Lake</td>
</tr>
<tr>
<td>Huron River (Geddes Pond and Allen Creek)</td>
</tr>
<tr>
<td>Malletts Creek</td>
</tr>
<tr>
<td>Swift Run</td>
</tr>
<tr>
<td>Honey Creek</td>
</tr>
</tbody>
</table>


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C. Regulations

Ann Arbor’s stormwater regulations are outlined in the City Code, Chapter 63: Stormwater and Soil Erosion and Sedimentation Control. Since early 2011, Chapter 63 requires stormwater management on newly constructed or redeveloped single and two-family residential properties that increase impervious area by 200 square feet or more. Property owners with properties falling under this category must complete the Impervious Area Worksheet documenting the total increase in impervious surface area as well as the treatment measures (e.g., rain barrel, rain garden, drywell, cistern, swale storage basin, porous pavement) they intend to implement. The code requires these property owners to implement enough treatment measures to store 0.04 cubic feet of stormwater per additional square foot of impervious area. Furthermore, property owners must ensure all downspouts are directed toward vegetated areas.

In addition to city-level regulations, developers in Ann Arbor must comply with regulations outlined by the Washtenaw County Drain Commission. The Commission requires all developments with impervious surfaces greater than 5,000 square feet in Ann Arbor to provide on-site stormwater management in accordance with the Rules of the Washtenaw County Drain Commissioner’s Office. While the Commission recommends non-structural controls, developers can implement either non-structural (source) controls or structural (site) controls to manage stormwater.

D. Current Components of Stormwater Management

The City of Ann Arbor uses 359 miles of underground pipes and over 11,000 inlets and catch basins to manage stormwater. The city operates a separate sewer system. One system collects, transports, and treats wastewater from homes, offices, restaurants, and elsewhere. That water is transported to a wastewater treatment plant where it is treated before it is discharged into the Huron River. The other system collects and transports stormwater from rainstorms and snowmelts. This stormwater is not treated before it is discharged into surface waters in the Ann Arbor Area.

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E. Green Infrastructure Projects and Programs in Ann Arbor

In addition to the gray infrastructure described above, agencies, groups, and individuals in Ann Arbor have invested in implementing green infrastructure techniques to manage stormwater. Here we describe several of the green infrastructure programs, incentives, and projects in the Ann Arbor area along with quantitative estimates describing the extent of their implementation.

1. Sylvan Avenue Green Street

In 2010, Ann Arbor’s Project Management Services Unit oversaw the Sylvan Avenue Permeable Pavement Project. The project upgraded an 800-foot long, 20-foot wide residential street using several LID techniques. As we describe later in this section, we estimate the project could reduce stormwater runoff by 0.2–0.7 million gallons each year. Some of the project’s components included:

- Installation of permeable asphalt pavement on the entire roadway
- Replacement of the curb, gutter, and sidewalk
- Installation of an underdrain with connections for residential sump pumps
- Installation of two water quality improvement structures

Figure 5 shows pictures of a portion of Sylvan Avenue in 2011. Public works staff involved with installing and maintaining the street report that initial material handling was challenging because it does handle differently than traditional materials, and cannot be packed tight for a completely flat surface because that would reduce permeability. Staff also reported that for scenarios where a street requires full reconstruction though, the additional effort and costs are not significant, and would make sense for the city to do again. Resurfacing only projects would require additional effort and likely wouldn’t be as cost effective. The design does have an underdrain as a backup to capture water that does not infiltrate under the street, and carries overflow to the

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main street piped stormwater system. City staff also know they are supposed to vacuum the street twice a year, but in the first year they have not vacuumed it at all.

The street also has anecdotes of plowing and salting benefits. When compared during the winter to a similar street, Valerie Strassberg of Nature’s Voice Our Choice reports that there is less ice, less snow, and it requires less plowing and salting. During freeze-thaw cycles, meltwater infiltrates rather than freezing as an ice layer. These benefits save public road maintenance expenses, improve water quality, and reduce public risk.

2. Easy Street Green Street

The Easy Street Pavement Rehabilitation Project was completed in late 2007. The project had several objectives including: improving stormwater management, calming traffic, increasing pedestrian access, and improving landscaping. As we describe later in this section, we estimate the project could reduce stormwater runoff by 3.3–13.3 million gallons each year. The project had two major components:

- Replacement of 3–3.5 feet of existing asphalt along outer edges of the street with porous pavers. The porous pavers can infiltrate 4–8 inches of water per hour, and have the capacity to infiltrate the stormwater from an area about 16 larger.
- Construction of five swales vegetated with native species.

The street is slightly sloped along its entire length with its crown running along the center. The project was designed to direct stormwater from the street toward the pervious pavers and swales along the side of the street. The pictures in Figure 6 (from top to bottom) show a section of Easy Street prior to construction; a section of Easy Street in 2009, two years after construction was completed, and a close-up of the permeable surface running along the street.

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Monitoring

As part of the project, the City of Ann Arbor contracted Stantec, Inc. to monitor pre- and post-construction flow and water quality data. Stantec collected pre-construction data in November 2005 and March to May in 2006; they collected post-construction data from May to July in 2009.

The parameters for their water quality analysis included total suspended solids (TSS), total phosphorus (TP), orthophosphate (OP), total copper (TCu), and total zinc (TZn). They monitored the concentrations of these constituents from the Easy Street site as well as from Buhr Park, which provided something to compare pre- and post-construction data against. The most useful results show the ratio of constituent concentrations from Easy Street to constituent concentrations from Buhr Park. Table 18 summarizes the results. Stantec found that, in general, total pollutant load at Easy Street was higher than the load at Buhr park during pre-construction monitoring. During post-construction monitoring, however, total pollutant load at Easy street was, in general, equal to or less than the load at Buhr Park. Overall, total pollutant loads were 30–90 percent lower under post-construction conditions than they were under pre-construction conditions.73

Table 18. Ratio of Total Event Pollutant Load at Easy Street to Load at Buhr Park

<table>
<thead>
<tr>
<th>Date</th>
<th>TSS</th>
<th>TP</th>
<th>PO4</th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/28/05</td>
<td>10.9</td>
<td>5.7</td>
<td>5.1</td>
<td>4.8</td>
<td>3.1</td>
</tr>
<tr>
<td>4/12/06</td>
<td>2.8</td>
<td>≤1</td>
<td>≤1</td>
<td>1.1</td>
<td>4.8</td>
</tr>
<tr>
<td>4/14/06</td>
<td>8.4</td>
<td>31.9</td>
<td>58.0</td>
<td>11.4</td>
<td>7.7</td>
</tr>
<tr>
<td>5/11/06</td>
<td>9.4</td>
<td>3.9</td>
<td>2.4</td>
<td>3.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>TSS</th>
<th>TP</th>
<th>PO4</th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/12/09</td>
<td>1.5</td>
<td>1.1</td>
<td>NA</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td>6/19/09</td>
<td>≤1</td>
<td>≤1</td>
<td>≤1</td>
<td>≤1</td>
<td>≤1</td>
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<tr>
<td>6/20/09</td>
<td>≤1</td>
<td>≤1</td>
<td>1.9</td>
<td>1.0</td>
<td>≤1</td>
</tr>
<tr>
<td>6/25/09</td>
<td>≤1</td>
<td>1.7</td>
<td>1.1</td>
<td>NA</td>
<td>4.2</td>
</tr>
<tr>
<td>7/23/09</td>
<td>9.6</td>
<td>3.4</td>
<td>1.7</td>
<td>4.9</td>
<td>4.1</td>
</tr>
</tbody>
</table>


Stantec used pre- and post-construction flow rates and modeling data to assess water quantity improvements derived from the project. Figure 7 summarizes their findings. The first section of the figure shows peak and total flow reductions for a rain event on April 7, 2006 and for a 2-year design storm under post-construction and ideal conditions74 under pre-construction conditions. The next two sections show the


74 Ideal conditions were modeled based on a design scenario with twice the area of porous pavers relative to the design used along with 14-foot wide, 2-foot deep swales along both sides of the street.
hydrographs for the April 7th event and the 2-year design storm under each of the scenarios. Under the 2-year design storm, modeling data suggest that post-construction conditions would reduce peak flow by about 50 percent and total flow by 80 percent from pre-construction conditions.

**Figure 7. Pre-Construction, Post-Construction, and Ideal Scenario Flows**

<table>
<thead>
<tr>
<th>Post-construction conditions</th>
<th>Peak Flow Reduction</th>
<th>Total Flow Reduction</th>
<th>Post-construction conditions</th>
<th>Peak Flow Reduction</th>
<th>Total Flow Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>74%</td>
<td>80%</td>
<td>49%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Ideal conditions</td>
<td>93%</td>
<td>86%</td>
<td>59%</td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

3. Mary Beth Doyle Park Redesign Project

Mary Beth Doyle Park is the largest park in Ann Arbor, located along Malletts Creek (a tributary to the Huron River). From 2006 to 2008, the park was closed for construction aimed at improving its capacity to store, infiltrate, and treat stormwater. The project’s main components included:

- A re-design of the 15-acre impoundment (removing 31,000 cubic yards of contaminated sediment, building a temporary stream to construct a sediment forebay, building an embankment dam and weirs, modifying the outlet structure, and landscaping).
- Creation of a 12-acre perched mitigation wetland within a larger wetlands preserve (including the planting of 25 species – 31,263 plugs, of grasses and forbs along the water’s edge).
- Improved public access to the park’s water features (including increased visibility of water features, education components, pedestrian pathways, and a bridge over the pond).

While extensive pre- and post-construction monitoring data are not available, research suggests the project has improved water quality and stormwater management in the area. The wetlands preserve, for example, can hold up to 15 million gallons of water at once and about 1.5 billion gallons of water flow through it each year. Combined, the pond and wetlands reserve remove about 1,000 pounds of phosphorous that would otherwise flow into Malletts Creek per year (or about 25 percent of all the phosphorous). Flows in Malletts Creek are more consistent post-construction, and are less susceptible to sudden spikes after large storm events as they were under pre-construction conditions.

In addition to water quality and quantity benefits, the project has improved habitat and has been a source of recreational enjoyment and public education. Planting efforts in the area have increased the quantity and diversity of native vegetation. Wetlands construction, along with these planting efforts, have improved wildlife habitat, primarily for a wide range of bird species that now frequent the area. Improved access to park elements, landscaping, reconstruction of playground equipment, and other amenities have increased the quantity and quality of recreation in the area. Informational signs are posted throughout the park detailing the specifics between the park’s improvements and stormwater management, and 1,500 students from Ann Arbor Public Schools come to the park each year to learn about its hydrology.

4. Rain Gardens

The Washtenaw County rain garden program began in 2005 with funding from a Clean Water Act 319 grant. Since then, funding for the program has shifted to the county and the City of Ann Arbor. Since its start, the program has funded the construction of about 10 rain gardens per year, for a total of over 50 rain gardens functioning in the area today. Recently, the program was expanded with the hire of a half-time employee, through

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Michigan State University extension. The staff person will assist in program development while will include the development of interpretive signage for participating locations.76

On average, the Ann Arbor area receives about 35 inches of precipitation per year. Much of this precipitation falls in the spring, followed by periods of extreme heat and minimal precipitation in the summer. Native plants tolerant of these conditions, along with other landscaping methods can create a rain garden capable of retaining large volumes of water during wet periods and surviving drought and heat during the summer months. By retaining stormwater before it enters the sewer system, these rain gardens are reducing the volume of stormwater runoff entering the area’s waterways, providing several different types of benefits. In total, the rain gardens funded by this program are capable of capturing about 25,000 gallons of water from one inch of rainfall.77 Given the area’s average annual precipitation, we estimate these rain gardens reduce stormwater runoff by about 875,000 gallons per year.

Rain gardens in Ann Arbor vary in size, distribution, land ownership, maintenance, and management. Below are three examples:

---

**Inhabited Residential Lot**

This property owner captures stormwater from his property as well as runoff from the adjacent street and neighboring properties. In exchange for these services his rain garden provides others, he derives several benefits. Some of these benefits include:

- Micro-climate benefits (e.g., cooling and humidity from the plants)
- Aesthetic benefits (e.g., the garden itself is full of plants, flowers, and trees that the property owner can enjoy from his patio)
- Water for his garden (e.g., he can use water collected in the garden on other plants on his property)
- Habitat for wildlife (e.g., the property owner has noticed an increase in the number of butterflies and birds in his yard, likely attracted by the rain garden)

---


Millers Creek Rainwater Project

The Michigan Department of Environmental Quality has funded a 4-year project that will promote the use of rain gardens upstream of Millers Creek to increase infiltration and reduce flooding and soil erosion. These efforts will reduce the negative impacts of large stormwater flows into the Creek from gray infrastructure.

Thurston Elementary School

In 2009, with support from the Huron River Watershed Council, several community members, and three third-grade classes, Thurston Elementary School, in Ann Arbor, added a 1,400 square foot rain garden to its property. This rain garden captures runoff from the school roof. But for the rain garden, this stormwater would have flowed through the city's stormwater sewer into nearby waterways. The rain garden increases on-site infiltration, provides habitat native plants, birds, and insects, and provides educational opportunities for students at the school. In addition to the third-grade students that helped build the rain garden, other students from the school help to maintain the rain garden.

5. Rate Incentives

Ann Arbor provides incentives for residential and commercial property owners to reduce their stormwater runoff through a credit program that decreases their stormwater bill based on which management technique(s) they implement. Residential
property owners have three options. If they become a *RiverSafe Home partner* they will save $5.20 per year; if they install 1-5 rain barrels they will save $7.52; if they create a rain garden, cistern, or drywell they will save $11.76 per year. Commercial properties are billed at a rate of $331 per impervious acre per quarter, plus a customer charge of $6.77 per quarter. Commercial property owners have three ways of reducing these fees through stormwater management: participate in the *Community Partners for Clean Streams* Program, install a stormwater management system as described in City Code Chapter 63, or implement an approved stormwater control (e.g. vegetated swales, porous pavement, retention ponds). Each of these options will decrease their customer charge by 17.3 percent ($3.50 per year).79

### 6. Summary of Identified Existing Green Infrastructure and Potential Future Green Infrastructure in the Ann Arbor Area

Earlier in this section, we described several initiatives in Ann Arbor that introduced green infrastructure as a means of managing stormwater. Here, we summarize these projects in terms of their components and the volume of water they capture. Table 19 presents our estimates. For permeable pavement and bioswales associated with Sylvan Avenue and Easy street, we assume they have the capacity to collect all of the precipitation that falls within their footprint up to the precipitation from an area five times larger than their footprint.80 Point estimates of stormwater retention and treatment for the wetland in Mary Beth Doyle Park and the rain gardens in the city were provided in other reports, summarized above. In total, existing green infrastructure projects reduce and/or treat over 1.5 billion gallons of stormwater.

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Reduced Stormwater Runoff (gallons per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sylvan Avenue</td>
<td>• Permeable pavement</td>
</tr>
<tr>
<td>Easy Street</td>
<td>• Permeable pavement</td>
</tr>
<tr>
<td></td>
<td>• Bioswales</td>
</tr>
<tr>
<td>Mary Beth Doyle Park</td>
<td>• 12 acres of wetlands</td>
</tr>
<tr>
<td>Rain Gardens</td>
<td>• 50 rain gardens</td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous sections.
Notes: A description of our methods for calculating these estimates is in Appendix B.

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80 The 2010 CNT report assumes drainage areas twice the size of the feature area for point estimates. Here we use the feature size and 5-times the feature size to estimate a range of values.
F. Economic Benefits of Green Infrastructure in Ann Arbor

In this section, we estimate the economic benefits derived from the existing green infrastructure in Ann Arbor as described in previous sections. Over 97 percent of this reduction comes from a single project, the 12-acre wetland in Mary Beth Doyle Park; the other 3 percent comes from Sylvan Avenue, Easy Street, and the city’s rain gardens. This section is divided into eight parts, each of which estimates the values associated with different benefit categories. The benefit categories we discuss in this section are:

- Water-related benefits
- Energy-related benefits
- Air quality-related benefits
- Climate change-related benefits
- Urban heat island-related benefits
- Community livability-related benefits
- Habitat-related benefits
- Public education-related benefits

1. Water-Related Benefits

The city’s existing green infrastructure, as represented by the four projects discussed in the previous section, reduces stormwater runoff by about 1.5 billion gallons per year. In the remainder of this section, we describe and quantify the economic values associated with two categories of water-related benefits:

- Water quality benefits of reduced stormwater runoff
- Flood benefits

Water quality benefits of reduced stormwater runoff

Water quality benefits for Ann Arbor come in terms of reducing the volume of untreated stormwater entering nearby waterways. Data from the city’s existing projects suggest that the wetland in Mary Beth Doyle Park treats about 1.5 billion gallons of stormwater each year. Other projects (Sylvan Avenue, Easy Street, and the city’s rain garden efforts) combine to decrease stormwater runoff by about 4.4–14.8 million gallons. The most direct way of considering these water quality benefits is to assume the city would provide these benefits via their conventional approach but for the green infrastructure. Consequently, the avoided costs of collecting, managing, and treating stormwater represent the marginal benefits green infrastructure projects provide.

To estimate avoided costs associated with the stormwater management that green infrastructure provides, we use the stormwater fees homeowners pay to the city. The revenues generated from these fees pay for the operations and maintenance costs of the city’s stormwater program and for capital improvement projects. The city’s stormwater fees are based on the amount of impervious land on each property. Table 20 summarizes the city’s stormwater fees for residential properties. For commercial and other properties, the city charges a flat rate of $331 per acre per quarter (or $1,324 per acre per year).81

Assuming average annual precipitation is 35 inches per year, the total volume of stormwater associated with each square foot of impervious area is about 21.8 gallons. Using the average impervious areas from each of the ranges in Table 20, we estimate the annual stormwater fee is about $1.34–$2.22 per 1,000 gallons of stormwater. In some instances, stormwater rates may not fully account for all of the costs associated with managing stormwater with gray infrastructure. Estimates from the literature suggest stormwater rates could range up to $4.60 per 1,000 gallons. Furthermore, while treatment costs associated with removing sediment from stormwater likely are at least partially included in these stormwater rates, considered alone they could be about $76.5 per million gallons of stormwater.\(^{82}\)

### Gray Infrastructure Costs

Some gray infrastructure techniques cost more than others. The table below summarizes some illustrative examples of gray infrastructure techniques that could be used to manage stormwater. These values represent total costs, not annual costs, so the avoided costs of implementing one of these techniques is less, on a per year basis, than the values below. At the high-end, though, the avoided costs associated with detention and retention basins likely are quite large.

<table>
<thead>
<tr>
<th>Gray Infrastructure Technique</th>
<th>Cost per Million Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface storage</td>
<td>$3.86</td>
</tr>
<tr>
<td>Deep tunnels</td>
<td>$5.33</td>
</tr>
<tr>
<td>Detention basins</td>
<td>$36,979.77</td>
</tr>
<tr>
<td>Retention basins</td>
<td>$47,089.90</td>
</tr>
</tbody>
</table>


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\(^{82}\) Wise, S., et. Al. No Date. Integrating Valuation Methods to Recognize Green Infrastructure’s Multiple Benefits. Center for Neighborhood Technology.
Applying the avoided cost of stormwater management as suggested by the full range of avoided stormwater rates ($1.34–$4.60 per 1,000 gallons), we estimate the value of the water-related benefits provided by each of the city’s four projects. Table 21 presents our results. Each year, these projects provide water-related benefits equal to $2.0–$7.0 million dollars. Over the next 50 years, the NPV of these benefits will be about $53.2–$184.6 million. In both cases, the water-related benefits provided by the 12-acre wetland in Mary Beth Boyle Park provide the majority of the benefits. Considered separately, the three non-wetland projects have an annual water-related value of about $5,800–$68,300, and an NPV of about $0.2–$1.8 million.

### Table 21. Avoided Costs from Reduced Stormwater Runoff Provided by Ann Arbor’s Green Infrastructure

<table>
<thead>
<tr>
<th>Reduced Stormwater Runoff (gallons per year)</th>
<th>Avoided Cost (per year)</th>
<th>50-Year NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sylvan Avenue</td>
<td>0.2–0.7 million</td>
<td>$200–$3,200</td>
</tr>
<tr>
<td>Easy Street</td>
<td>3.3–13.3 million</td>
<td>$4,400–$61,000</td>
</tr>
<tr>
<td>Mary Beth Doyle Park</td>
<td>1.5 billion</td>
<td>$2.0–$6.9 million</td>
</tr>
<tr>
<td>Rain Garden Program</td>
<td>0.9 million</td>
<td>$1,200–$4,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>About 1.5 billion</strong></td>
<td><strong>$2.0–$7.0 million</strong></td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous sections.

### Reduced flooding

This past spring broke the record for the wettest spring in Ann Arbor’s history.83 Although the summer was relatively dry, heavy rains in August flooded residential streets in several areas.84 There are not estimates available describing the extent of damages from these floods. In 2007, the local government responded to the need for increased flood prevention with The City of Ann Arbor Flood Mitigation Plan. The Plan discusses flood mitigation strategies and provides specific recommendations at the watershed level. While the Plan doesn’t specifically address using green infrastructure techniques as a way of reducing flooding, it does highlight the importance of open space in the floodplain. To that end, the Plan calls for an assessment of existing green spaces in the floodplain, a plan to develop green spaces in the floodplain, and land acquisition and construction efforts to help support the transition from development to green spaces in the floodplain.85

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To the extent that it reduces the volume of stormwater runoff and the speed with which stormwater enters nearby waterways, green infrastructure can decrease the severity of flooding events incurred by these residents.\textsuperscript{86} Data are unavailable to estimate the potential impact of green infrastructure on future flooding events in the city.

2. Energy-Related Benefits

In general, green infrastructure projects provide energy-related benefits insofar as they decrease energy consumption, which in turn decreases the amount of money households, commercial and public entities, and other building owners and operators spend on energy. These benefits include:

- Reduced energy use in buildings with green roofs.
- Reduced energy use in buildings with nearby trees.

Data describing the four projects we consider in this case study suggest that no trees were planted and no green roofs were installed for stormwater management purposes that would decrease the amount of energy used in buildings, and thus provide this energy-related benefit.

3. Air Quality-Related Benefits

In this section, we analyze two types of air quality-related benefit associated with green infrastructure. In general, green infrastructure provides air quality-related benefits by removing harmful pollutants from the air as well as decreasing the emissions of those pollutants in the first place. Improvements in air quality have economic value insofar as they reduce the costs associated with air pollution (e.g., health-related costs from respiratory illness and habitat destruction). More specifically, the air quality-related benefits we discuss in this section include:

- Improved air quality from vegetation on green roofs and from trees.
- Reduced emissions of pollutants from energy production.

While there likely are trees associated with some of the four projects we discuss in this case study, there are insufficient data to estimate the number of new trees planted. Furthermore, there were no data suggesting that any green roofs were installed as a part of the four projects. Table 22 summarizes the results of our analysis of the value of air quality-related benefits from reduced emissions stemming from avoided water treatment.

The four projects reduce the amount of stormwater that would have otherwise gone into the sewer system by about 1.5 billion gallons per year. Using the avoided energy from the reduction in stormwater treatment, we can estimate the weight of avoided emissions of NO\textsubscript{2} and SO\textsubscript{2}. Ann Arbor’s four green infrastructure projects decrease the total weight of airborne pollutants associated with energy production by about 3.7 tons per year, worth about $17,600–$18,000 in air quality benefits. The NPV of the air quality benefits from reduced emission, over the next 50 years, is about $0.5 million.

\textsuperscript{86} DeLaria, M. 2008. \textit{Low Impact Development as a Stormwater Management Technique}. Rocky Mountain Land Use Institute.
Table 22. Air Quality-Related Benefits from Reduced Energy Production

<table>
<thead>
<tr>
<th>Annual reduction in energy use</th>
<th>About 1.0 million kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual pollutant reduction (tons of all four pollutants per year)</td>
<td>About 3.7</td>
</tr>
<tr>
<td><strong>Value of air quality-related benefits from reduced energy production</strong></td>
<td><strong>Annual Benefit (per year)</strong></td>
</tr>
<tr>
<td></td>
<td>$17,600–$18,000</td>
</tr>
</tbody>
</table>


Notes: A description of our methods for calculating these estimates is in Appendix B.

4. Climate Change-Related Benefits

In this section, we analyze two types of climate change-related benefits associated with green infrastructure. In general, green infrastructure provides climate change-related benefits by removing CO₂ from the atmosphere as well as by decreasing the volume of CO₂ emissions in the first place, which could mitigate some of the potential costs associated with climate change. More specifically, green infrastructure reduces atmospheric CO₂ in two ways:

- Carbon sequestration by trees and vegetation on green roofs.
- Reduced carbon emissions from energy production.

While there likely are trees associated with some of the four projects we discuss in this case study, there are insufficient data to estimate the number of new trees planted. Furthermore, there were no data suggesting that any green roofs were installed as a part of the four projects. Table 23 summarizes the results of our analysis of the value of climate change-related benefits from reduced emissions stemming from avoided water treatment.

Table 23. Climate Change-Related Benefits from Reduced Energy Production

<table>
<thead>
<tr>
<th>Carbon absorption (tons per year)</th>
<th>684–700</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Benefit (per year)</strong></td>
<td><strong>50-Year NPV</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total value of climate change-related benefits from trees and green roofs</strong></td>
<td><strong>$10,300–$54,000</strong></td>
</tr>
</tbody>
</table>


Notes: A description of our methods for calculating these estimates is in Appendix B.

The four projects reduce the amount of stormwater that would have otherwise gone into the sewer system by about 1.5 billion gallons per year. Using the avoided energy from the reduction in stormwater treatment, we can estimate the weight of avoided emissions...
of CO\textsubscript{2}. Ann Arbor’s four green infrastructure projects decrease the total weight of CO\textsubscript{2} emissions associated with energy production by about 684–700 tons per year, worth about $10,300–$54,000 in climate change-related benefits. The NPV of these benefits from reduced emissions, over the next 50 years, is about $0.3–$2.4 million.

5. Heat Island Effect

Green infrastructure can decrease the intensity of the negative impacts associated with the heat island effect. In its most severe sense, the heat island effect can increase urban temperatures to levels that pose dangers to human health and well-being. June, July, and August are, historically, the hottest months in Ann Arbor with average monthly high temperatures of 80\textdegree–83\textdegree F, and record high temperatures of 103\textdegree–105\textdegree F during those months.\textsuperscript{87} There is no evidence suggesting any heat-related deaths in Ann Arbor in 2011. In July of 2011, however, several people sought medical attention for heat-related illness and fatigue during a heat wave that contributed to at least three deaths in the State of Michigan.\textsuperscript{88} There are insufficient data to estimate the number of heat-related injuries associated with the heat island effect or the economic value associated with those injuries. That is not to say, however, that green infrastructure provides no economic benefits related to the heat island effect in the Ann Arbor area.

6. Community Livability

In Section II of this report, we list several ways in which green infrastructure can improve community livability. There are insufficient data to estimate the values of these benefits derived from existing or potential future green infrastructure in the Ann Arbor area, but existing research suggests that these values are positive. Below are some examples of the types of community livability benefits associated with green infrastructure projects:

• Increasing home values by improving aesthetics.
• Improving health and well-being by increasing the quantity and improving the quality of recreation opportunities nearby.
• Improving well-being by reducing noise pollution.

7. Habitat-Related Benefits

Different types of habitat provide different sets of services from which individuals derive benefits. Most green infrastructure projects cover too little land to provide quantifiable habitat benefits. Each of the city’s rain gardens, for example, likely only covers a few hundred square feet. Research and anecdotal evidence suggests that even these small spaces can provide habitat in the otherwise urban environment. To the extent that these rain gardens increase the amount of permeable, vegetated area available in the city, they will increase the value individuals derive from habitat-related benefits. See Section II of this report for more detail on how green infrastructure in urban areas can provide habitat-related benefits.


Other projects, such as the wetland in Mary Beth Doyle Park, cover more land and provide benefits described in previous sections (e.g. benefits related to reduced stormwater runoff) as well as benefits such as habitat provision for wildlife. Mary Beth Doyle Park offers about 12 acres of wetland habitat. Assuming an average annual value of $4,000 derived from wetland-related benefits, the park provides about $48,000 in benefits per year. There are insufficient data to estimate the potential extent of wetland construction, conservation, or restoration in the Ann Arbor area as these activities are highly restricted by the availability of suitable land. But, following the assumptions above, if the wetlands in the park continue to function over the next 50 years, the NPV of the services these wetlands provide is about $1.3 million.

8. Public Education Benefits

We do not quantify the economic value of public education opportunities and benefits provided by green infrastructure in the Ann Arbor area, but it is important to recognize that it can play an important role. Not only do the green infrastructure sites provide locations for learning about natural processes, water quality, and ecology, but they also help to demonstrate the effects that people can have on other members of their community, for both positive and negative. In Mary Beth Doyle Park, for example, informational signs are posted detailing how the park’s improvements help manage stormwater. Furthermore, about 1,500 students from Ann Arbor Public Schools go to the park each year as part of education efforts aimed at teaching hydrology and other lessons based on the wetland ecosystem.

G. Summary of Economic Benefits in Ann Arbor

Our estimates of economic benefits for the four projects in Ann Arbor find water-related benefits (avoided costs from reduced stormwater runoff) to be the highest category of benefits, as Table 24 shows. Several categories of benefits cannot be quantified though, and some of these unquantified categories such as community livability and public education can play important roles for local success in implementation support and long-term maintenance. Nearly all of the value in each of the benefit categories is derived from the 12-acre wetland in Mary Beth Doyle Park. Wetlands provide a wide range of benefits in many different categories (e.g., stormwater runoff reduction, habitat provision, emissions reduction, and learning opportunities). Green streets and rain gardens provide some of these benefits, but to a smaller scale as they tend to take up less space and retain less water than large-scale wetland projects. To the extent that future green infrastructure projects in more urban areas (such as green streets and rain gardens) can incorporate tree planting, the types of benefits and the value of those benefits associated with the projects will increase. Furthermore, none of these projects included green roofs, which provide benefits in many different categories. Overall, green infrastructure in Ann Arbor provides the primary categories of quantifiable and unquantifiable benefits not at the individual site level, but at the regional scale and larger. This suggests that private benefits to the individual alone without government or community support or mandate are unlikely to be sufficient to generate an efficiently high level of installation and maintenance.
Table 24. Summary of Benefits from Existing and Potential Green Infrastructure Projects in Ann Arbor

<table>
<thead>
<tr>
<th>Benefit Description</th>
<th>Annual Benefit ($/year)</th>
<th>50-Year NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of avoided costs from reduced stormwater runoff</td>
<td>$2.0–$7.0 million</td>
<td>$53.2–$184.6 million</td>
</tr>
<tr>
<td>Reduced flooding</td>
<td>Not Quantified</td>
<td>Not Quantified</td>
</tr>
<tr>
<td>Total value of improved air quality from emissions reduction</td>
<td>$17,600–$18,000</td>
<td>$0.5 million</td>
</tr>
<tr>
<td>Total value of reduced carbon emissions</td>
<td>$10,300–$54,000</td>
<td>$0.3–$2.4 million</td>
</tr>
<tr>
<td>Heat island effect</td>
<td>Not Quantified</td>
<td>Not Quantified</td>
</tr>
<tr>
<td>Community livability</td>
<td>Not Quantified</td>
<td>Not Quantified</td>
</tr>
<tr>
<td>Value derived from wetland habitat</td>
<td>$48,000</td>
<td>$1.3 million</td>
</tr>
<tr>
<td>Public education benefits</td>
<td>Not Quantified</td>
<td>Not Quantified</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$2.1–$7.1 million</strong></td>
<td><strong>$55.3–$187.0 million</strong></td>
</tr>
</tbody>
</table>

Source: ECONW with data from previous tables.
V. GENERAL CONCLUSIONS

Our case study investigations in this report highlight the diverse and substantial economic benefits provided by green infrastructure. These values demonstrate the important economic benefits that communities and regions can achieve by increasing their usage of green infrastructure. Energy savings provide benefits onsite, as do several other categories such as education and livability that are difficult to quantify. The monetarily high value categories though, particularly concerning water quality and air quality, are distributed across broad geographical scales. This means that the benefits to these communities and the greater region might be greater than the costs, but if all costs are borne by the individual site owner, market forces could be insufficient to motivate. Particularly if individuals feel that stormwater management is a government responsibility, market forces alone, without public regulatory or incentive-based intervention, are unlikely to lead to levels of green infrastructure that maximize their potential contribution to net well-being of the Great Lakes region.
APPENDIX A. CALCULATIONS AND ASSUMPTIONS FOR MILWAUKIE CASE STUDY

This appendix contains details describing the calculations and assumptions we used in the Milwaukee case study. The order of this appendix follows the order of the citations in that section. Throughout our analysis, we estimate annual values of existing green infrastructure and the net present value (NPV) of potential green infrastructure over the next 50 years. We assume all potential green infrastructure is implemented linearly over the next 50 years and we use a 3 percent discount rate.

Summary of Energy-Related Benefits in Milwaukee

Green Roofs - To estimate the energy-related benefits from green roofs, we applied the methodology described in the 2010 CNT Report for green roofs. We assume the annual heating degree days in Milwaukee is 7,087 and the annual cooling degree days is 616.\(^1\) We assume thermal resistance values of 11.34 for a conventional roof and 23.4 for a green roof.\(^2\) We assume an average electricity price of $0.1001 per kWh and an average natural gas price of $0.0000046 per Btu.\(^3\)

\[
\text{[616 cooling degree days} \times 24 \text{ hours per day} \times ((1/11.34)-(1/23.4))] / 3,412 \text{ conversion factor} = 0.197 \text{ kWh per square foot}
\]

\[
\text{[7,087 heating degree days} \times 24 \text{ hours per day} \times ((1/11.34)-(1/23.4)]} = 7,730.224 \text{ Btu per square foot}
\]

Trees - To estimate the energy-related benefits from trees, we applied the methodology described in the 2010 CNT Report for trees. We assume all trees are medium-size and are planted on a street or in a park. These trees reduce electricity use by 67 kWh per tree per year and natural gas use by 2,099 Btu per tree per year.

Summary of Air Quality-Related Benefits in Milwaukee

Green Roofs and Trees - To estimate the air quality-related benefits from green roofs and trees, we applied the methodology described in the 2010 CNT Report. We multiply the area of green roofs by the average annual pollutant uptake per square foot. We multiply the number of trees by the average annual pollutant uptake per tree per year. Then we multiply the total quantity of pollutant reduction by the estimated value per pound. Table A-1 summarizes the values we used in our calculations.

---


### Table A-1. Summary of Air Pollution Reduction Assumptions for Green Roofs and Trees

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Average Annual Uptake on Green Roofs (lbs/SF)</th>
<th>Average Annual Uptake by Tree (lbs/tree)</th>
<th>Total Value ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td>3.00x10⁻⁴–4.77x10⁻⁴</td>
<td>0.63</td>
<td>$3.34</td>
</tr>
<tr>
<td>O₃</td>
<td>5.88x10⁻⁴–9.20x10⁻⁴</td>
<td>0.2</td>
<td>$3.34</td>
</tr>
<tr>
<td>SO₂</td>
<td>2.29x10⁻⁴–4.06x10⁻⁴</td>
<td>0.42</td>
<td>$2.06</td>
</tr>
<tr>
<td>PM-10</td>
<td>1.14x10⁻⁴–1.33x10⁻⁴</td>
<td>0.26</td>
<td>$2.84</td>
</tr>
</tbody>
</table>


### Reduced Emissions

To estimate the air quality-related benefits from reduced emissions from energy production, we applied the methodology described in the 2010 CNT Report. We use the energy reductions from green roofs and trees as described above. We assume all of the reduced runoff would have been treated by a trickling filter treating over 100 million gallons per day, which uses about 672 kWh per million gallons. This is a low estimate as the water in the combined sewer area likely would have been treated by an advanced treatment facility, which uses more energy per gallon. Our assumptions on avoided emissions and emission value are in Table A-2.

### Table A-2. Summary of Air Pollution Reduction Assumptions for Reduced Emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Average Electricity Reduction (lbs/kWh)</th>
<th>Average Natural Gas Reduction (lbs/Btu)</th>
<th>Total Value ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td>0.001937</td>
<td>0.00000000721</td>
<td>$3.34</td>
</tr>
<tr>
<td>SO₂</td>
<td>0.005259</td>
<td>0.0000000266</td>
<td>$2.06</td>
</tr>
</tbody>
</table>


### Summary of Climate Change-Related Benefits in Milwaukee

To estimate the climate change-related benefits from green roofs, trees, and reduced energy use, we applied the methodology described in the 2010 CNT Report. We multiply the area of green roofs by the average annual carbon absorption rate per square foot (0.121844–0.126248 lbs CO₂/SF). We multiply the number of trees by the average annual carbon absorption rate per tree (444 lbs CO₂/tree). We multiply the energy reductions by the average carbon emissions associated with energy production (1.3488 lbs of CO₂/kWh and 0.00011689 lbs of CO₂/Btu). We multiply the carbon absorption by a range of values from the 2010 CNT Report ($0.00756–$0.0286/lb of CO₂). Furthermore, for our high range estimate, we assume the value, in real terms, increases by 2.5 percent per year.  

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4 Center of Neighborhood Technology. 2010. *The Value of Green Infrastructure.*

5 Center of Neighborhood Technology. 2010. *The Value of Green Infrastructure.*

APPENDIX B. CALCULATIONS AND ASSUMPTIONS FOR ANN ARBOR CASE STUDY

This appendix contains details describing the calculations and assumptions we used in the Ann Arbor case study. The order of this appendix follows the order of the citations in that section. Throughout our analysis, we estimate annual values of existing green infrastructure and the net present value (NPV) of potential green infrastructure over the next 50 years. We assume all potential green infrastructure is implemented linearly over the next 50 years and we use a 3 percent discount rate.

Summary of Existing Green Infrastructure Programs and Reduced Stormwater Runoff

Permeable Pavement – Data from Ann Arbor identified 2 green infrastructure projects that installed a total of 168,000 square feet of permeable pavement. The Easy Street Project had a total of 152,000 square feet of permeable pavement. We calculated this by dividing the total cost of the pavers ($1,114,000) by the price per square foot ($7.35).\(^1\) The Sylvan Avenue project had a total of about 16,000 square feet, assuming it was about 800 feet long and 20 feet wide.\(^2\) To estimate the reduction in stormwater runoff from permeable pavement, we applied the methodology described in the 2010 CNT Report for permeable pavement. We assume a range of effectiveness rates, 50–80 percent and a drainage area equal to the size of the project and 5 times the size of the project.

\[
(35 \text{ inches of precipitation per year} \times 168,000 \text{ square feet} \times 50\% \text{ effectiveness}) \times \text{unit conversion} = 1,832,600 \text{ gallons per year}
\]

\[
(35 \text{ inches of precipitation per year} \times 168,000 \text{ square feet} \times 80\% \text{ effectiveness}) \times 5 \times \text{unit conversion} = 7,330,400 \text{ gallons per year}
\]

Bioretention – Data from Ann Arbor identified one green infrastructure project that installed a bioretention area. We assume the bioretention area associated with Easy Street is the same size as the permeable pavement, 152,000 square feet. To estimate the reduction in stormwater runoff from bioretention, we applied the methodology described in the 2010 CNT Report for bioretention and infiltration. We assume a range of effectiveness rates, 50–80 percent and a drainage area equal to the size of the project and 5 times the size of the project.

\[
(35 \text{ inches of precipitation per year} \times 152,000 \text{ square feet} \times 50\% \text{ effectiveness}) \times \text{unit conversion} = 1,658,067 \text{ gallons per year}
\]

\[
(35 \text{ inches of precipitation per year} \times 152,000 \text{ square feet} \times 80\% \text{ effectiveness}) \times 5 \times \text{unit conversion} = 6,632,267 \text{ gallons per year}
\]

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Rain Gardens – Data from Ann Arbor identified over 50 rain gardens in the City. A recent report suggested that these rain gardens have the capacity to collect 25,000 gallons of stormwater from one inch of rainfall.  

35 inches of precipitation per year x 25,000 gallons per inch = 875,000 gallons per year

Summary of Air Quality-Related Benefits in Ann Arbor

Reduced Emissions – To estimate the air quality-related benefits from reduced emissions from energy production, we applied the methodology described in the 2010 CNT Report. We assume all of the reduced runoff would have been treated by a trickling filter treating over 100 million gallons per day, which uses about 672 kWh per million gallons. This is a low estimate as some of the water may have been treated by an advanced treatment facility, which uses more energy per gallon. Our assumptions on avoided emissions and emission value are in Table B-1.

Table B-1. Summary of Air Pollution Reduction Assumptions for Reduced Emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
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</table>


Summary of Climate Change-Related Benefits in Ann Arbor

To estimate the climate change-related benefits from green roofs, trees, and reduced energy use, we applied the methodology described in the 2010 CNT Report. We multiply the energy reductions by the average carbon emissions associated with energy production (1.3488 lbs of CO₂/kWh and 0.00011689 lbs of CO₂/Btu). We multiply the carbon absorption by a range of values from the 2010 CNT Report ($0.00756–$0.0286/lb of CO₂). Furthermore, for our high range estimate, we assume the value, in real terms, increases by 2.5 percent per year.

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4 Center of Neighborhood Technology. 2010. *The Value of Green Infrastructure.*

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