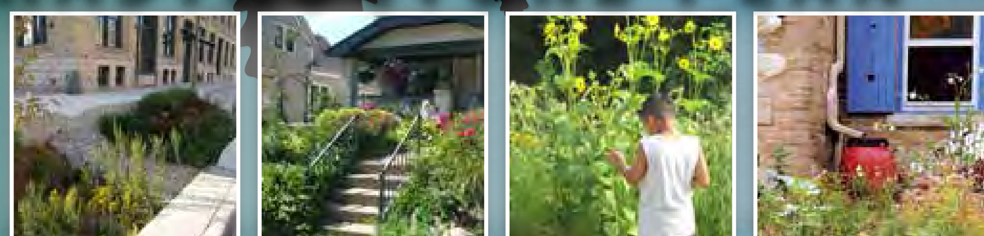
MMSD
PARTNERS FOR A CLEANER ENVIRONMENT

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

REGIONAL GREEN INFRASTRUCTURE PLAN



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Contents

EXECUTIVE SUMMARY

Over the past several decades, the Milwaukee region has transformed its approach to managing stormwater in sanitary and combined stormwater/sanitary pipes. Looking to the future, green infrastructure is one piece of the multi-tiered approach to meeting the Milwaukee Metropolitan Sewerage District's (MMSD's) **2035 Vision for zero basement backups, zero overflows, and improved water quality.** Widespread green infrastructure plays an important part of achieving the Vision by capturing stormwater and allowing it to soak into the ground or evaporate instead of entering sewers and contributing to sewer overflows or basement backups. Other necessary approaches include MMSD work (like Greenseams® and flood management) and municipal work (like system maintenance and private property work to reduce inflow and infiltration).

Green infrastructure complements the region's grey infrastructure (sewer pipes, storage tunnels, and reclamation facilities) that has been and will continue to be the backbone for meeting water quality goals and flood management for the region. Grey infrastructure can be expensive, and building bigger pipes will not solve our water quality problems.

The Regional Green Infrastructure Plan (Plan) documents how to meet the 2035 Vision goal of capturing the first 0.5 inch of rainfall on impervious surfaces, the equivalent of 740 million gallons of stormwater storage. Capturing the first 0.5 inch of rainfall in green infrastructure is an essential and cost-effective component to meeting the 2035 Vision. Together, MMSD and its partners can work together to implement this Plan's new, green vision.

A new discharge permit condition requires MMSD to add one million gallons of green infrastructure capacity to the region annually. This is the first permit in the country with a green infrastructure requirement in the body of the permit and is a first step to achieving the 740 million gallons of stormwater capacity needed to achieve the 2035 Vision.

Green infrastructure such as rain barrels, complements the region's grey infrastructure by storing and reusing rainwater, helping sewers to function as designed.

FIGURE 1

REGIONAL GREEN INFRASTRUCTURE STRATEGIES

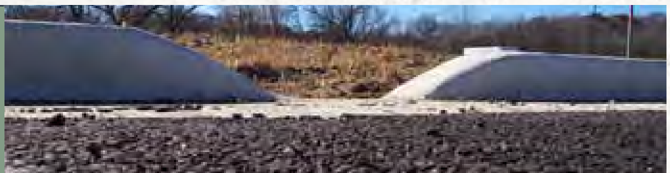
Green infrastructure strategies capture stormwater, provide natural flood management, and bring a multitude of benefits to municipalities and residents. Each strategy shown below has already been implemented throughout the region, and much more is needed to achieve the 2035 Vision goals. The Plan focuses heavily on the strategies that would treat impervious surfaces and turf grass areas to provide economic, social, and environmental benefits to the region.

GREEN ROOFS

Business owners and public property owners with large flat roofs were mapped in the Plan and are encouraged to participate in the Regional Green Roof Initiative Program.

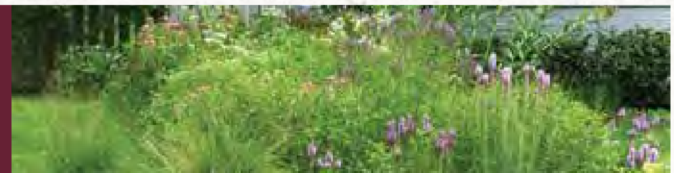
RAINWATER CATCHMENT

The Plan encourages residents and business owners to harvest rainwater. Doing so reduces energy costs and reduces unwanted stormwater from entering the sewer system.



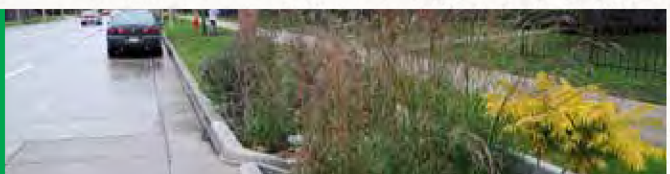
POROUS PAVEMENT

The Plan recommends use of porous materials for public and private streets and parking lots.



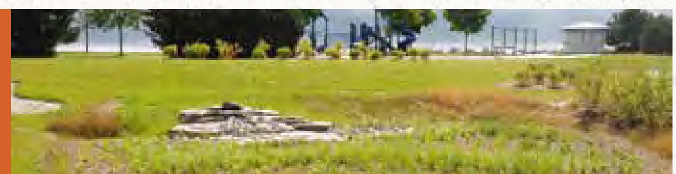
NATIVE LANDSCAPING

The Plan encourages the public, business owners, and municipalities to replace turf grass with native landscaping to reduce runoff and save money through reduced landscape maintenance.



GREEN ALLEYS, STREETS, AND PARKING LOTS

The Plan calls for green alleys, streets, and parking lots that include several green infrastructure strategies, offering multiple economic, social, and environmental benefits.



BIORETENTION/BIOSWALES

Bioretention and bioswales can be used along transportation corridors and parking lots.

RAIN GARDENS AND SOIL AMENDMENTS

The Plan encourages residents to plant rain gardens to prevent stormwater from entering the sewer system too quickly. The Plan includes soil amendments to increase water holding capacity in lawns and improve grass growth when native landscaping is not preferred.

STORMWATER TREES

The Plan encourages municipalities to plant trees. They hold rainwater on their leaves and branches, infiltrate it into the ground, absorb it through root systems and evapotranspire it to the atmosphere.

WETLANDS

Wetlands (not quantified in this Plan) also known as bogs, marshes, and swamps allow rainwater to pool and slowly infiltrate into the ground.

GREENWAYS

Greenways (not quantified in this Plan) include riparian and non-riparian buffer zones and strips that store and drain stormwater runoff into the ground naturally.

SUMMARY ANALYSIS AND RESULTS

Through this Plan, MMSD undertook a detailed data analysis of the opportunities and constraints for implementing green infrastructure strategies (Figure 1) in the seven watersheds in the MMSD planning area. Through extensive data collection and mapping, the analysis quantified the number of roads, buildings, and parking lots that can be treated with green infrastructure in order to meet the 2035 Vision of capturing 0.5 inch of rainfall per storm from impervious surfaces, which is equivalent to 740 million gallons of storage.

The Plan analysis involved collecting, creating, and analyzing extensive data—including impervious area, soils, land use, property ownership, groundwater, topography, separate/combined sewer areas, tree canopy, and other data.

The planning area has 91 square miles of impervious area made up of streets, buildings, parking lots, airports, and other imperviousness (Figures 2 and 3). The analysis considered different land uses that can be targeted with a combination of green infrastructure strategies. This approach will help the region make green infrastructure implementation decisions based upon localized conditions.

FIGURE 3

Impervious Area by Type and Ownership in the MMSD Planning Area

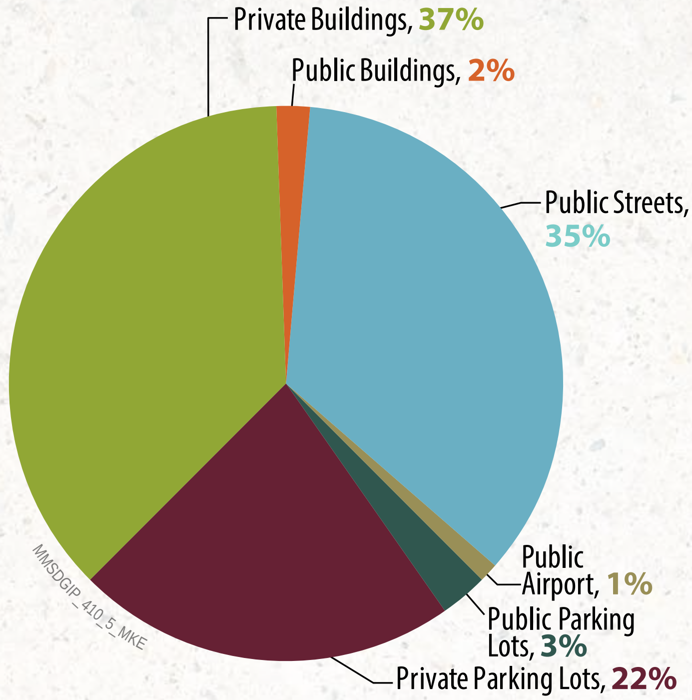
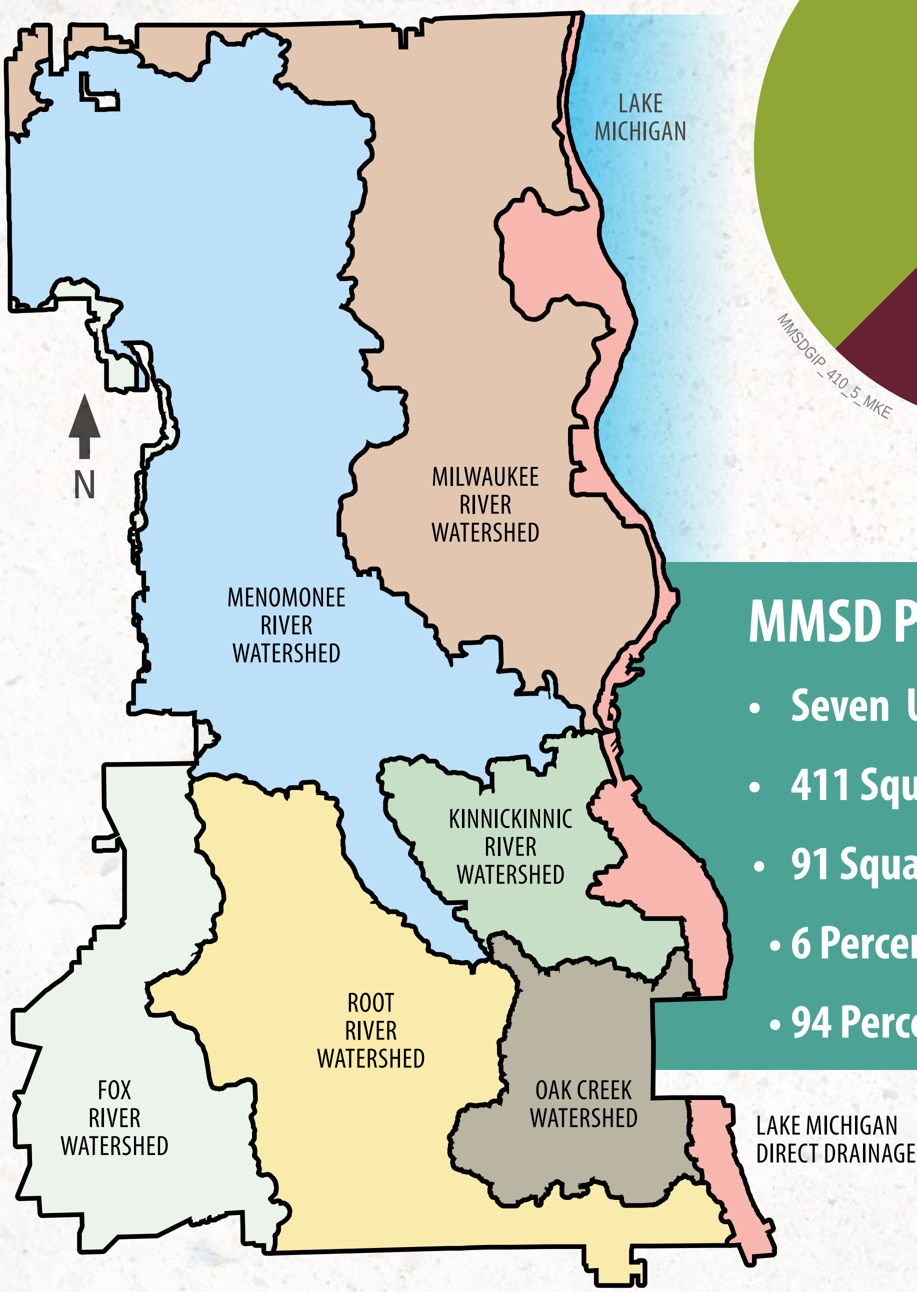


FIGURE 2



MMSD Planning Area

- **Seven Unique Watersheds**
- **411 Square Miles**
- **91 Square Miles of Impervious Area**
- **6 Percent Combined Sewer Area**
- **94 Percent Separate Sewer Area**

The storage volume provided by each green infrastructure strategy to meet the 2035 Vision goal of 740 million gallons of stormwater throughout the planning area is shown in Figure 4. Porous pavement and bioretention/rain gardens provide the majority of storage volume from green infrastructure targeting impervious areas, while soil amendments and native landscaping provide a comparable amount of storage targeting turf grass areas.

The results in Table 1 show overall quantities that need to be implemented regionwide to achieve the 2035 Vision. The Plan also contains specific green infrastructure recommendations for each of the seven MMSD planning area watersheds—providing planning information for municipalities to make more cost-effective spending decisions.

Watershed-specific characteristics such as land use, informed MMSD about what strategies would work in each unique watershed and the implementation amounts necessary to meet the 2035 Vision rainwater capture goal. Watershed-specific recommendations enable municipalities to make more cost-effective spending decisions.

Adding 740 million gallons of stormwater capacity through green infrastructure holds 14.8 billion gallons of stormwater each year.

FIGURE 4
Storage Percentage by Green Infrastructure Strategy[1]

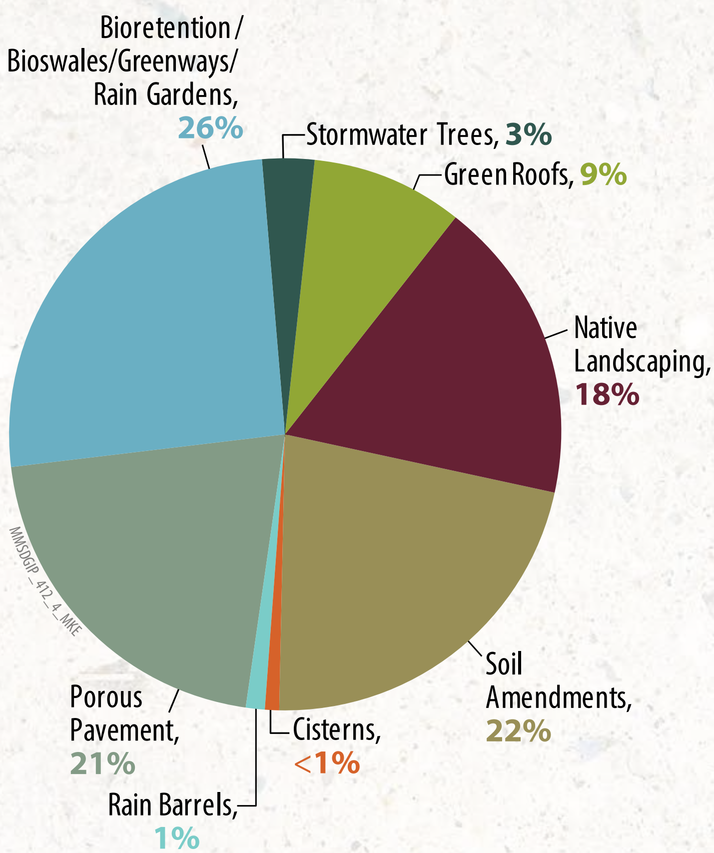


TABLE 1
Planning Area Green Infrastructure Quantities[1]

Green Infrastructure Strategy	Quantity	Description
Green Roofs	1,490 acres	Equivalent to 13,000 buildings with new green roofs (assumes 5,000 SF per roof)
Bioretention/Bioswales/ Greenways/Rain Gardens	650 acres	Equivalent to 189,000 rain gardens (10 feet by 15 feet each)
Stormwater Trees	738,000	Equivalent to nine new trees per average city block
Native Landscaping	8,600 acres	Equivalent to 1,700 average city blocks with native landscaping
Porous Paving	1,190 acres	Equivalent to 10,300 average city blocks having 25 percent porous pavement
Rain Barrels	152,000	Equivalent to 152,000 homes with one rain barrel each
Cisterns	2,020	Equivalent to 2,020 larger buildings with a cistern (assumes minimum 6,500 SF roof)
Soil Amendments	15,200 acres	Equivalent to 2,900 average city blocks with soil amendments

1 *The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.*

TRIPLE-BOTTOM-LINE BENEFITS

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

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Economic Benefits

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

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

Increased Property Values

The triple-bottom-line analysis indicates a potential property value increase of $667 million ($409 million in residential areas, $238 million in commercial areas, and $20 million in industrial areas) after Plan strategies are fully implemented.

Social Benefits

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

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

> *"With over 60 percent of the pollutants now coming from stormwater, there is no simple end-of-pipe solution. The solution necessitates the engagement of the citizens throughout communities who assume the responsibility for stormwater generated on their own property and act to reduce its impact."*
>
> **Source:** Implementation Plan and Priority Project List for the Kinnickinnic River Watershed (summary of Milwaukee Area Household Survey conducted by the Southeastern Wisconsin Watersheds Trust)

Environmental Benefits

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

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

PLAN IMPLEMENTATION COSTS

The cost of green infrastructure is well balanced by its benefits. The Plan considers costs in two different ways:

- Stand-alone Costs: The costs associated with stand-alone or retrofit projects (installing a green roof on top of an existing building or replacing conventional pavement with porous pavement, for example) .
- Incremental Costs: The incremental costs of green infrastructure represent the cost difference between conventional construction and construction that incorporates green infrastructure (such as the incremental cost of installing a green roof instead of a conventional roof replacement or the cost difference between conventional pavement and porous pavement). Incremental cost is also sometimes referred to as the additional or marginal cost of green infrastructure. The average incremental cost per gallon is $1.76 in this Plan.

FIGURE 5

Incremental Capital Cost per Gallon of Storage

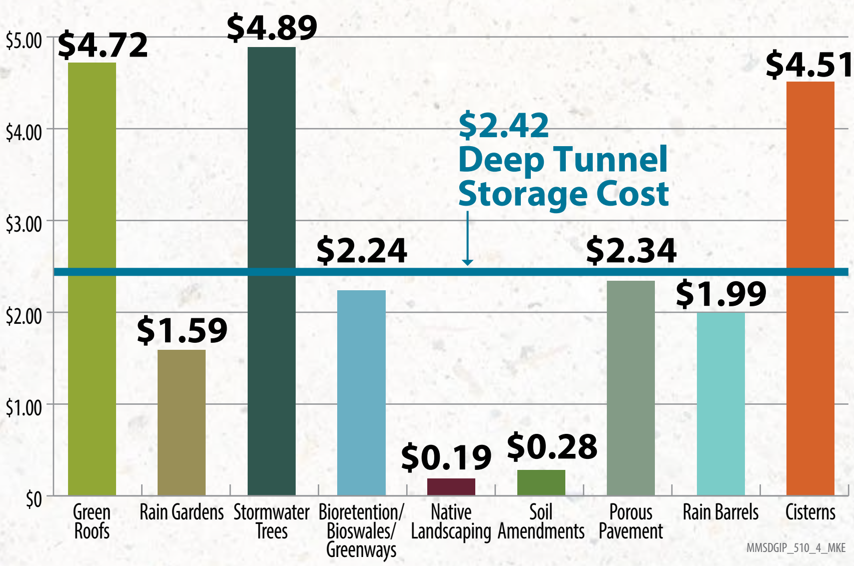


Figure 5 shows the incremental capital cost per gallon of storage capacity. The cost per gallon storage capacity provides a comparison of the relative cost of storage by green infrastructure strategy. Most of the strategies are estimated to provide storage capacity at a lower unit cost than the $2.42 cost per gallon of Deep Tunnel storage, as reported in "Fresh Coast Green Solutions" (MMSD 2009). The Plan recommends using each of the strategies and not just the least expensive ones because achieving the 2035 Vision requires a portfolio of green infrastructure strategies that can address buildings, streets, parking lots, and turf grass areas.

The Plan implementation cost reflects the incremental cost to include the efficiency of constructing green infrastructure with planned capital construction projects.

Figure 6 shows the Plan incremental capital costs for green infrastructure applied by land use and Figure 7 shows the Plan incremental capital cost by green infrastructure strategy. To achieve the 2035 Vision goal of providing 740 million gallons of new storage capacity, the Plan estimates a capital cost of $1.3 billion for full implementation, or approximately $59 million per year. This reflects a cost savings of $850 million or nearly 40 percent compared to green infrastructure constructed as stand-alone projects that would otherwise cost $2.15 billion. This means that significant cost savings can be realized by including green infrastructure in planning and preliminary design discussions, rather than trying to implement after the fact. The Plan also estimates incremental annual operation and maintenance costs at $10.4 million. Costs are roughly split between the public and private sectors.

FIGURE 6
Plan Green Infrastructure Investment Target Area

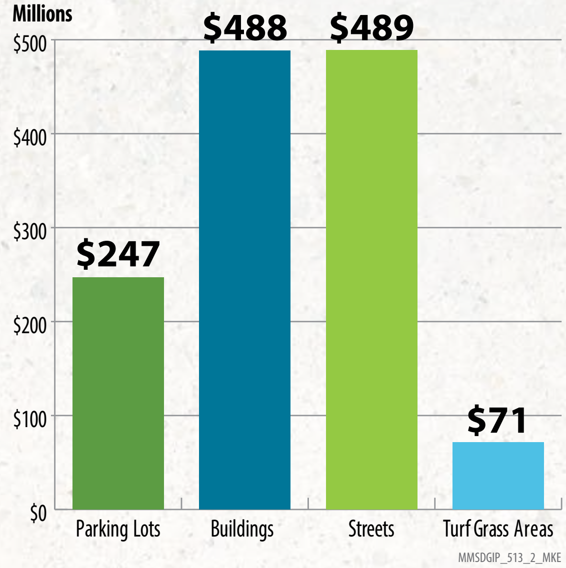
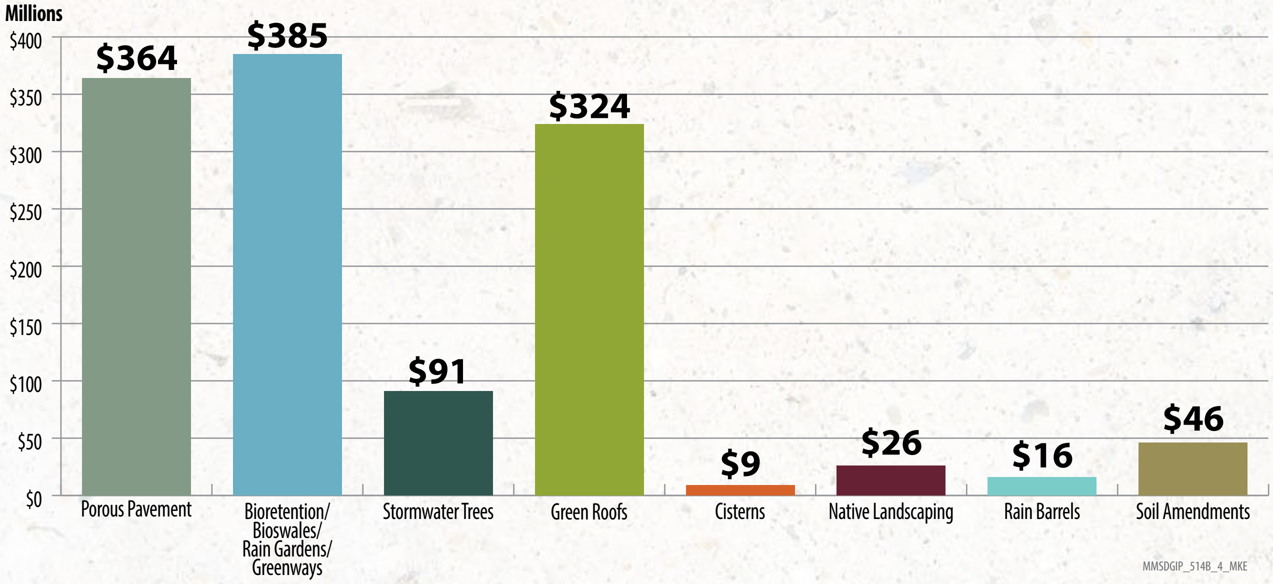


FIGURE 7
Plan Cost by Green Infrastructure Strategy



The Plan provides a cost-effective path to achieving the 2035 Vision. The analysis considered the costs and benefits of multiple green infrastructure strategies and land use characteristics, enabling informed recommendations for each watershed. Now, MMSD, municipalities, and residents have the data necessary to strategically invest in green infrastructure to help reduce basement backups and sewer overflows.

RECOMMENDATIONS

The Plan identifies the types and amount of green infrastructure needed to achieve the MMSD 2035 Vision rainfall capture goals. This will require actions within the next 5 years to establish a foundation for long-term success. Specific action items and timelines are provided in the Plan for the following overarching recommendations (Figure 8).

Expand Collaboration. Success requires participation from residents, municipalities, partnering agencies, and commercial/industrial property owners. While the Plan is regional, implementation will vary in each municipality. Collaboration among agencies and groups developed through demonstration projects and programs (rain barrel, rain garden, green roofs, etc.) will be reinforced and expanded.

Develop Programs and Implement Projects. Several great programs are already in place. The Plan recommends additional demonstration projects and expansion of current green infrastructure programs to include the suite of strategies anticipated for each watershed, working across political boundaries.

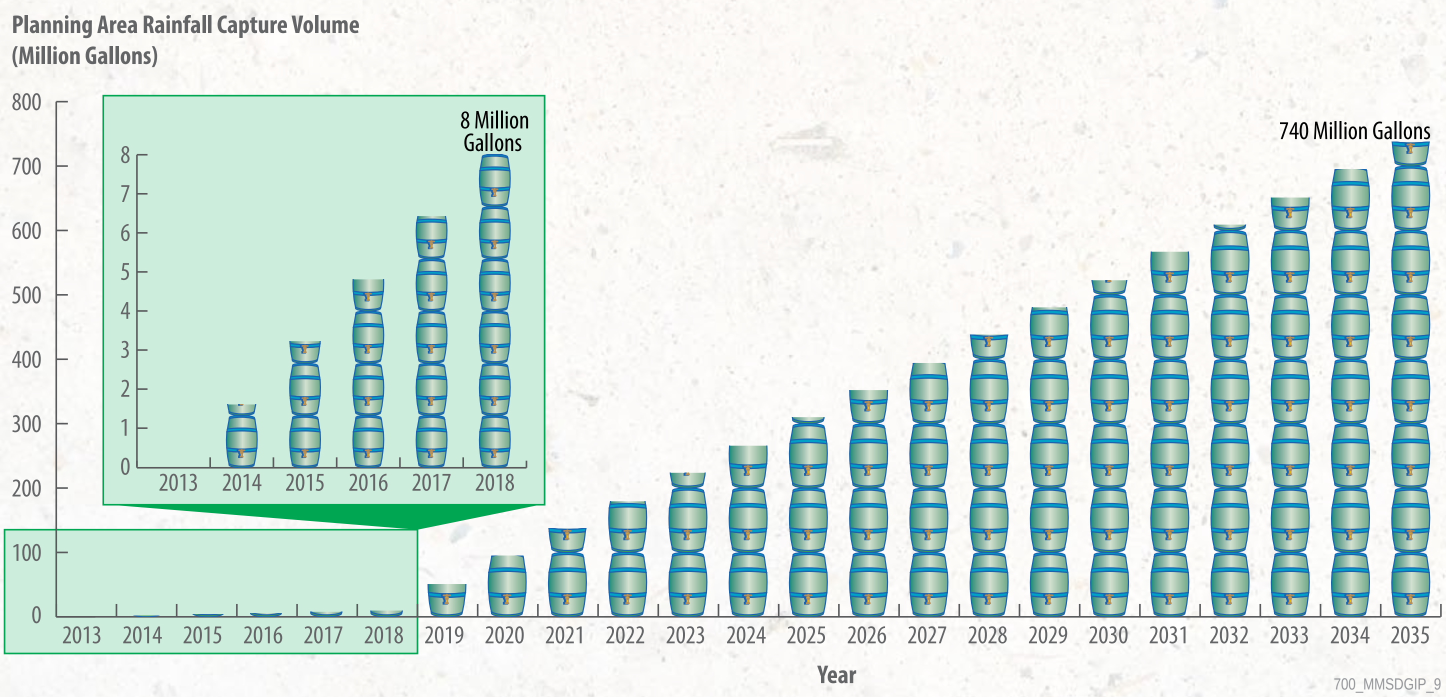
Standardize. Standardizing when green infrastructure is required, how it is designed, how it is reviewed and approved, and how it is maintained, will make it easier to implement across the region.

Fund. Funding construction and maintenance is a critical success factor. Identifying new/redevelopment green infrastructure requirements, funding methods, and making appropriate investments to spur local green infrastructure innovation and job training are all part of achieving cost-effective green infrastructure solutions for the region.

Learn, Share, and Adapt. As local best practices continue to develop, the region's municipalities should learn from each other and cultivate a supportive environment to share information and resources. Adapting to incorporate best implementation practices as they change over time will provide great value to the region.

FIGURE 8

Timeline for Achieving an Equivalent 0.5-inch Rainwater Volume Capture



Rain garden ground breaking

GROUNDBREAKING PLAN PROMOTES INTEGRATED WATERSHED MANAGEMENT

The Plan for the Milwaukee region offers the following unique aspects:

+ It is the first plan for a major metropolitan area that looks beyond the combined sewer system.
+ It includes the separate sewer system in the analysis to demonstrate how green infrastructure complements private property inflow and infiltration reduction and how it supports TMDL requirements.
+ The level of green infrastructure commitment was made without a consent decree or state order.
+ Its triple-bottom-line analysis is the first to document benefits to both the combined and separate sewer systems.
+ It promotes native landscaping in turf grass areas to reduce runoff and improve water quality. Where turf grass is preferred, the Plan offers soil amendments as an alternative that improves turf grass health, while adding water holding capability.

MMSD's 2035 Vision for zero basement backups, zero overflows, and improved water quality are important to everyone. These issues are not just happening here in the Milwaukee region—the effects of extreme storms continues to grip the world. MMSD continues its leadership role to mitigate climate change and its effects through innovative and sustainable projects, but recognizes that participation by everyone is crucial for success.

MMSD Resources and Related Programs

MMSD – **mmsd.com**

H2OCapture – MMSD's Green Infrastructure Website – **h2ocapture.com**

Private Property Inflow and Infiltration Reduction Program – **basementconnection.mmsd.com**

GREEN INFRASTRUCTURE IN THE MILWAUKEE REGION

MMSD has a long history of environmental stewardship and has implemented holistic approaches to improve water quality and protect residents from the effects of flooding. With a changing climate, it has never been more important to manage stormwater flow to improve drainage and water quality. MMSD has put additional focus on using green infrastructure as a cost-effective means to protect the region's property and water resources. Green infrastructure reduces the volume of stormwater entering the sewer systems and complements the Private Property Inflow and Infiltration Reduction Program. MMSD continues its leadership role to mitigate climate change and its effects through innovative and sustainable projects, but recognizes that participation by everyone is crucial for success.

INTRODUCTION

MMSD's grey infrastructure, such as sewer pipes, storage tunnels, and reclamation facilities, has been and will continue to be the backbone for meeting water quality goals and flood management protection for the region. Grey infrastructure is expensive and building bigger pipes will not solve all water quality problems. Capturing the first 0.5 inch of rainfall in green infrastructure on impervious surfaces is an essential and cost-effective component to meeting the 2035 Vision of zero overflows and zero basement backups.

In 2009, MMSD published "Fresh Coast Green Solutions" (Figure 9) to educate the public and municipalities on 10 key green infrastructure strategies and their benefits (see next page). The Regional Green Infrastructure Plan (Plan) presents broad implementation strategies for both the short and long term and emphasizes capturing stormwater runoff with permeable surfaces to mimic natural processes. Such strategies take advantage of infiltration and evaporation to reduce stormwater runoff. This section explains these strategies and the existing programs that will be expanded in order to meet the goals of the 2035 Vision.

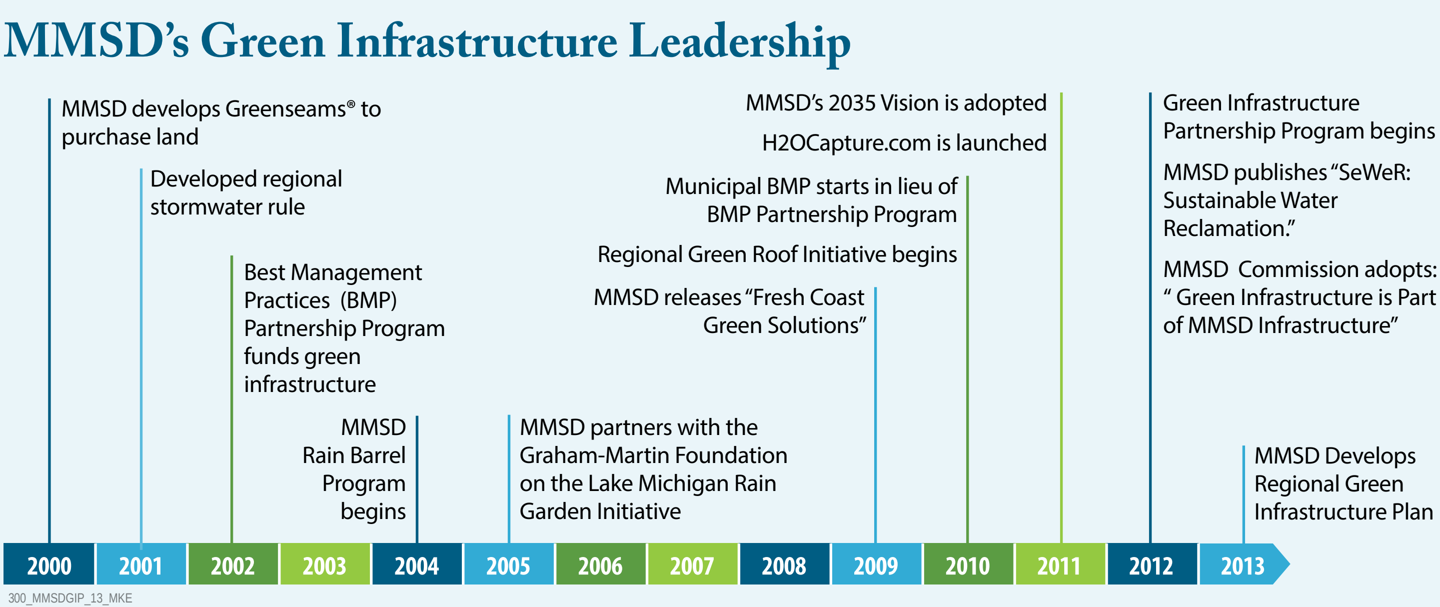
SUCCESSFUL STRATEGIES AND PROGRAMS

Since the 1990s, MMSD has implemented green infrastructure strategies (Figure 10) because they either hold or slow down the natural flow of water to discharge points and because they complement grey infrastructure by adding capacity. Green strategies also clean and reduce the amount of stormwater runoff volume and pollution carried into creeks, rivers, and Lake Michigan. Using this holistic approach to watershed management provides natural stormwater and flood management features and helps meet existing and pending water quality regulations, while preserving aquatic species, protecting wildlife habitat, and beautifying neighborhoods.

MMSD leads several programs that have been a great success and that will be expanded over the next several years, including the following:

- Rain Barrel Program
- Lake Michigan Rain Garden Initiative
- Regional Green Roof Initiative
- Green Infrastructure Partnership Program
- Greenseams®

FIGURE 9



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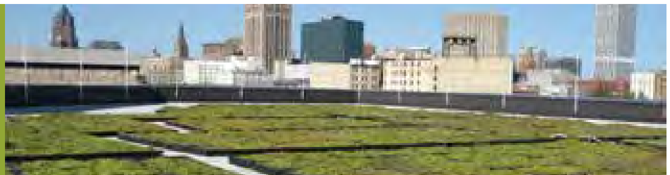

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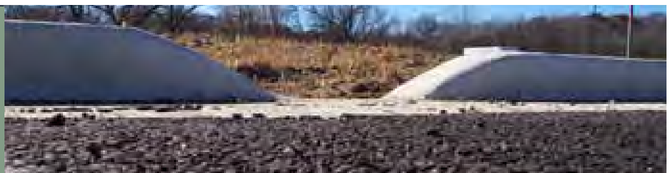

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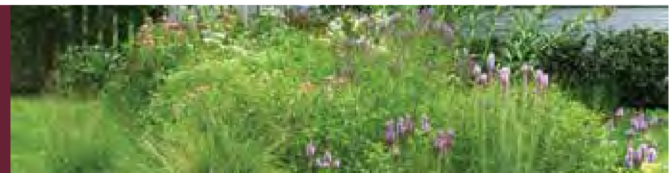

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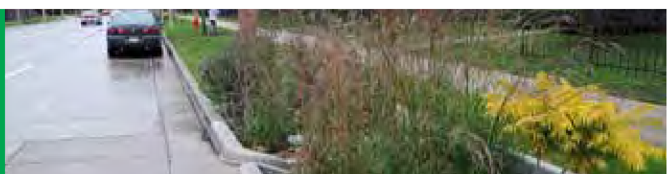

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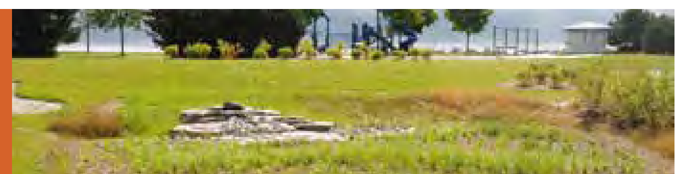

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An MMSD rain barrel stores 55 gallons of water, preventing that water from carrying pollution into area waterways. Residents reduce their water bill when rainwater is used to irrigate lawns, gardens, and plants.

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Rain Barrel Program

In 2004, MMSD started a comprehensive rain barrel program. MMSD's rain barrel program includes reusing 55-gallon food-grade drums, retrofitting them for stormwater collection, and managing their distribution. MMSD partnered with the Milwaukee Community Service Corps—a non-profit organization that helps young adults learn job skills and make positive community impacts—to build and deliver the barrels. Eventually the program grew and several other organizations and retailers were brought on to meet demands and offer a variety of barrels to consumers. All orders can be placed on MMSD's website (mmsd.com). To meet the 2035 Vision, many more barrels need to be installed across the region.

Lake Michigan Rain Garden Initiative

According to the Wisconsin Department of Natural Resources (WDNR), rain gardens can absorb 30 percent more water than a conventional, well-manicured lawn. The Lake Michigan Rain Garden Initiative (a partnership between the Graham-Martin Foundation and MMSD) promotes replacing grass with rain gardens, especially near downspouts, so that rainwater will infiltrate/absorb into the ground. MMSD's website offers how-to guides and grant application instructions. Homeowners can apply for a grant, and each year plants are provided at a reduced price, typically at a 50 percent discount compared to retail prices.

Neighborhoods have climbed on the bandwagon and implemented native plantings to manage stormwater, increase their property values, and to be good environmental stewards.

Increased Participation in Rain Garden Initiative Planned
Residents formed the Walnut Way Conservation Corp and planted rain gardens to help reduce sewer overflows and to revitalize their neighborhood.
Photo Source: Greater Milwaukee Water Quality Connections, a joint publication by MMSD, the Joyce Foundation, and 1000 Friends of Wisconsin.

Golda Meir Library, University of Wisconsin—Milwaukee

Rockwell Automation

Silver City Townhomes

Mequon Nature Preserve

Regional Green Roofs
Millions of gallons of stormwater are absorbed by green roofs throughout the region each year. They provide energy cost savings and more green space.

Regional Green Roof Initiative

Green roofs can hold millions of gallons of stormwater each year. Private, public, and non-governmental institutions in the region can reap the benefits of installing green roofs because they capture stormwater, reduce heating and cooling costs, and extend the life of the roof. Since 2003, MMSD has awarded grants to encourage building owners to install them. To date, 9 acres of green roofs have been funded by MMSD throughout the region, such as on Milwaukee's Central Public Library, the Mitchell Park Domes, the University of Wisconsin-Milwaukee campus, and a variety of public and privately-owned businesses.

Currently, MMSD is providing incentive funding to increase green roof coverage within the region. The Regional Green Roof Initiative currently provides money for an approved green roof project. An example of a local green roof installation's ability to store stormwater is Rockwell Automation's global headquarters on South 2nd Street. There are two dozen varieties of sedum, native wildflowers, and perennials growing in custom-blended growing media engineered to be lighweight, retain water, and promote growth that collect 40,000 gallons of rainwater or more each storm. It was completed in 2010 and is the largest single-level green roof in Wisconsin. According to a story in the Milwaukee Journal Sentinel Newspaper on July 22, 2012, the project collects more than 70 percent of all the rain that falls on it. Between June 2010 and June 2012, Rockwell's plantings absorbed 500,000 gallons of water.

The next step is increased investments and participation in green roofs, particularly in urban areas. For this Plan, the consultant team mapped all large flat roofs in each watershed and cataloged whether buildings are privately or publicly owned. This will help MMSD and others incorporate green roofs into long-range capital improvement plans and identify best candidates. For more information on green roof benefits, installations, maintenance, or funding, visit www.h2ocapture.com.

Green Infrastructure Partnership Program

The Green Infrastructure Partnership Program was launched in 2012; it was the transformation of a green infrastructure program that began in 2003. Through this program, MMSD provides funding support for projects to demonstrate the importance of green infrastructure as a sustainable practice in managing the volume, rate, and quality of stormwater runoff. These projects may also catalyze more widespread green infrastructure that can benefit municipal storm and sanitary sewers, as well as the MMSD system. All projects must include education and outreach, and maintenance must be committed to.

Since 2011, MMSD invited applicants to propose green improvements and or redevelopment projects incorporating green infrastructure. In 2012, there were 20 applications and MMSD funded 13 of these projects. Two of the more significant projects are in the final stages of construction:

+ MMSD awarded $100,000 to the City of Milwaukee Housing Authority's Westlawn development for the installation of bioswales as part of the redevelopment.
+ MMSD awarded $125,208 to American Rivers for the South 6th Street Community Space redevelopment that will be part of Milwaukee's "Green Corridor." It uses a combination of green infrastructure strategies, such as porous pavement, Aqua-blocks™, native landscaping, and bioswales.

Greenseams®

To date, MMSD has preserved over 2,500 acres of land through Greenseams® and its goal is to acquire another 10,000 acres by 2035 to provide more flood management and wildlife habitat protection throughout the region.

Greenseams®

MMSD created the Greenseams® program to purchase and preserve land, particularly in flood-prone areas to prevent future flood damages. All land acquired remains undeveloped, providing recreational opportunities and protecting properties by providing the ability to store rain and melting snow. Wetlands restoration at these sites can provide further water storage and habitat benefits. This program will continue to be part of MMSD's overall watershed management strategy, but it is not dealt with extensively in the Plan. The Plan focuses on treating impervious areas and turf grass. To learn more about the program visit mmsd.com.

Deep Tunnel

Grey infrastructure, such as MMSD's Inline Storage System or Deep Tunnel, is critical to the region's growth and to eliminating overflows and basement backups. Capturing stormwater through green infrastructure will reduce stormwater runoff in both the combined sewer and sanitary sewer service areas, making it an important part of the 2035 Vision.

EXISTING REGIONAL EFFORTS

Green infrastructure complements grey infrastructure and existing watershed programs to provide a holistic approach to water management. MMSD will look for ways to incentivize its use and allocate funds towards projects that incorporate these proven strategies. Green infrastructure strategies help:

- Provide storage to reduce regional flooding
- Provide storage to lessen the burden on the combined sewer system and Deep Tunnel
- Reduce inflow and infiltration (stormwater entering the sanitary sewer system)
- Reduce stormwater pollution from entering rivers and Lake Michigan, thereby improving water quality

MMSD owns and operates about 300 miles of regional sewers that collect wastewater from 28 municipalities. All of the municipalities own and operate their own sewers—that's collectively about 3,000 miles of pipes. In addition, private sewer laterals from homes and businesses account for about another 3,000 miles of pipes. Sewer pipes, the Inline Storage System or Deep Tunnel, and water reclamation facilities are known as "grey infrastructure". Green infrastructure can improve the function of the grey infrastructure storage and sewer system. When planning capital improvement projects like street repairs or sewer replacement, municipalities can stretch their spending dollars by investing in cost-effective green infrastructure at the same time. These investments benefit residents because water captured and stored during extreme storms will help reduce basement backups and sewer overflows, protecting homes and Lake Michigan.

When planning capital improvement projects to repair or replace streets and sewers, municipalities can stretch their spending dollars by investing in cost-effective green infrastructure.

Lateral Replacement

Workers inspect a sewer lateral as part of MMSD's Private Property Inflow and Infiltration Reduction Program. Funding is set aside for the next 10 years and includes incentives for incorporating green infrastructure into the work, such as re-routing stormwater to a rain garden that would have flowed to the sanitary sewer, similar to the Shorewood Disconnects Program.

Private Property Inflow and Infiltration Reduction Program Reduces Flooding in Hard-Hit Areas

Ninety-four percent of the MMSD planning area is a separate sewer service area, while only 6 percent is a combined sewer service area. As a result, the Plan is designed to reduce combined sewer overflows, but also complement the MMSD's Private Property Inflow and Infiltration Reduction Program.

In April 2011, the MMSD Commission approved the policy and formally established the MMSD Private Property Inflow and Infiltration Reduction Program and has committed funding towards the program. Under the program, not only are sewer lateral rehabilitation and foundation drain disconnects eligible costs to be reimbursed, but site grading and green infrastructure solutions are also encouraged to remediate problems. For example, disconnecting foundation drains and installing sump pumps that direct water to soak into rain gardens is an excellent solution to reduce basement backups.

The Plan complements the Private Property Inflow and Infiltration Reduction Program by reducing the amount of excess clear water that enters privately-owned sanitary sewer laterals, a common source of the problem. Several green infrastructure strategies retain and infiltrate stormwater, and when properly located, they direct stormwater away from sanitary and combined sewers.

What is Inflow and Infiltration?

Excess water that flows into sanitary sewer pipes from groundwater and stormwater is called inflow and infiltration. Infiltration (from groundwater) seeps into sewer pipes through holes, cracks, joint failures, and broken connections. Inflow (from stormwater) rapidly flows into sewers via roof downspouts connected to the sewer, building foundation drains in homes without a sump pump, unintended storm drain cross-connections, and through holes in manhole covers.

Watershed Restoration Plans

MMSD, SEWRPC, and the Southeastern Wisconsin Watersheds Trust (SWWT) recently developed watershed restoration plans for the Kinnickinnic, Menomonee, and Root River watersheds that includes a long list of partners and green infrastructure projects aimed at solving water quality problems. Based on watershed pollution mapping, the plans identified priority areas for improvements. The plans also noted that education and outreach will be particularly important to garner residential participation in private property improvements.

The Plan supports these efforts by providing additional information to help every watershed identify priority implementation locations and key strategies based on the unique characteristics of each watershed. As part of the Plan's mapping and data gathering, locations were identified with the highest pollutant loadings (meaning significant opportunities where green infrastructure can improve water quality).

> *"With over 60 percent of the pollutants now coming from stormwater, there is no simple end-of-pipe solution. The solution necessitates the engagement of the citizens throughout communities who assume the responsibility for stormwater generated on their own property and act to reduce its impact."*

Source: Implementation Plan and Priority Project List for the Kinnickinnic River Watershed (summary of Milwaukee Area Household Survey conducted by the Southeastern Wisconsin Watersheds Trust)

Shorewood Addresses Flooding with Grey and Green Infrastructure

Shorewood has an aging sewer system with almost half the village connected to a combined sewer system. Widespread flooding in 1997 and 1999 raised public concern and spurred action. A Wet Weather Management Plan was implemented to withhold stormwater from the system, reducing both volume and peak flow. The central component of the plan was the disconnection of residential downspouts in parts of the village's combined sewer area. Rain barrels, rain gardens, and simple infiltration over lawns (away from sewer laterals) better manages the rainwater in those neighborhoods. In addition, inlet restrictors and street storage slows the flow from streets to pipes. In some areas sewer lines were upgraded, redirecting rain water to nearby storm sewers.

The work progressed through five targeted project areas over 5 years. The goal of removing 50 percent of the roof area from the combined sewer area was surpassed with over 240 roofs and 985 downspouts disconnected—an equivalent of 11 acres of impervious surface. In addition, 61 rain gardens and 268 rain barrels were installed.

Source: Greater Milwaukee Water Quality Connections, a joint publication by MMSD, the Joyce Foundation, and 1000 Friends of Wisconsin

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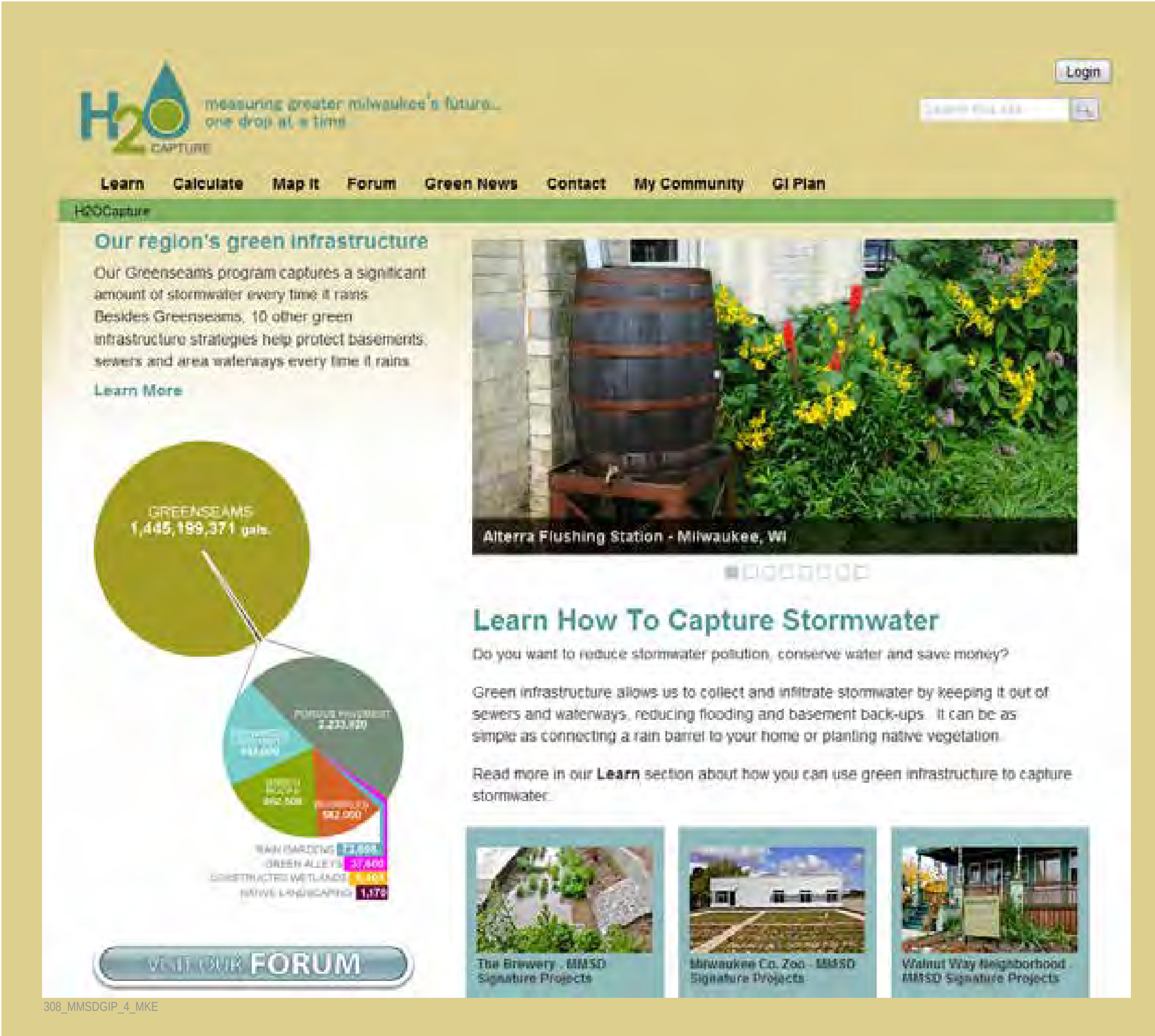


Interactive Green Infrastructure Website

H2OCapture.com informs the public and tracks regional successes in green infrastructure installation.

TRACKING SUCCESS: H2OCAPTURE.COM

Measuring performance and providing green infrastructure information to the public is an important way to ensure metrics are met and people are educated. In 2011, MMSD developed H2OCapture.com to track and map green infrastructure implementation in the region and has maintained it ever since. Essentially, the region's success is summarized here. With the click of a mouse, a user can see how many rain barrels, bioswales, Greenseams® projects, or green roofs have been implemented in the region. It is also a repository for a multitude of information on green infrastructure best practices. Visit h2ocapture.com to view green infrastructure initiatives throughout the region. There are active discussions with other interested parties to evolve the website to become a regional resource.

A new discharge permit condition requires that MMSD add 1 million gallons of new, constructed green infrastructure capacity to the region annually. This is the first permit in the country with a green infrastructure requirement in the body of the permit.

REGIONAL GREEN INFRASTRUCTURE PLAN GOALS

MMSD seeks to work closely with its 28 municipalities, counties, non-governmental organizations, and the public to capture more stormwater, harvest more rainwater for reuse, and to provide economic, social, and environmental benefits for all. The overarching goal of the Plan is to help the region strategically and cost-effectively implement solutions to help meet the MMSD 2035 Vision of zero sewer overflows and zero basement backups.

GREY INFRASTRUCTURE

When too much stormwater gets into combined and sanitary sewer pipes, the system fills up, causing sewer overflows and basement backups. This happens when stormwater enters the combined sewer system or via inflow and infiltration of stormwater into sanitary sewer pipes. When this happens, the system fills up, resulting in combined and sanitary sewer overflows. MMSD has significantly invested in grey infrastructure treatment and storage capacity. While overflows now happen only about twice a year on average, MMSD and the region want to eliminate all overflows. One part of the solution is widespread green infrastructure. Only adding grey infrastructure that would only be used twice per year on average is not cost effective, nor would it make significant headway in meeting water quality goals.

A key focus of the Plan is to reduce stormwater runoff from impervious surfaces throughout the region. Impervious surfaces, such as parking lots, roofs, and driveways, cause more stormwater runoff into sewers, leading to flooding, basement backups, public health problems, and pollution in waterways (see "Before" in Figure 11). By capturing stormwater runoff from these surfaces with green infrastructure strategies (for example, porous pavements and native plantings), MMSD will increase rain infiltration, reduce stormwater runoff and flooding, manage impacts to public health, and improve water quality. Stormwater infiltration into the ground close to where the precipitation falls allows plants to infiltrate and absorb water through root systems and evaporate it to the atmosphere (see "After" in Figure 11).

THE 2035 VISION PROTECTS RESIDENTS, BUSINESSES, AND MUNICIPALITIES

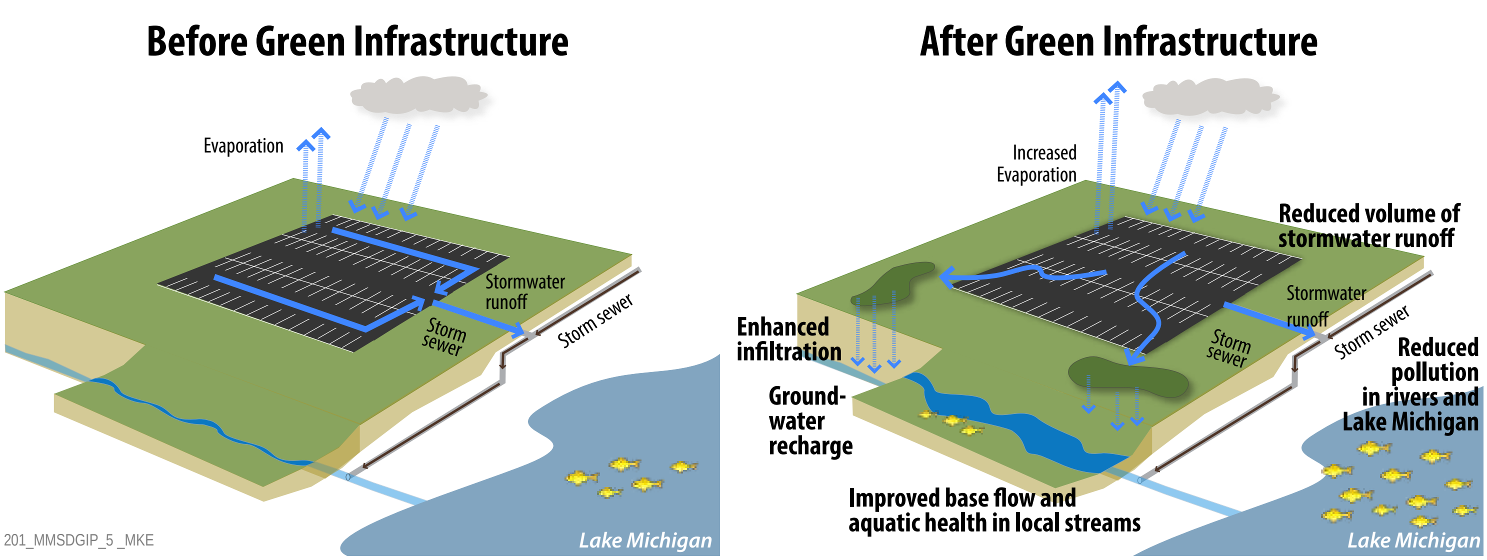
The MMSD Commission adopted the 2035 Vision Statement in 2011 to achieve its goals of zero overflows and zero basement backups. Guiding principles of the approved 2035 Vision include:

+ **Sustainable Bottom Line:** MMSD's future planning, design and operational decisions will be made based on a sustainable bottom line approach, also referred to as a triple-bottom-line. This approach considers balanced economic, social, and environmental values. The Plan has incorporated a triple-bottom-line benefits analysis to capture the economic, social, and environmental values provided by green infrastructure.
+ **Water Quality Leadership and Collaboration:** MMSD will continue to expand its leadership role in developing regional approaches that protect and improve water quality. It will also continue to develop and foster strategic alliances in its planning and project implementation. The Plan calls for regional collaboration among local government, state

FIGURE 11

Green Infrastructure Reduces Impact of Stormwater from Impervious Surfaces

Using natural processes and plants to reduce stormwater from impervious surfaces will protect property, rivers, and Lake Michigan by increasing infiltration and evaporation



Engaging the public in the benefits of the Plan and on MMSD's 2035 Vision is key to widespread green infrastructure implementation.

The Plan provides a cost-effective path to achieving the 2035 Vision. Costs and benefits of multiple green infrastructure strategies were analyzed, and land use characteristics informed the type and amount of strategies to implement in each watershed. Now, MMSD, municipalities, and residents have the data necessary to strategically invest in green infrastructure to help reduce basement backups and sewer overflows.

government, planning agencies, private property owners, and non-governmental organizations, each having an important role and a vested interest in water quality improvements.

Two Strategic Objectives were developed for the 2035 Vision that relate to the Plan. They include:

+ **Integrated Watershed Management:** This integrated approach of the 2035 Vision will focus on the infrastructure of the watersheds, seeking a healthy balance between two types of infrastructure: grey and green. The Plan considers watershed-specific characteristics to select appropriate green infrastructure implementation solutions.
+ **Climate Change Mitigation/Adaptation with an Emphasis on Energy Efficiency:** Climate change has had an effect on recent precipitation patterns, and precipitation has a direct effect on the region's sewer systems. While that direct effect is not to the point where design changes are recommended at this time based on climate modeling contracted by MMSD, green infrastructure is a safe "no regrets" strategy. The expanded use of green infrastructure in the Plan will help to save energy, mitigate climate change, and make the region more resilient in the face of intense storms.

In 2012, MMSD began work to develop the Plan and accomplish the following:

+ Evaluate and compile geographic information system (GIS) data for the MMSD planning area, including roads, buildings, parking lots, turf grass, and public/private ownership information to identify opportunities and constraints for green infrastructure.
+ Develop short-term and long-term implementation goals aligned to meeting MMSD's 2035 Vision and Strategic Objectives.
+ Develop a triple-bottom-line analysis and business case for green infrastructure implementation.
+ Create recommendations for more detailed analysis and implementation evaluation under subsequent planning.

Mequon flooding June 2008

Plan Objectives

The Plan is, in essence, a blueprint for how stakeholders throughout the region can maximize their investments in green strategies and help solve these and other environmental problems. The Plan builds upon prior green infrastructure success in the region to meet the following objectives:

- Capture the equivalent of the first 0.5 inch of rainfall from impervious surfaces with green infrastructure.
- Strive towards the 2035 Vision rainwater harvest goal of the first 0.25 gallon per square foot (SF) of area of rainfall for reuse.
- Complement MMSD's Private Property Inflow and Infiltration Reduction Program and Integrated Regional Stormwater Management Program.
- Help municipalities and other entities prioritize green infrastructure actions.
- Help meet receiving water quality standards by acknowledging Watershed Restoration Plan recommendations for the Menomonee and Kinnickinnic Rivers.
- Meet MMSD's discharge permit requirement for green infrastructure volume capture.

Stakeholder Involvement is Key to Success

Implementing green infrastructure requires work that starts in each of the 28 municipalities that MMSD serves. To obtain input and to help prioritize needs, a Technical Steering Committee for the Plan was formed. The Committee includes staff from local municipalities, the Wisconsin Department of Natural Resources (WDNR), Southeastern Wisconsin Regional Planning Commission (SEWRPC), the University of Wisconsin—Milwaukee School of Freshwater Sciences, and local environmental health advocacy organizations. Implementing the Plan will require ongoing involvement from these and other organizations, and from property owners as more detailed planning and implementation occur in the next phase of the Plan.

SUMMARY OF ANALYSIS AND RESULTS

As part of MMSD's 2035 Vision of zero overflows and basement backups, the MMSD Commission approved a goal of capturing the first 0.5 inch of rainfall from impervious surfaces with green infrastructure. Through extensive data collection and mapping, the Plan identifies multiple application opportunities for widespread green infrastructure that will reduce runoff, improve water quality, and reinvigorate neighborhoods.

Writing the Plan involved collecting, creating, and analyzing extensive data —including impervious area, soils, land use, ownership, groundwater, topography, separate/combined sewer areas, tree canopy, and more. This section describes the analyses performed to develop a green infrastructure plan to meet MMSD's ambitious 2035 Vision rainfall capture goal. At a basic level, it describes the data analysis performed and the combinations of green infrastructure strategies that shall be applied to different land use types. This approach will help the region make good green infrastructure implementation decisions based upon localized conditions.

LAND USE-BASED GREEN INFRASTRUCTURE STRATEGIES FOR STORMWATER MANAGEMENT

As discussed in previous sections and in MMSD's publication "Fresh Coast Green Solutions," there is a wide array of green infrastructure strategies available to mitigate urban and suburban stormwater. For the purposes of the Plan, 10 strategies were used to address the primary land use areas targeted for green infrastructure in the region. Table 2 lists the strategies and their intended applications.

TABLE 2
Green Infrastructure Strategy Use in the Plan

Green Infrastructure Strategy	Applicability
Green roofs	Green roofs, also known as vegetated roofs, living roofs, and eco-roofs, are applicable to relatively flat roof areas.
Rain gardens	Rain gardens treat relatively small areas of imperviousness from residential lots.
Stormwater trees	Stormwater trees are used to treat street impervious area by infiltrating stormwater, taking it up in roots, and evapotransporating it.
Bioretention/ Bioswales/Greenways	Bioretention is a larger, more engineered version of a rain garden and is primarily applicable to the street rights-of-way (ROW), parking lots, and to soak up stormwater runoff from non-residential sloped roofs.
Native landscaping	Native landscaping is applied to larger pervious areas, such as large turf grass areas, to reduce stormwater and pollution from pervious areas. (This is separate from the native landscaping that is typically included in rain gardens and bioretention).
Porous pavement	Porous pavement is associated with treating imperviousness from parking lots and the street ROW.
Rainwater catchment (rain barrels and cisterns)	Rainwater harvesting with rain barrels and cisterns is used to collect roof stormwater. Stormwater may be reused to water landscaping and urban agriculture.
Soil amendments	Soil amendments/improvements such as compost addition and soil aeration are included for residential yards.
Green alleys, streets, and parking lots	These strategies are included in the Plan through the use of other strategies such as porous pavement, stormwater trees and bioretention/bioswales.
Wetlands	Wetlands are recommend in this Plan, but not quantified. Restoring wetlands is supported through the Greenseams® program. Constructed wetlands are encouraged and can be implemented in exchange for other green infrastructure strategies where site specific conditions support constructed wetlands.

PERFORMANCE BY STRATEGY

Table 3 includes the assumed stormwater performance capacities for the green infrastructure strategies. The capacities were developed based on typical configurations and material properties of the strategies, and they are generally consistent with the capacity ranges noted in MMSD's publication "Fresh Coast Green Solutions." While the benefits and capacities will vary based on site-specific conditions, the values in the table are indicators for planning purposes. The annual performance varies dramatically among practices, largely due to the variation in the amount of impervious area that a given strategy can manage. For example, 1 SF of bioretention is expected to manage, on average, stormwater runoff from 12 SF of impervious area and one rain barrel captures 350 SF of residential roof runoff, while 1 SF of green roof only treats 1 SF of impervious area (i.e., the rainfall that falls directly on it). Annual runoff capture performance is based on average Milwaukee region rainfall.

TABLE 3

Assumed Stormwater Performance Capacities by Green Infrastructure Strategy[1]

Green Infrastructure Strategy	Unit of Measure	Potential Storage Capacity (gallon)[2]	Expected Impervious Area Managed Per Unit (SF)	Equivalent Capacity (inches from contributing area)[3]
Green roofs	SF	1.1	1	1.70
Rain gardens	SF	4.4	12	0.58
Stormwater trees	Each	25	157	0.26
Bioretention/Bioswales/ Greenways	SF	7.5	12	1.00
Native landscaping[4]	SF	0.4	N/A	0.58
Porous pavement	SF	3.0	4	1.20
Rain barrels	Each	55	350	0.25
Cisterns	Each	1,000	6,500	0.25
Soil amendments[4]	SF	0.2	N/A	0.39

[1] The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.

[2] This is the physical storage capacity per storm.

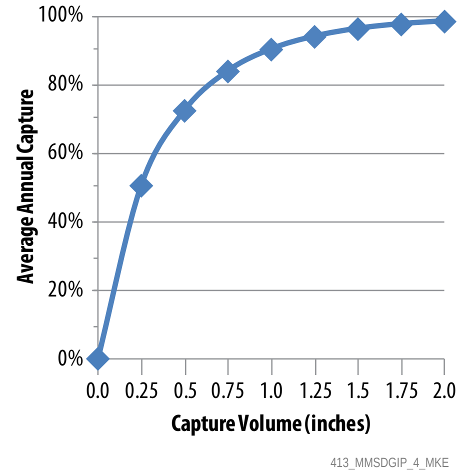
[3] Annual capture is determined using equivalent capacity with Figure 12.

[4] Capacities for native landscaping and soil amendments are estimated based on Natural Resources Conservation Service runoff curve number changes during a 2-inch rainfall.

Quantifying the volume of stormwater each strategy would manage determined how much "bang for the buck" each strategy provides, and it helped determine the amount of infrastructure needed to meet the equivalent volume of the 2035 Vision rainfall capture goal. Green infrastructure capacity and performance are tracked in two ways: on a potential physical storage capacity basis and on an average annual basis. Green infrastructure performance tracking on an annual basis factors in the potential storage capacity, drainage area, and local rainfall characteristics to determine benefits, such as pollutant reduction, while the physical storage capacity provides information relevant to MMSD's 2035 Vision rainfall capture goals and WPDES permit.

Tradeoffs occur between constructing larger volumes for per storm rainfall capture and annual rainfall capture efficiency. As shown in Figure 12, larger capture volumes are incrementally less "efficient" (or cost effective) on an annual performance basis because the available storage is used less often. This is because the percent of rainfall captured reaches a point of diminishing return—meaning designing for smaller storms is more efficient because the storage volume is full for many storms, while big storms don't happen that often so designing for these larger storms all the time is not as cost-effective. The analysis considered both per storm volume and annual volume capture to fully evaluate all benefits to the region.

FIGURE 12
Rainfall Capture Analysis Based on Daily Rainfall Data at Milwaukee's General Mitchell International Airport (1940-2011)



The storage volume of capturing 0.5 inch of rainfall from 4 acres is the same storage volume as capturing 2 inches of rainfall from 1 acre. On an annual basis, the 0.5 inch of rainfall capacity over 4 acres is much more efficient, because the infrastructure capacity is utilized for most storms.

GREEN INFRASTRUCTURE ANALYSIS BY WATERSHED

Stormwater impacts are directly linked to the amount and type of impervious land cover. This section describes the process and methodology used to analyze the MMSD planning area for green infrastructure opportunities and constraints.

Land use and impervious area data were used to develop specific green infrastructure implementation goals to capture an equivalent of the first 0.5 inch of rainfall from the planning area's imperviousness. The results from the land use and impervious area analysis informed important green infrastructure implementation information including: pollutant reductions, combined sewer overflow reductions, construction costs, and maintenance costs.

Impervious Area

Knowing watershed impervious area leads to understanding the green infrastructure capture goals and then developing green infrastructure solutions tailored to the type of impervious area present. To evaluate this need, an extensive geographic information system (GIS) database was developed to identify specific impervious areas and suitable locations for green infrastructure implementation. Features used to create the impervious cover layer included building footprints, roadways, and parking lots. Data for sidewalks, driveways, and garages were not available. Therefore, an estimate of imperviousness was made to account for these areas.

Land Use and Ownership Analysis

Knowing the land use type where impervious area exists allows informed decisions on the right type of green infrastructure strategies to recommend. Consequently, the impervious GIS layer was combined with the property parcel data to determine land use-based impervious area.

Detailed land use information provided by SEWRPC enabled recommendations on the appropriate green infrastructure strategies and implementation targets. For example, rain gardens are used to treat residential impervious area, whereas a combination of porous pavement, stormwater trees, and bioretention is recommended for local streets. The land use and impervious area information provided the basis to determine the amount of each green infrastructure strategy needed to achieve the 2035 Vision (Figure 13).

Land use ownership was further refined to identify publicly- and privately-owned properties. This allowed for a more detailed evaluation of the green infrastructure strategy recommendations and will influence implementation options. For example, demonstration projects and standard institutionalized design procedures can be more effective implementation methods on public property than on private property. On private property, effective methods include incentives or redevelopment requirements. While not analyzed in this document, reducing unnecessary imperviousness (depaving) is an important stormwater-friendly strategy on public and private property. A land use map for the planning area is provided in the Appendix (Figure A-1).

FIGURE 13

TARGETED AREAS AND APPLICABLE GREEN INFRASTRUCTURE STRATEGIES

In each watershed, the consultant team categorized and mapped land use types to target areas for green infrastructure implementation.

STREET RIGHT-OF-WAY IMPERVIOUSNESS

Street ROWs represent 37 percent of the region's impervious area and are publically owned, which provides greater control over strategy implementation than on private lands.

Primary Green Infrastructure Strategies

+ Porous Pavement
+ Bioretention
+ Stormwater Trees

Summary of Data Analysis

Road pavement edge and street ROW information were used to calculate the impervious and pervious areas within the street ROW. The impervious area was increased by 15 percent to account for sidewalks and driveway aprons.

Stormwater trees can be planted by themselves or as part of more engineered stormwater systems.

Permeable pavers transformed the Josey Heights subdivision in Milwaukee to reduce stormwater runoff.

RESIDENTIAL IMPERVIOUSNESS

Rain barrels and rain gardens enable residents to "do their part" when it comes to environmental stewardship. These strategies directly complement MMSD's Private Property Inflow and Infiltration Reduction Program to help achieve zero basement backups and sewer overflows.

Primary Green Infrastructure Strategies

+ Rain Barrels
+ Rain Gardens

Summary of Data Analysis

Residential building footprint data and the land use data were used to calculate residential impervious area. An additional 30 percent was added to the residential impervious area to account for garages, driveways, sidewalks, and patios which could use porous pavement if desired.

Donated rain barrel from the Great Waters Group of the Sierra Club, beautifully painted by local artist Cheri Briscoe.

A rain garden in Bay View absorbs stormwater before it flows into the sewer.

RESIDENTIAL YARDS

Not all residents want rain gardens in their yards. Soil amendments can improve turf grass growth while capturing more rainfall.

Primary Green Infrastructure Strategies

+ Soils Amendments
+ Rain Gardens

Summary of Data Analysis

Residential impervious area was subtracted from the total residential area to estimate the residential pervious area. Fifty percent of the remaining area was estimated as turf grass.

Photos courtesy of Melissa Tashjian, Kompost Kids, Inc.

Kompost Kids, Inc. gather food residuals from area businesses to create compost/ high quality soil.

Photos courtesy of Melissa Tashjian, Kompost Kids, Inc.

Kompost Kids volunteers composted the plates, cups, and food residuals from the Bay View Bash to make amended soils.

NON RESIDENTIAL BUILDING IMPERVIOUSNESS

Large commercial and governmental buildings represent a significant amount of imperviousness in the region, and their large flat roofs lend themselves to green roof implementation, as well as large volume cisterns for rainwater harvesting. Bioretention will be implemented for pitched roofs and other impervious area, such as sidewalks, plazas, and driveways.

Primary Green Infrastructure Strategies

- Green Roofs
- Bioretention
- Cisterns

Summary of Data Analysis

Non-residential building footprint and land use data were used to calculate non-residential building impervious area. The commercial portion of the non-residential impervious acreage was increased by 30 percent to account for sidewalks, small buildings, and miscellaneous impervious areas that were not included in the building layer.

This green roof on the Milwaukee Public Museum was installed under one of MMSD's funding programs.

Cisterns range from buried plastic to concrete tanks to stainless steel units such as these at the Woodlawn Library in Delaware.

PARKING LOT IMPERVIOUSNESS

Parking lots represent 21 percent of the region's impervious surfaces and can be treated with porous pavement and bioretention.

Primary Green Infrastructure Strategies

- Porous Pavement
- Bioretention

Summary of Data Analysis

Parking lot area was estimated within Milwaukee County using Light Detection and Ranging data, and outside of Milwaukee County using land use data.

This bioretention area at Bradford Beach absorbs parking lot stormwater, protecting Lake Michigan.

Dedicated in November 2012, Milwaukee County's Sports Complex parking lot features over 2 acres of permeable pavers.

LARGE TURF GRASS AREAS

Large turf grass areas are both publicly and privately owned and can be replanted with native vegetation to capture more rainfall, protect habitat, and lower maintenance costs.

Primary Green Infrastructure Strategies

- Native Landscaping

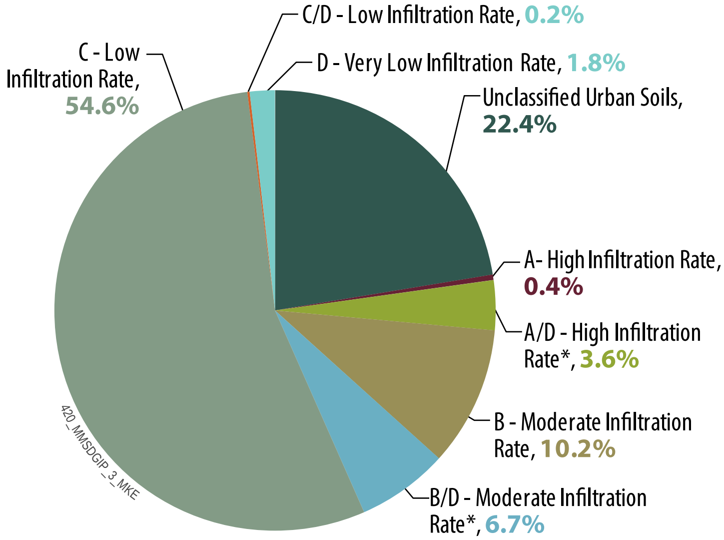
Summary of Data Analysis

Large turf grass areas were estimated by subtracting known impervious areas, forested areas, and natural areas from non-residential properties. Fifty percent of this remaining area was estimated as turf grass.

Native landscaping at Lisbon and 100th Street in Milwaukee captures more rainfall than turf grass would.

Native landscaping at the Zeeland School District in Michigan reduces maintenance costs, improves water quality, and provides an educational opportunity.

FIGURE 14
Soils Classification in the Planning Area



** For dual classifications the soil will have a very low infiltration rate unless drained*

Soils

Understanding soil infiltration characteristics is important when evaluating green infrastructure strategy performance and rainfall infiltration benefits. Soil infiltration is an important parameter when designing rain gardens, bioretention, and porous pavement. The majority of the planning area has soils with low to moderate infiltration rates. However, properly designed green infrastructure can still be effective in capturing rainfall in these soil types. The Plan considered the hydrologic soil group classifications for the region (Figure 14). Hydrologic soil group classifications vary from Type A sand soils, having high infiltration potential, to Type D clay soils, having very low infiltration potential.

Much of the region has low infiltration potential or unclassified urban soils that may impact the type or configuration of green infrastructure strategies. Unclassified urban soils have been disturbed through construction, fill, grading, and development, and are consequently difficult to classify. Low soil infiltration potential soils dominate in the region, so soil amendments could be useful to improve water storage potential. Green infrastructure implementation, even on low infiltration soils, can still be beneficial; however, green infrastructure strategies should not rely solely on infiltration to achieve intended results. During detailed green infrastructure design, site investigations and soil testing can help identify soil compaction, building debris, contamination, pH, lack of plant nutrients, and other potential issues. These issues can be addressed through the use of soil amendments, underdrains, and other appropriate techniques.

Watershed Area

In the 411-square-mile MMSD planning area, about 6 percent of the area, or 26 square miles, is the combined sewer service area (CSSA). The remainder is the separate sewer service area (SSSA), which makes up 385 square miles. Table 4 breaks this down by watershed. There are green infrastructure implementation benefits in both the SSSA and CSSA, with water quality and drainage improvements to the SSSA and combined sewer overflows reduced in the CSSA. The Plan considers green infrastructure opportunities in both areas to document the benefits to the region's rivers and Lake Michigan.

TABLE 4
Drainage Area by Watershed

Watershed	Separate Sewer Service Area (square miles)	Combined Sewer Service Area (square miles)	Total Area (square miles)
Kinnickinnic River	20.7	4.0	24.7
Lake Michigan Direct Drainage	19.8	1.5	21.3
Menomonee River	126.0	5.7	131.7
Milwaukee River	80.1	14.9	95.0
Oak Creek	24.9	0.0	24.9
Root River	71.8	0.0	71.8
Fox River (Mississippi River Watershed)	41.8	0.0	41.8
Total	**385.1**	**26.1**	**411.2**

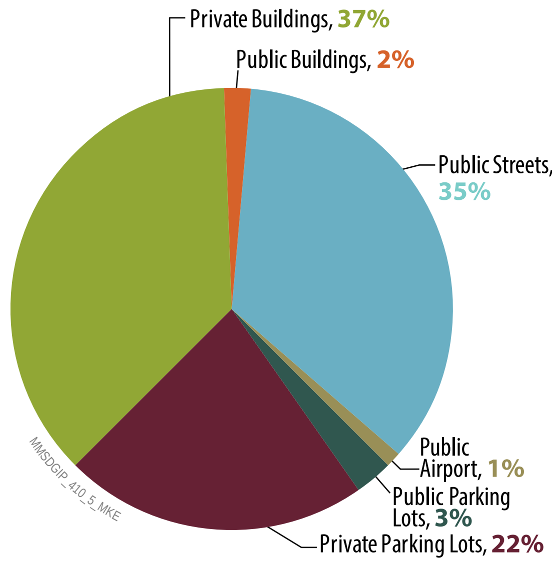
Summary Results of Impervious Area Analysis

The recommended distribution of green infrastructure is based upon the size, implementation opportunities, and constraints of each watershed.

The impervious area type is used in conjunction with land use information to determine realistic treatment goals and appropriate green infrastructure strategies for achieving the goals. The impervious area information indicates a variety of green infrastructure strategies will be needed to achieve the overall 2035 Vision goals. For example, with the three major impervious area categories of streets, buildings, and parking lots, to make progress in the region towards capturing an equivalent of 0.5 inch of rainfall, green infrastructure implementation strategies (see Table 3) will be needed for each of the impervious area types based on the type of opportunity they present. Figure 15 shows a breakdown of impervious area by type and land ownership in the MMSD planning area.

FIGURE 15

Impervious Area by Type and Ownership in the MMSD Planning Area



The 91.1 square miles of impervious area within the MMSD planning area equates to an average impervious area of approximately 2,300 SF per person.

Understanding Watershed Impervious Areas Leads to Tailored Green Infrastructure Solutions

Using MMSD's 2035 Vision goals of capturing the first 0.5 inch of rainfall, applying that to the impervious area, and considering the first 0.25 gallon per square foot for rainwater harvesting, the following capture volume goals apply to each watershed. Some impervious surfaces may already meet the 2035 Vision goals through disconnection to pervious areas or coverage by existing tree canopy. To account for this, the 2035 Vision capture goals were adjusted to account for existing tree canopy in the public right-of-way (ROW) (to be conservative, adjustments were not made for canopy in other areas). Based on detailed tree canopy data from the City of Milwaukee, which account for nearly 44 percent of the non-freeway street imperviousness in the planning area, 20 percent of the street impervious area is estimated to be covered by the tree canopy (City of Milwaukee 2009).

Therefore, the total impervious area used to calculate the 2035 Vision goals was given a credit of 6.4 square miles to account for existing tree canopy (20 percent of the non-freeway ROW imperviousness). This results in a need for 740 million gallons of green infrastructure storage (Table 5 and Figure 16).

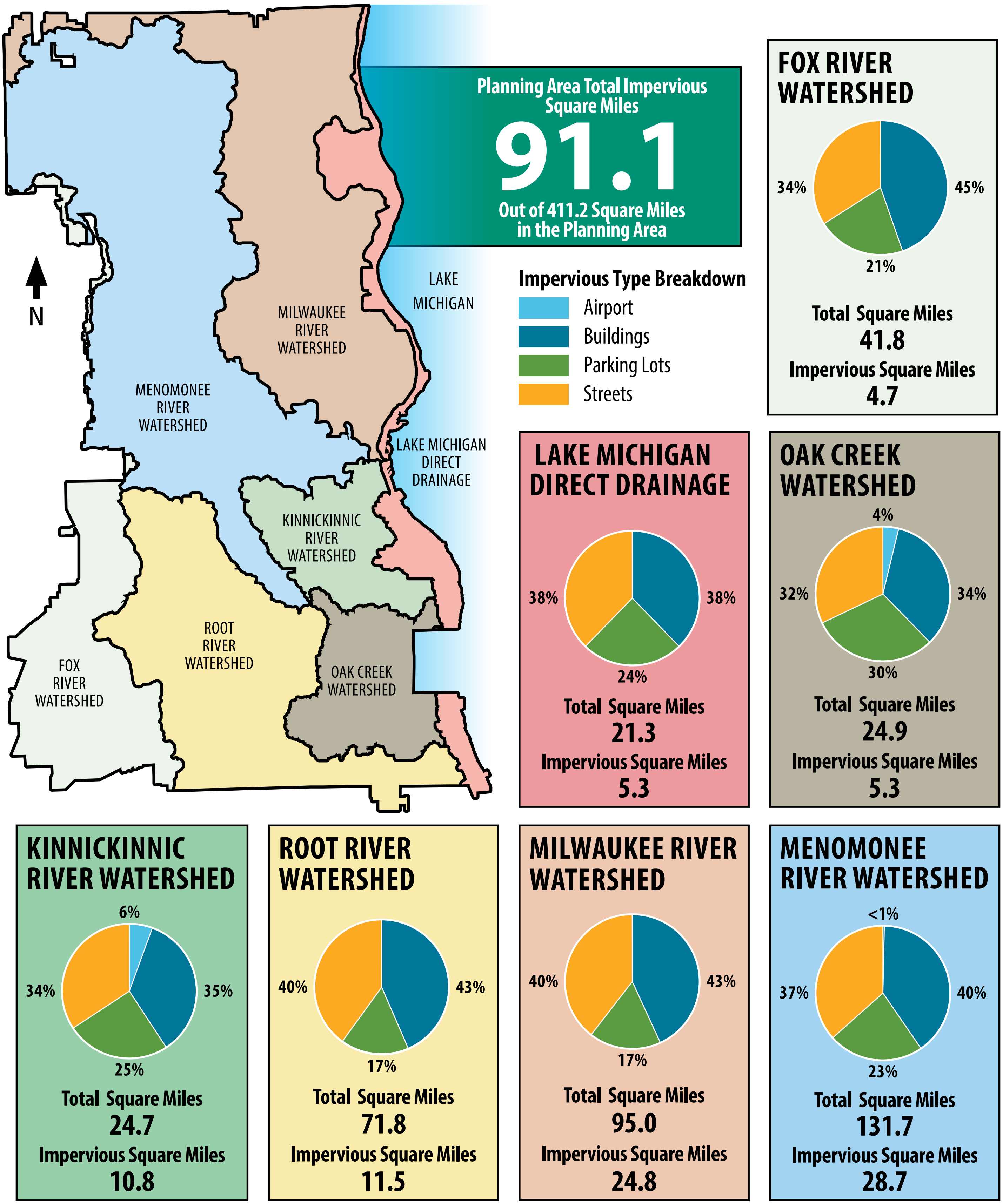
TABLE 5

Volume Capture Goals by Watershed

Watershed	Total Imperviousness (square miles)	Million Gallons to Harvest the First 0.5 Inch of Rainfall	Million Gallons to Harvest 0.25 Gallon per SF
Kinnickinnic River Watershed	10.8	93.9	75.3
Lake Michigan Direct Drainage	5.3	46.1	36.9
Menomonee River Watershed	28.7	249.4	200.0
Milwaukee River Watershed	24.8	215.5	172.8
Oak Creek Watershed	5.3	46.1	36.9
Root River Watershed	11.5	99.9	80.2
Fox River (Mississippi River Watershed)	4.7	40.8	32.8
Total	**91.1**	**791.7**	**634.9**
Total Adjusted for Existing Tree Canopy (rounded to nearest 10 million gallons)	**84.7**	**740.0**	**630.0**

FIGURE 16
Impervious Area Type by Watershed

The total amount of green infrastructure needed in each watershed to meet the goal is closely related to the total amount of imperviousness. As different runoff surfaces require different green infrastructure strategies to achieve the capture goal, the percentage of buildings, parking lots, and streets influences the green infrastructure strategy recommendations.



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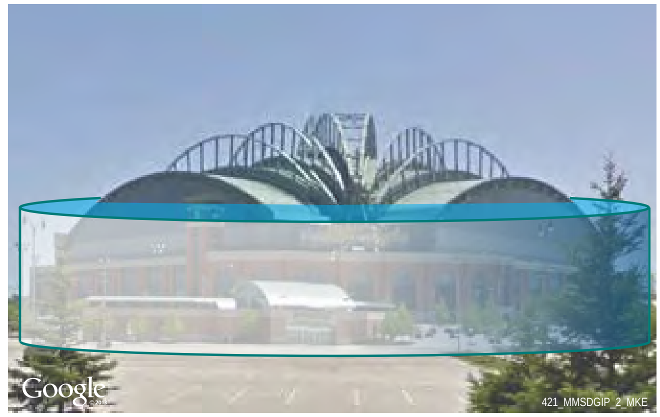
Due to unresolved technical and regulatory issues regarding plumbing code regulations for rainwater harvesting (for toilet flushing or pumped irrigation, for example), implementation of rainwater harvesting other than cisterns and rain barrels is not calculated at this time. It is unclear what the treatment requirements will be for various end uses and their associated costs. This is an opportunity for improvement discussed later in this Plan.

A modest additional allowance for rainwater harvesting costs will be added due to regulatory uncertainty. Rainwater harvesting also has a limited season for irrigation use. While the level of rainwater harvesting from rain barrels and cisterns is expected to be substantial, it will fall well short of the 2035 Vision rainwater harvesting goal of capturing 0.25 gallon per SF (0.4 inch).[1] If harvesting regulations are revised, reconsidering the rainwater harvesting goal to apply to building imperviousness may be appropriate. A preliminary estimate of applying the 0.25 gallon per SF to building imperviousness would result in a storage capture goal of approximately 246 million gallons. (From Figure 15, buildings represent 39 percent of the region's imperviousness. Using Table 5, 39 percent of the 630 million gallon goal of harvesting the first 0.25 gallon per square foot equals 246 million gallons.)

FIGURE 17

The rainfall capture goal of 740 million gallons would fill two thirds of Miller Park!



CONSTRAINTS TO GREEN INFRASTRUCTURE IMPLEMENTATION

With the total additional capture goal of 740 million gallons determined, constraints to green infrastructure implementation were examined. Constraints were mapped and impervious area calculated in the following areas:

+ **Topographic slopes greater than 12 percent:** Indicates areas where stormwater may not be able to be captured due to the stormwater runoff velocity and the inability to easily construct infiltration strategies on steeper slopes. Green roofs, rain barrels, and cisterns would still be possible.
+ **Depth to bedrock less than 6 feet:** Indicates locations where infiltration may be limited due to shallow bedrock. Porous pavement, green roofs, rain barrels, and cisterns would still be possible.
+ **Depth to groundwater less than 6 feet:** Indicates locations where infiltration may be limited due to shallow groundwater impeding infiltration. Green infrastructure may still be possible through appropriate designs. Porous pavement, green roofs, rain barrels, and cisterns would still be possible.
+ **High-density parcels:** Parcels that are small and have a significant portion already occupied by a building may have limited area for bioretention. Rain barrels, small cisterns, and small rain gardens may still be possible.
+ **Parcels with less than a 15-foot setback from the ROW:** Parcels with buildings that have less than 15-foot setbacks from the street ROW may have limited potential for bioretention/rain garden implementation. Standard practice is to have a 10-foot setback from buildings for bioretention. Parcels with less than 5 additional feet (i.e., a total of 15 feet) for a rain garden or bioretention could be constrained for green infrastructure implementation. Creative solutions, like two properties sharing a rain garden may be possible. Rain barrels and cisterns may still be possible.

Approximately 9 percent of all imperviousness in the planning area was determined to have a constraint. While most constraints will allow for some level of green infrastructure implementation, if the area was constrained it was not considered for green infrastructure implementation in this Plan (although creative solutions are encouraged). The primary treatment for large flat roofs is a green roof and this strategy is unaffected by the implementation constraints.

A map of the various constraints to green infrastructure is provided in the Appendix (Figure A-2).

Considering the constraints to green infrastructure implementation such as steep slopes, shallow groundwater, and high density development, enables informed decisions on green infrastructure strategy choices for successful implementation.

1 $\frac{0.25 \text{ gallon}}{\text{SF}} \times \frac{\text{cubic foot}}{7.48 \text{ gallon}} \times \frac{12 \text{ inches}}{\text{foot}} = 0.4 \text{ inch}$

Key Analysis Assumptions

A summary of important information used and assumptions made in the green infrastructure analysis includes the following:

+ Target areas by type and ownership based on the GIS analysis.
+ Capture volume/efficiency by green infrastructure strategy.
+ Implementation levels (i.e., the amount of green infrastructure per year).
+ The average annual runoff coefficients for turf grass and impervious areas (assumed to be a 15 percent and 85 percent, respectively, split based on other comparable areas).
+ Average annual precipitation (34.81 inches) for the 72-year record (1940 through 2011) at the National Weather Service rainfall gauge at Milwaukee's General Mitchell International Airport. Changes in rainfall trends indicative of a changing climate were not evaluated, but could be considered in the future.
+ The implementation period in years (approximately 22 years to meet the 2035 Vision timeline).
+ The relationship between stormwater reduction and combined sewer overflow reduction within the CSSA. A value of 20 percent efficiency was developed based on previous modeling results in "Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee" (MMSD 2011). Reductions in flow to the Deep Tunnel is estimated as 66 percent efficient based upon typical green infrastructure performance.
+ Typical pollutant (total suspended solids [TSS] and total phosphorus [TP]) concentrations for both urban stormwater runoff and CSO discharge.

GREEN INFRASTRUCTURE RECOMMENDATIONS TO MEET 2035 VISION GOALS

The Plan determined unconstrained area by ownership (public or private) and impervious land use type to understand the green infrastructure implementation potential. In addition to impervious area opportunities, opportunities to address turf grass areas with green infrastructure were also considered. Figure 18 summarizes the types of areas that make up the approximately 107,000 acres with green infrastructure potential. Green infrastructure addressing the entire area is not needed to achieve the volume equivalent of the 2035 Vision goal. Individual watershed-specific potential is prorated based on the watershed-specific characteristics.

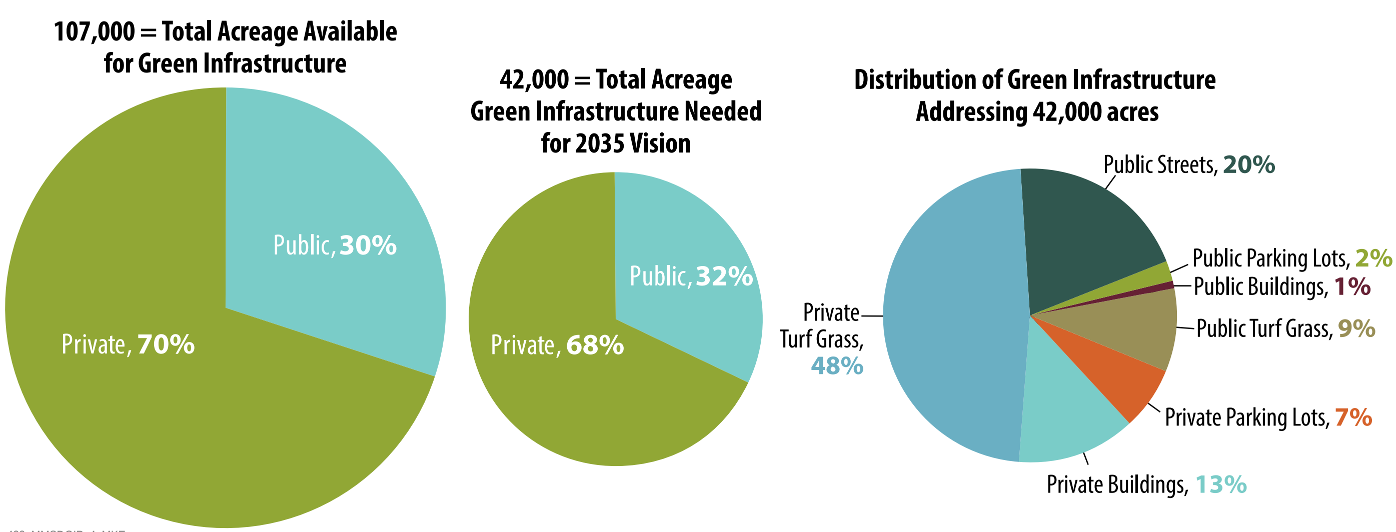
Green infrastructure implementation on public areas was estimated to range from 1.8 percent per year on parking lots and roads to 2.5 percent per year on parks. Implementation potential on private areas was estimated to range from 1.0 to 1.3 percent per year for buildings and parking lots and 2.0 percent per year on turf grass areas. The implementation levels for private impervious areas are within the range of redevelopment rates expected for the region based on feedback from the Technical Steering Committee, U.S. Environmental Protection Agency (USEPA) estimates, and a review of recent stormwater permitting activity.

Figure 18 also summarizes the types of area that make up the nearly 42,000 acres targeted for green infrastructure to achieve the 2035 Vision.

FIGURE 18

Green Infrastructure Planned for Over 42,000 Acres

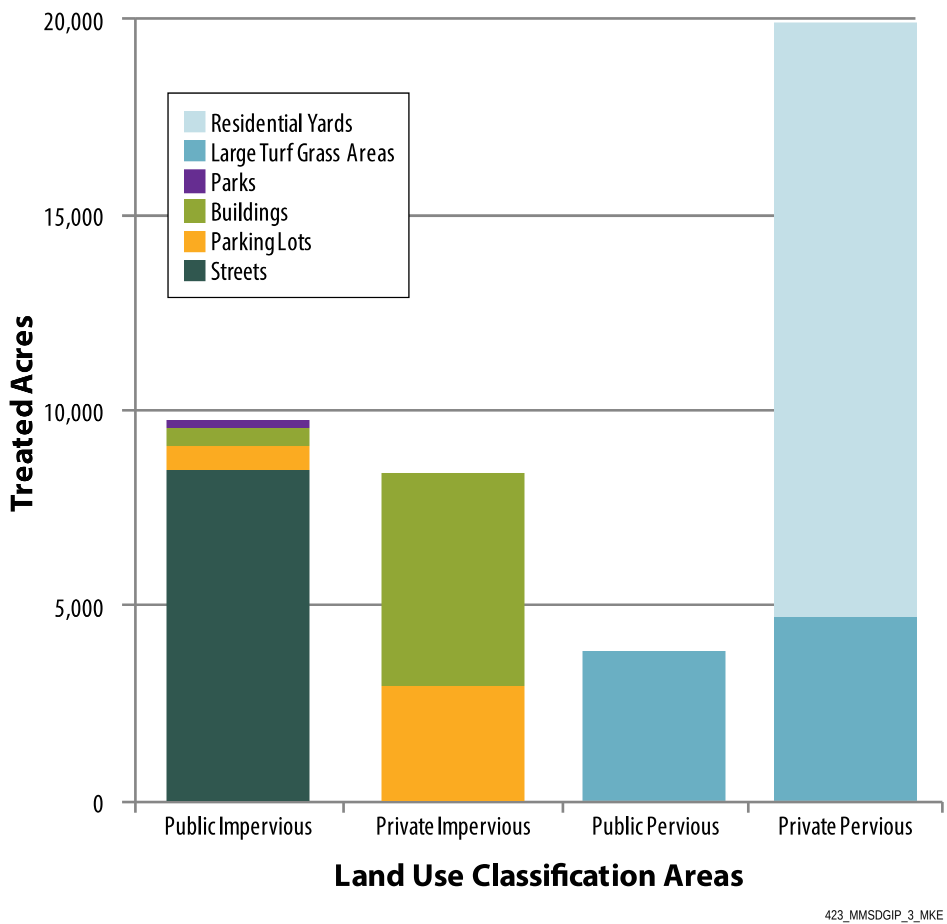
Green infrastructure addressing 42,000 acres is needed to achieve the volume equivalent of the 2035 Vision rainwater capture goal.



Green infrastructure strategies were selected for each of the pervious and impervious target areas to meet the equivalent volume of capturing the first 0.5 inch of rainfall over the impervious area. Figure 19 shows the amount of public and private property areas to be addressed by green infrastructure. The chart shows the amount of each land use that would be managed with green infrastructure at full completion of the Plan for impervious areas and turf grass areas. This represents one possible implementation scenario that could be used to meet the equivalent volume of capturing 0.5 inch of rainfall over the region's impervious area. Although any number of other scenarios could be used, this represents a reasonable combination for planning purposes.

The higher implementation level assumption on publicly-owned lands than on private lands is because green infrastructure can be more easily implemented on public lands. Implementation on private property also remains vital to achieve the 2035 Vision for zero basement backups and zero overflows—private property owners' participation will be a key to success.

FIGURE 19
Summary of Public/Private Turf Grass and Impervious Area



The storage volume provided by each green infrastructure strategy to meet the 2035 Vision goal of 740 million gallons of new storage is shown in Figure 20. Porous pavement and bioretention/rain gardens provide the majority of storage volume from green infrastructure targeting impervious areas, while soil amendments and native landscaping provide a comparable amount of storage targeting turf grass areas. Overall, green infrastructure from impervious areas provides approximately 60 percent of the volume goal, with the remaining 40 percent provided by green infrastructure from turf grass areas.

Based on the capture capability of each green infrastructure strategy, the 740 million gallons of green infrastructure storage translate into 14.8 billion gallons of annual stormwater capture per year on average. As shown in Figure 21, bioretention/rain gardens and porous pavement together contribute approximately 60 percent of the annual stormwater capture volume. Annual capture volume from the soil amendments and native landscaping on turf grass areas provides less than 20 percent of the annual capture volume due to the smaller volume available for storage in these strategies and because they only capture rainfall that directly falls on them.

Table 6 lists the quantity of green infrastructure needed to meet the volume goals for the region. The next section describes the watershed-specific recommendations. This quantity of green infrastructure is ambitious to meet the 2035 Vision rainfall capture goal. To achieve this level of green infrastructure implementation, participation on private and public properties will be required. Strategies to implement green infrastructure at this scale are included in the Recommendations section.

FIGURE 20
Storage Percentage by Green Infrastructure Strategy

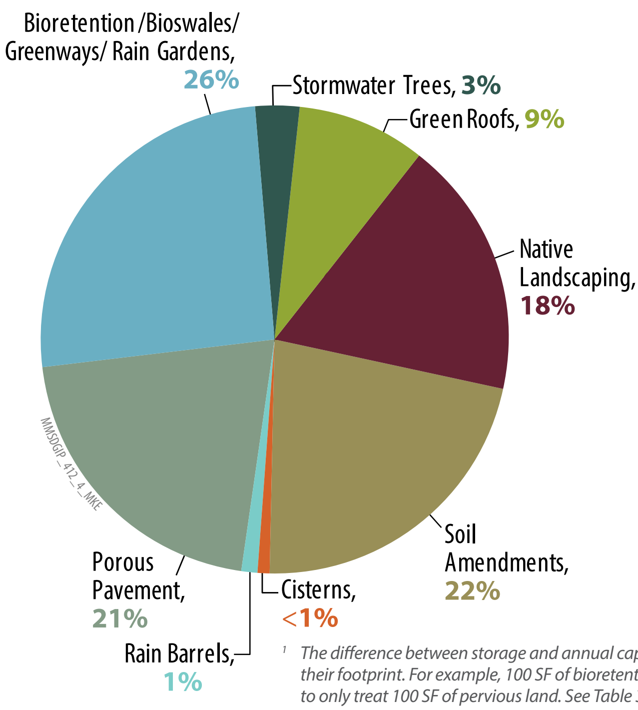
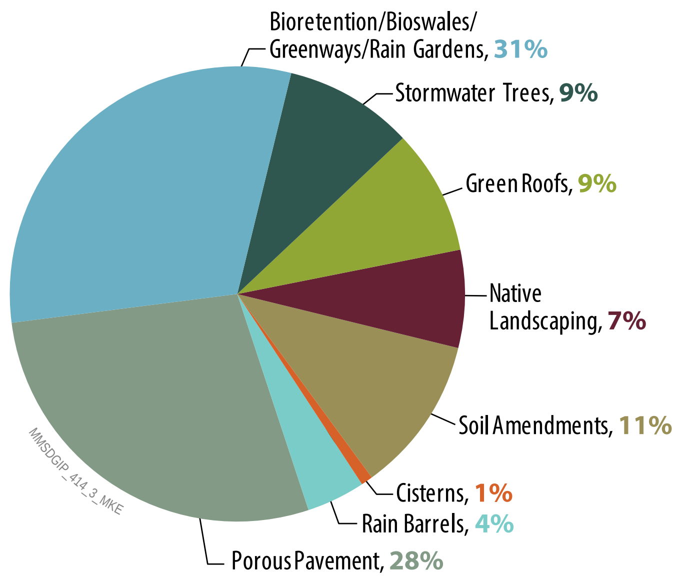


FIGURE 21
Yearly Runoff Volume Capture by Green Infrastructure Strategy[1]



1 The difference between storage and annual capture is due to the ability of some green infrastructure strategies to treat areas much larger than their footprint. For example, 100 SF of bioretention can treat up to 1,200 SF of impervious area, whereas 100 SF of soil amendments are assumed to only treat 100 SF of pervious land. See Table 3 for additional information and discussion.

TABLE 6
Planning Area Green Infrastructure Quantities[1]

Green Infrastructure Strategy	Quantity	Description
Green Roofs	1,490 acres	Equivalent to 13,000 buildings with new green roofs (assumes 5,000 SF per roof)
Bioretention/Bioswales/ Greenways/Rain Gardens	650 acres	Equivalent to 189,000 rain gardens (10 feet by 15 feet each)
Stormwater Trees	738,000	Equivalent to nine new trees per average city block
Native Landscaping	8,600 acres	Equivalent to 1,700 average city blocks with native landscaping
Porous Pavement	1,190 acres	Equivalent to 10,300 average city blocks having 25 percent porous pavement
Rain Barrels	152,000	Equivalent to 152,000 homes with one rain barrel each
Cisterns	2,020	Equivalent to 2,020 larger buildings with a cistern (minimum 6,500 SF roof)
Soil Amendments	15,200 acres	Equivalent to 2,900 average city blocks with soil amendments

1 The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.

Urban Ecology Center in Riverside Park incorporates stormwater capture and harvesting through a combination of green infrastructure strageties such as rain barrels, cisterns, porous pavement, and native landscaping.

GREEN INFRASTRUCTURE WATERSHED PRIORITIES

Multiple benefits are realized wherever there is green infrastructure. Strategic implementation near areas with basement backups, drainage problems, high pollutant concentrations, and high sewer inflow and infiltration areas, will more directly contribute to achieving the MMSD 2035 Vision. Opportunities for green infrastructure where there are open spaces, where there already are green infrastructure projects, and where there is redevelopment can serve as catalysts for green infrastructure. This section considers watershed priorities where there are multiple benefits from green infrastructure and summarizes watershed-specific green infrastructure recommendations to achieve the 2035 Vision.

WATERSHED PRIORITIZATION ANALYSIS

To prioritize subbasins within the MMSD planning area for green infrastructure, an analysis was conducted based on spatial data for a number of important watershed factors. The results provide insight into where green infrastructure will provide multiple benefits. Together with project collaborators, these areas could potentially be prioritized for the next phase of the Plan, enabling efficient development of conceptual designs.

The factors investigated for the analysis were selected based on discussions with MMSD and the Green Infrastructure Technical Steering Committee. The factors are grouped into two categories: 1) opportunities for green infrastructure implementation, and 2) areas with multiple potential green infrastructure benefits. These benefits center around the goals of MMSD's 2035 Vision—to achieve zero sewer overflows, zero basement backups, and improved water quality by the year 2035.

Table 7 presents the factors considered in the analysis and their reasons for consideration.

TABLE 7
Prioritization Analysis Factors

Factor		Reason for Consideration
Opportunities for Green Infrastructure Implementation		
1	Vacant Land	Opportunity for easy implementation on vacant parcels
2	Redevelopment Areas	Opportunity for easy implementation within redevelopment areas
3	Areas with Existing Green Infrastructure Strategies	Builds on momentum and success of other green infrastructure projects
4	Parks	Creates new park amenities where there are large open spaces
5	Selective Sewer Separation Opportunities	Opportunity to route storm sewer flow through green infrastructure
6	Potential Stream Corridor Rehabilitation Locations	Opportunity for planned implementation and complements projects by reducing pollutants
Areas with Multiple Potential Green Infrastructure Benefits		
7	High Inflow Areas to the Deep Tunnel	Green infrastructure could reduce inflow to the Deep Tunnel by managing a portion of wet-weather flow
8	Known Basement Backup Areas	Green infrastructure could reduce basement backup risk by managing a portion of wet-weather flow
9	Potential Drainage Problem Areas	Historical stream locations can be correlated with increased surface flooding potential; green infrastructure could help by managing a portion of wet-weather flow
10	Potential High Sewer Inflow and Infiltration Areas	High levels of stormwater in sanitary sewer pipe indicate higher sewer inflow and infiltration rates. Green infrastructure could help these areas by managing a portion of wet weather flow
11	High Pollutant Loading Areas[1]	Green infrastructure could reduce pollutant loads by managing a portion of stormwater and associated pollution

[1]From SEWRPC's ***A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds****, 2007.*

ANALYSIS APPROACH

Mapping of Spatial Data

Spatial data for each of the factors was mapped and intersected with subbasin polygons in GIS to identify subbasins with the highest opportunities and benefits.

A 1,000-foot buffer was placed around the data for Factors 4 (Parks) and 6 (Potential Stream Corridor Rehabilitation Locations) to capture surrounding area that may also present an opportunity for green infrastructure implementation. The data for Factor 7 (High Inflow Areas to the Inline Storage System or Deep Tunnel) includes all subbasins within the MMSD planning area, regardless of whether or not a subbasin is directly tributary to the Deep Tunnel because reduced stormwater flow anywhere in the region benefits the sewer system. The data for Factor 9 (Potential Drainage Problem Areas) was generated by intersecting historical stream location data with land use data for developed areas. The data for Factor 10 (Potential High Sewer Inflow and Infiltration Areas) was generated by overlaying areas with estimated pre-1954 housing stock (where foundation drains are typically connected to the sanitary sewer system) with non-conforming metersheds that were determined by MMSD based on flow measurement analyses.

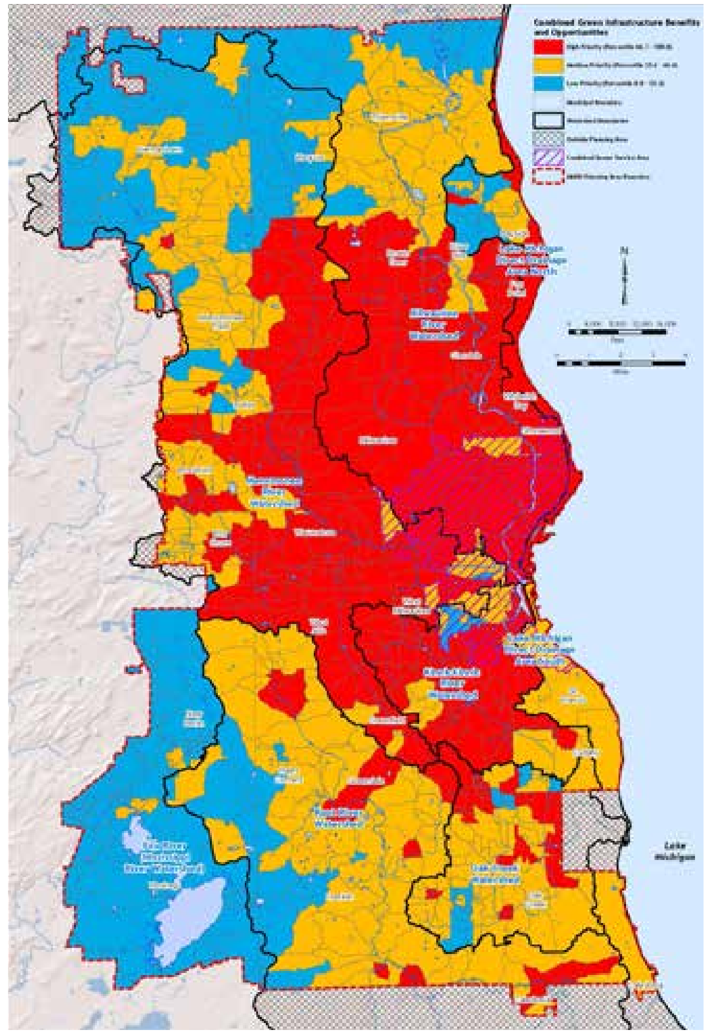
Priority Rankings

At the September 12, 2012 Green Infrastructure Technical Steering Committee meeting, members provided feedback on whether they considered a factor to be of primary or secondary importance. Most factors were considered to be of primary importance. The majority of members felt that Selective Sewer Separation Opportunities and Potential Drainage Problem Areas were secondary when prioritizing for green infrastructure implementation, and MMSD accepted this recommendation.

Using these primary/secondary classifications, a weighted average area percentage across all factors was calculated with the primary factors having a weight of 1 and the secondary factors having a weight of 0.5. The subbasins were then ranked from highest to lowest.

ANALYSIS RESULTS

Maps showing several of the factors, including the regional benefits and opportunities summaries, are included in the Appendix (see Figures A-3 through A-14). The maps show that, while the highest potential for benefit is in areas where older infrastructure exists, green infrastructure implementation opportunities are distributed throughout the entire MMSD planning area.



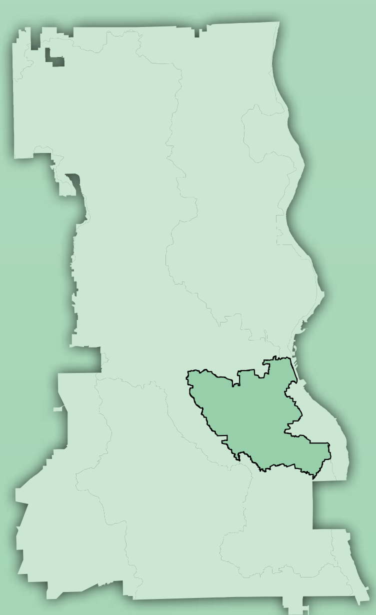
The analysis identified priority implementation locations within the region and within each watershed. Additional information and larger maps are found in the Appendix.

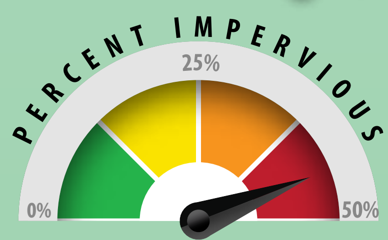
While green infrastructure will provide benefits wherever implemented, the highest-ranked subbasins are recommended for priority in-depth evaluation and analysis to develop conceptual plans. Benefits are further explained in the following section.

WATERSHED SPECIFIC RECOMMENDATIONS

What follows are one-page, watershed-specific summaries that highlight recommended green infrastructure to meet the 2035 Vision. Recommendations were based on individual characteristics of each watershed. The summaries include percent imperviousness in each watershed, investment in green infrastructure based upon impervious area type or turf grass area, and cost by green infrastructure strategy to capture the equivalent of the first 0.5 inch of rainfall from impervious area in the watershed.

Kinnickinnic River Watershed





Quantities of Green Infrastructure Planned to meet 2035 Vision in the Kinnickinnic River Watershed

Porous Pavement: 1,210 average city blocks with porous pavement

Bioretention / Rain Gardens: 22,000, 10-foot by 15-foot gardens

Stormwater Trees: 10 new trees per average city block

Green Roofs: 1,000 buildings with green roofs**

Cisterns: 200 large buildings*** with cisterns

Native Landscaping: 200 average city blocks converted to native landscaping

Rain Barrels: 17,100 homes with one rain barrel

Soil Amendments: 200 average city blocks with soil amendments

Watershed Green Infrastructure Investment: $142 million

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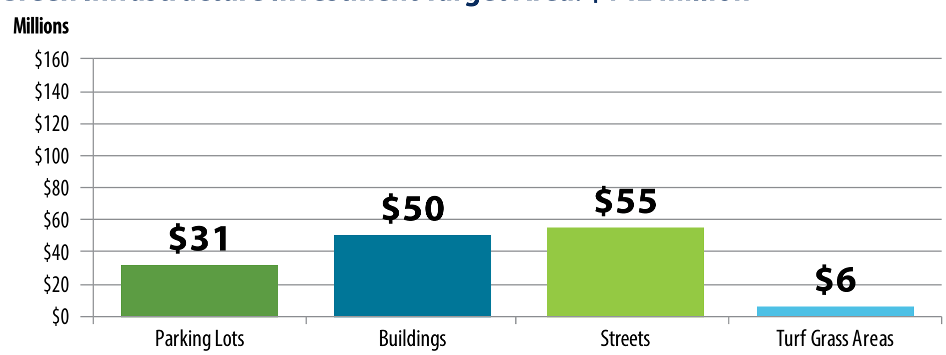
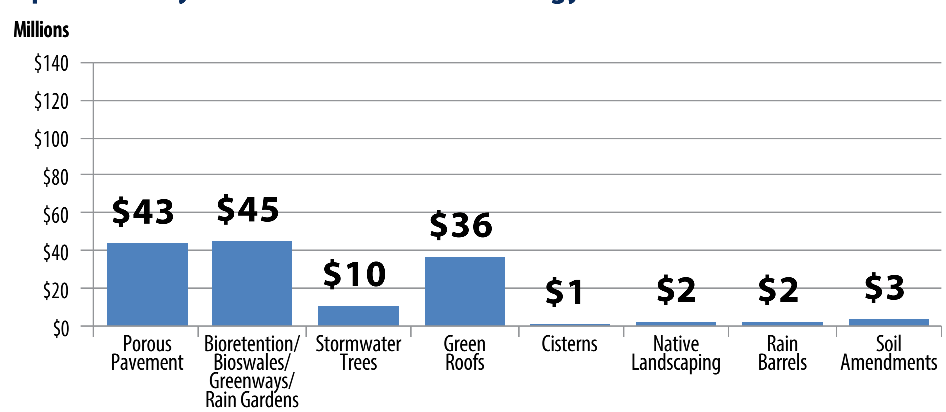
The Kinnickinnic River Watershed has the highest percent impervious area in the MMSD planning area and has high concentrations of total suspended solids and phosphorus. In areas of West Allis, the City of Milwaukee, and portions of Greenfield, there are high levels of inflow and infiltration. Coordination among private property inflow and infiltration reduction practices, sump pump installation, and building rain gardens could significantly reduce inflow and infiltration into sanitary sewers. Green infrastructure is consistent with recommendations of the Kinnickinnic River Watershed Restoration Plan. There are areas with limited installation potential due to high-density developments. Buildings in these areas may still be treated with green roofs, cisterns, and rain barrels. Implementation on streets and parking lots will be important where the dense development occurs due to the limited potential for implementation on some private properties.

Green Infrastructure Investment Target Area: $142 million



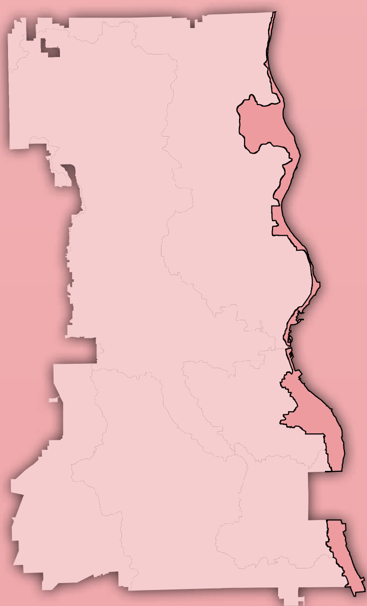
Capital Cost by Green Infrastructure Strategy*

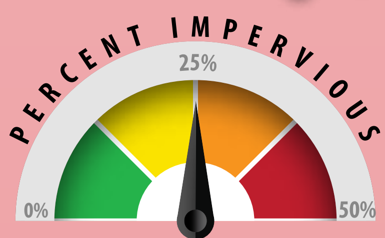


** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.*

*** 5,000 SF average green roof* **** Large Buildings >6,500 SF roof*

Lake Michigan Direct Drainage





Quantities of Green Infrastructure Planned to meet 2035 Vision in the Lake Michigan Direct Drainage

Porous Pavement: 570 average city blocks with porous pavement

Bioretention / Rain Gardens: 12,000, 10-foot by 15-foot gardens

Stormwater Trees: 9 new trees per average city block

Green Roofs: 1,000 buildings with green roofs**

Cisterns: 90 large buildings*** with cisterns

Native Landscaping: 100 average city blocks converted to native landscaping

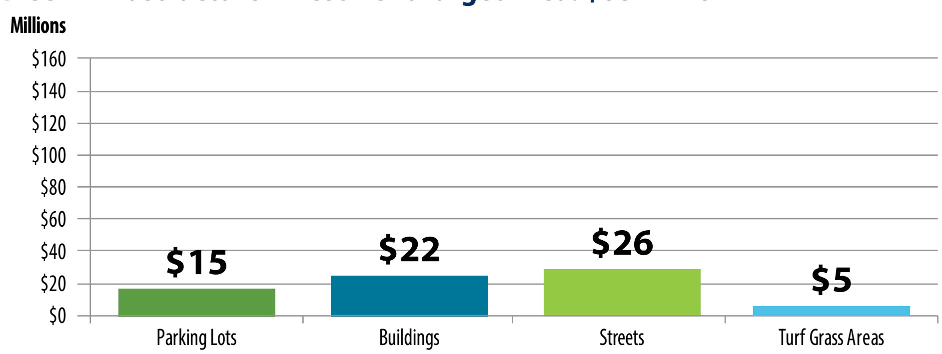
Rain Barrels: 11,400 homes with one rain barrel

Soil Amendments: 200 average city blocks with soil amendments

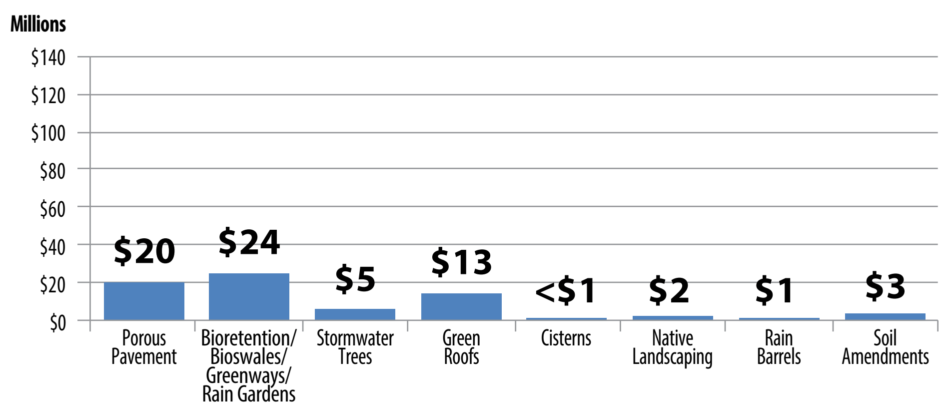
Watershed Green Infrastructure Investment: $68 million

The Lake Michigan Direct Drainage is the smallest watershed in the MMSD planning area. The watershed is split into two halves near the mouth of the Milwaukee River with the northern half having relatively low imperviousness and the southern half having higher imperviousness. The majority of the watershed has few constraints on green infrastructure installation. However, the combined sewer area south of the Milwaukee River has constraints including high groundwater and high-density development. Green roofs, cisterns, and rain barrels will be important on private property in this part of the watershed as it will have a positive impact on reducing combined sewer overflows.

Green Infrastructure Investment Target Area: $68 million

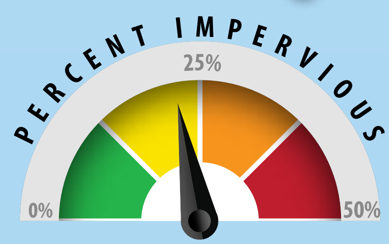


Capital Cost by Green Infrastructure Strategy*



** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies.*
The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.
*** 5,000 SF average green roof* **** Large Buildings >6,500 SF roof*

Menomonee River Watershed



Quantities of Green Infrastructure Planned to meet 2035 Vision in the Menomonee River Watershed

Porous Pavement: 3,330 average city blocks with porous pavement

Bioretention / Rain Gardens: 59,000, 10-foot by 15-foot gardens

Stormwater Trees: 9 new trees per average city block

Green Roofs: 4,000 buildings with green roofs**

Cisterns: 680 large buildings*** with cisterns

Native Landscaping: 500 average city blocks converted to native landscaping

Rain Barrels: 45,100 homes with one rain barrel

Soil Amendments: 900 average city blocks with soil amendments

Watershed Green Infrastructure Investment: $410 million

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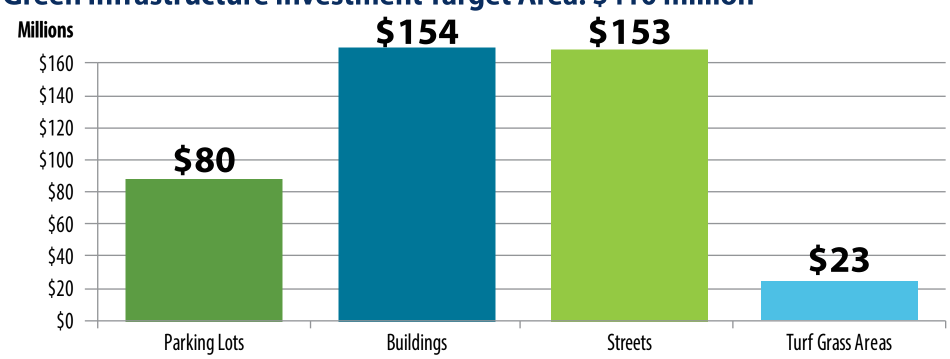
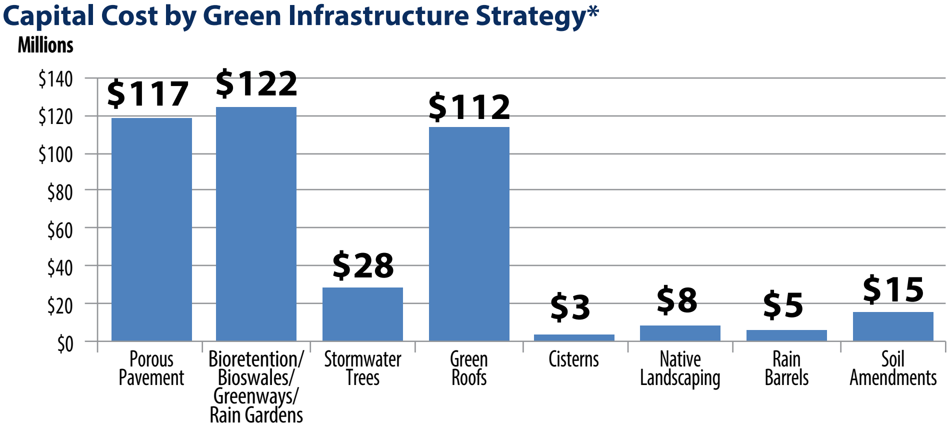
The Menomonee River Watershed is the largest watershed in the MMSD planning area and also has the highest impervious area. Portions in the City of Milwaukee, in the eastern part of Wauwatosa, and near Honey Creek in West Allis have high inflow and infiltration and some basement backups. Coordination among private property inflow and infiltration reduction practices, sump pump installation, and rain garden installations could significantly reduce inflow and infiltration. There is moderate to high stormwater pollution downstream of the confluence of the Little Menomonee River and the Menomonee River. Green infrastructure implementation is consistent with the Menomonee River Watershed Restoration Plan. There are areas with high groundwater that will require design considerations to protect groundwater quality. Green roofs and rain barrels or cisterns are the best option for treating building imperviousness in these areas.

Green Infrastructure Investment Target Area: $410 million



Capital Cost by Green Infrastructure Strategy*

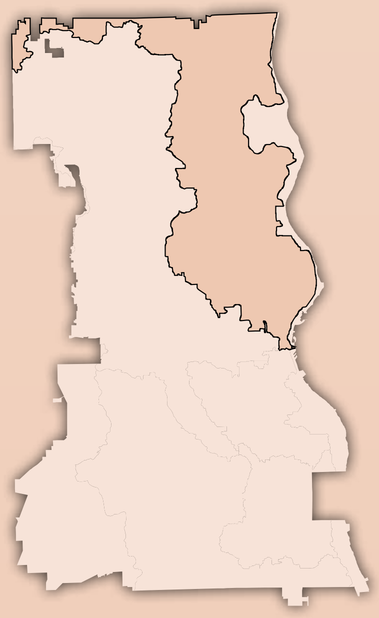


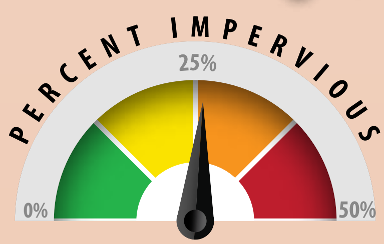
** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.*

*** 5,000 SF average green roof*

**** Large Buildings >6,500 SF roof*

Milwaukee River Watershed





Quantities of Green Infrastructure Planned to meet 2035 Vision in the Milwaukee River Watershed

Porous Pavement: 2,710 average city blocks with porous pavement

Bioretention / Rain Gardens: 50,000, 10-foot by 15-foot gardens

Stormwater Trees: 10 new trees per average city block

Green Roofs: 4,000 buildings with green roofs**

Cisterns: 500 large buildings*** with cisterns

Native Landscaping: 500 blocks converted to native landscaping

Rain Barrels: 41,400 homes with one rain barrel

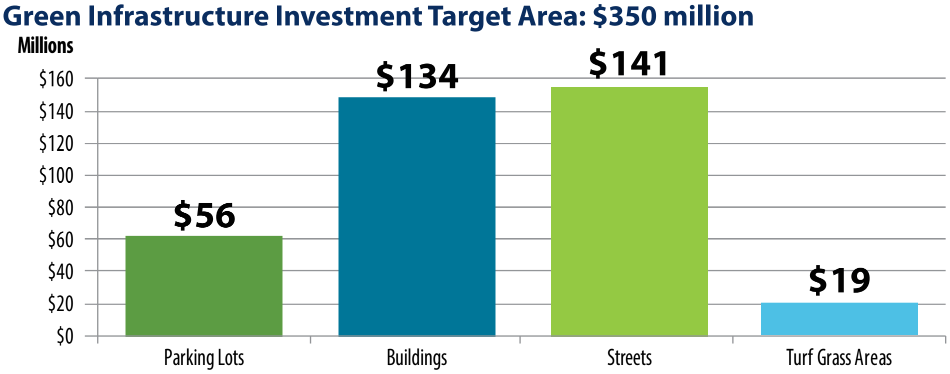
Soil Amendments: 700 average city blocks with soil amendments

Watershed Green Infrastructure Investment: $350 million

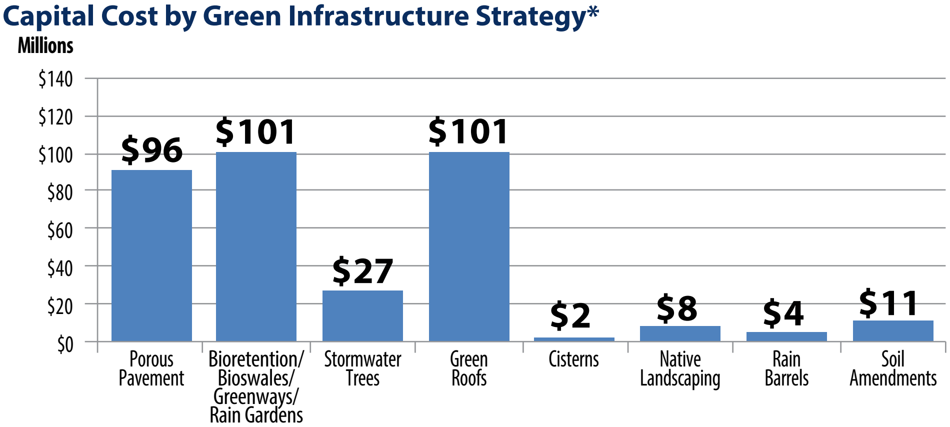
601_MMSDGIP_3_MKE

The Milwaukee River Watershed is the second largest watershed in the MMSD planning area. It has lower imperviousness in the north of the planning area with (generally) increasing levels of imperviousness moving towards the south. The majority of basement backups have been documented in the Lincoln Creek subwatershed. This area also includes sewers with high inflow and infiltration. Coordination between private property inflow and infiltration reduction practices and rain garden installations will be important. High building density may limit green infrastructure implementation, making installation of bioswales and porous pavement in streets, parking lots, and green roofs especially important in the downtown area. There is moderate stormwater pollution from total suspended solids and phosphorus in the Lincoln Creek area. Except for areas with high-density building development, the watershed has relatively few constraints to green infrastructure implementation.

Green Infrastructure Investment Target Area: $350 million



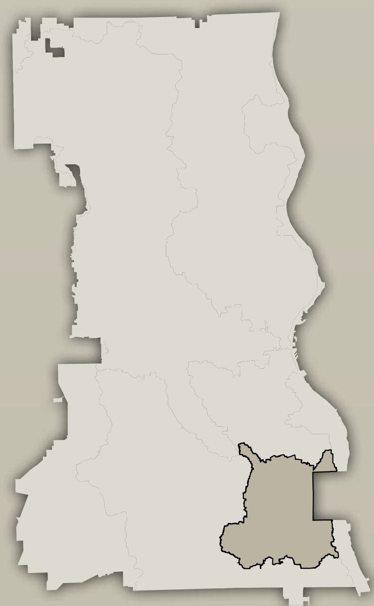
Capital Cost by Green Infrastructure Strategy*

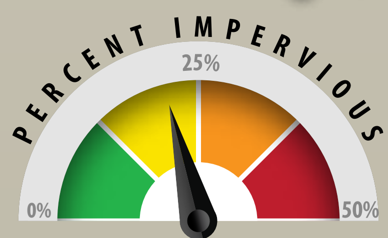


** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.*

*** 5,000 SF average green roof* **** Large Buildings >6,500 SF roof*

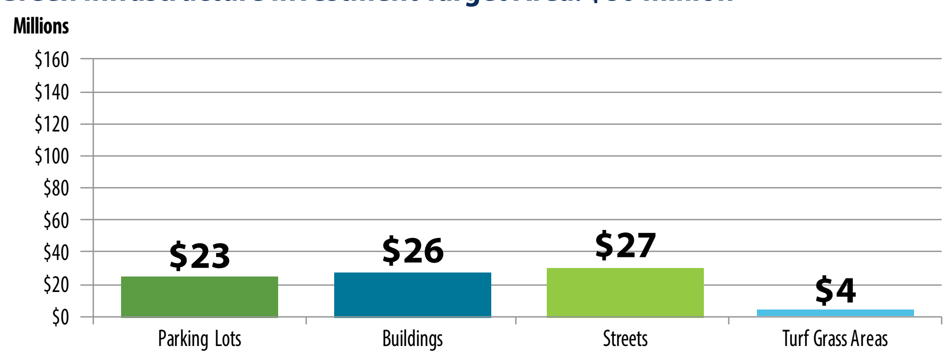
Oak Creek Watershed



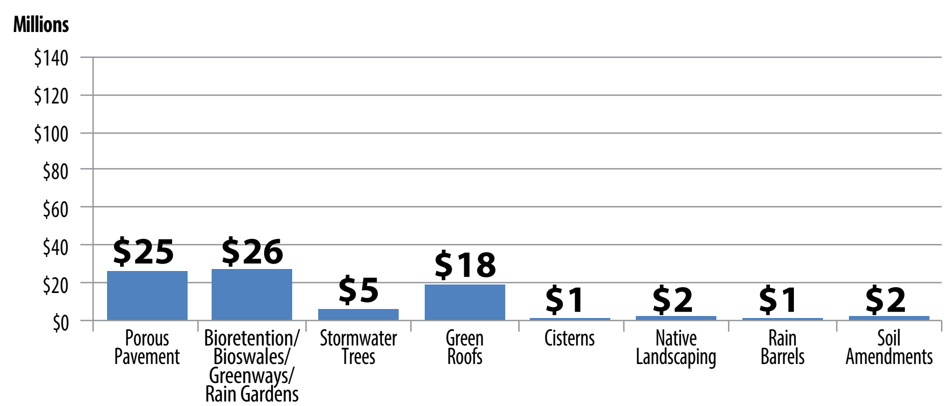


Much of the impervious area in the Oak Creek Watershed is just east of Highway 41, a largely commercial and industrial corridor. Of all the watersheds in the MMSD planning area, the Oak Creek watershed has the highest proportion of imperviousness from parking lots. Consequently, green infrastructure to treat parking lot imperviousness will be important to meet 2035 Vision goals.

Green Infrastructure Investment Target Area: $80 million



Capital Cost by Green Infrastructure Strategy*



** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies.*
The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.
*** 5,000 SF average green roof* **** Large Buildings >6,500 SF roof*

Quantities of Green Infrastructure Planned to meet 2035 Vision in the Oak Creek Watershed

Porous Pavement: 730 average city blocks with porous pavement

Bioretention / Rain Gardens: 12,000, 10-foot by 15-foot gardens

Stormwater Trees: 9 new trees per average city block

Green Roofs: 1,000 buildings with green roofs**

Cisterns: 150 large buildings*** with cisterns

Native Landscaping: 100 average city blocks converted to native landscaping

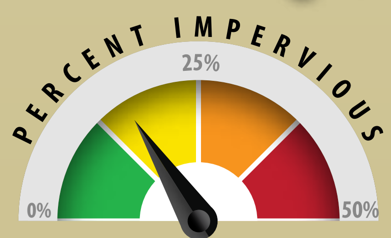
Rain Barrels: 7,100 homes with one rain barrel

Soil Amendments: 100 average city blocks with soil amendments

Watershed Green Infrastructure Investment: $80 million

604_MMSDGIP_2_MKE

Root River Watershed



Quantities of Green Infrastructure Planned to meet 2035 Vision in the Root River Watershed

Porous Pavement: 1,260 average city blocks with porous pavement

Bioretention / Rain Gardens: 25,000, 10-foot by 15-foot gardens

Stormwater Trees: 9 new trees per average city block

Green Roofs: 1,000 buildings with green roofs**

Cisterns: 280 large buildings*** with cisterns

Native Landscaping: 200 average city blocks converted to native landscaping

Rain Barrels: 22,400 homes with one rain barrel

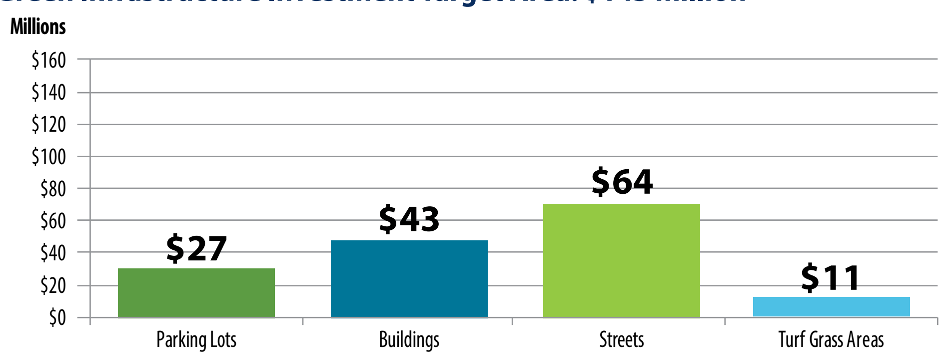
Soil Amendments: 500 average city blocks with soil amendments

Watershed Green Infrastructure Investment: $145 million

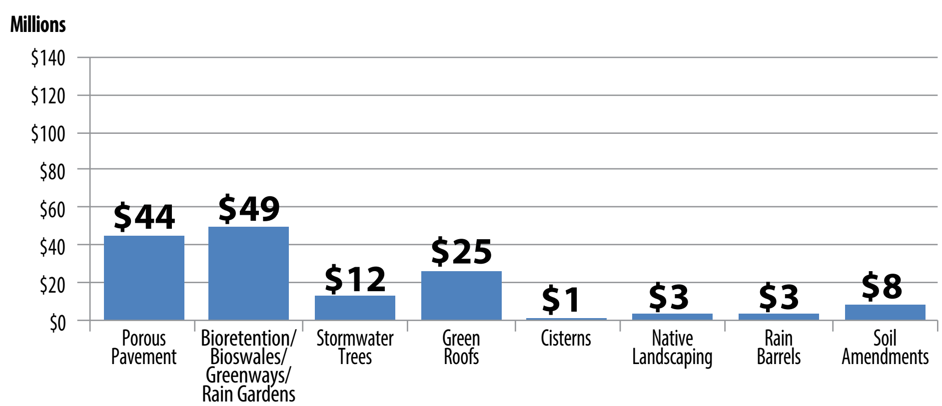
605_MMSDGIP_3_MKE

The Root River Watershed has the second lowest percent imperviousness. However, there is high stormwater pollution from total suspended solids in the southern portion of the watershed. Limitations to green infrastructure include shallow bedrock and high groundwater in the Greendale and Hales Corners areas. Therefore, projects in these areas should include measures to protect groundwater quality with green infrastructure design. Using green infrastructure strategies such as green roofs, rain barrels, and cisterns offer potential to treat building imperviousness in this area of the watershed.

Green Infrastructure Investment Target Area: $145 million

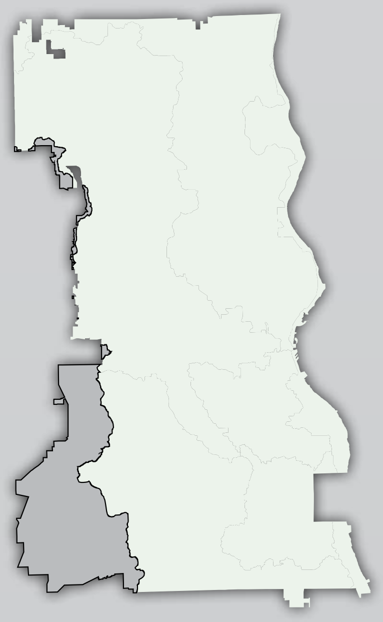


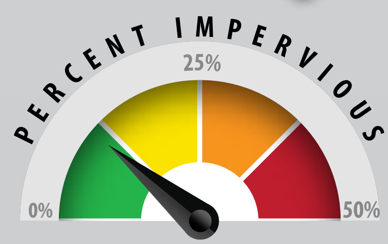
Capital Cost by Green Infrastructure Strategy*



** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies.*
The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.
*** 5,000 SF average green roof* **** Large Buildings >6,500 SF roof*

Fox River Watershed





Quantities of Green Infrastructure Planned to meet 2035 Vision in the Fox River Watershed

Porous Pavement: 500 average city blocks with porous pavement

Bioretention / Rain Gardens: 10,000, 10-foot by 15-foot gardens

Stormwater Trees: 8 new trees per average city block

Green Roofs: 1,000 buildings with green roofs**

Cisterns: 110 large buildings *** with cisterns

Native Landscaping: 100 average city blocks converted to native landscaping

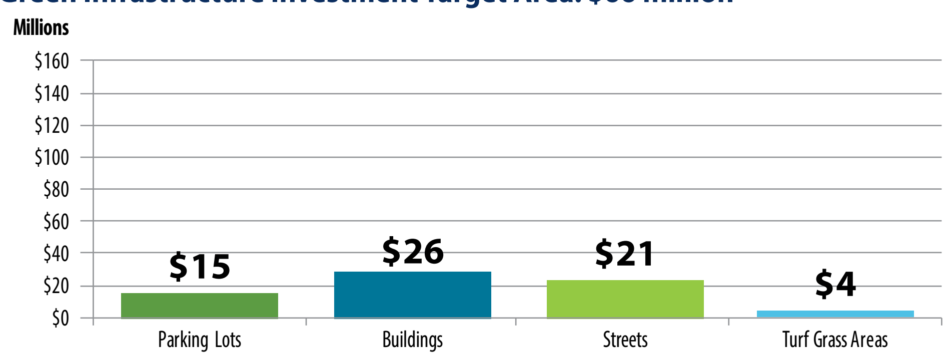
Rain Barrels: 7,300 homes with one rain barrel

Soil Amendments: 200 average city blocks with soil amendments

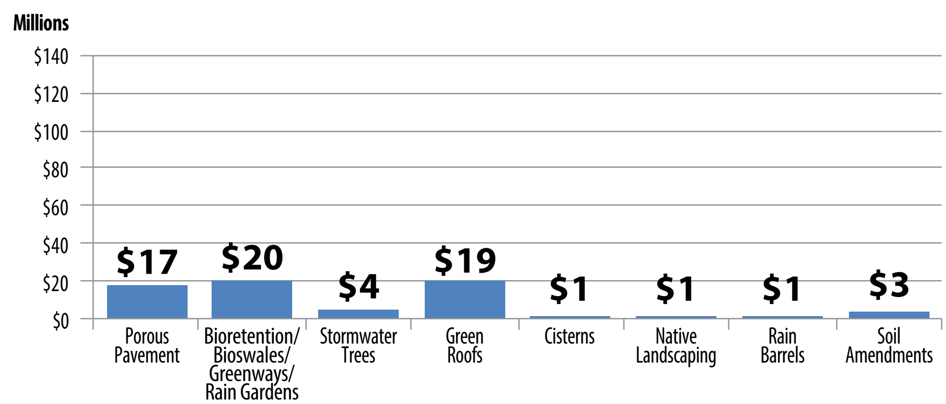
Watershed Green Infrastructure Investment: $66 million

The MMSD planning area portion of the Fox River watershed has only a small area of separate sewers. Consequently, green infrastructure strategies that focus upon inflow and infiltration reduction to the MMSD system will provide the most regional benefits. This watershed has the lowest overall percent imperviousness and the highest proportion of imperviousness coming from buildings. Green infrastructure recommendations emphasize strategies for buildings with green roofs, cisterns, rain gardens, and rain barrels. Portions of the southwest portion of this watershed have steep slopes that suggest green roofs, cisterns, and rain barrels instead of ground-based green infrastructure strategies.

Green Infrastructure Investment Target Area: $66 million



Capital Cost by Green Infrastructure Strategy*



** The green infrastructure strategies green alleys, streets, and parking lots are made up of other strategies. The wetlands green infrastructure strategy is encouraged but not quantified in the Plan.*

*** 5,000 SF average green roof*

**** Large Buildings >6,500 SF roof*

GREEN INFRASTRUCTURE BENEFITS AND COSTS

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

TRIPLE-BOTTOM-LINE BENEFITS

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

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

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

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

501_MMSDGIP_3_MKE

TABLE 8
Triple-Bottom-Line Analysis Factors

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

TRIPLE-BOTTOM-LINE SUMMARY

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

Economic Benefits

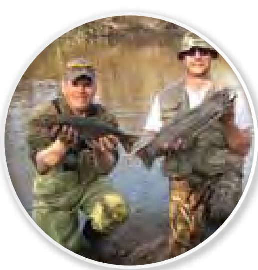
Green infrastructure can save money compared to traditional sewer infrastructure. The most compelling economic benefits of green infrastructure are often related to its ability to help sewers work better. Economic benefits quantified in more detail in the Plan include the following:

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

Social Benefits

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

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



Environmental Benefits

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

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

TRIPLE-BOTTOM-LINE ANALYSIS

Economic Benefits

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

Green Job Opportunities

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

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

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

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

Reduced Infrastructure Costs

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

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

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

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

Reduced Pumping and Treatment

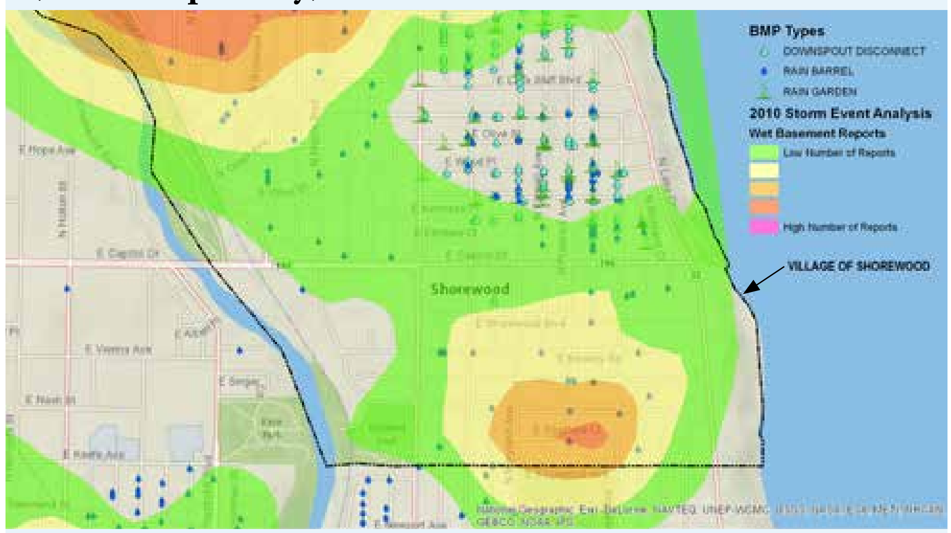
By capturing stormwater that would otherwise enter the Deep Tunnel, green infrastructure reduces the need for tunnel pumping and associated wastewater treatment. Annual reductions in flow to the Deep Tunnel from areas with green infrastructure is estimated at 66 percent based upon typical green infrastructure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

Increased Property Values

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

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

Green Infrastructure with Reduced Basement Backups (one example only)



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

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

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

Social Benefits

Improved Quality of Life and Aesthetics

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

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

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

Improved Green Space

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

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

Menomonee Valley Redevelopment

Incorporating green infrastructure in redevelopment project revitalizes community.

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

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

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

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

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

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

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

13th District Green Corridor Improvements

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

Photos courtesy of Garden District Neighborhood Association (GDNA 2012)

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

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

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

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

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

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

Environmental Benefits

Captured Stormwater Volumes (Quantity)

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

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

Reduced Pollutant Loadings (Quality)

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

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

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

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

Increased Groundwater Recharge

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

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

Carbon Reduction

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

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

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

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

Reduced Energy Use for Cooling

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

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

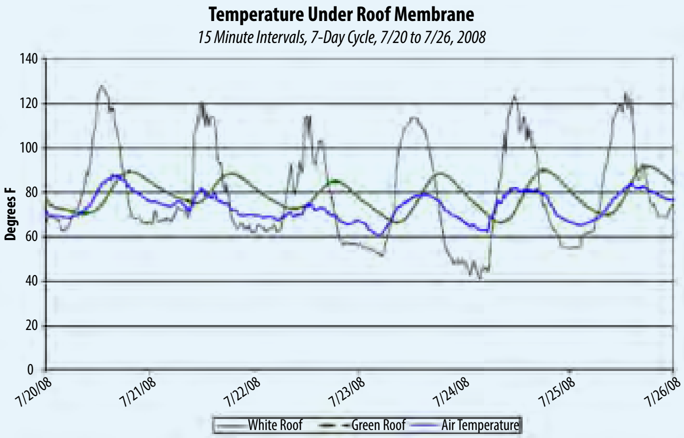
Improved Air Quality

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

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

Walmart's Energy Efficient Green Roofs

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



Source: Walmart, Inc (courtesy of Arup)

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

ACHIEVING THE MMSD 2035 VISION

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

Zero Basement Backups

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

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

Zero Sewer Overflows

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

Improved Water Quality

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

Improved Drainage

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

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

WHAT WILL IT COST?

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

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

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

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

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

TABLE 9

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

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

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

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

[3] *PWD is Philadelphia Water Department.*

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

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

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

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

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

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

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

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

FIGURE 23
Incremental Cost per Gallon of Storage*

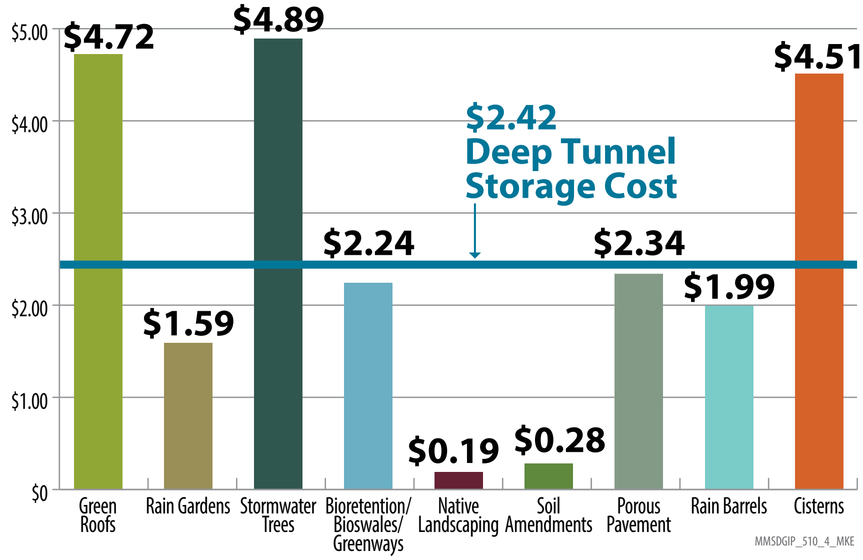


FIGURE 24
Incremental Cost per Square Foot Managed*

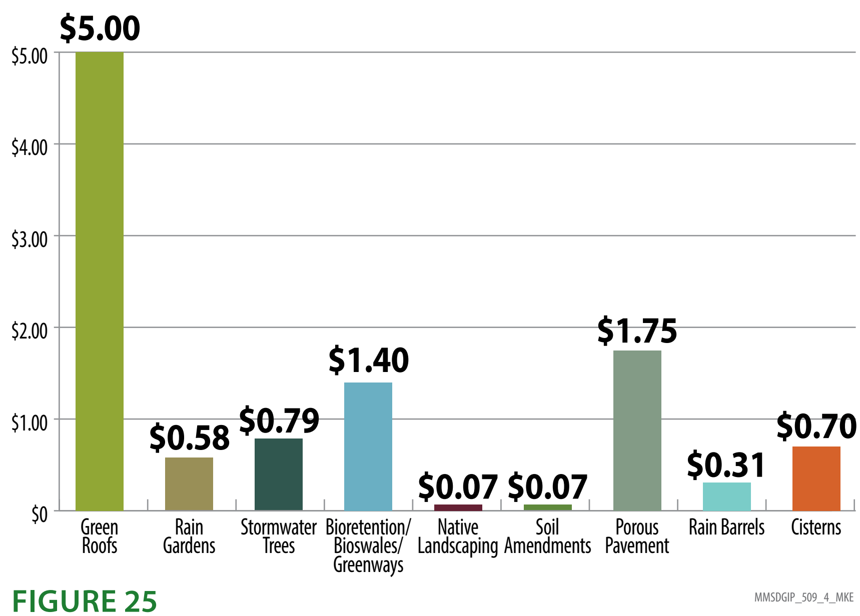
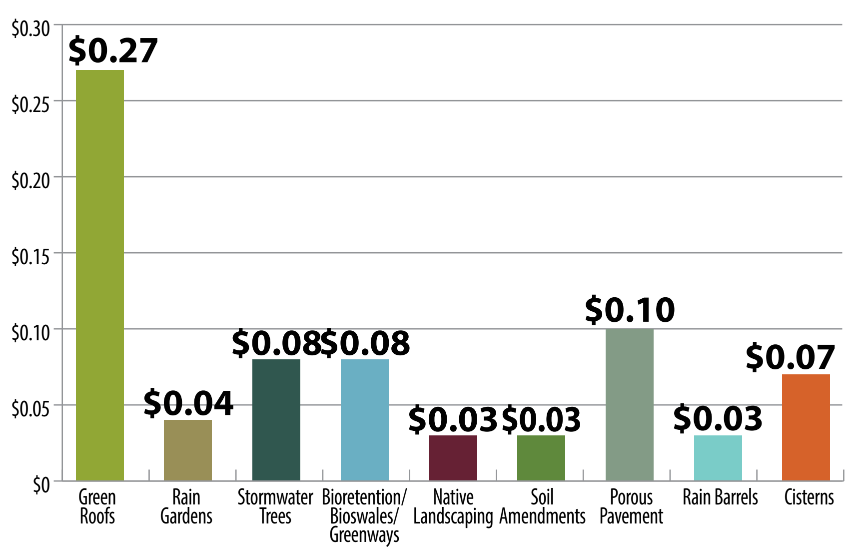


FIGURE 25
Incremental Cost per Annual Gallon Captured*



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

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

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

FIGURE 26

Plan Investment by Land Use

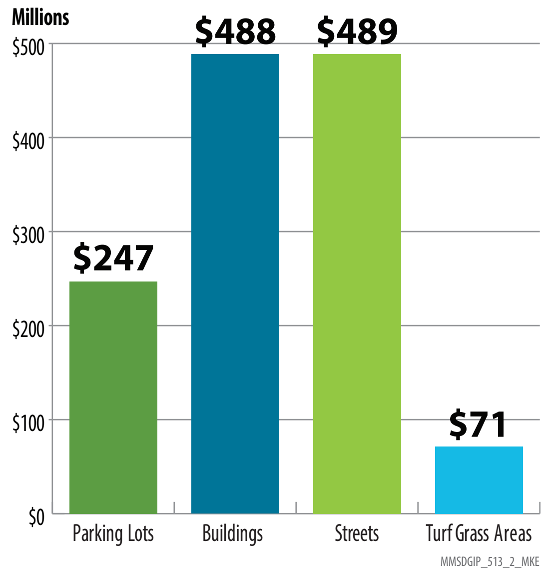
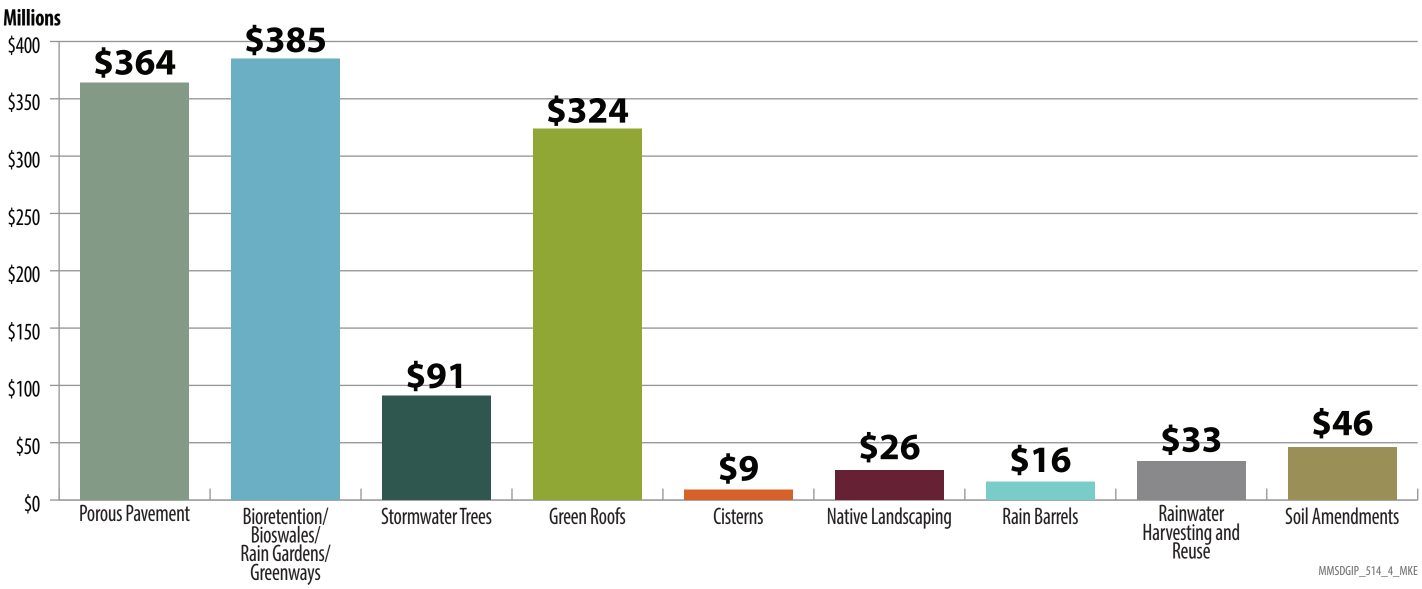


FIGURE 27

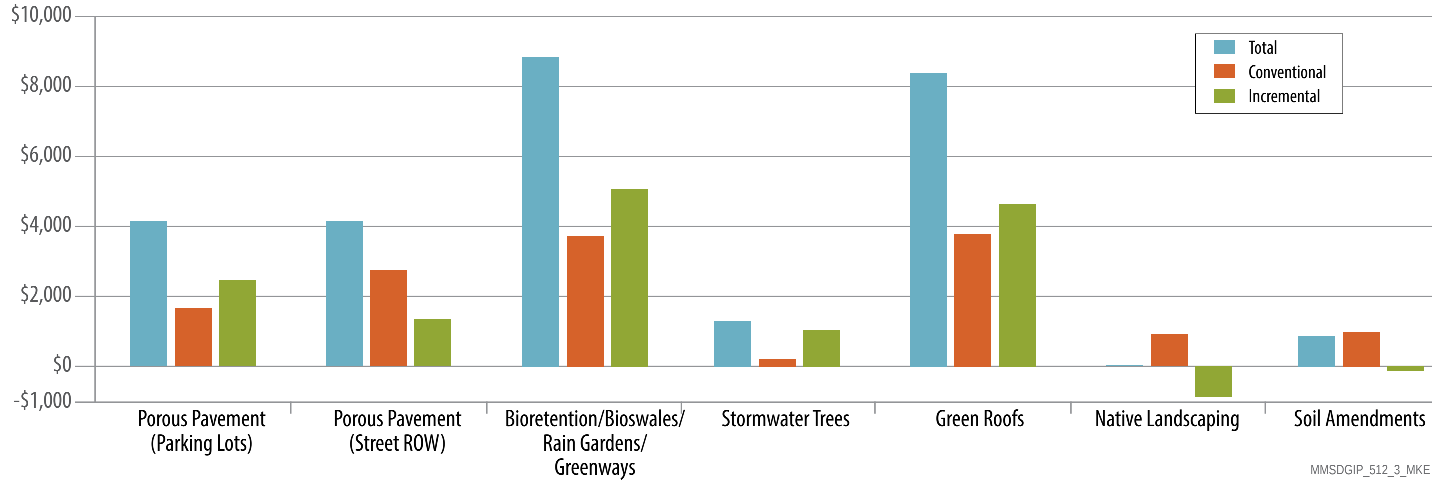
Incremental Cost by Green Infrastructure Strategy



Operation and Maintenance Costs

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

FIGURE 28
Estimated Annual Operation and Maintenance Costs per Acre



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

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

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

Plan Cost Summary

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

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

RECOMMENDATIONS

Metropolitan regions across the nation may emulate the Milwaukee region as it reaps economic, social, and environmental benefits due to green infrastructure implementation. While the previous information in this Plan explained what green infrastructure is needed and why, this section focuses on how and when the region can take certain steps to meet the 2035 Vision goals. MMSD, municipal leaders, community groups, and neighbors can all contribute to achieving the goals of zero basement backups, zero overflows, improved water quality, and improved drainage. The Plan builds on regional efforts and standardizes programs and implementation strategies to streamline widespread green infrastructure implementation. Creative funding solutions and green infrastructure requirements for new and redevelopment projects will be needed, yet the triple-bottom-line benefits they provide make these efforts worth the time and investment. The result will be achieving the 2035 Vision goals while beautifying neighborhoods, installing more resilient infrastructure, and having more green jobs. Further, MMSD will be doing its part to protect our most prized resources in Wisconsin—rivers and Lake Michigan—for future generations to enjoy.

WHAT DO WE NEED TO SUCCEED?

The types and amounts of green infrastructure needed to achieve the MMSD 2035 Vision's rainfall capture goals are known.* This will require actions within the short-term to establish a foundation for long-term success. Implementation in the first 5-years is based on current MMSD funding levels and puts into place the standards, funding, and processes necessary to achieve the 2035 Vision (Figure 29). The journey to long-term success will require that the Region act on the following overarching recommendations:

Expand Collaboration. The MMSD planning area includes 28 municipalities. While the Plan is regional, implementation of some parts of the Plan will need to be on a municipality-by-municipality basis. The collaborations among agencies and groups developed through demonstration projects and programs (rain barrel, rain garden, green roofs, etc.) will be reinforced and widely expanded.

Develop Programs and Implement Projects. The region has the benefit of learning from successful green infrastructure demonstration projects that have been in place for several years. More need to be implemented to expand the capacity of the current green infrastructure program to include the suite of strategies anticipated for each watershed.

Standardize. Standardizing when green infrastructure is required, how it is designed, how it is reviewed and approved, and how it is maintained, will make it easier to implement across the region.

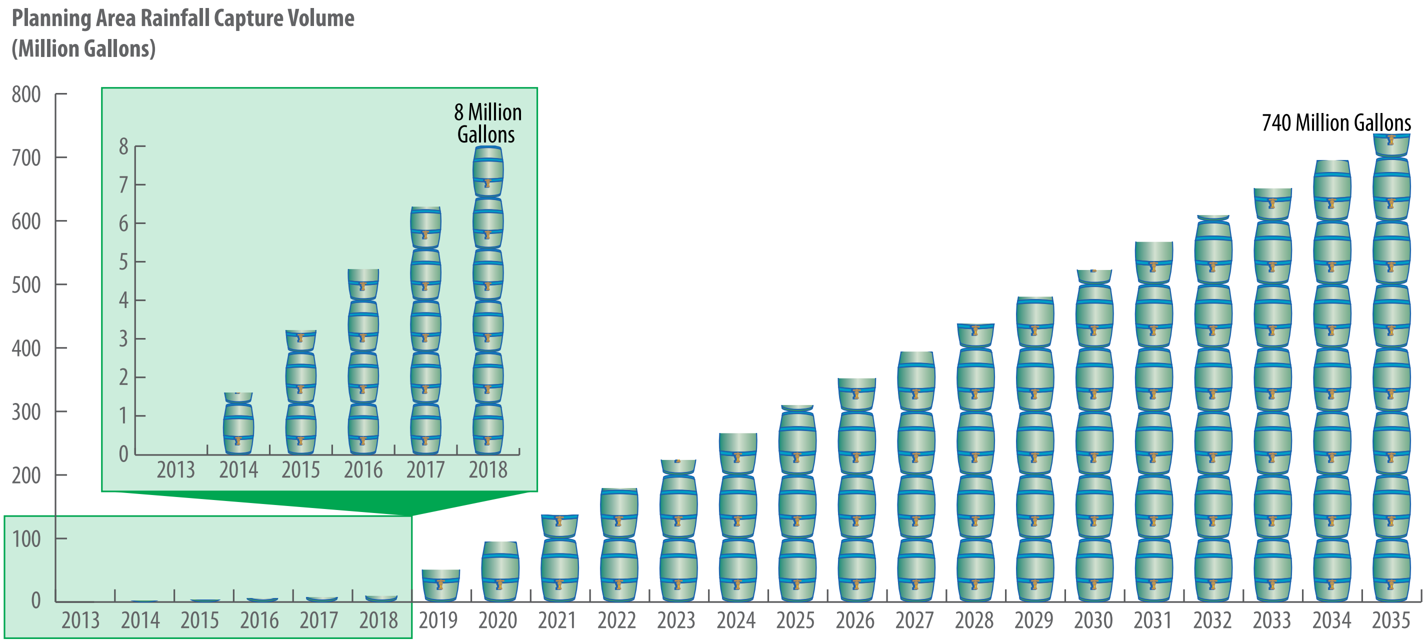
Fund. During the development of the Plan, the Plan's Technical Steering Committee identified 1) how to fund green infrastructure construction, and 2) maintenance funding, as its two most critical success factors in implementing green infrastructure. Identifying new/redevelopment green infrastructure requirements, funding methods, and making appropriate investments to spur local green infrastructure innovation and jobs training are all part of achieving cost-effective green infrastructure solutions for the region.

Learn, Share, and Adapt. The Plan has benefited from elements of other successful regional plans, such as Philadelphia, New York City, Onondaga County (New York) and others. While each plan is specific, they all have a common strategy: adaptive management. Implementation success must be tracked and adjustments made to meet long-term goals. As local best practices continue to develop, the region's municipalities should learn from each other and cultivate a supportive environment to share information and resources. Adapting to incorporate best implementation practices as they change over time will provide value to the region.

**Note: this goal exceeds MMSD's current WPDES permit*

These five overarching recommendations are discussed in further detail with recommended timelines.

FIGURE 29
Timeline for Achieving an Equivalent 0.5-inch Rainwater Volume Capture



Expand Collaboration
Summary Recommendations and Timeline

2013 Develop and implement a green infrastructure training plan for government leaders, public works officials, schools, residents, commercial and industrial property owners, and developers

2013-2017 Continue to cultivate strong regional partnerships emphasizing green infrastructure

Through the Green Infrastructure Technical Steering Committee, discuss green infrastructure implementation benefits for TMDL and MS4 permit requirements

2014 Develop internal MMSD project green infrastructure evaluation standards

2014-2017 Add participants to the Green Infrastructure Technical Steering Committee and clearly define roles as regional standards are developed

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EXPAND COLLABORATION

Key Findings

While developing the Plan, a Technical Steering Committee was formed with representatives from local municipalities, WDNR, SEWRPC, non-governmental organizations, and others. An atmosphere of collaboration and excitement around transforming the region with green infrastructure already exists. The spirit of working together will need to be strengthened and broadened to include other participants. Green infrastructure programs in other municipalities have benefited from a strong emphasis on education and technical training for all stakeholders. The region's past educational and technical training efforts should be revised and expanded, and a team should continue to develop the existing regional message to promote green infrastructure.

Recommendations

1. Through the Green Infrastructure Technical Steering Committee, discuss green infrastructure implementation benefits for meeting municipal permit requirements. The Plan will help to meet certain regulatory requirements that already exist, such as the municipal separate stormsewer system (MS4) permit (required by WDNR) and future requirements such as TMDL implementation to reduce pollutants from stormwater runoff. The Technical Steering Committee should inform municipal leaders of possible credits towards current program requirements they could receive when green infrastructure implementation occurs. More demonstration projects for green streets, green infrastructure in parks, stormwater trees, and rainwater harvesting are needed to educate the public and advance green infrastructure construction. This discussion is an important first step to broadcasting the benefits of the Plan.

2. Develop and implement a green infrastructure training plan for government leaders, public works and engineering officials, schools, residents, commercial and industrial property owners, and developers. Other green infrastructure implementation programs successfully built excitement around their plans through public education and training. A key feature of these technical educational efforts is communicating the benefits of green infrastructure and rewarding participation. Recommendations for an MMSD regional training plan include:

   + Involve counties and municipalities in the training plan development
   + Provide an opportunity for positive publicity for involved partners
   + Expand communication of MMSD's Fresh Coast Green Solutions green infrastructure brand
   + Include green infrastructure implementation challenges for individuals, businesses, communities, schools, etc.
   + Emphasize the triple-bottom-line benefits of the Plan, and tailor messaging to target audiences

   The training plan could provide an opportunity for the public to submit ideas for green infrastructure implementation and a forum for recognition, such as an annual awards and recognition program for projects and municipalities. It would also engage the public in meaningful volunteer and recreational opportunities centered around green infrastructure (for example: rain garden plantings, photo contests, green infrastructure geocaches, etc.). Reinvigorating the awards program MMSD conducted in 2004-2006 would be one approach where participants could receive grant awards or be recognized at conferences, such as Clean Rivers, Clean Lake.

Expand communication of MMSD's green infrastructure brand to promote implementation as other regions have done:

- "Fresh Coast Green Solutions"—Milwaukee, Wisconsin
- "Save the Rain"—Syracuse (Onondaga County) New York
- "Green City, Clean Waters"— Philadelphia, Pennsylvania
- "1,000 Rain Gardens"—Madison, Wisconsin

3. Continue to develop MMSD green infrastructure project evaluation standards for internal projects. The Plan complements existing MMSD projects, especially the Private Property Inflow and Infiltration Reduction Program and integrated regional flood management initiatives. MMSD should look for opportunities to expand green infrastructure implementation with the Private Property Inflow and Infiltration Reduction Program and other clear water removal projects. The Private Property Inflow and Infiltration Reduction Program could also encourage residential drainage reviews to ensure proper grading around homes prevents wet basements, thus reducing basement backups and overflows. Continue to evaluate all MMSD capital projects for green infrastructure opportunities to take advantage of the cost savings associated with implementing green infrastructure as part of a normal capital improvement program. For example, as streets are disturbed by sewer reconstruction, the project restoration plan should consider green infrastructure options. MMSD has started this process by creating standard operating procedures (SOPs) that will consider green infrastructure opportunities with each capital project. As evaluating capital projects for green infrastructure opportunities becomes standardized, MMSD will look for green infrastructure retrofit opportunities on MMSD-owned properties.

Regional Green Infrastructure Plan Technical Steering Committee Meeting

MMSD and municipalities working together on the Menomonee River watershed-based stormwater permit has led to national recognition and the region receiving the U.S. Water Prize.

Photo courtesy of Southeastern Wisconsin Watersheds Trust

MMSD will consider green infrastructure implementation opportunities in future capital projects.

4. Add participants from the development community to the Green Infrastructure Technical Steering Committee as regional standards are developed. The committee should also include representatives from local organizations who have experience with, or who will be responsible for, installing and maintaining green infrastructure and will discuss with and formalize participant roles. Representatives to consider should include the following:

   + MMSD planning area municipalities
   + State regulators
   + Counties
   + Non-governmental organizations (Southeastern Wisconsin Watersheds Trust, and others)
   + The new/redevelopment community

   Within the Menomonee River watershed, some of these organizations are already collaborating to improve stormwater quality through a recently issued watershed-based permit. The effort to move forward with this permit has been supported through a USEPA grant and has garnered awards for the region. Continuing these types of regional collaborations will be important to successful Plan implementation.

Public education about the benefits of green infrastructure will help green infrastructure gain public acceptance, avoid surprises, and help develop a successful implementation track record.

DEVELOP PROGRAMS AND IMPLEMENT PROJECTS

Key Findings

The Plan includes green infrastructure on both impervious and pervious areas across public and private properties, and the Plan addresses each of these green infrastructure investment areas. The consultant team identified areas with multiple opportunities for green infrastructure and provided locations for more in-depth analysis, tying green infrastructure to subbasin-specific benefits. Priority locations should be considered for early implementation. The Plan identified certain green infrastructure strategies that would benefit from innovative, high-visibility demonstration projects that monitor performance and that provide results. Expanding existing MMSD green infrastructure programs (rain barrels, rain gardens, and green roofs) and developing new programs will expedite green infrastructure implementation.

DEVELOP PROGRAMS AND IMPLEMENT PROJECTS

Summary Recommendations and Timeline

2013-2035	Implement watershed-specific green infrastructure goals to achieve the 2035 Vision
2013-2014	Develop detailed sub-watershed analysis for three to five priority sub-watershed areas to inform early green infrastructure implementation; consider green infrastructure, TMDL, drainage problems, and Private Property Inflow and Infiltration Reduction Program objectives
2014	Develop key performance indicators to track green infrastructure implementation progress at the watershed and regional levels
2013	Develop a standardized green infrastructure project reporting process to track progress
2017 - 2018	Compare demonstration project results to findings elsewhere
2016-2017	Develop community-specific plans
2013-2017	Implement and monitor visible and innovative demonstration projects, especially green streets, stormwater trees, green infrastructure in parks, and rainwater harvesting
2014	Develop educational materials for key types of properties
2013-2017	Expand the MMSD green roof program
2013	Develop 2013 green infrastructure incentive funding policy
2014	Expand the MMSD rain barrel program to include totes
2014	Expand the MMSD rain garden program
2016-2018	Develop a Regional Green Infrastructure Service Center
2013-2017	Develop MMSD technical capacity for stormwater trees, porous pavement, soil amendments, and native landscaping
2015	Develop a warehouse and screening tool for green infrastructure opportunities

A regional green infrastructure requirement will necessitate regional standards that require technical support and review expertise. Regionally available expert resources can help supplement busy municipal staff potentially through a Regional Green Infrastructure Service Center that could provide efficient technical resources to the region. Providing regional operation services and maintenance equipment similar to how some communities in the region have shared specialized maintenance equipment should be evaluated. Grassroots and NGO-led outreach is another effective means of public education.

Public education prior to or integrated into green street and other green infrastructure strategy implementation is needed to inform and educate the public about the benefits of green infrastructure in their neighborhood and to garner their support and their input in the planning and design process.

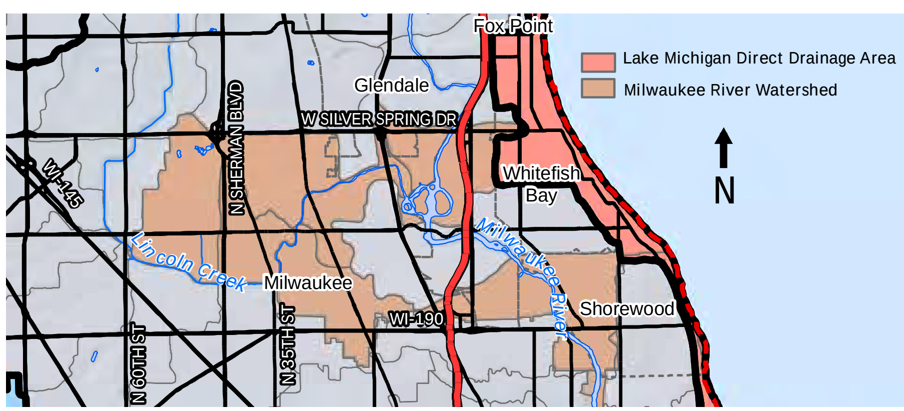
Recommendations

1. Develop detailed sub-watershed analyses for three to five priority sub-watershed areas to inform strategic, early-out green infrastructure implementation; consider green infrastructure, TMDL, drainage problems, and Private Property Inflow and Infiltration Reduction Program objectives. Sub-watershed analysis should be conducted in the high opportunity analysis subbasins identified in the Plan (Figure 30). The modeling should evaluate opportunities on public and private properties to meet the volume equivalent of the 2035 Vision rainfall capture goal. In the modeling, evaluate local sub-watershed needs (for example Private Property Inflow and Infiltration Reduction Program or drainage improvements). MMSD should consider how to optimize green infrastructure benefits across multiple objectives and costs. The findings should be developed and shared with local stakeholders to influence other implementation projects, especially those on public properties. This lead-by-example approach will promote widespread buy-in of implementation throughout the region. The analysis should be developed so it can be duplicated in other sub-watersheds.

FIGURE 30

High Opportunity Analysis Results

Subbasin areas that benefit the most from green infrastructure within each of the region's watersheds were identified as candidates for more detailed analysis. This Milwaukee River and Lake Michigan Direct Drainage watershed example shows high priority green infrastructure opportunity implementation areas.



2. Develop key performance indicators (Figure 31) to track green infrastructure implementation progress towards the 2035 Vision at the watershed and regional levels. The Plan's goals related to the 2035 Vision can be used to develop key performance indicators for the region, watersheds, and municipalities. Key performance indicators can be used during more detailed planning and analysis to weigh the trade-offs between implementing some of the green infrastructure strategies. For example, tradeoffs between triple-bottom-line benefits provided

by green streets vary depending upon the level of porous pavement, bioretention, and stormwater trees implemented. Developing key performance indicators helps people make informed decisions and track implementation progress. A web-based tool could be developed to provide "what-if" scenario analysis for various levels of implementation.

3. Expand the existing green infrastructure project report to track progress, building upon the current WPDES reporting requirement to document not only installed volume but also annual volume captured. The reporting and tracking process should include pertinent information such as type of strategy, per-storm event volume, impervious and pervious tributary area, annual volume, location, and design drawing information if applicable. For small-scale strategies (rain barrels and rain gardens), continue to use a simple, per installation credit approach. Reporting procedures should be noted on H2OCapture.com.
4. Compare demonstration project findings in other regions to establish/revise pollutant removal efficiency where needed.
5. Develop municipality-specific plans. Encourage and incentivize municipality-specific green infrastructure plan development/adoption when regional standards and funding mechanisms have been developed, or earlier when municipalities are eager to develop a plan. The municipality-specific plans should build off of the Plan and detailed sub-watershed plans.
6. Continue to implement and monitor visible and innovative demonstration projects, especially green streets, stormwater trees, green infrastructure in parks, and rainwater harvesting. Promote new green infrastructure strategies that are important to achieving Plan goals. Few green streets have been implemented to date, especially in higher density residential areas where little room is available for bioretention. Successfully implementing local green streets will establish a path to broad adoption, lower costs, and standardized designs. Stormwater tree demonstrations, including tree trenches, various soil volume planting tests, and variations in designs should be implemented and tracked to measure success. Green infrastructure in parks offers high visibility and typically low-cost implementation due to the amount of available open space. Green infrastructure on high-use public properties, such as schools, libraries, and other commonly used public spaces provides the opportunity to demonstrate the benefits of these projects.

FIGURE 31

Cincinnati's green infrastructure key performance indicator tool tracks progress and compares alternative scenarios.

712_MMSDGIP_1_MKE

City of Milwaukee's Green Streets Process

A standardized process increases implementation rates and saves money

The City of Milwaukee has developed a standardized process to evaluate green infrastructure opportunities with every street project in its street capital improvement plan. Green street strategies are defined early in the design process and include bioretention in terraces, medians, or open space; porous pavements in parking lanes and alleys; and stormwater tree trenches.

Median bioretention installation

Green infrastructure in median through the Marquette University campus

Stormwater trees planted in deep box along sidewalk

Photos courtesy of the City of Milwaukee

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Rainwater harvesting/reuse demonstration projects should be coordinated with expected regulatory changes. Rainwater harvest opportunities include schools and other facilities with year-round water use. Municipal engineers say additional regional education is needed on green infrastructure performance for the technology to become mainstream in the region. Consequently, documenting and communicating before and after conditions, volume reduction, maintenance, and cost should be included with any demonstration project. Locating demonstration projects near schools could build upon the science, technology, engineering, and math (STEM) curriculums in the region and create living laboratories for hands-on learning.

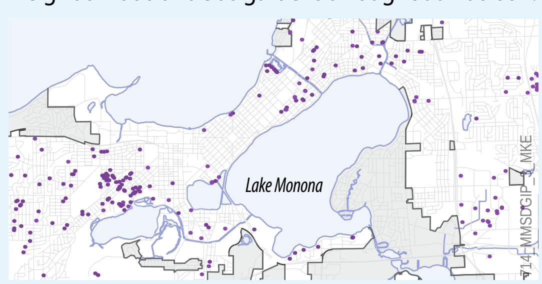
7. Develop educational materials for key property types. Information on common green infrastructure applications should be compiled in an easy-to-understand format for residential properties, streets, parking lots, schools, institutions, and commercial and industrial buildings. The educational materials should include the types of practices applicable in typical settings and direct users to the H2OCapture.com website for the latest standards, cost ranges, regulations, and incentive opportunities. Non-English speaking audiences should also be addressed.
8. Continue the successful MMSD green roof program, and expand the program as additional funding becomes available. Consider whether or not alternative (more cost-effective) green infrastructure strategies can be used or if green roofs are a necessary solution based upon site-specific conditions.
9. Develop a policy for MMSD green infrastructure incentive funding programs that compares cost per gallon as part of the funding analysis incentive review for equitable distribution among programs. A funding policy should recognize that incentive costs will vary by green infrastructure strategy. Note any exceptions, such as for high profile demonstration projects.
10. Expand the MMSD rain barrel program to include totes and consider partnering with other entities that install totes. Larger volume (250 gallon) totes or other sizes are readily available through vendors and food processors. Use rain barrel and tote purchase information to strategically market other green infrastructure strategies (rain gardens, stormwater trees, soil amendments, etc.).
11. Expand the MMSD rain garden program to include tree sales. Promote WDNR rain garden guidance to allow individuals to easily implement one on their own. Consider partnering with local greenhouses or the regional Master Gardener program to promote rain gardens. Inform rain garden plant purchasers about the rain barrel program, soil amendment benefits, and how to register their rain garden on H2OCapture.com.

    Target rain garden implementation in neighborhoods and watersheds with Private Property Inflow and Infiltration Reduction Program goals, especially where sump pump installations are planned. Target neighborhood rain garden implementation where TMDL implementation Plan recommendations or other specific goals promote rain gardens. Enlist additional partnerships for both plant supply and expertise, such as garden supply stores, and organizations, such as American Rivers, that specialize in neighborhood implementation.

Adams Street Rain Garden Demonstration

This beautiful rain garden on Adam's Street captures rainwater before it enters the sewer system.

The City of Madison has similar goals as Milwaukee for capturing rainwater and instituted a rain garden pilot project in the Vilas Neighborhood along Adams Street in 2006. After receiving a $40,000 grant from the WDNR, the City offered to build rain gardens in residents' yards between the sidewalk and the street where they were viable and where residents were willing to maintain them. Nine homeowners initially participated. The gardens were built by contractors in conjunction with the reconstruction of Adams Street. City engineering staff hired a consultant to help design and coordinate the plantings, and volunteers helped plant the gardens. Specially designed drain systems help the gardens efficiently capture runoff from streets and sidewalks. Placards in each garden that explain the purpose and benefits were prominently placed and the City continues to receive requests for more installations. The City's website touts progress towards meeting its "1,000 Rain Gardens" goal. Tracking each installation encourages more homeowners to design their own rain garden. There are now around 24 rain gardens in the Vilas Neighborhood and 500 gardens throughout Madison.



The City of Madison's website tracks rain garden installation.

Planting native landscaping instead of turf grass offers operation and maintenance cost savings and improves conditions for stormwater quality and quantity. In some cases this will require changes to local building codes.

12. Develop a Regional Green Infrastructure Service Center to provide technical advice and review of design documents in the region. The center would offer technical expertise to member municipalities, interpretation of new regulations and expertise on operation and maintenance issues. This service would reduce duplication of services if each municipality were to hire its own expert, providing a cost-effective resource to the region.

Creating a Regional Green Infrastructure Service Center would provide technical advice and review capabilities to municipalities.

13. Develop MMSD technical staff capacity for stormwater trees, porous pavement, soil amendments, and native landscaping to promote these strategies in the region. MMSD has not had any specific programs for these strategies. Providing regional leadership and information resources on H2OCapture.com around these key technologies should include:

    Stormwater trees. Provide regional coordination with urban forestry officials on tree planting standards and develop a list of species for specific settings. Lead regional efforts to promote coordination through local capital improvement programs for ash tree replacement and additional stormwater tree plantings. Increase tree plantings by offering trees for sale through the MMSD annual rain garden plant sale. Support technical innovation and tree planting success through stormwater tree demonstration projects. Emphasize the benefits of stormwater trees, regardless of whether they are located over impervious areas.

    Porous pavement. Collaborate with the Green Infrastructure Technical Steering Committee to develop regional solutions to porous pavement maintenance standards and equipment/training needs. Explore a co-op model of shared services and equipment. Use demonstration projects to generate more local project examples and track performance. Develop a parking lot retrofit screening program for strategic lots that are not expected to be reconstructed and that do not fall under the anticipated requirement for new/redevelopment projects.

    Soil amendments. Develop standard guidance for implementation by home owners and yard service companies. Soil amendments are for homeowners who value their turf grass lawns and will improve the lawns' water retention and infiltration capabilities. Support should be provided for research to document the performance of locally available materials and the benefits of various application approaches.

    Native landscaping. As part of the green infrastructure solutions offered to commercial and governmental properties, develop standard guidance for implementation, including expected cost savings from reduced mowing costs. As part of code and ordinance reviews, develop regional approaches to allow native landscaping to substitute for turf grass.

14. Develop a capital improvement plan (CIP) screening tool and incentive program to realize green infrastructure opportunities and cost savings. A mapping tool to share information on CIP projects in the region would provide regional green infrastructure collaboration opportunities. First address street CIP projects, then expand it to address other utilities (water, sewer, etc.). This planning tool ensures municipal leaders plan for green infrastructure early in the design process (before it's too late to include). Implementation costs are reduced when green infrastructure is done in conjunction with planned construction projects.

STANDARDIZE

Key Findings

There is no requirement for green infrastructure in the region. While changes to some municipal codes and ordinances allowing green infrastructure have occurred in recent years, there remain significant barriers within longstanding municipal codes, development ordinances, and review processes. A code and ordinance review by 1,000 Friends of Wisconsin in the Menomonee River watershed found that barriers within codes and ordinances are often similar among municipalities. Consequently, identifying solutions to these common barriers is important.

Green infrastructure implementation will be needed on public and private properties to capture runoff from impervious areas. Different mechanisms are needed to implement projects, depending upon whether the site is an existing, new, or redevelopment site (Figure 32).

Regulatory uncertainty exists within the plumbing code for rainwater harvesting because the current code does not differentiate between wastewater reuse and rainwater harvesting. This creates barriers to significant rainwater harvesting implementation for uses other than lawn and plant watering. The state regulations need to be clarified for rainwater harvesting and these changes cascaded down to the local code enforcement level. Incorporating these code revisions with water use from other sources, such as sump pump water, will provide benefits to both the MMSD Private Property Inflow and Infiltration Reduction Program and this Plan.

Design standards do not exist at the regional level for the MMSD recognized green infrastructure strategies. Consistent design standards, review checklists, and standardized maintenance expectations need to be developed for the region. Once in place, MMSD should provide fact sheets and training on these standards to green infrastructure designers, reviewers, and construction and maintenance personnel.

STANDARDIZE

Summary Recommendations and Timeline

2013-2014	Develop solutions to universal impediments to green infrastructure implementation within local codes, ordinances, and design standards
2013-2015	Update regional regulations to require green infrastructure with new and redevelopment projects
2016-2017	Provide incentives to municipalities to quickly update codes and ordinances
2013-2015	Allow flexibility for neighborhood or offsite implementation of the green infrastructure requirement
2013-2015	Work with the State on plumbing regulations to allow use of harvested rainwater and other water sources
	Develop rainwater harvesting and other water source use guidance consistent with state regulation changes
2013-2015	Develop regional design standards for the "Fresh Coast Green Solutions" green infrastructure strategies
2013-2015	Develop green infrastructure operation and maintenance standards
2020	Update standards every 5 years
2016	Provide training for design and maintenance standards
2013-2014	Include code revisions for related programs when developing code updates
2013-2014	Develop memorandums of understanding with key green infrastructure collaborators

FIGURE 32

Common approaches to green infrastructure implementation for public and private properties

Recommendations

1. Develop regional solutions to universal green infrastructure implementation impediments through municipal collaboration on local codes, ordinances, and design standards. Consider impediments identified through the Menomonee River watershed permit codes and ordinance review led by 1,000 Friends of Wisconsin as a starting point to build upon and consider all green infrastructure implementation barriers, whether or not they are specifically tied to codes and ordinances. For example, municipalities are concerned about operation and maintenance, and so addressing these factors regionally could offer efficiencies.

2. Update regional regulations to require green infrastructure with new and redevelopment projects. A regional green infrastructure requirement could be handled through a revision to MMSD's Chapter 13, which currently regulates stormwater quantity. Options could include allowing for more flexibility in the Chapter 13 quantity control goals when a green infrastructure strategy is employed on smaller-scale, new, and redevelopment projects. MMSD should consider lowering the area threshold for when the rule becomes applicable.

   Regulation is not the only mechanism that will be needed for infrastructure implementation. Impervious areas not covered under the new/redevelopment requirement should have other mechanisms explored to promote implementation. For example, properties not triggering the new/redevelopment green infrastructure requirement could have incentive programs to promote implementation. Incentive programs could include reductions in municipal stormwater fees in exchange for green infrastructure implementation, similar to the current practice in the City of Milwaukee. Promoting implementation, on residential properties may best occur through neighborhood-wide implementation campaigns and point-of-sale incentives to install rain barrels, rain gardens, and soil amendments.

   Incentive grant programs will also be needed to target certain types of green infrastructure, such as green roofs on existing buildings. Regulations, financial incentives, and funding are interrelated, making the final strategies for each type of impervious feature dependant on the details of the regulatory requirement and funding approach.

3. When implementing the green infrastructure requirement for new/redevelopment projects, provide incentives for municipalities to quickly update their local codes and ordinances for consistency. Example incentives include technical and financial assistance and demonstration project grants.

4. The flexible stormwater management options in Chapter 13 that allow for offsite implementation, a fee in lieu of meeting the requirement onsite, and neighborhood-wide implementation should also be included with the regional green infrastructure requirement. For example, neighborhood-wide implementation has already been used as a tool for redevelopment in the Menomonee Valley. This redevelopment effort provided regional stormwater solutions and addressed them for multiple parcels to speed the redevelopment process.

5. Work with the state on plumbing and building code regulations to allow use of harvested rainwater and other water sources consistent with recent revisions to the International Plumbing Code (IPC) and the Unified Plumbing Code (UPC). Collaboration at the state level should focus upon reducing regulatory uncertainty within plumbing code interpretation for rainwater harvesting where current codes do not differentiate between wastewater reuse and rainwater harvesting.

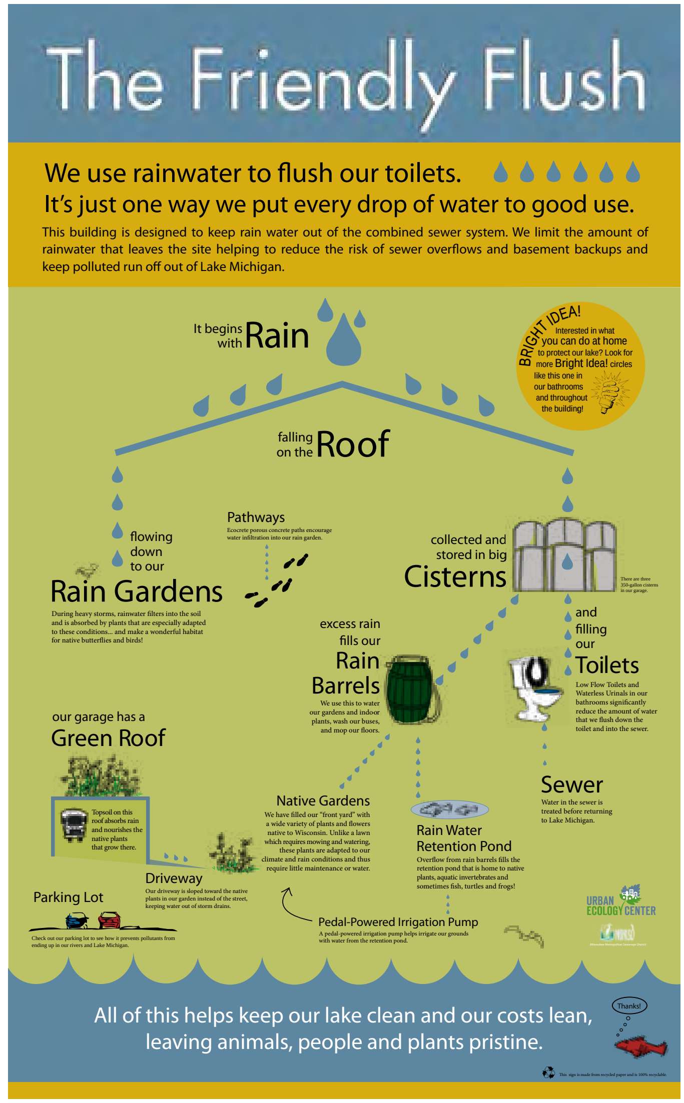
   Once made, the changes developed at the State level need to be clearly cascaded down to the local code enforcement level through educational outreach efforts.

A regional study should be conducted to examine the benefit of green infrastructure on regional flood management (MMSD's Chapter 13 rule). The study could make a strong case for relaxing this requirement if green infrastructure is implemented.

A new and redevelopment green infrastructure requirement in the Milwaukee area could lead to significant green infrastructure investment. In Philadelphia, a stormwater requirement for redevelopment is estimated to provide $1 billion of green infrastructure investment from new and redevelopment over the next 25 years. A Milwaukee region green infrastructure requirement will need to be developed collaboratively with the development community.

The benefits of regionalizing rainwater harvest code reviews should be considered to provide consistent interpretation across the region. This could potentially be incorporated as a resource within the Green Infrastructure Service Center. Rainwater harvesting code revisions are directly applicable to the Private Property Inflow and Infiltration Reduction regional initiative. Code revisions should consider other water sources, such as sump pump water and detention ponds, that could be easily harvested to provide solutions to regional water management efforts.

6. Develop regional green infrastructure design standards for the "Fresh Coast Green Solutions" green infrastructure strategies. Design standards should set minimum standards to achieve the Plan volume capture goals and include:
    - Rainfall design depth, design procedures, example construction details, and example photos of local installations
    - Site considerations, such as set-backs from buildings, utilities, minimum space requirements, and approaches that minimize inflow and infiltration to sewers and sewer laterals
    - Techniques to maximize stormwater pollution removal
    - Standardized procedures for calculating the strategy stormwater storage volume and annual treatment volume
    - Fact sheets for public officials, public works staff, the general public, and property owners
    - Capital cost estimates that compare the price of green infrastructure construction done in conjunction with planned capital projects to the cost of separate green infrastructure retrofits
    - Design review checklists
    - Design tools similar to the MMSD LID Quicksheet that simplify the design process for green infrastructure



The Urban Ecology Center implemented a rainwater harvesting facility to water plants and flush toilets. Meeting the plumbing code to use rainwater to flush toilets led to many monitoring requirements that are not practical for expanded rainwater harvesting in the region. Working with the state on plumbing code changes to streamline the regulatory process will be important to expanding rainwater harvesting in the region.

Image courtesy of the Urban Ecology Center

Standardizing green infrastructure design with up-to-date and regionally specific guidelines will help to provide consistency across the region, improve reliability, and streamline the design process.

Capital costs can be reduced when green infrastructure is implemented as part of a planned construction project, such as a streets capital improvement program or as new and redevelopment projects occur. This can provide up to a 30 to 40 percent cost savings compared to green infrastructure retrofits.

Vacuum Sweeper

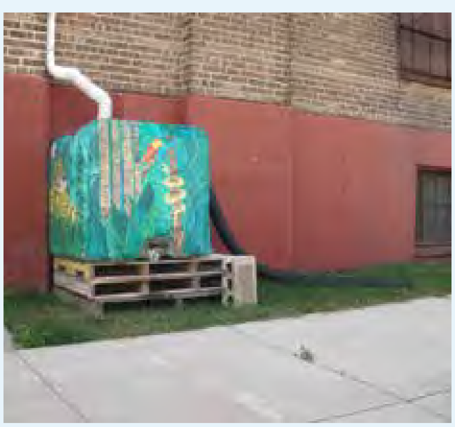
Standardizing green infrastructure strategy maintenance requirements will provide useful information on best practices, costs, and expectations for implementing green infrastructure strategies.

Photos Courtesy of Stormwater Compliance LLC

7. Develop operation and maintenance standards for the green infrastructure strategies that include:
   + Maintenance cost ranges with comparison to traditional maintenance requirements.
   + Maintenance schedules and inspection checklists.
   + Develop example agreements and expectations for maintaining strategies. Agreements should consider standard maintenance expectations for strategies implemented with public funding or to meet the recommended new and redevelopment green infrastructure requirement.
8. Encourage feedback, and then update design standards and maintenance procedures from implementation feedback. Review/revise standards every 5 years.
9. Provide training opportunities on the design and maintenance standards to planners, engineers, and officials in the region.
10. When reviewing local codes and ordinances and updating plumbing codes, consider complementary code revisions, such as harvesting water from cisterns, particularly where significant basement backups have occurred. Consider if a hung plumbing requirement for new/redevelopment projects should be required in chronic basement backup neighborhoods.
11. Develop example memorandums of understanding among organizations that may collaborate on green infrastructure implementation. Examples would be for schools, parks, WisDOT, and other public entities where cost-effective green infrastructure can be implemented in larger, open spaces.

Rainwater Harvesting Irrigates Community Garden

Bay View House Hidden Garden harvests rainwater to irrigate this community garden. American Rivers estimates that if rainwater harvesting were expanded to include all community gardens in the City of Milwaukee, 1.7 million gallons of drinking water a year could be saved.



Rainfall is captured on building rooftops, stored in a cistern, and piped to a community garden for irrigation

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FUND

Key Findings

Funding green infrastructure capital improvements and maintenance costs was rated the highest concern among stakeholders who provided feedback during the Plan development.

Green infrastructure needed to achieve the 2035 Vision goals will require implementation on both public and private properties. One method of private property implementation will likely be in the form of a green infrastructure requirement for new or redevelopment projects. Several more ideas are discussed below.

Recommendations

1. Use the current MMSD 5-year budget established for green infrastructure to implement demonstration projects and the next phase of green infrastructure planning.

2. During MMSD's next Facilities Planning process, develop a long-term funding plan to achieve the 2035 Vision for green infrastructure. The evaluation should holistically consider funding, new green infrastructure regulatory requirements, and incentives because each of these elements can affect the other. For example, if a new or redevelopment project has a green infrastructure requirement, then collecting funds separately for that green infrastructure is not needed. A broad range of funding and financing models should be considered including:

   + Property tax assessments
   + Municipal stormwater utilities
   + A regional or watershed-permit-based stormwater/green infrastructure utility
   + Smart growth and smart community grants for pilot projects
   + State and private grants for pilot projects
   + State revolving loan funding
   + Cost-sharing models that leverage local funding to obtain regional funding
   + Private funding of green infrastructure following energy service company (ESCO) models
   + Incentives for private property implementation that may be phased out over time
   + Issuing bonds to fund subbasin-scale demonstration projects or to establish local funds for a revolving fund program

   The analysis should consider if additional funding is needed for related work, such as TMDL implementation funding beyond what will be achieved through the Regional Green Infrastructure Plan.

   A variety of organizations have evaluated market-based approaches, as well as financial and non-financial incentives, to implement green infrastructure in regional case studies. Work currently underway through the Natural Resources Defense Council (NRDC) is exploring stormwater management utility options to fund green infrastructure in the MMSD planning area. Potential incentives, such as reduced stormwater fees for private property implementation or for depaving unnecessary imperviousness, could make green infrastructure even more cost-effective for property owners.

Funding, green infrastructure regulatory requirements, and implementation incentives need to be addressed holistically because each element affects the other.

FUND

Summary Recommendation and Timeline

2013-2017	Use the current MMSD 5-year budget to establish a foundation for the Plan
2014-2017	Through the next MMSD Facilities Planning process, develop a long-term green infrastructure funding plan
2015-2017	Based upon local demonstration project experience, refine the projected capital as well as operation and maintenance costs for the green infrastructure strategies
2017	Based upon the funding approach selected, determine staffing needs for green infrastructure program implementation
2013	Develop a jobs training program for green infrastructure installation and maintenance

Of the top 5 concerns the Green Infrastructure Technical Steering Committee expressed, funding was the highest priority.

1. **Funding**
2. **Ensure proper maintenance**
3. **Incentives for implementation on private property**
4. **Communicate the benefits of green infrastructure**
5. **Design standards**

3. Based on local demonstration projects, refine the capital and maintenance costs for the green infrastructure strategies. A reporting plan for capital costs should be developed as implementation progresses to establish local pricing trends. Similarly, a reporting plan should be developed to track operation and maintenance costs to inform people as green infrastructure maintenance becomes standardized. This information should be considered as part of the Facilities Plan funding analysis.

The Plan recommends a feedback mechanism to establish trends in capital and maintenance costs over time.

4. Based on the funding approach selected, determine staffing needs for green infrastructure program implementation. Staff will be needed to provide technical expertise and to manage various green infrastructure initiatives. Dedicated staff or staff augmentation is recommended to provide public information and education, particularly for public projects. This will be an important role as green infrastructure becomes more common in public projects, such as street reconstruction. Residents should be educated on the benefits of green infrastructure, on their role in maintaining it, and on the choices they have during the planning and design process.

   Although additional staff will be needed, those needs vary depending upon the funding mechanism to be selected in the Facilities Planning evaluation and on the level of outside consulting expertise desired. Some green infrastructure programs involve the hiring of outside consultants to meet workload demands, while others increase internal staff. A mix of solutions is possible depending on MMSD's preferences.

5. Develop a jobs training program for green infrastructure installation and maintenance. Partner with existing local organizations that specialize in growing plants and training people, such as Growing Power and the Milwaukee Community Service Corps.

Jobs training programs for construction and maintenance of green infrastructure will help deliver efficient green infrastructure service to municipalities.

LEARN, SHARE, AND ADAPT

Findings

The Plan is a long-term plan that will need to be reviewed and adjusted to meet the stormwater capture goal. Implementation is expected to progress over time, and new regulations may require revision to design standards. Consequently, periodic review of design standards and maintenance practices will provide opportunities for continual improvement of best practices.

Providing a venue for regional green infrastructure practitioners to share lessons learned and to highlight successes will support even more green infrastructure implementation.

Recommendations

1. Promote continuous improvement in design and maintenance practices. Provide regular opportunities, such as through the Clean Rivers, Clean Lake conference, webinars open to the green infrastructure practitioner community, and publicly available seminars to share green infrastructure implementation lessons learned in the region. Municipalities and decision makers leading green infrastructure efforts in the region should be recognized for their achievements.

LEARN, SHARE, AND ADAPT

Summary Recommendations and Timeline

2013-2035	Enable green infrastructure information sharing, such as through the Clean Rivers, Clean Lake conference
2018	Review design and operation and maintenance standards every 5 years
2018	Review the Plan every 5 years
2013-2017	Through demonstration projects, monitor different implementation strategies for soil amendments and stormwater trees
	Add project summary information to the H2OCapture.com mapping
2013	Update the H2OCapture.com website to share Regional Green Infrastructure Plan performance assumptions
2015	Develop consistent impervious area data across the region when regional GIS data updates occur
2017-2019	Incorporate smartphone technology as a tool for green infrastructure implementation where benifical

Events such as the Clean Rivers, Clean Lake Conference are an excellent venue to promote information sharing on green infrastructure strategies and local implementation successes.

Photos courtesy of the Southeastern Wisconsin Waterheds Trust

2. Review design and maintenance standards every 5 years based on demonstration project successes and lessons learned.

3. Review the Plan and progress towards meeting the 2035 Vision goals every 5 years. Adjust recommendations based upon implementation success and progress on other regional water management initiatives (TMDLs, Private Property Inflow and Infiltration Reduction Program, etc.).

4. Through demonstration project monitoring, test different implementation strategies for soil amendments to turf grass areas and stormwater trees. Monitoring and testing soil amendments are recommended because it is a low-cost practice that has the potential to be applied wherever turf grass exists in the region. One approach would place soil amendment test plots side-by-side to measure long-term performance and costs using a variety of techniques.

   Monitoring and testing stormwater trees is recommended because hundreds of thousands of ash trees will be dying in the region from insect damage (the Emerald Ash Borer) and will need to be replaced (City of Milwaukee 2009). At the same time, municipal engineers have reported trees dying after being planted near green infrastructure practices. Consequently, studying a variety of planting techniques and measuring growth and vitality over time would benefit the region and improve planting success for the many hundreds of thousands of trees that will need to be planted over the coming decades. Support monitoring and information sharing on best practices for managing nutrients from deciduous trees is also recommended. Each of these monitoring projects could be conducted in partnership with local universities.

5. The H2OCapture.com website has the potential to be a great resource for standards and tracking green infrastructure implementation in the region. At appropriate times, the website should be updated with:

   + Green infrastructure strategy performance assumptions used in the Plan
   + Project summaries for green infrastructure projects implemented in the region, including photos, site-specific performance, costs, and designs
   + Design standards, operation and maintenance standards, the Plan, and future updates

6. The region will benefit from consistent imperviousness information. The Plan identified that no consistent impervious data reporting approach exists, nor is there a consistent building layer. As green infrastructure is implemented in the region, a consistent data standard would help with future Plan updates, localized planning, and other uses within the region.

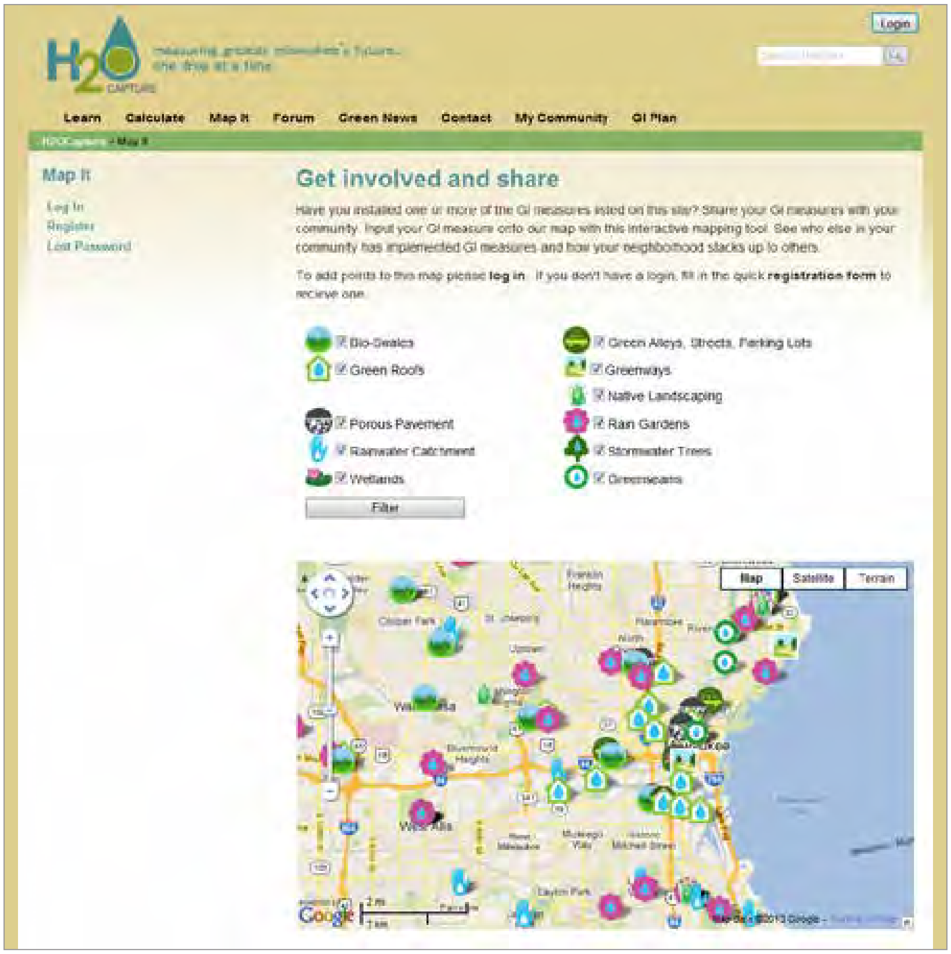

FIGURE 33

The H2OCapture.com website should be regularly updated to serve as an effective tool to track green infrastructure implementation progress. It can also provide standards and resources for the region.

H2OCapture.com (Figure 33) or another resource should be used as a platform for promoting regional capital improvement planning and green infrastructure collaborations. Building this capacity into the website would offer municipalities an easy way to see street construction projects as green infrastructure opportunities.

The website will need enhancement and should be used to measure progress towards meeting regional or municipality-specific green infrastructure implementation key performance indicators.

7. As smartphone use and availability continues to become the norm, mobile applications for green infrastructure will grow. Potential applications could include identifying locations for demonstration projects, maintenance conditions, disseminating information on priority locations for green infrastructure, tracking success, and other features that could benefit the region. Smartphone technology as a tool should be considered as green infrastructure increases across the region.

NEXT PHASE RECOMMENDATIONS

The consultant team recommends the following next steps for the next phase of the Regional Green Infrastructure Plan:

1. Develop and implement a green infrastructure training plan for municipal leaders, public works and engineering officials, schools, residents, commercial and industrial properties, and developers.
2. Develop detailed sub-watershed analysis for three to five priority sub-watersheds to inform on strategic early green infrastructure projects; consider green infrastructure, TMDL, drainage problems, and Private Property Inflow and Infiltration Reduction Program objectives.
3. Develop solutions to universal impediments to green infrastructure implementation within local codes, ordinances, and design standards.
4. Update regional regulations to require green infrastructure with new and redevelopment.
5. Develop regional green infrastructure design, as well as operation and maintenance standards.
6. Conduct a screening level analysis of funding options to inform the Facilities Planning process.

Acronyms and Abbreviations

BMP	best management practice
CDC	Centers for Disease Control
CIP	capital improvement plan
CO_2	carbon dioxide
CSSA	combined sewer service area
ESCO	energy service company
GIS	geographic information system
ISS	Inline Storage System (Deep Tunnel)
kWh	kilowatt hours
MMSD	Milwaukee Metropolitan Sewerage District
MS4	municipal separate stormsewer system
mWh	megawatt hours
NRDC	Natural Resources Defense Council
Plan	Regional Green Infrastructure Plan
PWD	Philadelphia Water Department
ROW	right of way
SEMCOG	Southeast Michigan Council of Governments
SEWRPC	Southeastern Wisconsin Regional Planning Commission
SF	square foot
SLAMM	Source Loading and Management Model
SOP	standard operating procedure
SSSA	separate sewer service area
STEM	science, technology, engineering, and math
SUNY ESF	State University of New York College of Environmental Science and Forestry
TBL	triple bottom line
TMDL	total maximum daily load
TP	total phosphorous
TSS	total suspended solids
USEIA	U.S. Energy Information Administration
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
UWM CED	University of Wisconsin—Milwaukee Center for Economic Development
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System

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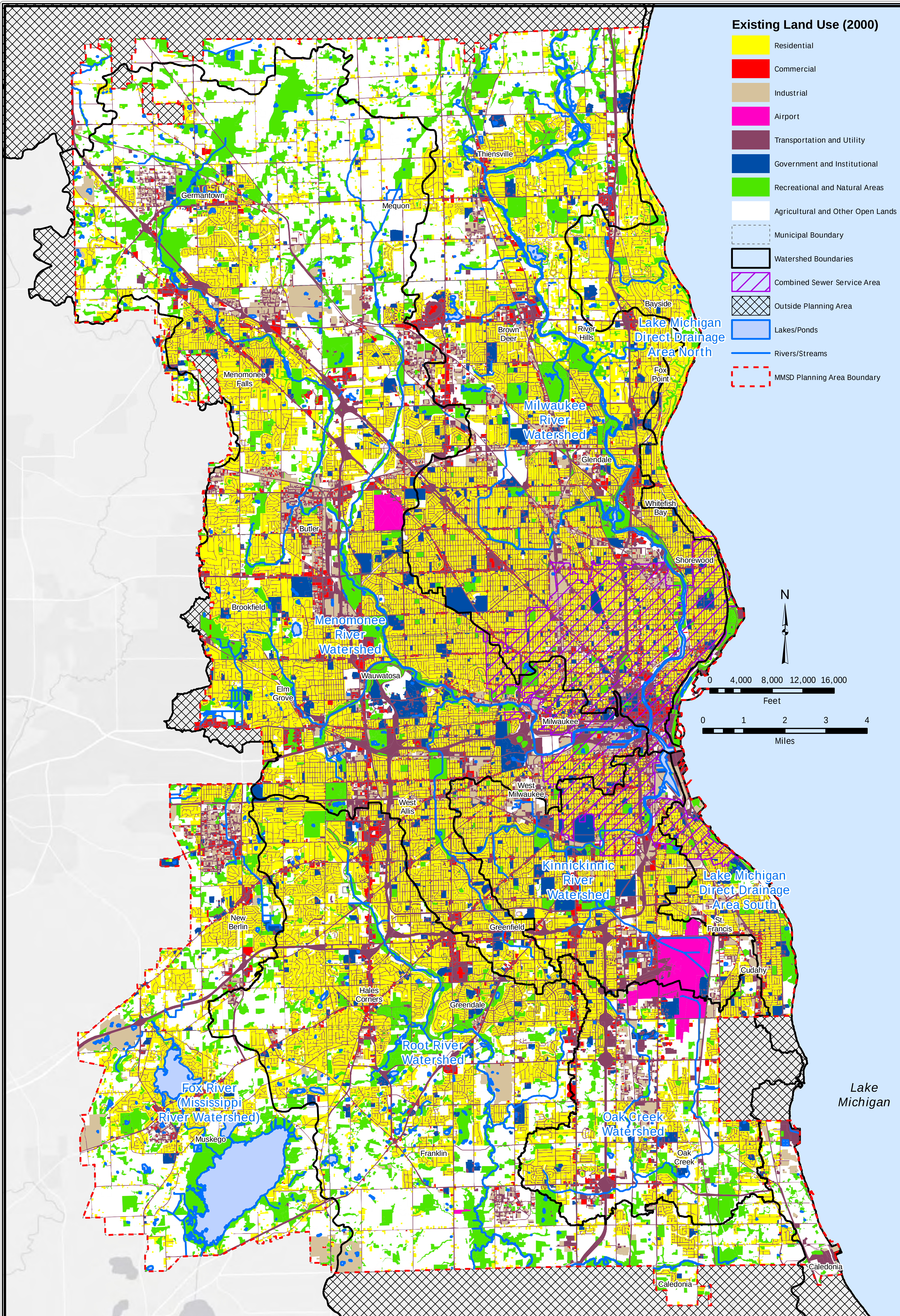
Map Appendix List



MMSD
PARTNERS FOR A CLEANER ENVIRONMENT

FIGURE **A-1**

LAND USE CLASSIFICATION
2000 LAND USE CLASSIFICATIONS WITHIN THE MMSD PLANNING AREA

Source: SEWRPC | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

2000_Land_Use_11x17_Portrait.mxd

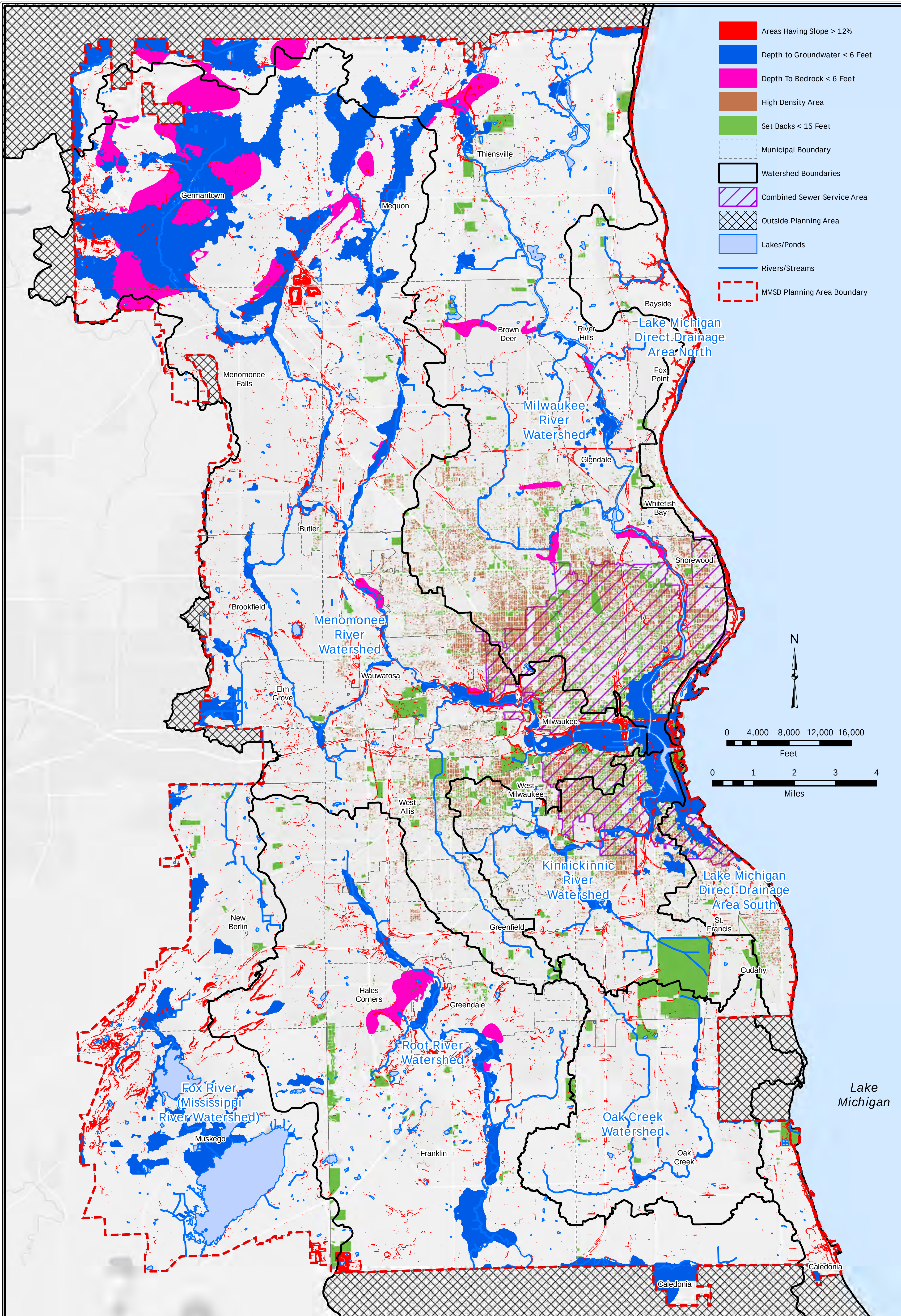


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FIGURE A-2

POTENTIAL CONSTRAINTS

GREEN INFRASTRUCTURE POTENTIAL CONSTRAINTS WITHIN THE MMSD PLANNING AREA

Source: MMSD | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

GI_Constraints_11x17_Portrait.mxd

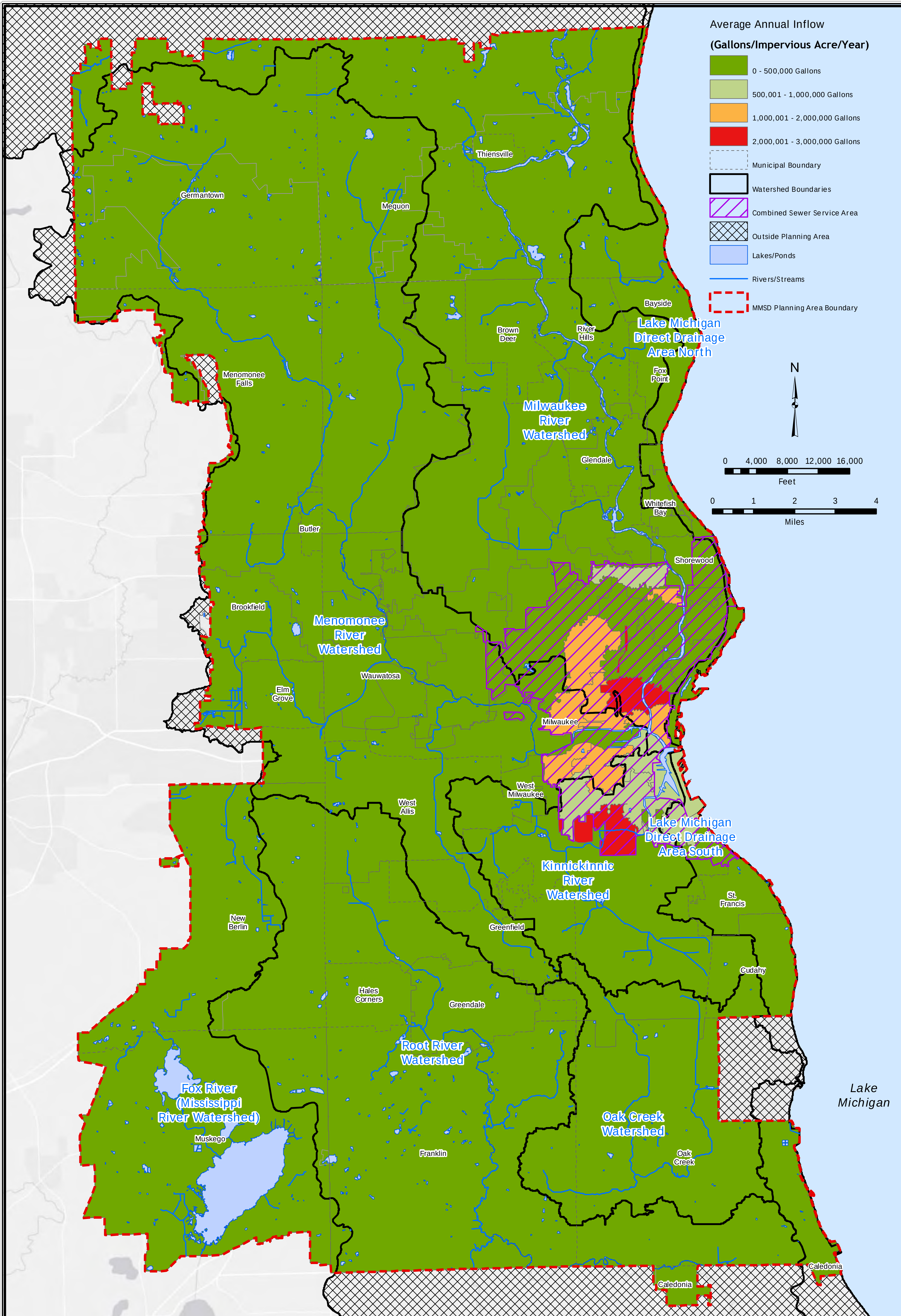

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FIGURE A-3

GREEN INFRASTRUCTURE BENEFITS
INFLOWS TO THE INLINE STORAGE SYSTEM (DEEP TUNNEL) WITHIN THE MMSD PLANNING AREA

Source: MMSD | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex5_High_Deep_Tunnel_Inflow_Areas_11x17_Portrait.mxd

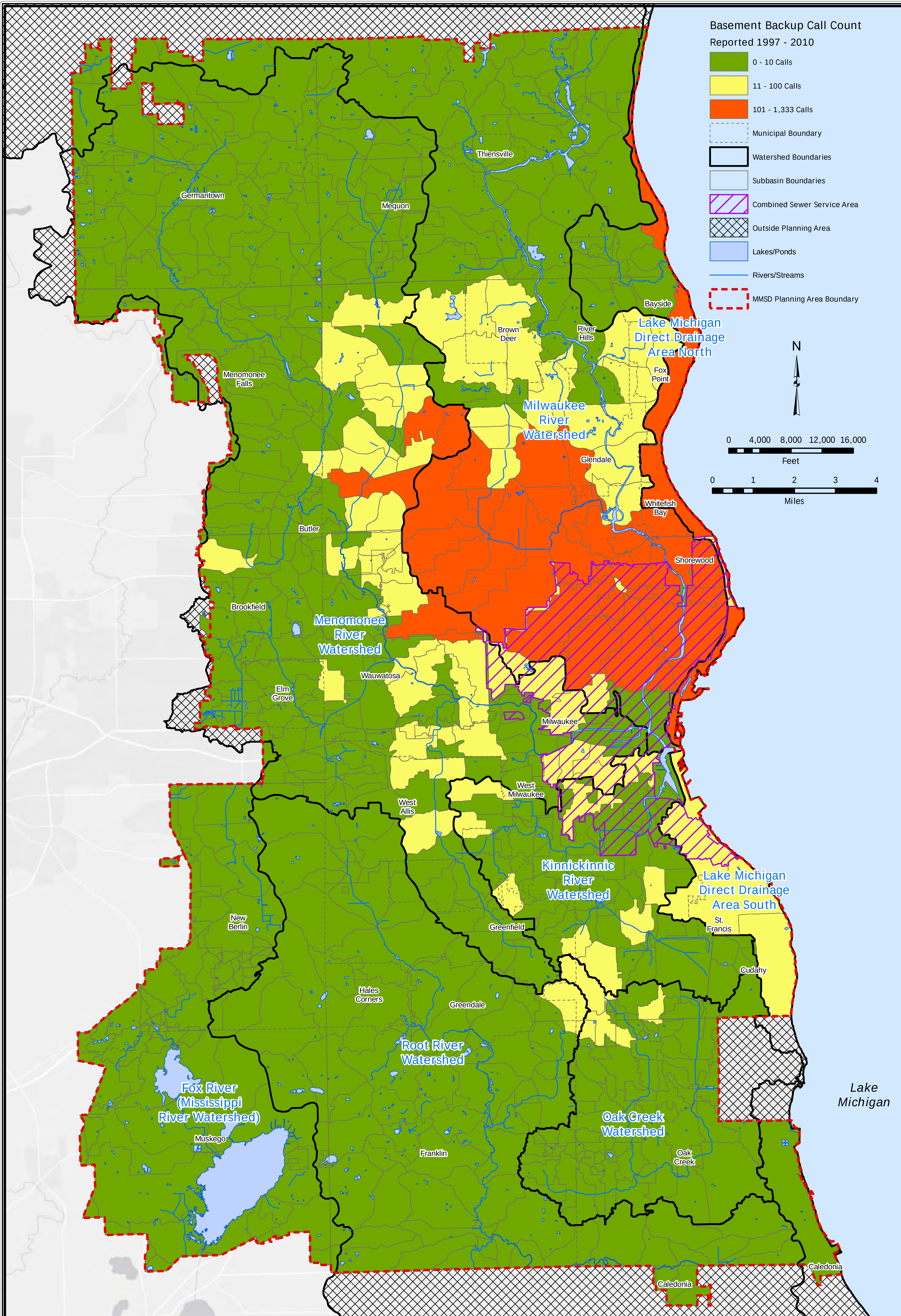

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FIGURE A-4

GREEN INFRASTRUCTURE BENEFITS

DOCUMENTED BASEMENT BACKUP CALLS BY SUBBASIN WITHIN THE MMSD PLANNING AREA

Source: MMSD | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex6_Known_Basement_Backup_Areas_11x17_Portrait.mxd

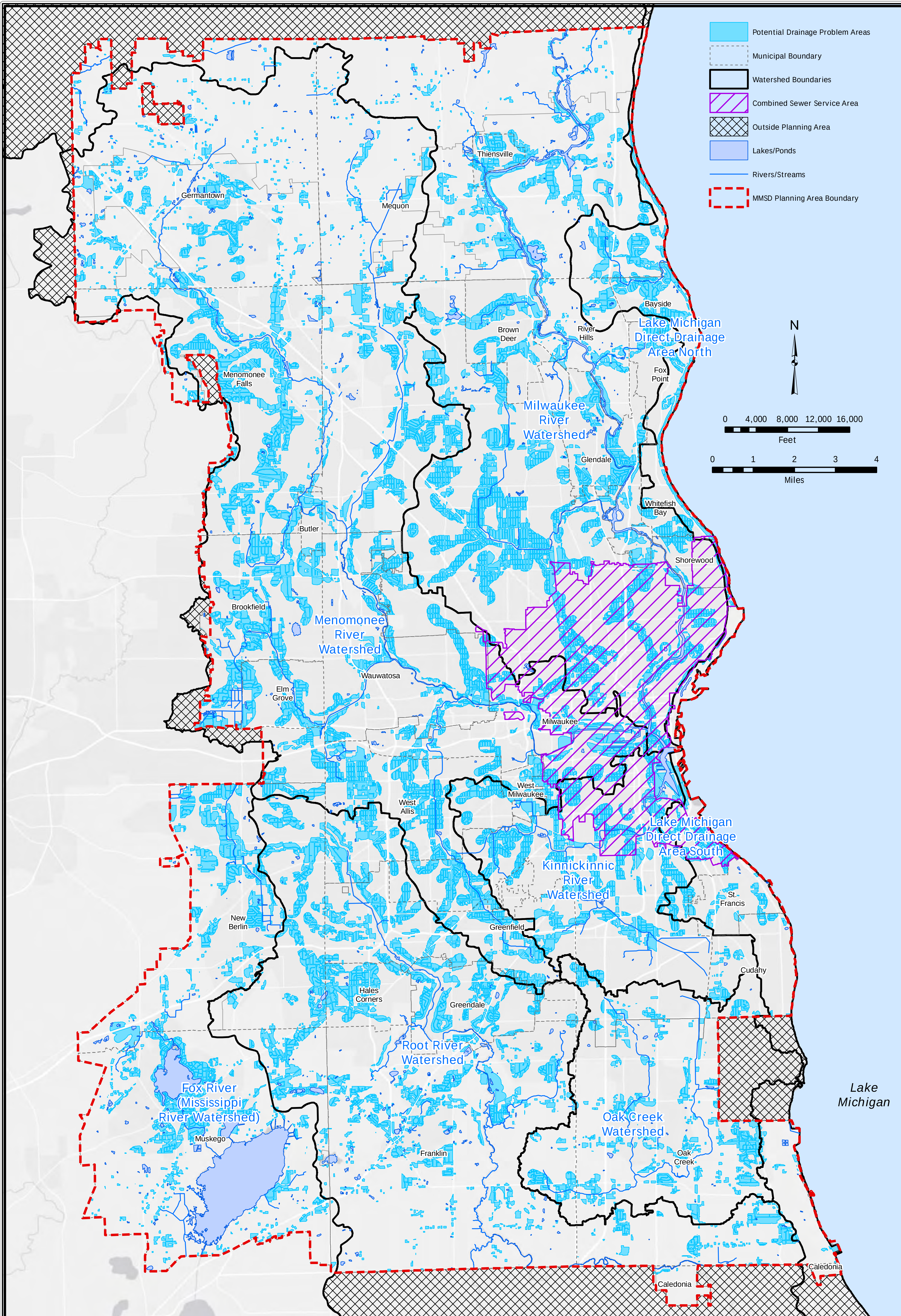

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FIGURE **A-5**

GREEN INFRASTRUCTURE BENEFITS

POTENTIAL DRAINAGE PROBLEM AREAS WITHIN THE MMSD PLANNING AREA

Source: MMSD	Updated: 4/19/2013	Regional Green Infrastructure Plan for the MMSD Planning Area

Ex7_Potential_Drainage_Problem_Areas_11x17_Portrait.mxd

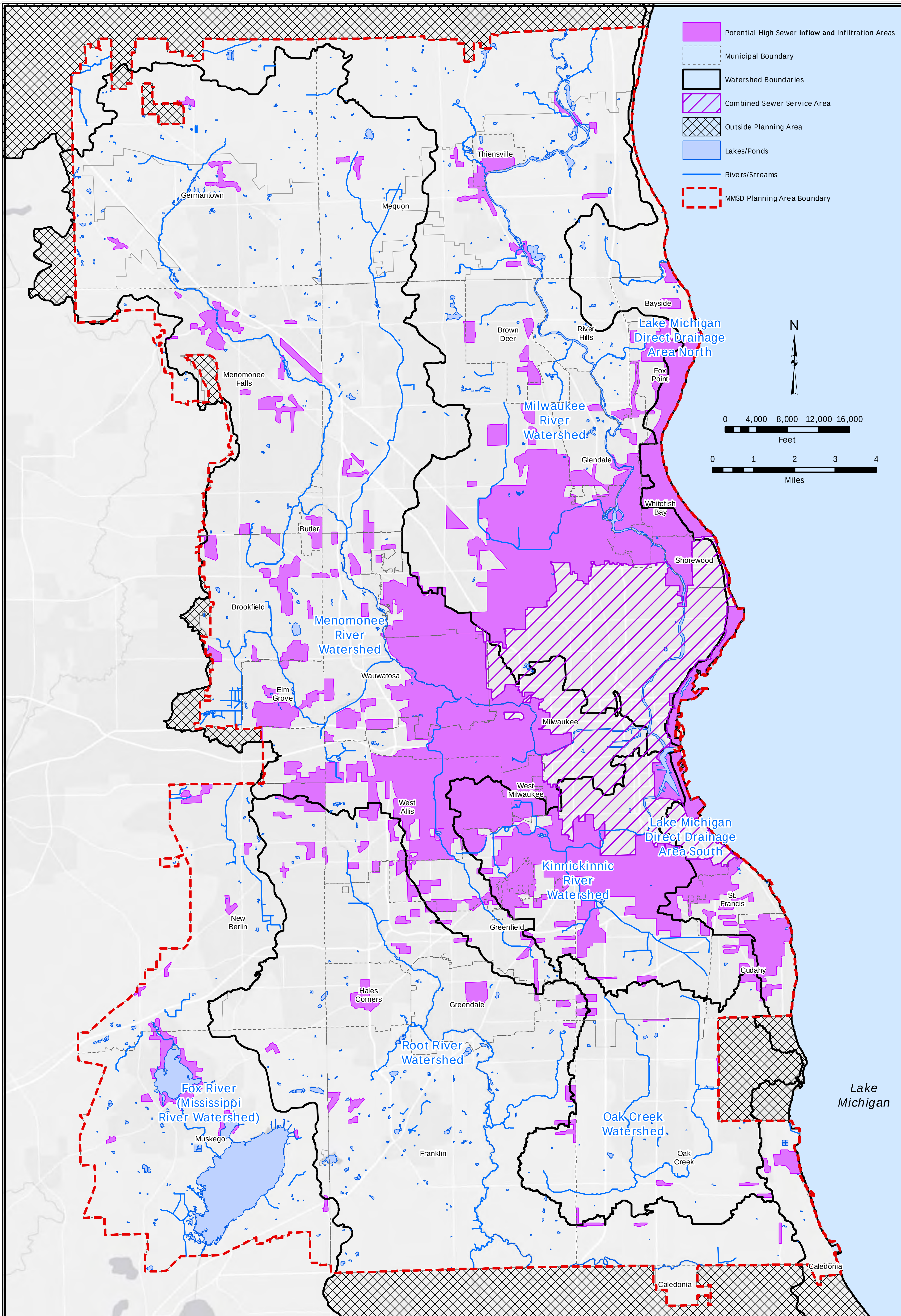

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FIGURE A-6

GREEN INFRASTRUCTURE BENEFITS

POTENTIAL HIGH SEWER INFLOW AND INFILTRATION AREAS WITHIN THE MMSD PLANNING AREA

Source: MMSD	Updated: 4/19/2013	Regional Green Infrastructure Plan for the MMSD Planning Area

Ex8_High_Infiltration_And_Inflow_Areas_11x17_Portrait.mxd

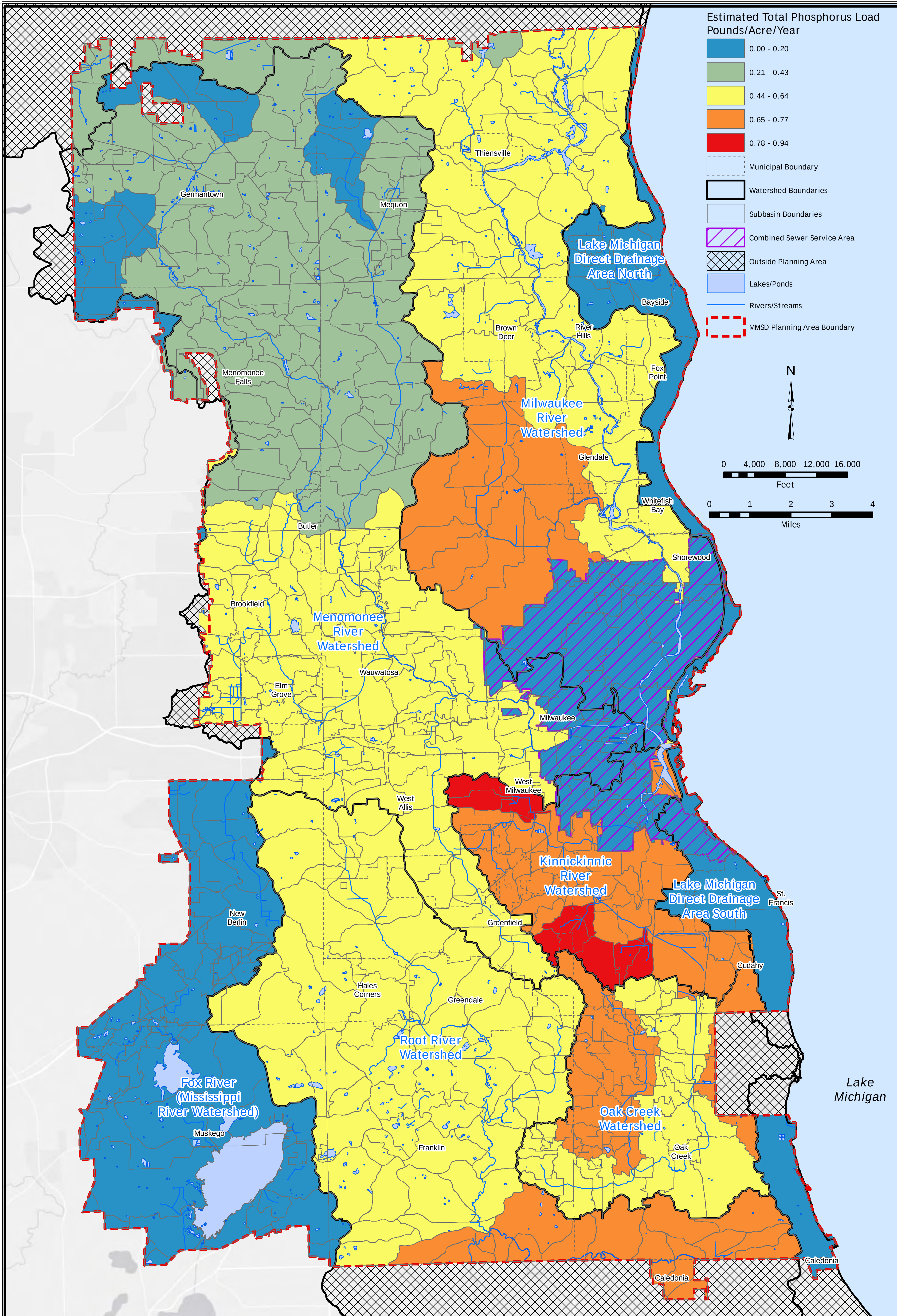

FIGURE A-7

GREEN INFRASTRUCTURE BENEFITS

ESTIMATED TOTAL PHOSPHORUS LOAD - POUNDS PER ACRE PER YEAR - WITHIN THE MMSD PLANNING AREA

Source: SEWRPC Regional Water Quality Management Plan | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex9a_High_Pollutant_Loading_Areas_Phosphorus_11x17_Portrait.mxd

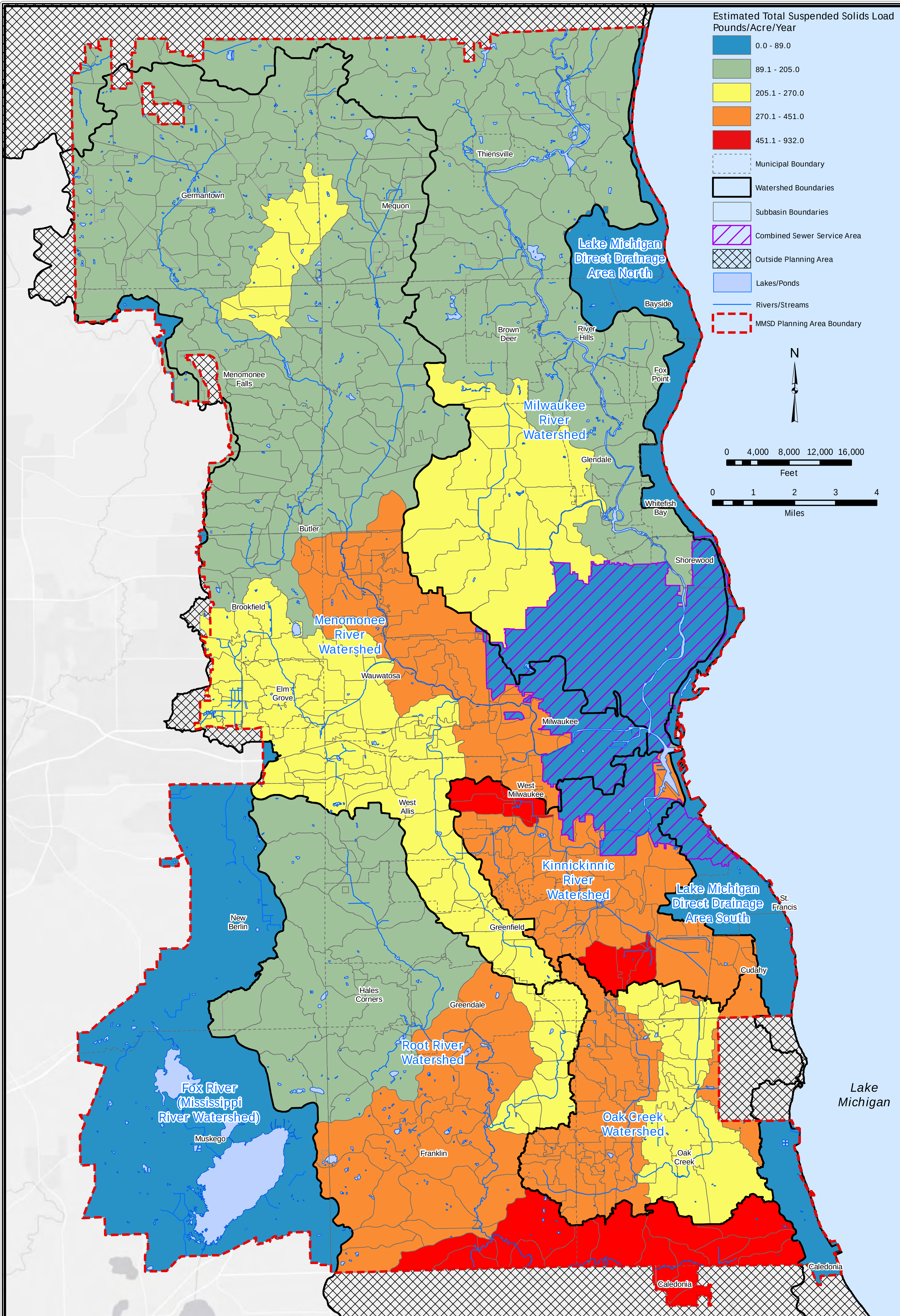

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FIGURE **A-8**

GREEN INFRASTRUCTURE BENEFITS

ESTIMATED TOTAL SUSPENDED SOLIDS LOAD - POUNDS PER ACRE PER YEAR - WITHIN THE MMSD PLANNING AREA

Source: SEWRPC Regional Water Quality Management Plan | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex9b_High_Pollutant_Loading_Areas_TSS_11x17_Portrait.mxd

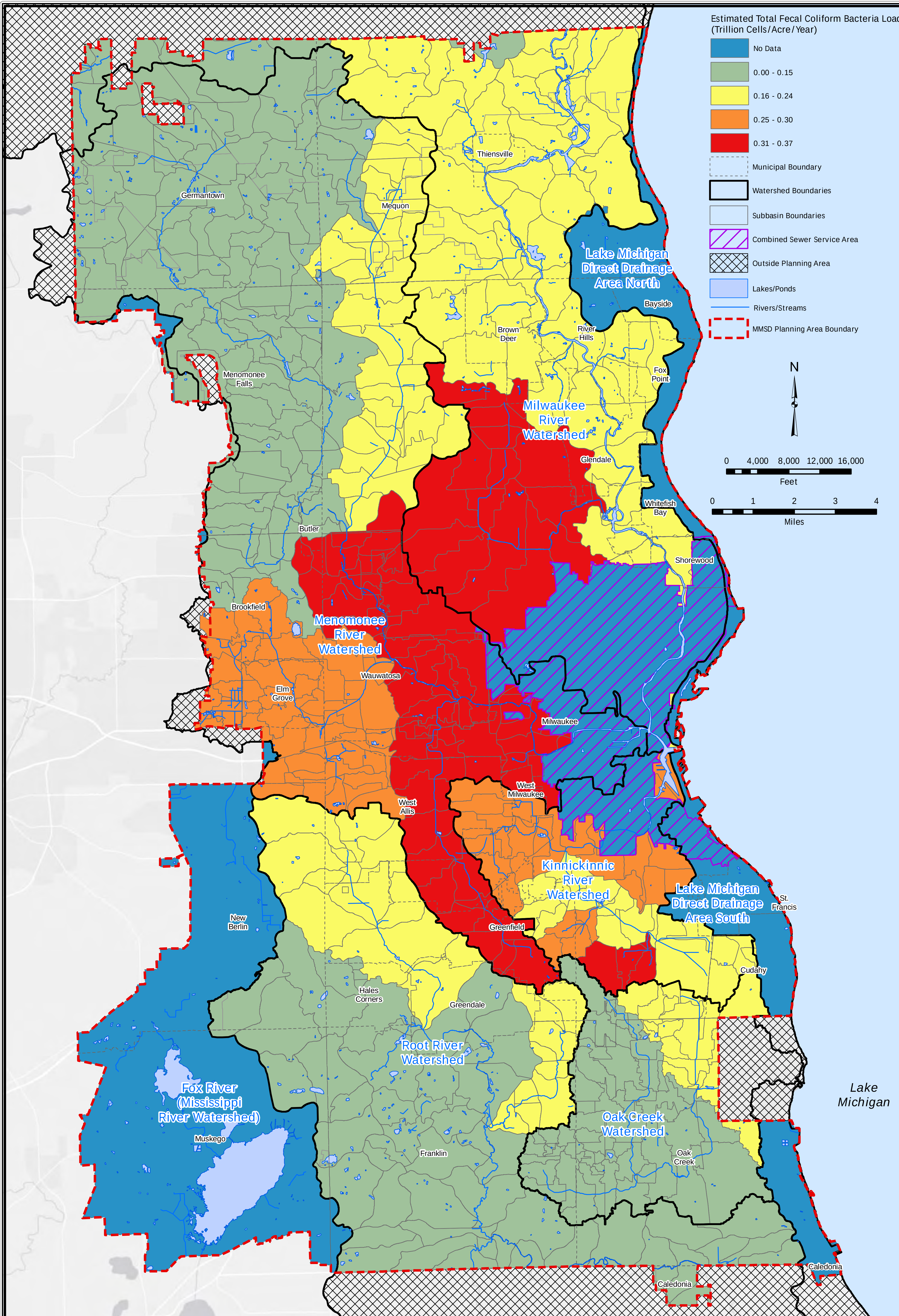

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FIGURE **A-9**

GREEN INFRASTRUCTURE BENEFITS
ESTIMATED FECAL COLIFORM BACTERIA LOAD - TRILLION CELLS PER ACRE PER YEAR - WITHIN THE MMSD PLANNING AREA

Source: SEWRPC Regional Water Quality Management Plan | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex9c_High_Pollutant_Loading_Areas_Fecal_Coliform_Bacteria_11x17_Portrait.mxd

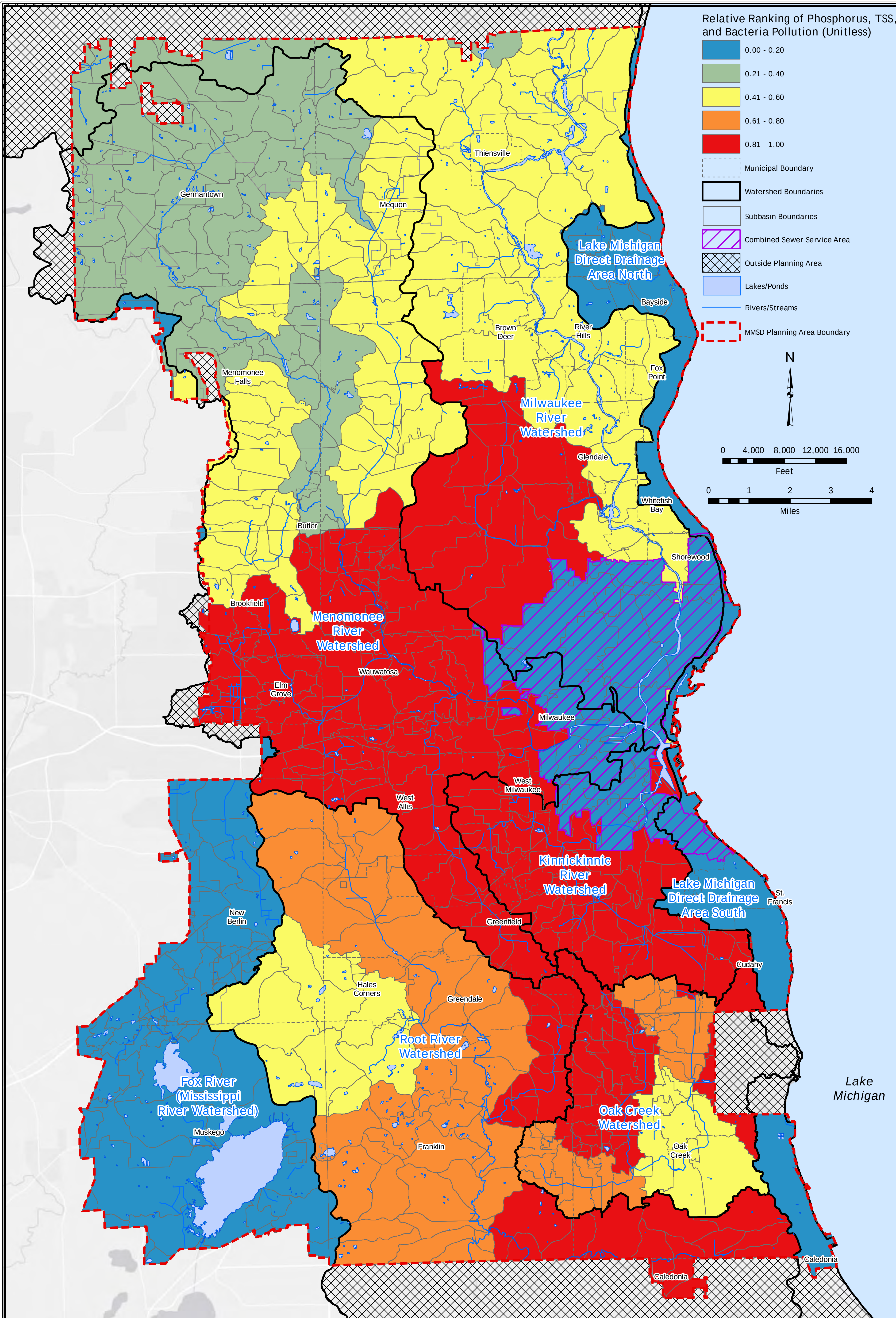

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FIGURE **A-10**

GREEN INFRASTRUCTURE BENEFITS
HIGH POLLUTANT LOADING AREAS WITHIN THE MMSD PLANNING AREA

Source: SEWRPC Regional Water Quality Management Plan | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex9_High_Pollutant_Loading_Areas_Phosphorus_11x17_Portrait.mxd

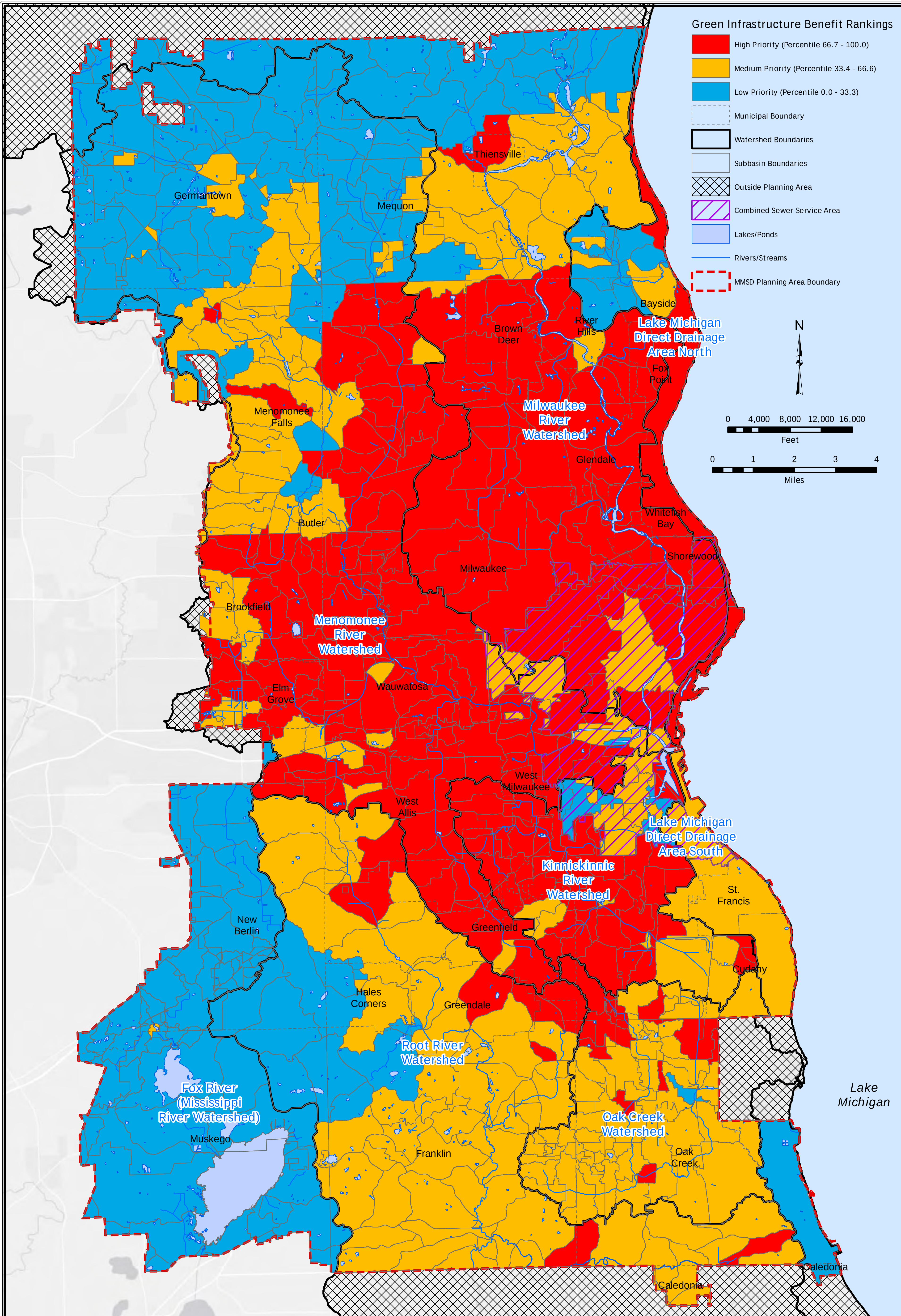

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FIGURE **A-11**

GREEN INFRASTRUCTURE BENEFITS
BENEFIT RANKINGS FOR GREEN INFRASTRUCTURE WITHIN THE MMSD PLANNING AREA

MMSD | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex10_Priority_Area_Benefits_Ranking_11x17_Portrait.mxd

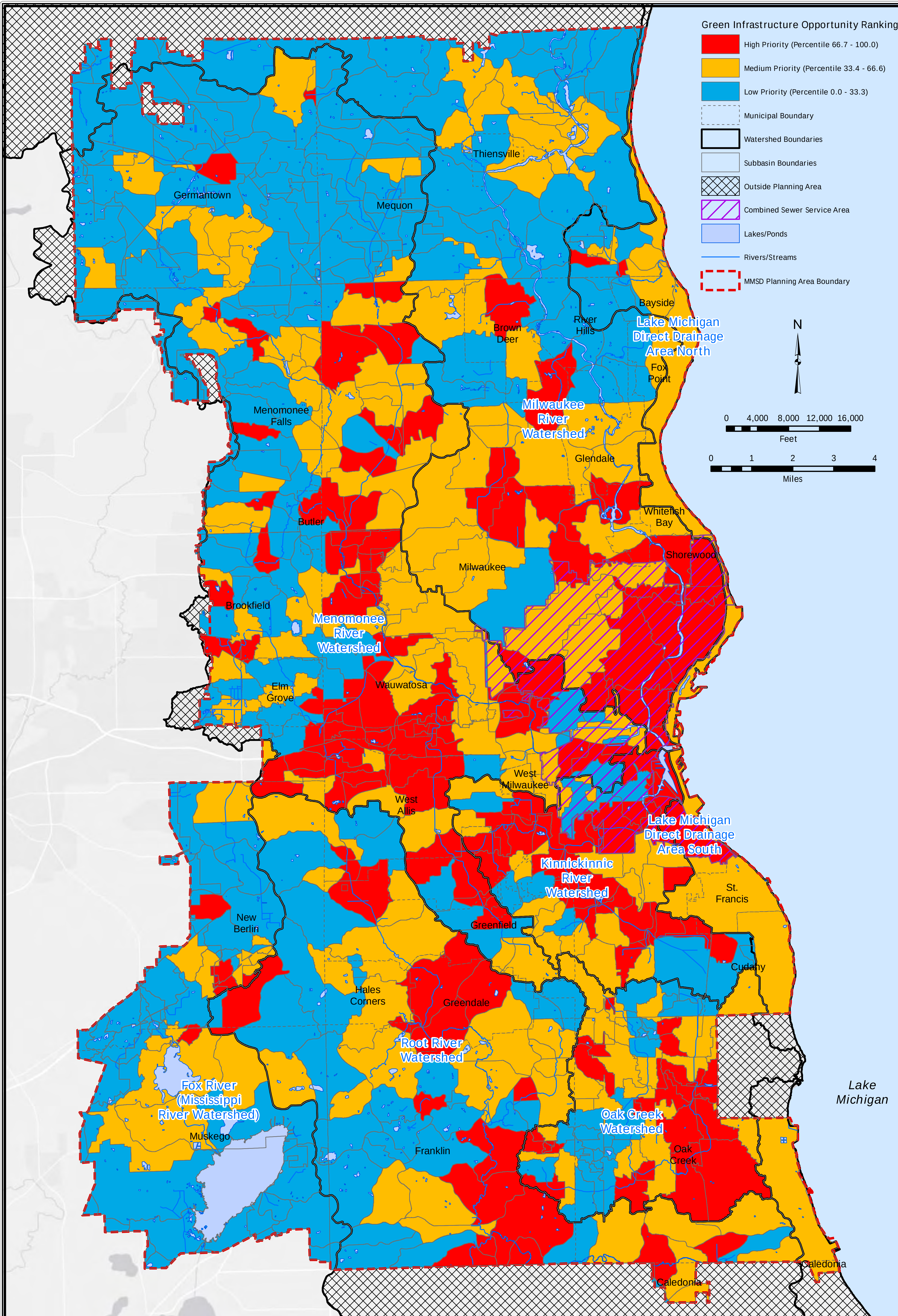

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FIGURE A-12

GREEN INFRASTRUCTURE OPPORTUNITIES

OPPORTUNITY RANKINGS FOR GREEN INFRASTRUCTURE WITHIN THE MMSD PLANNING AREA

MMSD	Updated: 4/19/2013	Regional Green Infrastructure Plan for the MMSD Planning Area

Ex11_Priority_Area_Opportunities_Ranking_11x17_Portrait.mxd

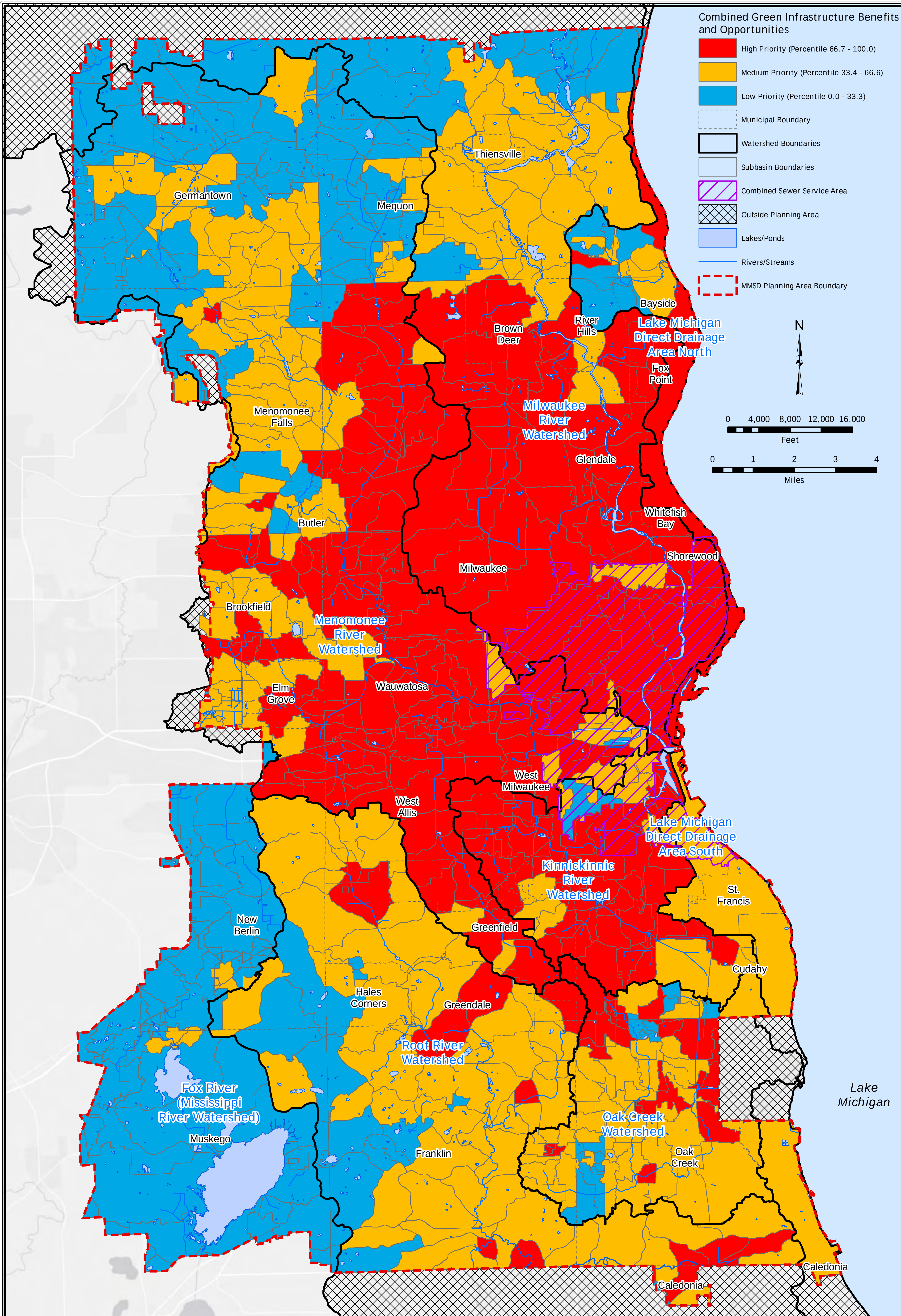

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FIGURE A-13

GREEN INFRASTRUCTURE BENEFITS

COMBINED BENEFIT AND OPPORTUNITY RANKINGS FOR GREEN INFRASTRUCTURE WITHIN THE MMSD PLANNING AREA

MMSD	Updated: 4/19/2013	Regional Green Infrastructure Plan for the MMSD Planning Area

Ex12_Priority_Area_Combined_Ranking_11x17_Portrait.mxd

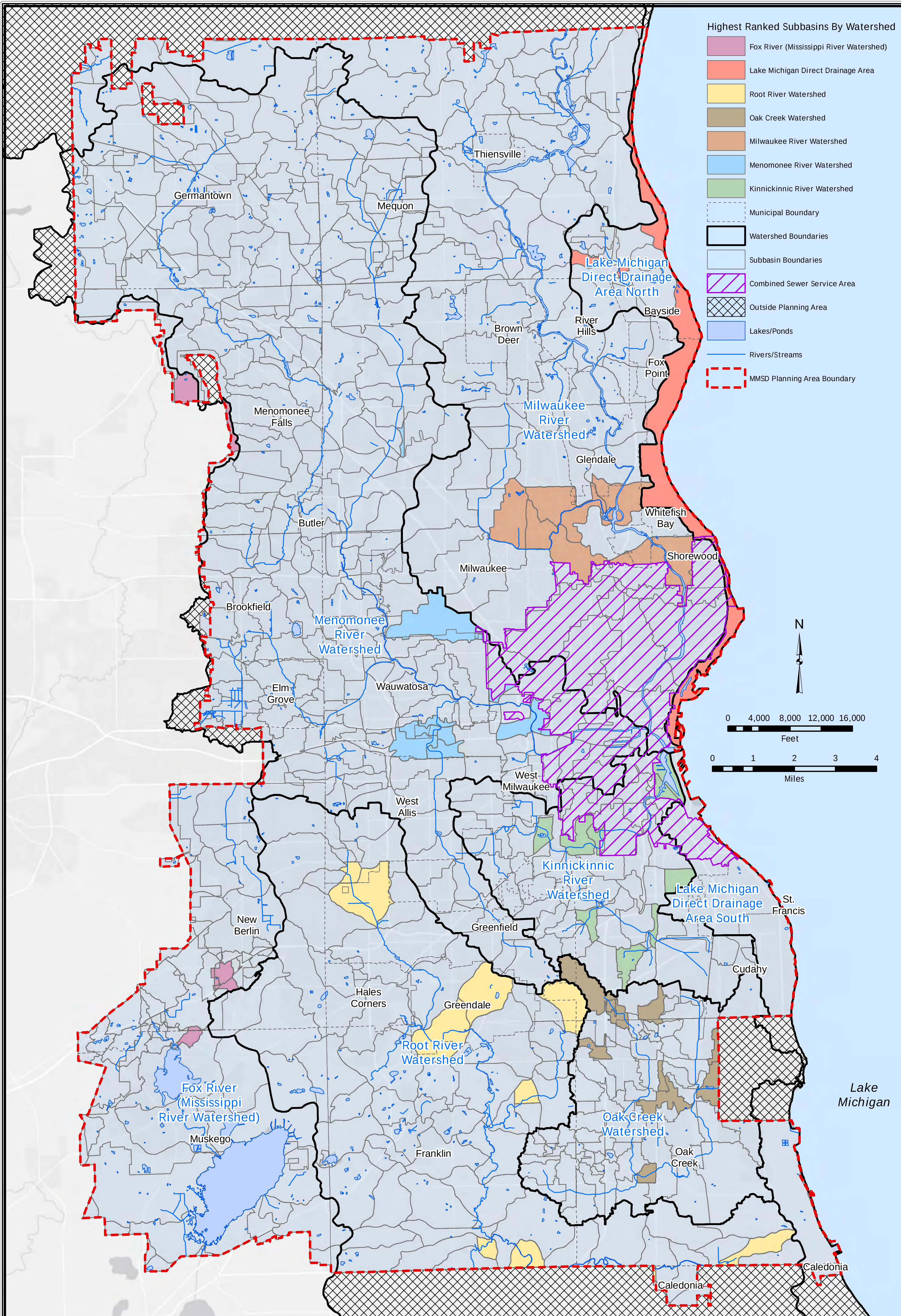

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FIGURE A-14

GREEN INFRASTRUCTURE RANKINGS

HIGHEST RANKED SUBBASINS BY WATERSHED WITHIN THE MMSD PLANNING AREA

MMSD | Updated: 4/19/2013 | Regional Green Infrastructure Plan for the MMSD Planning Area

Ex13_Highest_Ranked_Subbasins_By_Watershed_11x17_Portrait.mxd