Resilient Stormwater Management in the Great Lakes Region

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RISC SOLUTIONS

GREEN INFRASTRUCTURE LEADERSHIP EXCHANGE

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About RISC

Started in 2020 and funded by the Great Lakes Protection Fund (GLPF), the Resilient Infrastructure for Sustainable Communities (RISC) project was created to establish a resilience and finance leadership cluster of municipal resilience officers and other sustainability leaders across the binational Great Lakes Region. At that time, the project's key goals included promoting One Water and helping implement large-scale investments that lead to sustainable stormwater infrastructure and green neighborhoods in Great Lakes communities, thus directly addressing water quality and quantity challenges presented by the changing climate. Aside from providing a forum for collaboration and innovation on an inter-regional scale on new models for project delivery, investment, financing, and asset management, RISC was set up to ambitiously scale greening efforts throughout the Great Lakes Region, providing immediate benefits to the residents and improving resiliency to a changing climate.

In 2023, the leadership of RISC transitioned to the Green Infrastructure Leadership Exchange, a social impact network working toward equitable GSI implementation across the United States and Canada. The Exchange commissioned this report to capture the current status of stormwater management across the Great Lakes with a focus on current and potential RISC members, complementing the RISC Steering Committee's strategic planning efforts.

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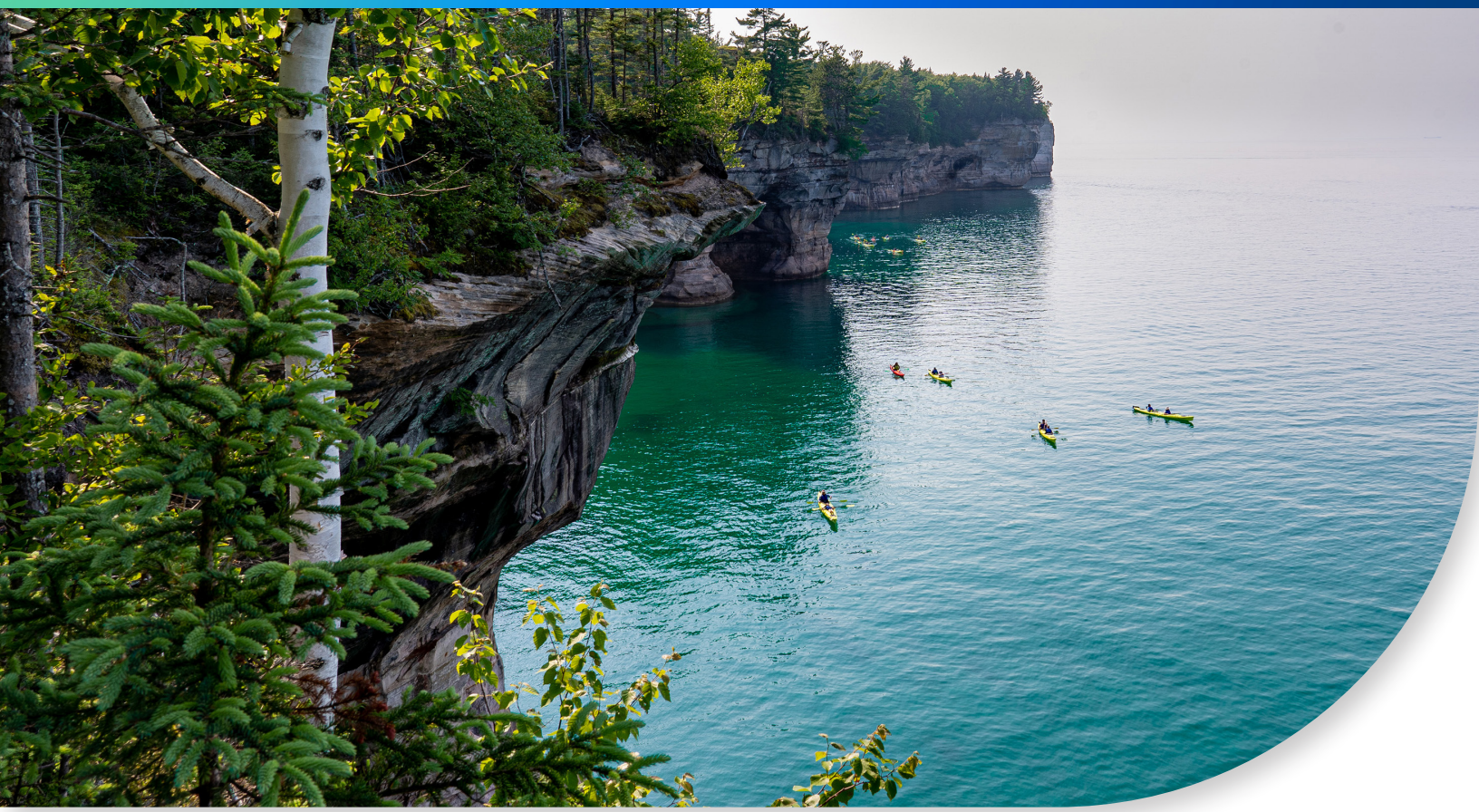


1. Executive Summary

The Great Lakes Region, home to the world's largest freshwater ecosystem, supports over 40 million residents and a $6 trillion regional economy (Council of the Great Lakes Region, 2017; NOAA, 2019). This ecosystem is vital for drinking water, recreation, and commerce, with activities like fishing, boating, and hunting contributing $52 billion annually to the economy and supporting 1.5 million jobs (Great Lakes Commission, 2017). Despite its significance, the region faces mounting challenges from climate change and urbanization. Over the past three decades, average annual precipitation in the region has increased by 5–15%, with extreme rain events rising by 45% (Marvel et al., 2023). These changes have overwhelmed aging stormwater infrastructure, leading to urban flooding, combined sewer overflows (CSOs), and degraded water quality. The resulting public health and environmental crises highlight the urgent need for innovative, equitable approaches to stormwater management.

This report, developed as part of the Resilient Infrastructure Sustainable Communities (RISC) project funded by the Great Lakes Protection Fund, examines the current state of green stormwater infrastructure (GSI) in the Great Lakes Region. To manage stormwater at its source, GSI employs natural processes that reduce runoff, improve water quality, and mitigate urban heat islands. Compared to traditional gray infrastructure, it also supports biodiversity, enhances public spaces, and promotes social equity (NRDC, 2022). Despite these advantages, scaling GSI remains challenging due to barriers such as inconsistent funding, workforce shortages, and fragmented planning.

Stakeholders identified funding as the most significant barrier to GSI implementation. While federal programs such as the Great Lakes Restoration Initiative (GLRI) and Bipartisan Infrastructure Law (BIL) provide substantial resources, smaller municipalities often struggle to access these funds due to capacity constraints and complex application processes (Gray-Green Community of Practice, 2022). Private capital and green bonds are increasingly

relevant for funding stormwater infrastructure in the U.S., as they provide necessary financial resources while promoting sustainable and environmentally responsible projects. By leveraging these funding mechanisms, municipalities can enhance stormwater management systems, reduce flood risks, and meet climate resilience goals. Frameworks such as stormwater utility fees are specially equipped to leverage them, although all newer forms of funding/financing will continue to require robust public engagement to overcome misconceptions and resistance. Case studies like Kitchener, Ontario, where a dedicated stormwater utility fee supports GSI maintenance and expansion, underscore the importance of stable revenue streams paired with transparent communication (City of Kitchener, 2023). Milwaukee Metropolitan Sewerage District's use of private finance is another example of non-government sources of capital that can be used to deploy large-scale water infrastructure solutions (Business Wire, 2025).

Workforce development also emerged as a critical challenge. Stakeholders emphasized the need for targeted training programs to address gaps in GSI design, installation, and maintenance expertise (U.S. Water Alliance, 2020). Programs such as the National Green Infrastructure Certification Program (NGICP) and Ontario's Fusion Landscape Professional certification offer scalable models for building a skilled labor force. These initiatives not only meet operational needs but also create pathways for underrepresented groups to enter the workforce, advancing economic equity.

Equity and environmental justice are central to effective GSI planning. Historically marginalized communities, particularly those in formerly redlined neighborhoods, face disproportionate risks from flooding and urban heat due to decades of disinvestment (Hughes et al., 2021). Programs like Milwaukee's "Space to Grow," which integrates GSI into schoolyards in underserved neighborhoods, demonstrate how equity-focused investments can simultaneously deliver environmental, social, and economic benefits (MMSD, 2023). Ensuring that GSI projects address systemic inequities requires democratizing decision-making processes and dedicating resources to underserved areas.

Innovative approaches to GSI design and asset management provide further opportunities for progress. Ann Arbor's Stormwater Best Management Practices Maintenance Manual exemplifies how municipalities can integrate GSI into urban planning, ensuring accountability and long-term functionality through adaptive management (City of Ann Arbor, 2022). Similarly, Buffalo's use of smart sewer technology has reduced CSOs by over 3 billion gallons since 2017, demonstrating the cost-saving potential of leveraging advanced data analytics (Buffalo Sewer Authority, 2023). These examples highlight the importance of blending green and gray infrastructure solutions to address immediate stormwater challenges while building long-term resilience.

To scale GSI in the Great Lakes Region, a multifaceted approach is essential. Sustainable funding mechanisms must be expanded to support smaller municipalities, paired with technical assistance to navigate grant applications and implement projects. Workforce development should prioritize partnerships with educational institutions to create robust training pipelines. Equitable planning requires engaging marginalized communities in decision-making processes and allocating resources to address historical disparities. Regional collaboration and resource sharing, facilitated by organizations like RISC, can streamline access to tools, data, and best practices, accelerating the adoption of GSI across jurisdictions.

By addressing these barriers and building on successful models, the Great Lakes Region can unlock the full potential of GSI to enhance climate resilience, protect water quality, and promote social equity. Through strategic investments, innovative design, and equitable planning, GSI offers a pathway to a more sustainable and inclusive future for Great Lakes communities.

2. Introduction: Changing Climate in the Great Lakes

The Great Lakes Region, the world's largest freshwater ecosystem, provides a diverse array of ecosystem services that are integral to both the environment and human life. Holding 90% of the United States' fresh surface water and supporting a regional economy valued at $6 trillion annually (Council of the Great Lakes Region, 2017; NOAA, 2019), this ecoregion is vital for drinking water, commercial fishing, shipping, and recreation. Activities such as fishing, hunting, and boating contribute an estimated $52 billion annually to the economy, supporting 1.5 million jobs and generating $60 billion in wages each year (Great Lakes Commission, 2017). The region's habitats, which include forests, wetlands, marshes, and dunes, provide refuge for over 3,500 species of plants and animals (NOAA, 2019). Despite these benefits, the Great Lakes face growing environmental challenges, particularly from climate change and human development.

Shifts in precipitation and temperature patterns have increased variability in water levels, with projections indicating that by the 2040s, Lakes Superior, Erie, and Huron will rise by 7.5, 11, and 17.3 inches, respectively, compared to 2010–2019 averages (Kayastha et al., 2022). These changes amplify risks such as nearshore flooding, shoreline erosion, and high-energy wave events. Moreover, the frequency of severe storms, including meteotsunamis and seiches, is expected to exceed the current annual average of 106 occurrences under future climate scenarios (Bechle et al., 2016). Such disturbances pose significant challenges to infrastructure, ecosystems, and coastal communities.

Urban areas in the Great Lakes Region face particularly acute challenges from increasing heavy precipitation, flooding, aging infrastructure, and extreme temperatures. Between

1992 and 2021, average annual precipitation in the region rose by 5–15% compared to the early 20th century, with extreme rain events increasing by 45% (Marvel et al., 2023). This trend, illustrated in Figure 1, shows a 15.4% increase in relative annual precipitation anomalies between 1950 and 2020, with the 2011–2020 decade being the wettest since 1950 (Environment and Climate Change Canada & U.S. Environmental Protection Agency, 2022a). The Fifth National Climate Assessment exemplifies this change with data from Greater Chicago, where the 10-year rainfall volume increased by approximately 30% between 1960 and 2020 and is projected to grow by another 15% by 2050 and 20% by 2100 (Vedachalam et al., 2023). This intensification of precipitation trends highlights the urgent need to modernize stormwater management to mitigate urban flooding, protect ecosystems, and ensure climate resilience.

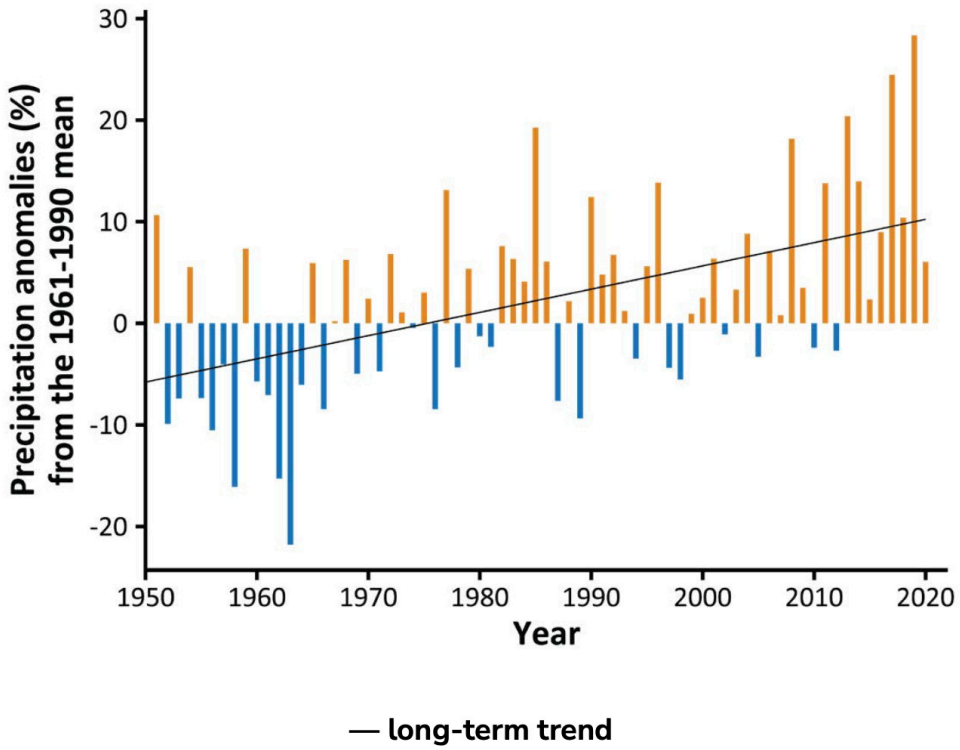


Figure 1. *Relative difference in annual precipitation in the Great Lakes from 1961 - 1990 mean precipitation (Source: Environment and Climate Change Canada & U.S. Environmental Protection Agency, 2022b).*

The growing need for effective stormwater management

These shifting precipitation patterns have overwhelmed stormwater systems across the Great Lakes Region, many of which were designed for historical weather patterns rather than the heightened intensity of current and projected conditions. Aging stormwater systems often lack the capacity to manage the increased volumes of water generated during extreme precipitation events, leading to frequent overflows. Overflowing drainage systems exacerbate urban flooding, inundating streets, homes, and businesses, and cause untreated wastewater to enter natural water bodies (Marvel et al., 2023; Environment and Climate Change Canada & U.S. Environmental Protection Agency, 2022a). Combined sewer overflows (CSOs), a result of outdated infrastructure that merges stormwater and wastewater flows, are particularly problematic. During heavy rains, CSOs release untreated sewage directly into rivers, lakes, and streams, posing severe risks to public

health and aquatic ecosystems (Vedachalam et al., 2023). These discharges contribute to the proliferation of harmful algal blooms, degrade water quality, and violate clean water regulations, leaving municipalities vulnerable to legal and regulatory penalties. The cascading public health and ecological impacts of these challenges make innovative stormwater management solutions essential (Ellis, 2014).

Historically, cities in the region have relied heavily on gray infrastructure, such as networks of concrete pipes, detention basins, and pumping stations, to manage stormwater. While these systems were effective in mitigating flood risks under past climate conditions, they are increasingly inadequate in handling the escalating intensity and frequency of extreme weather events (Bechle et al., 2016). Rigid by design, gray infrastructure channels water away as quickly as possible, which can exacerbate downstream flooding and fails to address interconnected challenges such as water quality and ecosystem health. Upgrading these outdated systems poses significant hurdles for utilities, including high costs, technical complexities, and the challenge of securing public and political support for long-term investments. As precipitation patterns continue to shift, the limitations of gray infrastructure highlight the necessity of integrating innovative and multifunctional approaches, such as GSI, into stormwater management (NRDC, 2022).

Consent decrees

Some utilities have begun updating their infrastructure to handle these challenges, often in response to consent decrees. These legally binding agreements between the U.S. Environmental Protection Agency (EPA), a state environmental agency, and utilities establish enforceable timelines for actions such as reducing CSOs, improving stormwater management, and achieving clean water compliance. For utilities like the Metropolitan Water Reclamation District of Greater Chicago (MWRD), the consent decree has been instrumental in driving the implementation of large-scale infrastructure projects. For example, MWRD's Tunnel and Reservoir Plan has expanded stormwater storage capacity to help manage increased precipitation and reduce CSOs, as required under the decree. The Illinois State Water Survey's Bulletin 75 highlights that a 1-inch increase in 100-year rainfall volumes adds 15 billion gallons of stormwater that must be managed within MWRD's service area (Ellis, 2014). Without the consent decree's structure and accountability, achieving these milestones would be significantly more challenging.

However, not all utilities operate under a consent decree. For example, the Milwaukee Metropolitan Sewerage District (MMSD) is tackling the challenge of intense storms without the framework provided by such an agreement. This, theoretically, can provide flexibility in achieving self-defined goals, but may also make it more difficult to secure funding, prioritize projects, and meet ambitious clean water goals, particularly as precipitation trends grow increasingly unpredictable. For utilities without consent decrees, building community and political will, as well as leveraging innovative financing mechanisms, becomes critical for

adapting to climate challenges. These challenges underscore the broader importance of modern stormwater management approaches, including both traditional methods and innovative solutions like GSI, to address water quality and quantity issues.

Stormwater management is foundational to mitigating the impacts of urban flooding, extreme precipitation, and runoff pollution. It encompasses a range of strategies, from traditional gray infrastructure like detention basins and storm drains to systems that improve water quality while managing water quantity. Combined sewer systems (CSSs), for example, represent a traditional approach where stormwater and wastewater are merged into a single network. However, during heavy rain events, these systems often overflow, discharging untreated water into natural waterways. Such discharges introduce contaminants, nutrients, and sediments that threaten water quality, ecosystem health, and public safety. Additionally, many CSSs were built based on historical precipitation patterns and are now ill-equipped to handle the increasing intensity and frequency of storms driven by climate change, compounding their vulnerabilities (Tuler et al., 2024). This mismatch between infrastructure capacity and modern precipitation patterns underscores the urgency of upgrading stormwater management systems to better protect communities and ecosystems.

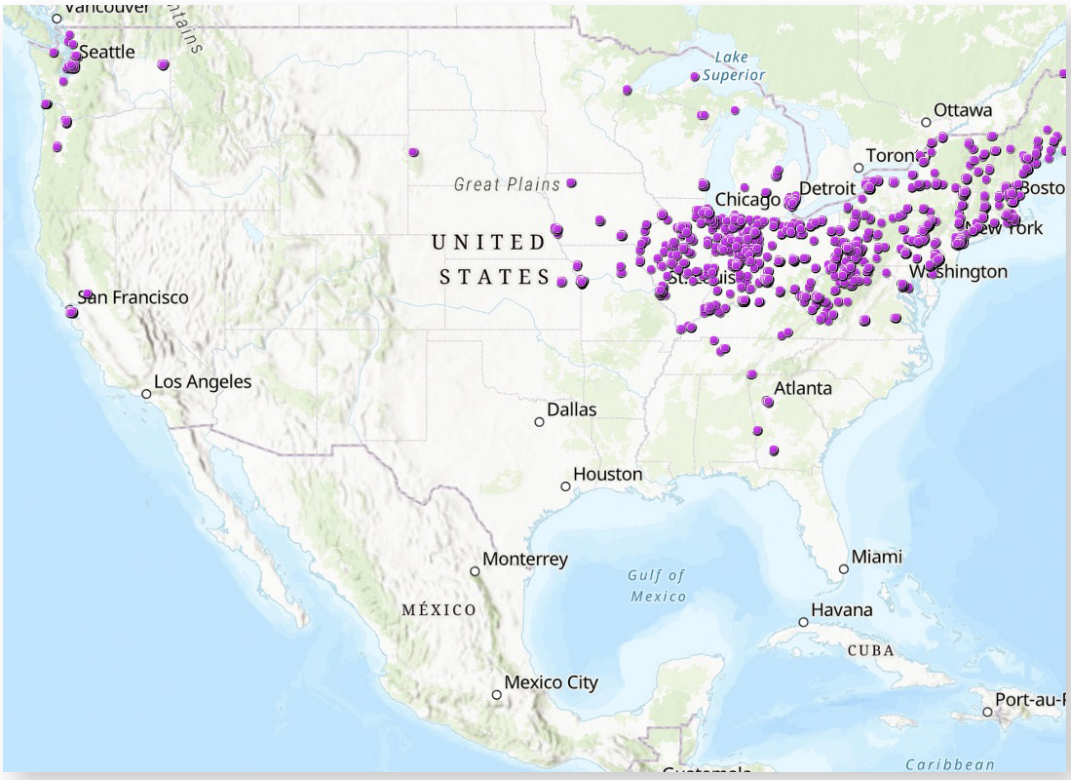


Figure 2. *Map showing the distribution of Combined Sewer Overflow (CSO) outfall locations across the United States. Approximately 700 communities, primarily in the northeast and around the Great Lakes Basin, operate combined sewer systems that contribute to CSO discharges. The map highlights these locations, underscoring the concentration of aging urban infrastructure in these regions. Detailed information about active CSO outfalls, including permit compliance and receiving waterbodies, can be accessed through the National Pollutant Discharge Elimination System (NPDES) database. (Source: U.S. Environmental Protection Agency, 2024).*

CSSs are disproportionately located in the northeastern United States and around the Great Lakes, reflecting the region's older urban infrastructure. Across the U.S., approximately 700 communities have combined sewer systems that experience combined sewer overflow (CSO) discharges, with a significant concentration in the Great Lakes Basin. In this region,

there are 233 CSSs (184 in the U.S. and 36 in Canada), serving both large cities and smaller communities (Environment and Climate Change Canada, 2024; U.S. Environmental Protection Agency, 2016). This means that nearly one-third of all U.S. combined sewer systems are located within the Great Lakes Basin, underscoring the region's heightened vulnerability to CSO challenges. The Great Lakes, as the world's largest freshwater system, face increased risks from these discharges due to their critical role in providing drinking water, supporting biodiversity, and serving as an economic hub. In 2014 alone, CSSs in the U.S. Great Lakes Basin discharged an estimated 22 billion gallons of untreated water, while Canadian systems contributed approximately 2.6 billion gallons in 2020 (U.S. Environmental Protection Agency, 2016; Statistics Canada, 2024). The environmental, public health, and economic stakes of these discharges demand comprehensive modernization of stormwater management systems.

Septic systems present their own unique challenges, particularly as climate change intensifies the frequency and severity of precipitation events. Unlike centralized sewer systems, septic systems are decentralized and rely on soil absorption to manage wastewater. This reliance on natural absorption makes them especially vulnerable to oversaturation during heavy rain events, which can result in untreated wastewater seeping into nearby water bodies or residential areas, posing significant environmental and public health risks. Aging and outdated systems exacerbate this problem, as they were not designed to handle the increased volume of runoff generated by impervious surfaces in modern developments or the extreme weather patterns associated with climate change (Ionescu, 2024).

These vulnerabilities are compounded by stormwater runoff, which can overwhelm septic systems and lead to system failures. The University of Michigan's study on outdated stormwater infrastructure reveals that traditional stormwater management approaches often fail to account for the interconnectedness of runoff pathways, worsening localized flooding and septic system malfunctions. Poorly managed runoff from driveways, lawns, and streets can inundate septic systems, causing untreated wastewater to enter waterways or back up into homes. For communities dependent on septic systems, these failures are not only costly to repair but also hazardous to local water quality and public health (Lynch, 2024). Addressing these challenges requires a coordinated approach to stormwater management that prioritizes system resilience and safeguards critical water resources.

3. The Role of GSI

As cities across the Great Lakes Region grapple with these complex stormwater management challenges—ranging from aging infrastructure to increased precipitation and runoff—there is a growing need for solutions that enhance system resilience while addressing both water quality and quantity. GSI is emerging as a pivotal tool for adaptation and resilience. GSI employs natural processes to manage stormwater through systems like rain gardens, vegetated rooftops, and roadside plantings (NRDC, 2022). These systems mimic natural hydrological cycles by capturing and filtering rainwater where it falls, reducing polluted runoff that contaminates rivers, lakes, and streams. Urban areas, which generate five times more runoff than forested areas, benefit significantly from GSI's ability to mitigate flooding and enhance water quality.

Beyond addressing stormwater challenges, GSI offers a transformative alternative by delivering a host of co-benefits. GSI systems—including rain gardens, green roofs, and permeable pavements—reduce runoff, improve water quality, and mitigate urban heat through increased vegetation and evapotranspiration. For instance, green roofs can lower ambient air temperatures by up to 5°F while reducing peak runoff by 50–60% during heavy rain events (EPA, 2013). By integrating GSI into urban planning, cities can simultaneously enhance resilience to climate challenges and improve the urban environment.

The economic benefits of GSI further strengthen its appeal. Compared to traditional gray infrastructure, GSI often proves to be more cost-effective over time. For example, Philadelphia's Green City, Clean Waters program is projected to save $7.2 billion in maintenance costs over 25 years compared to a gray infrastructure alternative while providing substantial environmental and social benefits (NRDC, 2022). Green roofs, which have double the lifespan of conventional roofs, also reduce maintenance costs, provide

energy savings, and improve urban biodiversity (NRDC, 2013). Furthermore, GSI projects stimulate local economies by creating jobs in design, installation, and maintenance, while reducing the economic burdens associated with flooding, such as property damage and loss of business productivity.

Despite these benefits, the adoption of GSI has been uneven across communities, often reflecting systemic inequities. Formerly redlined neighborhoods—many of which remain predominantly nonwhite—experience a higher share of flood risk due to decades of disinvestment and exclusion from infrastructure upgrades. In Chicago, for instance, homes in redlined areas are at significantly greater risk of flooding compared to those in historically greenlined neighborhoods, with $19.7 billion worth of homes in redlined areas at high flood risk compared to $3.6 billion in greenlined areas (Katz, 2021). This trend is mirrored across the Great Lakes Region, where lower-income neighborhoods of color have disproportionately borne the brunt of urban flooding and climate impacts.

These inequities extend beyond flood risk to include urban heat. Formerly redlined areas are, on average, 5°F hotter than non-redlined areas in the summer, due in part to a lack of tree canopy and green spaces (Katz, 2021). Such disparities illustrate the compounded challenges faced by marginalized communities, where the legacies of redlining and structural inequality perpetuate vulnerabilities to both flooding and extreme heat. The Tree Equity Score, a tool developed to assess the distribution of urban tree cover, highlights that neighborhoods with lower tree canopy coverage—many of which are underserved communities—also tend to face higher rates of heat-related stress. This underscores the need for targeted investment in GSI to address these overlapping challenges.

GSI in the Great Lakes Region

The Great Lakes Region has already seen significant investments aimed at enhancing resilience. Initiatives like the Great Lakes Restoration Initiative (GLRI), which has allocated $3.8 billion since 2010, demonstrate a commitment to conserving the region's natural resources. Additionally, the Bipartisan Infrastructure Law (BIL) has provided an additional $200 million annually to GLRI since 2022, further emphasizing the region's dedication to environmental sustainability (Gray-Green Community of Practice, 2022; LimnoTech, 2020). However, challenges remain in scaling up GSI projects. Many cities lack the readiness or resources to implement such projects at the necessary scale, and appealing to funders often requires demonstrating multifaceted benefits, including economic, social, and environmental outcomes.

To fully realize the potential of GSI, cities must prioritize equitable implementation. Addressing longstanding inequities requires democratizing decision-making processes and dedicating funding to underserved areas. Programs like the Metropolitan Water Reclamation District's (MWRD) "Space to Grow," which integrates GSI into schoolyards in

underserved neighborhoods, exemplify how equitable investments can simultaneously deliver environmental, social, and economic benefits. By prioritizing environmental justice communities, GSI projects can create resilient urban environments that address both immediate climate risks and systemic inequities.

As climate change intensifies, the integration of GSI into urban planning is essential for building resilient and equitable communities across the Great Lakes Region. By coupling its environmental and economic benefits with intentional efforts to address disparities, GSI offers a holistic approach to climate adaptation that ensures no community is left behind. Investments in GSI not only mitigate the immediate threats of flooding and heat stress but also lay the groundwork for a more sustainable and inclusive future, aligning with the broader goals of climate resilience and social equity.

GSI effectively reduces the volume of stormwater entering combined sewer systems and enhances natural filtration, thereby mitigating nutrient pollution and overflow events. For example, in Milwaukee, the implementation of GSI has resulted in the capture of approximately 14 million gallons of stormwater annually, significantly reducing the likelihood of combined sewer overflows and the associated nutrient pollution that contributes to harmful algal blooms and eutrophication in the Great Lakes region (City of Milwaukee, 2024). Moreover, GSI practices such as bioretention and rain gardens have been shown to filter pollutants like phosphorus and suspended solids from stormwater, enhancing water quality (Uni-Group USA, 2023). Rain gardens, for instance, have demonstrated a 96% removal rate of anthropogenic debris, including 100% of microplastic particles like black rubbery fragments, which are commonly derived from tire and road wear (Werbowski et al., 2021). By promoting infiltration and natural absorption, GSI addresses both flooding risks and water quality concerns. In areas with separate storm sewer systems, which are common in smaller Great Lakes communities, managing water near its source through GSI practices like rain gardens and green roofs is critical. These features not only reduce runoff but also filter pollutants, offering dual benefits in regions where expanding traditional gray infrastructure may not be practical or beneficial (City of Milwaukee, 2024; Werbowski et al., 2021).

In addition to addressing stormwater challenges, GSI provides significant social and economic advantages. It creates green spaces that enhance urban aesthetics, support mental health, and improve public well-being. Features like rain gardens and green roofs help mitigate urban heat island effects, making urban areas more livable by providing cooler and more comfortable environments. These spaces also promote recreational opportunities and support biodiversity by serving as habitats for wildlife. Economically, GSI investments generate job opportunities in design, construction, and maintenance, especially as the demand for sustainable infrastructure continues to grow. Training a local workforce to implement and maintain GSI not only contributes to regional economic

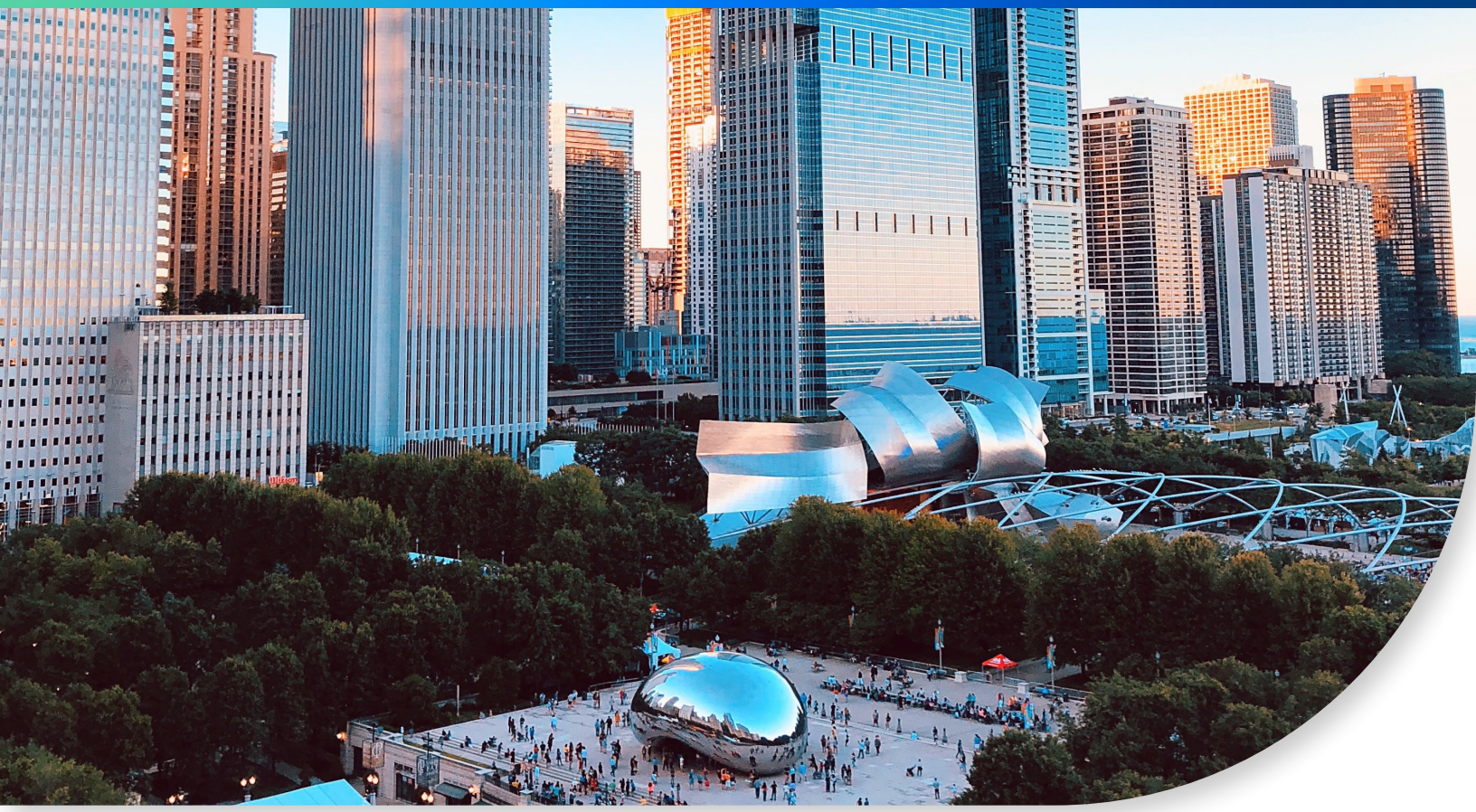
development but also ensures that these systems remain functional and effective over the long term. This holistic approach allows cities to address stormwater issues while simultaneously creating multifunctional landscapes that promote resilience and equity across the Great Lakes Region.

Despite its benefits, stormwater management in the Great Lakes basin faces several unique challenges. Many legacy cities—urban areas like Detroit, Cleveland, and Buffalo—have experienced significant population declines, averaging 35% since their mid-20th-century peaks (United States Census Bureau, 2021). Detroit, for instance, has seen a nearly 60% population decline, resulting in a 20% decrease in property tax revenue between 2008 and 2018 (Detroit Future City, 2020). These reductions leave municipalities with fewer resources to maintain extensive, aging infrastructure systems, which are often ill-equipped to handle increasing stormwater volumes caused by climate change and urbanization (CNT, 2020). This underfunding exacerbates challenges like combined sewer overflows, flooding, and water quality issues.

GSI offers a sustainable, cost-effective alternative by reducing reliance on outdated gray infrastructure, providing long-term savings, and improving public health outcomes. Research from the Center for Neighborhood Technology (CNT) demonstrates that doubling the square footage of GSI features near a home can increase its value by 0.28% to 0.78%, or $700 to $1,950 for a $250,000 home (CNT, 2020). At scale, a community of 10,000 homes could see $7 million to $20 million in added property value, potentially generating $8,000 to $23,000 in additional annual tax revenue per block over 20 years (CNT, 2020). This increased municipal revenue can fund further GSI installations, creating a virtuous cycle of economic and environmental resilience. By integrating natural processes into urban planning, GSI not only addresses immediate stormwater challenges but also enhances resilience, equity, and sustainability. Through green spaces, improved water quality, and economic opportunities, GSI contributes to a thriving Great Lakes ecosystem that benefits both the environment and its communities.

Site-specific conditions further influence the success of GSI. For example, areas with clayey or poorly drained soils may require soil amendments or engineered solutions to maximize infiltration (Baker et al., 2022; Saurette et al., 2021). Additionally, cold climates pose challenges like freeze-thaw cycles and salt exposure, which can damage permeable pavements and vegetation. However, intentional design—such as using salt-tolerant plants and freeze-resistant materials—can mitigate these challenges and ensure GSI remains effective year-round. Educating planners and stakeholders about these solutions is essential to increasing adoption across the region.

By integrating natural processes into urban planning, GSI not only addresses immediate stormwater challenges but also enhances resilience, equity, and sustainability. Through green spaces, improved water quality, and economic opportunities, GSI contributes to a thriving Great Lakes ecosystem that benefits both the environment and its communities.



4. The State of GSI Across the Great Lakes

Green infrastructure (GSI) in the Great Lakes region is increasingly recognized as a critical tool for addressing urban stormwater challenges while generating significant social, economic, and ecological co-benefits. For instance, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) has successfully employed a mix of green and gray infrastructure to mitigate stormwater issues, demonstrating the potential of hybrid approaches. However, as research underscores, differences between stakeholders—those favoring scientific, regulatory-driven strategies and those emphasizing integrated management approaches—can create barriers to collaborative efforts (Cousins, 2017).

Despite these challenges, cities across the Great Lakes region have made notable progress in implementing GSI. In Buffalo, New York, the Niagara River Greenway project incorporated GSI practices such as sand filters, stormwater planters, and rain gardens to reduce stormwater runoff by approximately 16 million gallons annually (U.S. Geological Survey, 2022). Similarly, a rain garden installation in Gary, Indiana, achieved an over 80% reduction in stormwater volumes entering the sewer system during monitored periods (U.S. Geological Survey, 2022). These examples illustrate GSI's capacity to enhance urban resilience while addressing critical stormwater management needs.

However, progress across the region is uneven. The U.S. Geological Survey's *Green Infrastructure in the Great Lakes—Assessment of Performance, Barriers, and Unintended Consequences* highlights that GSI implementation remains largely localized, with limited coordination between governments and agencies (Baker et al., 2022). Common

barriers include a lack of clear standards, insufficient funding, and uncertainty about GSI performance in varied urban contexts. For example, many municipalities lack essential data on how specific GSI practices—such as permeable pavements or urban tree canopies—perform under different environmental and operational conditions, complicating efforts to integrate these solutions into broader stormwater management frameworks (Baker et al., 2022).

To develop a comprehensive understanding of the opportunities and challenges associated with scaling up GSI across the Great Lakes region, a series of targeted interviews and meetings were conducted with stakeholders from diverse sectors. These stakeholders included municipal water authorities, regional planning organizations, nonprofit organizations, and academic institutions engaged in stormwater management, resilience planning, and environmental justice. The primary objective was to identify actionable strategies, address critical gaps, and explore opportunities for collaboration that could inform a regional framework for GSI expansion.

Participants shared valuable insights into their experiences with planning, implementing, and maintaining GSI initiatives. Discussions focused on funding mechanisms, equity considerations, asset management, and innovative design approaches, highlighting both the unique needs of individual municipalities and the shared challenges faced across the region. Key barriers such as funding constraints, maintenance limitations, and community engagement challenges emerged as recurring themes. These findings were synthesized into thematic sections, providing a foundation for actionable recommendations aimed at advancing GSI implementation across the Great Lakes region.

Insights were gathered from seven experts representing utilities, regional planning organizations, academic institutions, and environmental nonprofits, who shared their experiences with planning, implementing, and maintaining GSI initiatives. These experts provided perspectives on funding mechanisms, equity, asset management, and innovative design. The discussions highlighted the diverse needs and approaches across municipalities while underscoring common challenges such as funding barriers, maintenance limitations, and community engagement. The findings from these discussions were synthesized into thematic sections to inform actionable recommendations for advancing GSI in the region.

4.1 Planning and Resilience

Strategic planning and resilience are critical to scaling up GSI in the Great Lakes Region, as underscored in interviews with stakeholders. Participants consistently highlighted the need to align GSI projects with broader capital planning processes to maximize efficiency, reduce costs, and ensure comprehensive stormwater management. However, many municipalities struggle with competing budget priorities and siloed departmental operations, which frequently impede cross-departmental collaboration. When departments like transportation, water, and public works fail to coordinate, opportunities for cost-sharing and resource optimization are often lost, resulting in inefficiencies that deter GSI implementation.

Ownership of assets

One recurring issue raised in the interviews is the reluctance of utilities to take ownership of GSI assets, often leaving other agencies, such as transportation departments, to manage them. This lack of clarity around asset ownership can create operational challenges and

inefficiencies, further complicating efforts to integrate GSI into broader infrastructure initiatives.

Private ownership of GSI adds another layer of complexity, particularly in terms of long-term maintenance responsibilities. While challenges related to maintenance and accountability persist, some innovative projects demonstrate how private entities can successfully integrate GSI with broader community and environmental goals.

On the other hand, some municipalities have successfully embedded GSI into their public planning processes to streamline asset management. For instance, certain cities have established screening processes for capital projects to identify opportunities for GSI integration, demonstrating the potential of systematic approaches to advance GSI adoption. Leadership plays a pivotal role in this context, with supportive leaders driving innovation and collaboration, while unsupportive management can significantly hinder progress.

Davidson Park – A Model for Private Ownership of GSI

Harley-Davidson's Davidson Park in Milwaukee, Wisconsin, offers a compelling example of how privately owned green stormwater infrastructure (GSI) can address both stormwater management and broader community goals. Located within the Milwaukee Metropolitan Sewerage District's (MMSD) combined sewer system area, the park GSI features such as bioretention systems, stormwater trees, pervious pavers, and underground storage. These features collectively capture over 225,000 gallons of stormwater annually, contributing to flood mitigation and water quality improvement (CIS, 2024).

Financing and Partnerships:

The project highlights innovative financing strategies through the Fresh Coast Protection Partnership (FCPP). Harley-Davidson provided corporate sponsorship as a funding match, with milestone payments financed by MMSD under the FCPP and reimbursed upon project completion. This approach facilitated shared ownership of project outcomes while addressing funding challenges often associated with private GSI ownership (CIS, 2024).

Community Impact:

Beyond stormwater management, the park reclaims impervious surfaces to create valuable green space in a community ranked in the 94th percentile for lack of greenery and the 97th percentile for poverty and social vulnerability. Its design enhances urban aesthetics, reduces urban heat, and provides significant socio-economic benefits. Additionally, the project supported small businesses, achieving 54% participation from small, women-, minority-, and veteran-owned businesses (SWMBEs)—well above the 30% goal (CIS, 2024).

Davidson Park demonstrates how private ownership, combined with public funding and strong partnerships, can result in impactful, sustainable stormwater solutions that address equity, environmental, and economic goals.

Incorporating climate conditions

Another challenge raised by interviewees is the need for resilience-focused planning frameworks that adapt to changing climate conditions, such as increasing precipitation and more frequent extreme weather events. Stakeholders stressed that GSI planning must

not only address current needs but also anticipate future challenges. Some regional efforts provide promising examples. For instance, initiatives that incorporate GSI into climate mitigation and resiliency strategies showcase how coordinated planning can build long-term resilience. However, ensuring that these strategies remain effective amidst shifting climate realities requires continuous evaluation and adaptation.

To address these challenges, tools such as the Climate Resilience Evaluation and Awareness Tool (CREAT) offer utilities a structured approach to assess climate-related risks and develop adaptation strategies. CREAT, developed by the EPA, guides users through five key modules to evaluate potential climate impacts on utility assets and operations, design scenarios for future threats, and develop actionable adaptation plans.

The modules include:

1. **Climate Awareness:** Introduces basic utility information and raises awareness about climate impacts.
2. **Scenario Development:** Enables the design of threat scenarios using climate data.
3. **Consequences and Assets:** Identifies critical utility assets and outlines potential consequences.
4. **Adaptation Planning:** Inventories current resilience actions and helps design adaptation plans.
5. **Risk Assessment:** Assesses the risk posed by climate change and compares the risk reduction achieved through adaptation plans.

By incorporating CREAT results, utilities can demonstrate proactive planning, building stakeholder confidence that they are effectively addressing significant climate-related risks (EPA, 2024).

Tools like CREAT, along with its ability to integrate with other resources such as the Resilient Strategies Guide and the Vulnerability Self-Assessment Tool (VSAT), provide foundational support for utilities to address climate resilience challenges. However, gaps in accessible tools and resources for municipalities to effectively implement Green Stormwater Infrastructure (GSI) remain a concern. Recognizing this need, the Green Infrastructure Leadership Exchange and Geosyntec developed the Climate Resilience Resources Guide to offer practical strategies and tools for enhancing climate resilience through GSI.

The Guide explores the intersection of GSI and urban climate impacts, providing a framework for policy development, planning, design, and operations and maintenance to ensure GSI remains effective under changing climate conditions. It highlights potential resilience benefits, such as mitigating localized flooding, reducing urban heat, improving water quality, and supporting biodiversity. Additionally, it emphasizes the importance of equity, public engagement, and community-driven implementation to ensure GSI solutions meet the needs of vulnerable populations most affected by climate change. The Guide also includes a matrix of existing GSI climate resilience resources, case studies, and decision-making tools to support municipalities in navigating challenges and advancing resilient infrastructure.

These resources collectively aim to ensure GSI strategies remain adaptable, effective in mitigating evolving climate risks, and aligned with long-term sustainability and resilience goals (NRDC, 2022; CRRG, 2023).

Case Study: Planning for Resilience in Ann Arbor

The City of Ann Arbor, Michigan provides a compelling example of how strategic planning and resilience-oriented approaches can effectively scale GSI. Leadership has played a pivotal role in advancing Ann Arbor's GSI efforts, with the city leveraging its Stormwater Best Management Practices (BMPs) Maintenance Manual to integrate GSI into municipal frameworks and address historical maintenance gaps. This manual serves as a structured guide to managing GSI assets, emphasizing the importance of accountability and cross-departmental collaboration—key themes identified in stakeholder interviews.

Ann Arbor's maintenance manual underscores the city's proactive approach to ensuring that GSI projects achieve their intended outcomes. A comprehensive inventory of all BMPs—ranging from rain gardens and detention basins to bioswales and green roofs—provides the foundation for informed decision-making. This inventory not only catalogs existing assets but also delineates maintenance responsibilities across various jurisdictions, such as city parks, stormwater funds, and county departments. By resolving longstanding ambiguities over ownership and maintenance, the manual promotes accountability and ensures that GSI assets are preserved as valuable municipal resources.

The maintenance manual's strength lies in its standardized framework for defining, inspecting, and maintaining GSI features. Maintenance tasks are categorized by frequency, urgency, and type, creating a user-friendly matrix that allows for efficient resource allocation. For example, the manual outlines specific actions to address sediment accumulation, invasive species, and erosion—all common challenges that, if unaddressed, can compromise the functionality of GSI systems. The city also tailors maintenance efforts based on site context. High-visibility urban areas are maintained with a focus on aesthetics, while naturalistic settings are managed to prioritize ecological function. This dual approach helps balance community expectations with the technical requirements of stormwater management, an issue highlighted in stakeholder interviews that stressed the importance of public perception in GSI success.

Ann Arbor's commitment to integrating GSI into broader urban planning frameworks mirrors insights from regional stakeholders, who emphasized the need for cross-departmental collaboration. As noted in interviews, a lack of coordination among transportation, water, and public works departments often leads to inefficiencies and missed opportunities for cost-sharing. Ann Arbor addresses these challenges by embedding GSI into its capital planning processes. For instance, capital projects are systematically screened for GSI integration opportunities, ensuring that green infrastructure is considered during infrastructure upgrades. This approach parallels practices in other leading cities, such as Toronto, and showcases how planning committees can align GSI efforts with broader municipal objectives.

Leadership and climate resilience also play a critical role in Ann Arbor's success. The maintenance manual incorporates principles of adaptive management, enabling the city to refine its practices based on performance data and evolving climate conditions. This aligns with the regional emphasis on resilience, where stakeholders highlighted the importance of preparing for increased precipitation and changing weather patterns. Ann Arbor's adaptive approach not only safeguards its GSI investments but also positions the city to meet future challenges with agility.

Ann Arbor's comprehensive planning for resilience through its BMP Maintenance Manual underscores the critical role of strategic frameworks in scaling GSI. By aligning GSI with capital planning, fostering cross-departmental collaboration, and prioritizing adaptive management, the city has established a replicable model for municipalities across the Great Lakes Region. Its efforts demonstrate that integrating GSI into the fabric of urban planning not only enhances stormwater management but also builds community trust and prepares cities for the challenges of a changing climate.

The role of leadership

The importance of leadership in fostering collaboration and aligning priorities was a recurring theme in the discussions. Stakeholders noted that municipalities with active and supportive leaders are more likely to align GSI with broader infrastructure and climate goals. Conversely, the absence of such leadership can result in fragmented efforts and missed opportunities for collaboration. The interviews also highlighted the benefits of regional planning efforts, such as those that pool resources, develop shared tools, and promote cross-jurisdictional learning to address the complexities of GSI implementation.

To overcome these challenges, participants suggested prioritizing integrated planning frameworks that embed GSI into city-wide and regional infrastructure initiatives. They also emphasized the need for robust leadership, regional coordination, and adaptable planning to address the dynamic nature of climate challenges. By aligning GSI initiatives with resilience-focused goals, municipalities can create cost-effective, efficient, and sustainable stormwater management systems across the Great Lakes Region.

4.2 Innovative Design

Innovation in GSI design is crucial for addressing the complex challenges of urban stormwater management. Stakeholders have emphasized the necessity for creative, data-driven strategies to optimize GSI systems for both compliance and performance. Yet, many municipalities find themselves without the requisite tools, resources, and expertise needed to implement advanced designs, leading to inconsistencies and inefficiencies in project execution. This has underscored the need for standardized methodologies to guide GSI sizing and integration, a recurring theme in discussions where uncertainty about compliance requirements is often cited as a significant barrier.

Data integration and co-benefits

Despite these challenges, numerous case studies highlight the transformative potential of innovative GSI design and its ability to provide cost-effective solutions while delivering significant co-benefits. For example, the Buffalo Sewer Authority (BSA) utilized advanced data analytics to optimize its stormwater infrastructure, resulting in $145 million in cost savings and substantial improvements in system efficiency and environmental outcomes. This success demonstrates how integrating technology into decision-making processes can enhance the cost-effectiveness of GSI projects while addressing urban water challenges (Buffalo Sewer Authority, 2022).

To further support practitioners in quantifying and communicating the full value of GSI, the GSI Impact Hub was developed through a collaboration led by the Green Infrastructure Leadership Exchange, The Nature Conservancy, One Water Econ, and several government and technical partners, including significant contributions from the Northeast Ohio Regional Sewer District (Green Infrastructure Leadership Exchange et al., 2024). The GSI Impact Hub provides an interactive platform with tools, such as the GSI Impact Calculator, to evaluate the multiple economic, environmental, and social co-benefits of GSI. These tools assist stormwater agencies, planners, and advocates in assessing project impacts, including flood risk reduction, urban heat mitigation, improved water quality, and job creation.

By offering actionable, evidence-based insights, the GSI Impact Hub empowers stakeholders to make strategic, data-driven decisions that maximize GSI's value and advance equitable, resilient urban development. Its comprehensive resources and decision-support tools are transforming how cities and communities plan and implement green stormwater solutions to achieve the greatest impact.

Design standards

Standardized design specifications for right-of-way (ROW) projects have also proven invaluable in guiding municipalities through the GSI implementation process. These specifications provide clear frameworks that enable cities to seamlessly incorporate green infrastructure into existing urban landscapes. However, the need for continual refinement of these design standards is crucial to ensure long-term performance under various climatic conditions. Thus, expanding access to technical training and resources is essential for empowering municipalities to innovate in their GSI approaches effectively.

Similarly, Toronto's Green Streets initiative exemplifies the importance of standardized design specifications in integrating GSI into public spaces for multifaceted benefits. By implementing features such as permeable pavements, bioswales, and rain gardens within transportation corridors and parks, the initiative demonstrates how clear, adaptable design standards can guide municipalities in achieving objectives like flood mitigation, improved water quality, and enhanced urban aesthetics. These projects are also designed to address broader environmental challenges, such as urban heat island effects, providing a cooling impact equivalent to planting 100,000 new trees across the city (City of Toronto, 2022). This highlights the critical role of evolving design standards in optimizing the long-term performance and environmental value of GSI investments.

Integrating Technology and Blending Green and Gray Infrastructure

Effectively managing stormwater runoff and pollution in urban areas often requires a strategic integration of green and gray infrastructure solutions, further enhanced by the incorporation of advanced technologies. This hybrid approach leverages the strengths of both systems while utilizing technological innovations to optimize performance and resilience in the face of increasing climate variability and urban expansion (Newton, 2024).

Green infrastructure solutions, such as permeable pavements and bioretention systems, offer significant ecological benefits. Permeable pavements reduce stormwater runoff volume and mitigate localized flooding by allowing water to infiltrate surfaces, thereby lessening the environmental impacts of road salt by preventing water pooling and freezing (Newton, 2024). Bioretention systems complement this by improving water quality through vegetated basins that filter pollutants before they reach water bodies (Newton, 2024). These green solutions are most effective when integrated with gray infrastructure.

Gray infrastructure, including stormwater conveyance systems and retention tanks, provides reliable capacity for managing extreme weather events. When combined with green infrastructure, gray systems can handle excess stormwater during heavy precipitation events, complementing the infiltration and filtration capabilities of green solutions. This hybrid system ensures both the rapid removal of stormwater and the long-term ecological benefits of green infrastructure.

Advanced technologies further enhance this integration by enabling municipalities to optimize stormwater system performance. Tools such as artificial intelligence (AI) and the Internet of Things (IoT) enable real-time monitoring and adjustment of stormwater systems based on weather conditions, improving both green and gray infrastructure responsiveness and efficiency (Newton, 2024). For instance, IoT sensors can monitor water levels and pollutant loads in real-time, allowing for automated adjustments in stormwater retention or release to prevent flooding or environmental degradation.

4.3 Funding and Finance

Securing sustainable financing remains one of the most significant barriers to scaling up GSI in the Great Lakes Region. Stormwater utility fees have become a vital mechanism for funding these projects, creating dedicated resources for stormwater management while addressing urban infrastructure needs.

Buffalo Sewer Authority's Environmental Impact Bond

For instance, the Buffalo Sewer Authority (BSA) leveraged stormwater fees to issue a $54 million Environmental Impact Bond (EIB), the largest of its kind in the U.S., to fund its Rain Check 2.0 initiative (Buffalo Sewer Authority, 2021). This initiative focuses on retrofitting at least 200 acres of impervious surface, prioritizing stormwater mitigation and environmental justice in six key combined sewer overflow (CSO) basins.

The EIB represents an innovative financing model that ties performance outcomes to financial flexibility. If the targeted 200 acres of GSI are implemented by 2028, the bond allows Buffalo to refinance or retire the debt at a lower cost, incentivizing efficient project execution while ensuring accountability through third-party validation of environmental outcomes (Buffalo Sewer Authority, 2021). This approach has significantly accelerated the pace of GSI installation in Buffalo—from 9.5 acres per year during 2014–2020 to over 28 acres per year from 2021–2027—dramatically reducing CSOs, improving water quality, and mitigating flooding risks.

Buffalo's EIB highlights the potential of stormwater fees to align infrastructure financing with community and equity goals. By integrating GSI into historically underserved neighborhoods, the Rain Check 2.0 program reduces urban heat islands, enhances public green spaces, and creates approximately 700 jobs, many of which are accessible to local residents (Buffalo Sewer Authority, 2021). This model demonstrates how stormwater fees, when combined with mechanisms like EIBs, can overcome funding barriers and drive transformative environmental and social outcomes.

Innovative Financing Platforms

To further address financing challenges and unlock funding for GSI, new resources have been developed to support municipalities and stakeholders. The Lake Michigan Funding Resiliency Dashboard, created by American Rivers, WaterNow Alliance, and One Water Econ, is an actionable tool designed to help communities in Michigan and Illinois implement local resiliency plans and projects (American Rivers et al., 2024). This interactive platform guides users through identifying priority projects, valuing multiple benefits, and matching projects with appropriate funding and financing options. By streamlining the process of securing funds, the Dashboard empowers municipalities to advance nature-based stormwater solutions that align with resilience and equity goals.

Additionally, the Storm Store, developed by the Metropolitan Planning Council in collaboration with regional partners, provides an innovative credit trading platform to address stormwater management challenges in the Chicago area. The Storm Store enables municipalities, developers, and property owners to trade stormwater volume credits, incentivizing investments in GSI while achieving regulatory compliance. This market-based solution lowers project costs, reduces flood risks, and promotes widespread adoption of green infrastructure in both public and private sectors (American Rivers et al., 2024).

Case Study: Buffalo Sewer Authority

The Buffalo Sewer Authority (BSA) provides an exemplary case of innovative design in addressing urban stormwater management challenges. Buffalo's aging combined sewer system, constructed in the early 1900s, was originally designed to manage both sanitary and stormwater within a single pipeline. However, increased precipitation driven by climate change and stricter environmental regulations exposed significant limitations in this system. The city's infrastructure was unable to accommodate the growing volume of stormwater, leading to nearly 2 billion gallons of annual combined sewer overflows (CSOs). These overflows caused severe pollution in local waterways and placed Buffalo under federal and state mandates to significantly reduce its environmental impact.

Faced with financial constraints and a shrinking taxpayer base, BSA adopted an innovative solution to these challenges. Partnering with Xylem, BSA implemented a real-time decision support system (RT-DSS) as part of its Wastewater Network Optimization solution. This advanced system utilized data from a network of sensors installed across Buffalo's sewer system to dynamically manage water flows and storage capacity during rainfall events. By rerouting excess stormwater to treatment facilities when needed, the RT-DSS transformed Buffalo's traditional gravity sewer infrastructure into a high-tech, actively managed system. This approach effectively reduced the volume and frequency of CSOs while ensuring compliance with environmental standards.

The impact of this innovative design has been profound. Since its implementation in 2017, the RT-DSS has redirected over 3 billion gallons of stormwater that would have otherwise ended up in local waterways. This has substantially reduced pollution levels, improved water quality, and enhanced Buffalo's ability to meet regulatory requirements. Moreover, the financial implications were significant. Initially projected to cost $525 million, the city's CSO abatement efforts were reduced by $145 million, demonstrating the cost-effectiveness of integrating advanced technology into stormwater management systems.

Beyond immediate environmental and financial benefits, the RT-DSS also improves Buffalo's ability to adapt to climate variability. Each storm event contributes new data that enhances the system's predictive capabilities, enabling more refined and efficient responses to future weather challenges. This continuous improvement not only reduces maintenance costs but also ensures the system's long-term resilience, positioning Buffalo as a leader in sustainable urban water management.

Buffalo's success illustrates the transformative potential of leveraging technology and innovative design to optimize stormwater infrastructure. By addressing immediate challenges while building capacity for future resilience, the city provides a replicable model for municipalities nationwide. The integration of real-time monitoring, advanced analytics, and adaptive management demonstrates how data-driven decision-making can enhance the efficiency and sustainability of GSI projects. Through strategic investments and collaborative problem-solving, Buffalo has achieved significant environmental and economic benefits, showcasing the value of innovation in tackling urban water challenges.

Federal, State, and Provincial Programs and Funding

In addition to local revenue sources like stormwater fees, effective stormwater management in the Great Lakes Region relies on federal, state, and provincial programs that provide critical funding and support. Initiatives such as the Clean Water State Revolving Fund (CWSRF), FEMA's Building Resilient Infrastructure and Communities (BRIC) Program, and the Great Lakes Restoration Initiative (GLRI) enable municipalities to implement green infrastructure, improve water quality, and enhance climate resilience. These programs complement local financing mechanisms, creating a comprehensive funding strategy that allows communities to scale GSI and address long-term water management challenges.

Table 4-1: Possible Funding Sources

Funding Source	Funding	Description
Federal Government	Infrastructure Investment and Jobs Act (IIJA)	IIJA authorized $10 billion for states, tribes, local governments, and other entities to support the implementation of green infrastructure, water efficiency and restoration projects. Additionally, the IIJA authorizes $5 billion for the EPA to provide grants to states and tribes to help them address combined sewage and stormwater overflows.
Federal Government	Bipartisan Infrastructure Law (BIL)	Provides $1.2 trillion for infrastructure improvements, including $55 billion for water systems. Allocates $200 million annually to the Great Lakes Restoration Initiative (GLRI) and $50 billion for climate resilience infrastructure such as flood protection and ecosystem restoration. Supports disadvantaged communities through grants and forgivable loans for green and gray infrastructure projects.
Federal Government	Inflation Reduction Act (IRA)	IRA will invest nearly $370 billion in energy security and climate change efforts over a 10-year period. This includes $27 billion to the EPA for a new Greenhouse Gas (GHG) Reduction Fund, of which $8 billion is set-aside for low-income and disadvantaged communities; $3 billion for "Environmental and Climate Justice Block Grants" to reduce pollution and climate threats in disadvantaged communities; $19.5 billion for agricultural conservation programs through USDA; $2.2 billion for tree planting and related activities under the Urban and Community Forestry Program at USDA; and $1 billion funding for energy and water efficiency improvements.
Federal Government	Great Lakes Restoration Initiative (GLRI)	Administered by the EPA, GLRI funds targeted environmental projects in the Great Lakes, prioritizing stormwater management, pollution control, and GSI projects as part of broader ecosystem restoration efforts.
Federal Government	Clean Water State Revolving Fund (CWSRF)	Provides low-interest loans for water quality projects, including stormwater and green infrastructure initiatives. Supports large-scale efforts to improve water quality, manage runoff, and address combined sewer overflows (CSOs).
Federal Government	NRCS Environmental Quality Incentives Program (EQIP)	Provides financial and technical support for agricultural conservation practices that reduce runoff and nutrient pollution in the Great Lakes watershed, improving water quality and mitigating harmful impacts.
Federal Government	FEMA Building Resilient Infrastructure and Communities (BRIC) Program	Funds projects enhancing resilience to natural hazards, including stormwater initiatives that reduce flood risks and increase climate resilience in high-risk communities.
Federal Government	Sewer Overflow and Stormwater Reuse Municipal Grants (OSG)	Provides assistance to rural and financially distressed communities for CSO and SSO infrastructure projects. Requires 20% of funds to support green infrastructure and environmentally innovative activities.

Funding Source	Funding	Description
Federal Government	Environmental Protection Agency's Community Change Grant	The Environmental Protection Agency's Community Change Grant program addresses systemic environmental and climate injustices by providing substantial funding for community-driven initiatives. Eligible projects focus on pollution reduction, climate resilience, and local capacity building in disadvantaged communities. Grants include up to $20 million for large-scale investments and $3 million for engaging underrepresented populations. The program aims to foster equitable environmental outcomes while empowering communities to combat legacy pollution and adapt to climate change.
Federal Government	Five Star and Urban Waters Restoration Grant Program by NFWF	The Five Star and Urban Waters Restoration Grant Program, managed by the National Fish and Wildlife Foundation (NFWF), supports diverse local partnerships in restoring water quality and natural habitats. This program provides grants of up to $60,000 for projects that promote conservation, enhance biodiversity, and engage communities in environmental stewardship. Eligible applicants include local governments, state agencies, tribal governments, and non-profits. Funded projects aim to develop sustainable infrastructure, improve watersheds, and create long-term ecological and social benefits.
Federal Government	Flood Mitigation Assistance Program by FEMA	The Flood Mitigation Assistance (FMA) program, administered by FEMA, provides competitive funding to reduce repetitive flood risks and enhance community resilience. Eligible projects include flood control measures, property acquisition, and nature-based solutions. The program emphasizes infrastructure upgrades in areas prone to flooding, supporting compliance with hazard-resistant building codes. It also promotes equitable distribution of resources by prioritizing disadvantaged communities. Funding amounts vary based on project type and scope.
Federal Government	National Coastal Resilience Fund by NFWF	The National Coastal Resilience Fund (NCRF) by NFWF invests in planning, design, and implementation of nature-based solutions to enhance protection for coastal communities and improve habitats for fish and wildlife. The fund provides approximately $140 million annually for projects that address storm and flood risks, increase community resilience, and support biodiversity. Primary funding partners include NOAA and the U.S. Department of Defense, with additional contributions from the private sector. Projects funded by NCRF emphasize sustainable environmental solutions that integrate community and ecological benefits.
Federal Government	Southeast Michigan Resilience Fund by NFWF	The Southeast Michigan Resilience Fund is a public-private partnership managed by NFWF that supports projects reducing stormwater impacts through green stormwater infrastructure. The fund improves water quality, enhances habitats, and increases accessibility to public green spaces. With a maximum award of $400,000, eligible projects focus on integrating natural systems into urban and suburban landscapes to create resilient communities. Partners include Cleveland-Cliffs, the Kresge Foundation, and the Ralph C. Wilson, Jr. Foundation, among others.
Federal Government	Trees In Your Community Grant by USDA Forest Service	The Trees In Your Community Grant, administered by the USDA Forest Service, provides funding for urban forestry projects aimed at combating extreme heat, improving air quality, and fostering workforce development. This grant supports tree planting and maintenance in historically underserved and low-income communities. Funded through the Inflation Reduction Act (IRA), the program offers a maximum award of $1,500,000 to eligible local governments and organizations. The initiative prioritizes equitable access to green spaces and climate resilience, promoting healthier and more livable urban environments.

Funding Source	Funding	Description
State Government	Green Infrastructure Grant Opportunities (GIGO)	The State of Illinois' GIGO program provides funding for the construction of green infrastructure best management practices (BMPs) that "prevent, eliminate, or reduce water quality impairments by decreasing stormwater runoff into Illinois' rivers, streams, and lakes." The program has an annual budget of $5 million and awards two to 10 awards per year. Eligible applicants include local watershed groups, land conservancies or trusts, public and private for profit and nonprofit organizations and institutions, governments (county, municipal, township, or state), universities and colleges, park districts and other local land managing agencies, soil and water conservation districts, and conservation organizations. GIGO provides up to 75 percent of the approved project costs (85 percent for projects in disadvantaged areas).
State Government	Affordability and Planning Grant by EGLE	The Affordability and Planning (AP) Grant is part of Michigan's EGLE Clean Water Plan, designed to address critical water infrastructure needs. This grant focuses on improving the affordability and sustainability of drinking water infrastructure, ensuring residents have access to safe, healthy drinking water. Eligible applicants include local governments and other organizations, with a maximum award of $500,000 per applicant and $2,000,000 for applications involving multiple communities. This initiative aims to support infrastructure improvements that promote long-term water quality and affordability, with over $5.7 million in total funding available.
State Government	Clean Water Fund Program by Wisconsin DNR and DOA	The Clean Water Fund Program (CWFP), administered by Wisconsin's Department of Natural Resources (DNR) and Department of Administration (DOA), is a revolving loan fund supporting wastewater and stormwater infrastructure projects. This program helps municipalities comply with Wisconsin Pollutant Discharge Elimination System (WPDES) permits and improve water quality. Eligible projects include planning and construction efforts to mitigate flooding, enhance coastal resilience, and restore natural systems. With no maximum loan amount, the CWFP is a flexible and vital resource for sustainable water infrastructure financing.
State Government	Nonpoint Source Pollution Control Financial Assistance Program	The State of Illinois administers the Nonpoint Source Pollution Control Financial Assistance Program under Section 319(h) of the Clean Water Act. Funds can be used for the development, update, and implementation of watershed-based management plans including the development of information/education programs and for the installation of best management practices. The Illinois EPA expects to award $4.5 million in funding during FY2024.
State Government	Stormwater Fee/Tax	Stormwater management is increasingly financed through mechanisms such as stormwater fees or taxes, which provide dedicated funding for both gray and green infrastructure projects aimed at reducing flooding, managing stormwater runoff, and mitigating pollution from combined sewer overflows (CSOs). These fees are often calculated based on the amount of impervious surface area on a property, reflecting the contribution of runoff to the stormwater system. Many municipalities and special districts use these funds to sustain stormwater infrastructure and implement new projects. For instance, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) supports its stormwater initiatives through a dedicated Stormwater Management Fund. This fund, which appropriated $97 million in 2022, is backed by a combination of tax levies, user charges, and other revenue streams like land rental and sewer permits. By ensuring a stable and equitable funding source, stormwater fees and taxes enable municipalities to address pressing water management challenges while supporting long-term resilience and environmental health.

Funding Source	Funding	Description
Private Sector	Environmental Impact Bond (EIB)	EIBs are a tool for helping cities finance innovative programs and projects where traditional sources of financing may be harder to access. These bonds draw in private capital for investments in environmental projects such as GSI for improving water quality and are repaid based on the relative success of the project in achieving anticipated outcomes. In addition to financial de-risking, key benefits of the impact bond model are ease of execution, which can accelerate funding for innovative uses, lack of a long-term privatization, or encumbrance of an asset, and a very high degree of flexibility.

Private Finance

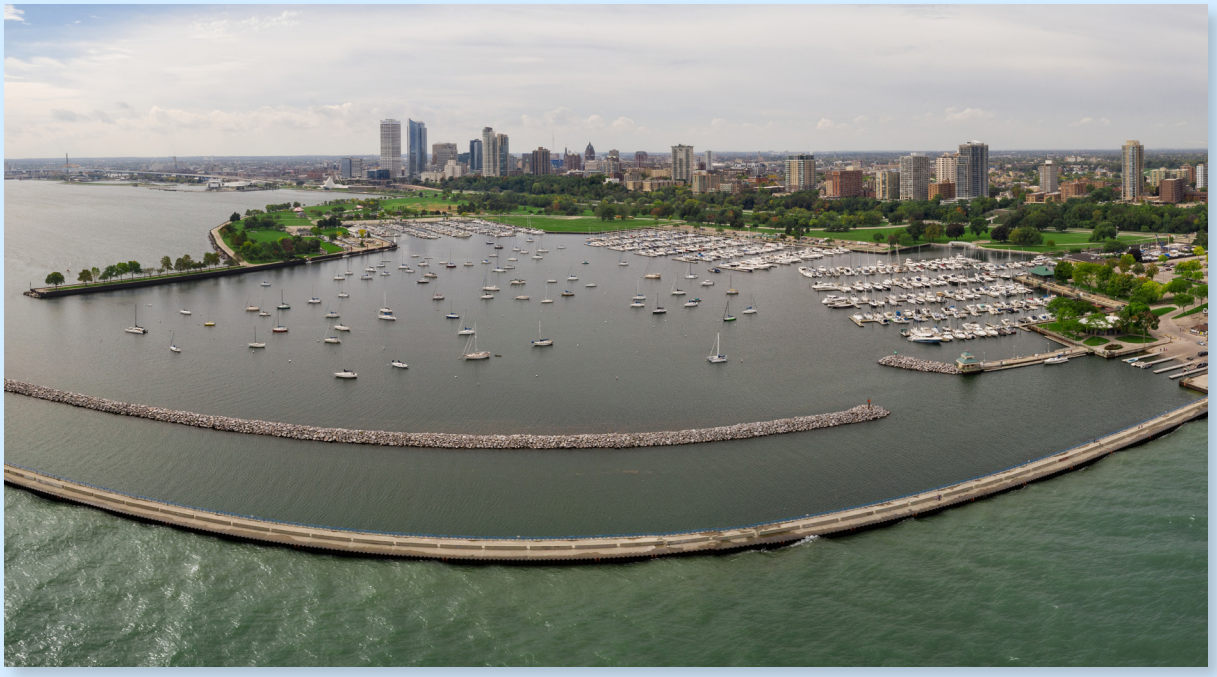
Private financing involves the use of funds sourced from non-governmental entities such as corporations, private investors, and financial institutions to support public projects. This form of financing is typically more expensive but can be valuable in sectors where public capital is inadequate to meet all investment needs. It offers flexibility, can drive innovation, and is crucial in reducing performance risks associated with project outcomes.

While government borrowing remains a staple for obtaining low-cost capital, it often does not suffice to meet the comprehensive demands of the water sector (Higgins, Male, & Sinha, 2021). As a result, private financing has emerged as a critical complement, filling the financial gaps that public funding cannot cover. This approach not only diversifies the funding landscape but also introduces efficiency and accountability into project execution.

Advanced procurement strategies, such as "pay-for-success" models, leverage private finance effectively by linking payments to the achievement of predetermined outcomes, like enhanced water quality or reduced stormwater runoff. These models encourage innovative solutions and ensure that financial expenditures can be offset by risk transfer from a public to a private partner while contributing to tangible environmental benefits. Integrating private financing can thus play a pivotal role in enabling municipalities to expand their infrastructure, enhance sustainability, and deliver on community and environmental goals within the Great Lakes Region.

The Milwaukee Metropolitan Sewerage District (MMSD) stands out as a pioneering utility in the Great Lakes region, particularly in its strategic use of private financing to enhance Green Stormwater Infrastructure (GSI). In January 2020, MMSD embarked on a groundbreaking partnership by signing the region's first-ever Community-Based Public-Private Partnership (CBP) with Corvias Group LLC (its business unit later spun-off as CIS, LLC). This collaboration was aimed at drastically reducing sewer overflows and enhancing stormwater management capabilities across its service area.

Case Study: MMSD's Stategic Use of Private Financing



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MMSD's ambitious targets include zero overflows by 2035 and capturing the first half-inch of rainfall on all impervious surfaces—equivalent to 740 million gallons of stormwater. To achieve these goals, the partnership with CIS integrates private investment at-risk, focusing on the planning, design, procurement, and construction phases of GSI projects. This innovative financing model not only mitigates financial risk but also ensures cost efficiency over traditional methods. Finally, despite the use of private finance, MMSD negotiated a contract with CIS that ensured a lower price per gallon of stormwater detained/retained while using green techniques than using gray infrastructure.

The partnership's approach is highlighted by its "pay-for-performance" strategy, which holds financial disbursements contingent upon achieving specified outcomes. This method ensures that investment is directly tied to tangible environmental improvements, such as increased GSI capture capacity, with a minimum target of 20 million gallons. Moreover, the partnership prioritizes community and economic development; so far, 50% of the projects are located in low-to-moderate income areas and the partnership has awarded 46% of the contracts to Small, Veteran, Women, and Minority Business Enterprises, partnering with local workforce programs, and engaging in extensive stakeholder and community interaction.

This CBP model not only showcases MMSD's commitment to innovative, sustainable infrastructure but also sets a precedent for effective public-private collaborations using private finance in the water management sector. By leveraging non-traditional funding and implementing large-scale GSI projects, MMSD is leading the way in creating more resilient urban environments in the Great Lakes region.

4.4 Equity and Environmental Justice

Equity and environmental justice are pivotal considerations in the planning and implementation of GSI. These principles ensure that the investments made in these systems benefit all community members equitably, especially those who are marginalized and underserved. Flooding disproportionately impacts low-income and minority populations, as well as vulnerable groups like the elderly or individuals with disabilities, who face amplified challenges during and after flood events. For instance, transportation disruptions and power outages hinder access to daily necessities, while low-income residents often struggle to afford flood insurance, cleanup costs, or necessary repairs to mitigate future risks. Historically, Black, Indigenous, and People of Color (BIPOC) residing in disinvested neighborhoods bear a greater burden of flooding and environmental degradation due to systemic inequities in infrastructure and resource allocation (Lowe et al., 2013; U.S. Water Alliance, 2020).

Programs like the Great Lakes Environmental Justice Program illustrate how data-driven strategies can address these inequities. Through targeted tools and resources, the program equips environmental justice communities to implement GSI projects tailored to their specific needs, enhancing resilience and equity. For example, SEMCOG's Equity Emphasis Areas Application allows stakeholders to assess demographic and socioeconomic indicators at various geographic scales, enabling communities to prioritize areas for stormwater management projects that address environmental and social vulnerabilities. This tool supports initiatives like the development of affordable and accessible housing in areas with high concentrations of seniors with disabilities, demonstrating how data can guide impactful planning (SEMCOG, 2024).

MMSD's Commitment to Supplier Diversity

The Milwaukee Metropolitan Sewerage District (MMSD) exemplifies how equity-focused procurement policies can foster economic growth while advancing environmental justice. MMSD has established a Small and Minority-Owned Business Enterprise (SWMBE) program, ensuring that 20% of its annual procurement budget is allocated to SWMBE firms—a goal it has consistently exceeded, averaging 22% over the past five years. By integrating SWMBE participation into contracts for GSI projects, MMSD creates inclusive opportunities for local businesses owned by women, minorities, and veterans (MMSD, 2024).

Certified SWMBE firms gain visibility through MMSD's public vendor directory, allowing them to compete for contracts in construction, professional services, and more. This initiative not only diversifies MMSD's vendor base but also strengthens community wealth by prioritizing local workforce utilization. MMSD's program highlights the intersection of equity and stormwater management, showcasing how inclusive procurement practices can promote economic sustainability alongside environmental benefits (MMSD, 2024).

Workforce development

Workforce development is a critical challenge for utilities, particularly in the context of GSI installation and maintenance. Stakeholders consistently highlight the importance of robust partnerships with educational institutions, such as community colleges, to develop targeted training programs that address these gaps. These initiatives are essential not only to fill existing workforce shortages but also to create sustainable economic opportunities

within underserved communities, ensuring that the knowledge and skills necessary for GSI projects are embedded within the communities they serve (U.S. Water Alliance, 2020).

The water sector offers some exemplary programs in workforce development. Prince George's County's (Maryland) Clean Water Partnership Mentor Protégé Program develops the capacity of small, local, and minority-owned firms in stormwater management and GSI projects. Participants receive comprehensive training in areas such as blueprint reading, cost estimating, leadership, and strategic planning. Supportive services, including business coaching, financial assistance, and access to bid opportunities, empower firms to compete successfully for contracts. Since its inception, the program has supported over 35 firms, resulting in approximately $23 million in expenditures directed toward local and minority-owned businesses, fostering economic growth and local expertise essential for the success of GSI initiatives (Clean Water Partnership, 2023).

Similarly, Milwaukee's Water Equity Taskforce addresses systemic barriers to entry in the water workforce, emphasizing living-wage employment opportunities for individuals in historically marginalized communities. Through partnerships with local educational institutions, Milwaukee Water Works (MWW) has established robust training pipelines. Programs such as MWW's youth apprenticeship program introduce high school students to careers in water distribution and machinery repair, while college internships provide hands-on experience in water quality laboratories and treatment plants. Additionally, the Fresh Coast Ambassador Program connects high school students to paid green infrastructure work, fostering career readiness through partnerships with workforce development boards.

RISC's recent *Green Job Creation in the Nation's Largest Stormwater Programs* report further underscores the potential of workforce development in the GSI sector. Green infrastructure projects supported by initiatives like the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA) are estimated to generate nearly 933,000 green jobs over the next decade. Programs such as the National Green Infrastructure Certification Program (NGICP) provide targeted training for entry-level workers, ensuring they acquire essential skills for constructing, inspecting, and maintaining green stormwater systems. These certifications, combined with pathways that do not require advanced degrees, make green jobs accessible to a broad and diverse workforce, addressing equity gaps while creating economic opportunities (Khaleghi et al., 2023).

The report highlights successful examples of green job training programs, such as Milwaukee Metropolitan Sewer District's (MMSD) partnership with BIG STEP, which created over 1,700 green jobs in 2022 alone. The program emphasizes inclusion, with 60% of participants being people of color and 14% women. Such initiatives illustrate the potential for GSI projects to promote equity and build community resilience while addressing critical workforce needs.

Innovative workforce development efforts like these not only tackle immediate labor shortages but also contribute to broader equity and inclusion goals. By fostering opportunities for local residents and emphasizing diversity in hiring and contracting practices, these programs ensure the economic, social, and environmental benefits of water sector investments are equitably distributed. As utilities across the Great Lakes region scale up GSI, these models provide valuable lessons in building inclusive and sustainable talent pipelines.

Public engagement and communication

Public education and outreach are essential to ensuring that communities understand and actively support GSI initiatives. Engagement strategies that are inclusive and tailored

to the specific needs of communities can amplify the social, environmental, and economic benefits of GSI while fostering trust and collaboration between municipal entities and local residents. Establishing Community Advisory Boards (CABs) composed of diverse local representatives has proven to be an effective strategy. These boards ensure that feedback from various stakeholders is gathered and integrated into project planning while also promoting transparent communication and co-creation of solutions that align with community priorities. For instance, the Space to Grow initiative in Chicago exemplifies the power of collaboration by partnering with schools and local organizations to transform schoolyards into multifunctional spaces. These spaces simultaneously manage stormwater, enhance recreational opportunities, and educate the community on the importance of green infrastructure (Metropolitan Water Reclamation District of Greater Chicago [MWRD], 2024).

Urban installations of GSI, such as community gardens and urban farms, have the potential to transform neighborhoods by fostering a stronger connection between people and their environment. These installations not only provide ecological and water management benefits but also enhance food security, mitigate urban heat islands, and create spaces for social interaction and environmental stewardship. Engaging communities in the planning and implementation of GSI ensures that projects reflect local priorities and knowledge. Collaborative planning methods, such as co-design workshops and surveys, empower residents to influence project design, location, and functionality. This approach not only enhances the relevance and acceptance of GSI projects but also fosters long-term sustainability through local ownership and stewardship.

Prioritizing equity and environmental justice in GSI projects ensure that the benefits extend to underserved and marginalized communities. Programs like Space to Grow in Chicago prioritize low-income neighborhoods for schoolyard transformations, providing these communities with improved infrastructure and green spaces that mitigate flooding and reduce urban heat. Similarly, Detroit's urban farms focus on neighborhoods with limited access to healthy food and high vulnerability to flooding, demonstrating how GSI can address environmental and social inequities simultaneously (MWRD, 2024; Planet Detroit, 2021).

Urban Farms as Models for GSI and Community Engagement

Detroit's urban farms, including Freedom Farm and Brother Nature Farm, illustrate how GSI can serve as a valuable tool for stormwater management while simultaneously addressing systemic inequities. These farms absorb rainwater, reducing strain on the city's sewer system, while also providing fresh produce and fostering a sense of community ownership (Planet Detroit, 2021). Similarly, Baltimore's Real Food Farm uses bioswales, retention ponds, and other GSI elements to mitigate runoff and educate residents about sustainable agricultural practices (American Rivers, 2015).

Detroit's Keep Growing Detroit initiative incorporates input from local growers and community members to create stormwater management systems that align with urban agriculture goals, capturing significant amounts of rainwater while enhancing food security and economic opportunities (Planet Detroit, 2021).

Effective public engagement and communication are critical to the success of GSI initiatives. By integrating community voices, utilizing multiple communication channels, and prioritizing equity, municipalities can ensure that GSI projects address environmental challenges while enhancing social cohesion and community well-being. Programs in

Chicago, Detroit, and Baltimore illustrate the transformative potential of GSI when paired with thoughtful and inclusive engagement. These initiatives provide a model for how municipalities can foster resilient, sustainable, and equitable communities through green infrastructure.

4.5 Asset Management and Maintenance

Asset management is a critical framework for ensuring the long-term sustainability, equity, and efficiency of GSI systems in the Great Lakes region. By treating GSI as an integral component of stormwater management rather than an optional enhancement, municipalities can optimize resource allocation, enhance system performance, and address key challenges such as equity, workforce development, and financial constraints. Stakeholder insights emphasize that integrating GSI into comprehensive infrastructure planning and budgeting is essential for building resilience and fostering equitable outcomes across diverse communities.

A foundational aspect of asset management is the creation of comprehensive inventories cataloging GSI assets, such as permeable pavements, rain gardens, and retention basins. By documenting the location, condition, and remaining useful life of assets, municipalities can conduct lifecycle cost analyses to guide decisions on repair, rehabilitation, maintenance, and replacement. This proactive approach reduces long-term costs, extends the service life of GSI assets, and aligns with best practices from the Environmental Finance Center Network (2014) and the Handbook on Wastewater Management (Taber, 2016).

Recent guidance from the Southwest Environmental Finance Center, developed in partnership with the Green Infrastructure Leadership Exchange, provides a robust framework for GSI asset management through the Asset Management Switchboard platform. This resource emphasizes the importance of systematic data collection, preventative maintenance, and strategic planning to ensure long-term performance (University of New Mexico Southwest Environmental Finance Center, 2024). The Asset Management Switchboard highlights tools and strategies to optimize asset management practices, improve operational efficiency, and support financial sustainability for GSI systems.

Moreover, integrating maintenance responsibilities into asset management plans proactively addresses one of the most significant barriers to the success of GSI systems: inadequate upkeep. Maintenance gaps can undermine the benefits of GSI, including stormwater capture, urban cooling, and flood reduction. The Fresh Coast Protection Partnership in Milwaukee exemplifies how integrating maintenance into asset management frameworks can overcome these challenges.

Lessons from the Resilient Infrastructure Sustainable Communities (RISC) reports highlight the importance of considering maintenance needs during the early design and budgeting phases of GSI projects. This proactive approach enables municipalities to meet regulatory requirements, such as Wisconsin Pollutant Discharge Elimination System (WPDES) permits, while maximizing long-term community and environmental benefits.

The Chesapeake Bay Program model provides additional insights into robust asset management frameworks, particularly how strategic planning can support maintenance and resilience. While its primary focus is on the Chesapeake Bay watershed, the program's approach to combining planning with local capacity-building efforts is widely recognized and can offer valuable lessons for the Great Lakes region. Its inclusion in the National Climate

Assessment (NCA5) highlights how transferable principles, like community collaboration and adaptive management, can enhance resilience and compliance with regulatory frameworks in other regions.

Fresh Coast Protection Partnership - A Model for GSI Maintenance

The Fresh Coast Protection Partnership (FCPP) in Milwaukee provides an exemplary model for addressing GSI maintenance challenges. This community-based partnership incorporates maintenance into its core operations by partnering with workforce development programs to build local capacity and create career pathways in the green infrastructure sector. The FCPP's Mentor Protégé program equips small, women, minority, and veteran-owned businesses (SWMBEs) with the skills and resources needed to effectively maintain GSI systems.

Key Achievements:
Developed 9.14 million gallons of stormwater capture capacity between 2020 and 2022.
Achieved an average SWMBE participation rate of 67% across its projects (MMSD & CIS, 2022).

By incorporating maintenance into all phases of GSI planning and leveraging comprehensive frameworks like those from the Southwest Environmental Finance Center, municipalities can ensure these systems remain functional, cost-effective, and equitable over time. Proactive asset management, including systematic maintenance and lifecycle planning, will help municipalities achieve regulatory compliance while delivering sustained environmental, social, and financial benefits to the communities they serve.

Advancing Equity Through Asset Management

The FCPP and similar frameworks illustrate how asset management can drive social equity in GSI implementation. By prioritizing investments in neighborhoods that experience disproportionate flooding, combined sewer overflows, and other environmental burdens, these programs ensure that GSI projects deliver critical benefits to vulnerable populations. For example, in Milwaukee, the FCPP identifies high-priority project locations based on community needs and environmental vulnerabilities, ensuring equitable distribution of resources and enhancing neighborhood resilience.

The Community-Based Partnership (CBP) structure further embeds equity into asset management by fostering transparent communication of Level of Service (LOS) goals and linking them to measurable outcomes. These goals include improved water quality, flood mitigation, and reduced urban heat islands, which directly benefit communities facing environmental and socioeconomic challenges. By aligning LOS agreements with public expectations and demonstrating tangible outcomes, municipalities can build public trust and sustain stakeholder support for GSI investments.

The CBP model also emphasizes innovative financing mechanisms, such as performance-based contracts and partnerships with private capital, to reduce financial burdens on municipalities and ensure long-term maintenance. For example, the CBP model's legal framework (Figure 3) illustrates how public partners oversee approvals and funding while private partners assume risk and manage execution, including operations and maintenance. This structure not only promotes cost-effectiveness but also creates opportunities for workforce development and capacity-building through collaboration with local stakeholders.

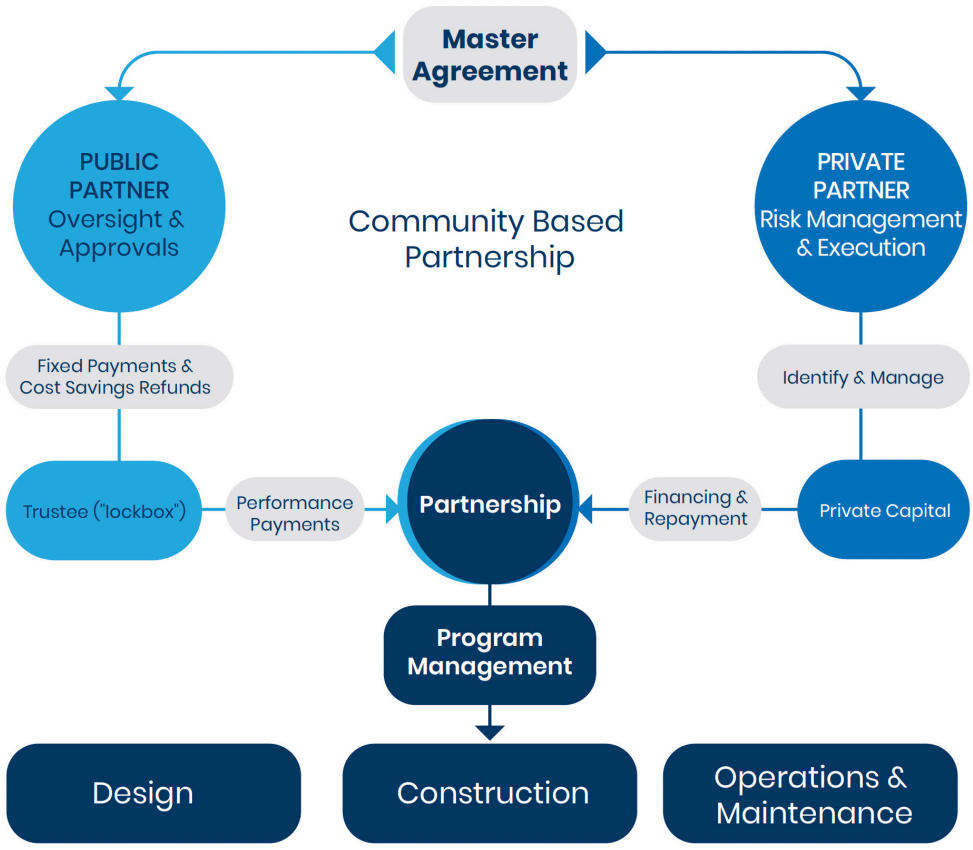


Figure 3. *Legal Framework structure for a CBP partnership (Vedachalam et al., 2023).*

By leveraging innovative partnership models, embedding maintenance into asset management plans, and prioritizing equity in GSI investments, municipalities can overcome significant challenges and unlock the full potential of GSI systems. These strategies ensure that GSI initiatives not only address pressing environmental issues but also advance social equity, improve community resilience, and create healthier, more sustainable urban environments.

Criticality assessment

A critical aspect of asset management is assessing the likelihood and consequences of asset failure. This process, known as criticality assessment, helps municipalities prioritize resources for the most essential assets, reducing disruptions and ensuring reliable service delivery. For example, in Toronto, the city has implemented a detailed risk and criticality analysis framework as part of its municipal asset management plan. This framework identifies high-priority assets such as stormwater infrastructure in areas prone to flooding, enabling targeted investments to prevent system failures and minimize public disruption (City of Toronto, 2019). Similarly, in Milwaukee, criticality assessments have been utilized to guide investments in GSI and ensure that limited resources are allocated to projects with the highest impact on flood mitigation and water quality improvement (Milwaukee Metropolitan Sewerage District, 2020).

Integrating a planning component into the criticality assessment process further enhances its effectiveness by aligning asset priorities with broader municipal goals and strategies. The City of Brampton exemplifies this approach through its comprehensive

asset management strategy, which includes climate adaptation planning. Brampton incorporates criticality assessments into its Climate Change Adaptation Plan to identify vulnerabilities in its stormwater management system. This enables the city to proactively address infrastructure gaps while aligning with future growth and climate change scenarios (City of Brampton, 2021). These efforts are tied directly to municipal planning documents, ensuring alignment between criticality assessments and the city's broader vision for sustainable urban development.

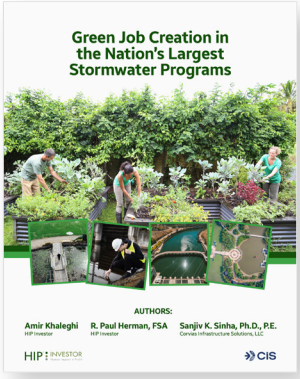
Additionally, defining and maintaining a level of service (LOS) agreement ensures that GSI systems meet public expectations and regulatory requirements while linking service outcomes to funding and operational priorities. For example, Milwaukee's "Flood Management and Green Infrastructure Plan" integrates LOS goals to ensure that its stormwater systems can handle projected increases in extreme weather events. This includes tying LOS benchmarks directly to funding initiatives, such as leveraging state and federal grants to retrofit existing systems and construct new infrastructure (Milwaukee Metropolitan Sewerage District, 2020).

Similarly, Brampton uses LOS standards to communicate expected outcomes to stakeholders and align those outcomes with its asset management plans. This includes setting measurable performance indicators for stormwater infrastructure, such as response times for flooding incidents and reduction targets for combined sewer overflows (CSOs). By incorporating LOS goals into long-term municipal budgets, Brampton ensures that funding and operational activities are consistently aligned with desired service outcomes.

Embedding planning components into criticality assessments enhances municipalities' capacity to make informed, forward-looking decisions that balance immediate needs with long-term goals. This integration not only supports efficient resource allocation but also builds resilience into infrastructure systems, ensuring they remain robust in the face of evolving challenges. Furthermore, clearly communicating LOS goals and how they tie into broader planning initiatives fosters public trust and secures continued support for GSI investments.

Data sharing and equitable asset management

Equity and data sharing are integral to effective asset management in the context of GSI. Stakeholder feedback consistently highlights the need for equitable resource allocation, particularly in underserved communities facing significant environmental and infrastructure challenges. Utilizing standardized and comparable data to guide decision-making ensures that GSI investments address the areas of greatest need, fostering long-term benefits for marginalized populations. Mapping tools and data-sharing platforms play a critical role in identifying strategic opportunities for equitable investment, enabling municipalities to align funding with community priorities (Khaleghi et al., 2023).



The Green Job Creation in the Nation's Largest Stormwater Programs report, supported by the Great Lakes Protection Fund, underscores the transformative potential of data-driven approaches to asset management. For example, regional data-sharing initiatives foster collaboration among municipalities and stakeholders, accelerating the dissemination of best practices and success stories. Mapping tools can overlay demographic and environmental data to identify areas where GSI projects would have the most significant equity and environmental impact, ensuring that investments are both targeted and effective (Khaleghi et al., 2023).

Despite these advantages, implementing robust asset management frameworks for GSI faces several challenges. Smaller municipalities, in particular, often struggle with limited resources, inadequate integration of GSI into broader capital and operating budgets, and fragmented coordination among transportation agencies, municipalities, and community-based organizations (Khaleghi et al., 2023). Public-private partnerships, while promising in providing financing and technical expertise, are often inaccessible to smaller agencies due to high costs and complex requirements.

To address these challenges, Resilient Infrastructure for Sustainable Communities (RISC) has identified key opportunities to advance GSI asset management. These include providing municipalities with technical assistance, model documents, and maintenance plans to streamline the development of asset management frameworks. Additionally, sharing tools and regional data fosters a collaborative environment that accelerates learning across the Great Lakes Region, enabling municipalities to implement innovative and equitable solutions more efficiently (Khaleghi et al., 2023).

RISC plays a pivotal role as a repository, educator, advocate, and connector in scaling up GSI through asset management. As a repository, RISC compiles and disseminates best practices, templates, and resources, providing municipalities with actionable guidance. As an educator, RISC facilitates peer learning through webinars, workshops, and case studies, showcasing successful approaches to GSI management. As an advocate, RISC promotes policies that integrate GSI into regional and national infrastructure priorities, emphasizing equitable and sustainable funding. Finally, as a connector, RISC fosters partnerships among municipalities, educational institutions, and private sector stakeholders, encouraging resource-sharing and collaborative solutions (Khaleghi et al., 2023).

Scaling up GSI in the Great Lakes Region requires a robust asset management framework that prioritizes lifecycle cost analysis, criticality assessments, and equitable resource allocation. By embedding GSI into comprehensive infrastructure plans and leveraging data-sharing platforms, municipalities can enhance the resilience and sustainability of their systems. RISC's efforts to facilitate collaboration, knowledge-sharing, and advocacy are essential for addressing regional challenges and unlocking the full potential of GSI investments. This holistic approach not only strengthens GSI systems but also ensures their benefits are equitably distributed, enhancing the social, economic, and environmental well-being of the Great Lakes communities (Khaleghi et al., 2023).

Case Study: City of Brampton, Ontario

The City of Brampton's Stormwater Asset Management Plan (AMP) provides a comprehensive framework for prioritizing and optimizing stormwater infrastructure management, ensuring long-term functionality and financial sustainability. Developed to meet the requirements of Ontario's O.Reg. 588/17 under the Infrastructure for Jobs and Prosperity Act, 2015, the plan aligns with provincial mandates to create strategic asset management plans for core municipal assets. Approved by the Brampton City Council in June 2022, the Stormwater AMP integrates seamlessly with the city's broader corporate asset management strategy, contributing to its long-term goals of maintaining service levels, reducing risks, and adapting to climate change.

The Stormwater AMP is designed to achieve several objectives. It reduces long-term costs by emphasizing proactive maintenance, lifecycle activities, and risk-based strategies. It provides financial transparency for stormwater charge payers, detailing major capital expenditures and investments. By focusing on regular maintenance, it minimizes the risk of system failures and costly retrofits while also predicting future costs through robust monitoring of past and present spending. Furthermore, the plan supports climate resilience by incorporating adaptive measures to address the growing challenges posed by flooding and extreme weather events.

Central to the AMP is a risk management framework that assesses assets based on their failure consequences and likelihood, ensuring that high-risk assets are prioritized to maximize safety, environmental protection, and financial sustainability. This framework is supported by comprehensive data from advanced assessments like CCTV inspections and bathymetry surveys, which inform the strategic lifecycle management, including routine maintenance and system upgrades necessary for accommodating population growth.

Additionally, the plan incorporates robust climate resilience measures to address the impacts of climate change on the stormwater system. It includes Low Impact Development (LID) standards such as rain gardens and vegetated swales, alongside updated modeling techniques and strategic alignments with Brampton's Climate Change Adaptation Plan and Environmental Master Plan. This ensures the infrastructure is resilient and sustainable.

Financial sustainability is crucial, with the city estimating an annual need of $24.3 million for stormwater management from 2021 to 2030. To support this, a dedicated stormwater charge, increasing annually by 2.2%, helps balance necessary funding with projected revenues, taking into account inflation and potential climate-related impacts. The AMP's commitment to continuous improvement is evident in its development of an Asset Information Improvement Roadmap aimed at enhancing data management and governance. This initiative is part of a broader effort highlighted in the 2022 State of Local Infrastructure Report, which assesses Brampton's extensive infrastructure portfolio and emphasizes the importance of integrating the AMP into the city's financial and planning processes to maintain robust, adaptable, and sustainable stormwater services.

In conclusion, Brampton's Stormwater Asset Management Plan represents a proactive and comprehensive approach to infrastructure management, balancing risk, lifecycle maintenance, climate adaptability, and financial strategies to support the city's growth and environmental goals. Through this plan, Brampton demonstrates a commitment to transparent and resilient management of its stormwater systems.

5. Conclusion

The Great Lakes Region has made significant strides in advancing GSI as a key strategy for managing stormwater, addressing climate challenges, and fostering equity. Through collaborative efforts across public, private, and nonprofit sectors, the region has developed a strong foundation for scaling up GSI implementation. However, realizing the full potential of GSI will require addressing persistent barriers, leveraging emerging opportunities, and focusing on actionable strategies that align with the priorities and challenges identified by RISC members and stakeholders.

5.1 Key Developments

Scaling up GSI in the Great Lakes Region involves integrating it as a core component of stormwater management, supported by robust funding mechanisms, strategic planning, and innovative design. Members of the RISC network have identified several key developments that demonstrate the region's progress. Funding opportunities, such as the Great Lakes Restoration Initiative (GLRI), Environmental Impact Bonds (EIBs), and the Bipartisan Infrastructure Law (BIL), have created pathways for advancing GSI projects, although access to these funds remains challenging for smaller municipalities. Programs like the National Green Infrastructure Certification Program (NGICP) and the Fusion Landscape Professional (FLP) certification program have begun addressing workforce development needs, creating pathways for skilled labor while promoting GSI as a viable career option.

Equity and environmental justice have also become central to GSI implementation in the region. Stakeholders emphasize the importance of ensuring that GSI investments address systemic inequities, particularly in marginalized and underserved communities.

Standardized data and mapping tools have emerged as critical resources for guiding equitable decision-making and prioritizing investments. Collaborative leadership, including partnerships with higher education institutions and community-based organizations (CBOs), has fostered the sharing of best practices and tools, helping to scale GSI efforts while addressing challenges in asset management and infrastructure maintenance.

Innovative design has further propelled GSI adoption, with examples like Toronto's Green Streets Initiative and Buffalo's smart sewer system demonstrating the value of combining advanced technologies with traditional GSI solutions. These efforts not only enhance system performance but also optimize resource use, reduce costs, and improve climate resilience.

5.2 Opportunities for Growth

Despite these advancements, significant opportunities remain to enhance the scalability and impact of GSI across the Great Lakes Region. Expanding access to funding is a top priority, particularly for smaller municipalities that lack the capacity to navigate complex grant applications or sustain long-term maintenance costs. RISC can play a critical role in providing technical assistance, developing model documents, and advocating for regrant programs to make funding more accessible and equitable.

Workforce development remains another pressing need. Expanding training programs, certifications, and partnerships with educational institutions can help address the regional shortage of skilled labor for GSI design, installation, and maintenance. Programs like NGICP and FLP can be scaled and integrated into community college curriculums, ensuring a steady pipeline of trained professionals while fostering economic opportunities in underserved communities.

Regional collaboration and resource sharing present additional opportunities for growth. Creating a centralized repository for data, tools, and success stories can streamline access to valuable resources and promote peer learning among RISC members. Mapping initiatives, including social, project, and risk mapping, can help identify strategic opportunities for investments, ensuring that GSI projects build on one another and maximize regional impact.

Equity and public engagement must remain at the forefront of GSI efforts. Greater public education and outreach can foster community buy-in, address misconceptions, and elevate GSI as an integral part of stormwater management. Engaging marginalized communities in planning and decision-making processes will ensure that investments address local needs and priorities while building trust and long-term support.

5.3 Future Areas of Focus for RISC Members

RISC members are uniquely positioned to lead the scaling of GSI in the Great Lakes Region by serving as a repository, educator, advocate, and connector. As a repository, RISC can compile and disseminate relevant reports, best management practices (BMPs), and templates to support municipalities in planning, implementing, and maintaining GSI systems. As an educator, RISC can offer peer-learning opportunities, webinars, and training sessions tailored to members' varying levels of familiarity with GSI.

As an advocate, RISC can address systemic barriers by identifying policy challenges and proposing actionable solutions. This includes advocating for funding mechanisms that match municipal needs, promoting equity-focused criteria for investment, and supporting the inclusion of GSI in capital and operating budgets. As a connector, RISC can facilitate

partnerships among municipalities, community-based organizations, and the private sector, fostering collaboration and resource-sharing.

Specific areas of focus should include:

- **Expanding funding access:** RISC can support smaller municipalities by offering technical assistance, developing regrant programs, and creating model funding applications.
- **Workforce development:** Partnering with community colleges and certification programs can help build a skilled labor force for GSI design, installation, and maintenance.
- **Regional resource sharing:** Expanding RISC's centralized repository and facilitating data-sharing initiatives to further promote collaboration and accelerate learning across jurisdictions.
- **Equity and engagement:** Prioritizing investments in underserved communities and fostering public participation in GSI planning and decision-making will ensure that benefits are equitably distributed.
- **Climate resilience planning:** Developing adaptive frameworks and integrating GSI into climate action plans will prepare the region to address future challenges effectively.

By focusing on these areas, RISC members can build on the strengths and opportunities identified in this report to create a scalable, sustainable, and equitable framework for GSI implementation. Through collaboration, innovation, and advocacy, the Great Lakes Region can serve as a model for resilient and inclusive stormwater management, ensuring a thriving future for its communities and ecosystems.

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