Making Detroit's Green Stormwater Infrastructure Count: A Report

Prepared by

The Nature Conservancy

August 2023

Photo: © Fauna Creative

Acknowledgements:

We would like to thank all the organizations and individuals who participated in the creation of this report in any capacity, especially the authors from the West Michigan Environmental Action Council, Grand Valley State University, American Rivers, and GEI Consultants (listed below) and contributors Susan Rusinowski from Detroit Future City, and William Shuster from Wayne State University. Your expertise, engagement, and thoughtful work were critical to the execution of this report.

In addition, this report would not have been possible without the willingness of many different people to share information for the sake of advancing research. We would like to thank all the data providers that supplied information about stormwater management projects – including engineered drawings, budgets, and stormwater calculations – as well as those who participated in interviews to share their experiences, perceptions, and insights about green stormwater infrastructure in Detroit. Together, these data points provided the foundation for this report and contribute to a broader body of work that is advancing efforts in Detroit to become a greener, more climate resilient city.

Finally, we would like to extend our gratitude to the Fred A. and Barbara M. Erb Family Foundation, who provided the financial support for this research. Thank you for standing behind this important work and for your dedication to healthy outcomes in our Great Lakes.

Authors:

- Sam Haapaniemi, The Nature Conservancy
- Patrick Doran, The Nature Conservancy
- Valerie Strassberg, The Nature Conservancy
- Elaine Isely, West Michigan Environmental Action Council
- Erik Nordman, Grand Valley State University
- Paul Isely, Grand Valley State University
- Christian Glupker, Grand Valley State University
- Shanyn Viars, American Rivers
- Scott Dierks, GEI Consultants
- Emma Giese, GEI Consultants
- Lydea Noye, GEI Consultants

Preferred Citation:

Haapaniemi S, Doran P, Strassberg V, Isely E, Nordman E, Isely P, Glupker C, Viars S, Dierks S, Giese S, Noye L. *Making Detroit's Green Stormwater Infrastructure Count: A Report.* 2023.

Contents

Figures

Tables

I. Executive Summary

Detroit faces significant challenges from unmanaged stormwater, including surface flooding and combined sewer overflows (CSOs). The increased rainfall volumes and intensity expected with climate change will only add to this risk. Therefore, stormwater management that can address increased rainfall, reduce downstream pollution, and support healthy communities will play a critical role in the future of Detroit and the surrounding region.

In this report, The Nature Conservancy in Michigan (TNC) examines 1) the ongoing needs for stormwater management in Detroit, 2) the opportunity to leverage stormwater management into broader impact, 3) the approaches and perceptions of stormwater management designers, and 4) the costs and benefits of a suite of existing stormwater management projects. Our goal was to better understand how vegetated or green stormwater infrastructure (GSI) solutions could be deployed more effectively to meet Detroit's needs around stormwater management and resilient communities. This in turn will help build climate resilience and improve downstream water quality.

Generally speaking, "green" practices are those that incorporate infiltration, evapotranspiration, and evaporation, although this definition is not rigid, and practices can have varying degrees of environmental and community benefit depending on the individual installation. These nature-based solutions can also improve air quality, reduce urban heat stress, provide recreational spaces, and foster healthier communities.

Our findings include insights into designers' perceptions of stormwater management barriers, opportunities, risks, and approaches in Detroit—especially for vegetated GSI—which we have summarized and categorized in this report. These findings provide a framework in which knowledge sharing and uptake of greener approaches to stormwater management would be most effective.

For example, we found that project designers generally held pragmatic business views—they felt that GSI must make business sense to get adopted, that project developers will target minimum requirements, and that GSI is only one of many competing priorities on a development site. They also cited concerns about the risk and difficulty of installing GSI. They believed that site conditions were prohibitive in many cases in Detroit, and that GSI often requires additional incentive.

The interviews also highlighted some areas of continued confusion. There is varying expertise among firms, some of the relevant stormwater policies get conflated, and there is still some persistent confusion around terminology. However, the interviews also identified leverage points where there is potential to make GSI easier, cheaper, and more common; these include consistency in process and permitting, designer influence in the process, and integrated landscape and civil teams.

We also heard about the bright spots that designers saw around pursuing GSI practices over traditional gray infrastructure. They believed that developers had a basic understanding of the stormwater requirements, and that designers and developers share a pragmatic approach to these projects that can be influenced by trusted information. The designers we interviewed largely recognized that there is additional value to vegetated GSI (such as scenic greenspace, urban heat reduction, and other community benefits) and had a good working relationship with the Detroit Water and Sewerage Department's (DWSD) Stormwater Management Group. They noted that drawing a better connection between stormwater management policies and the broader need for stormwater management could help with understanding among developers.

These themes—both the perceived barriers and opportunities—provide a better picture of what it will take to make GSI common practice in Detroit. To build the evidence base to test these barriers and shift or corroborate perceptions, we did an in-depth analysis of the modelled stormwater management performance and real costs and benefits of site-scale stormwater management solutions that have been installed in Detroit since the 2018 adoption of the City's [Post Construction Stormwater Management Ordinance](https://detroitmi.gov/sites/detroitmi.localhost/files/2020-12/Ordinance%20with%20Cover%20-%20Post-Construction%20Stormwater%20Management%20-%20Approved%20Revision%20November%202020.pdf).[1] Standardizing the performance and cost data allowed for accurate comparison across projects and provides new cost estimates that can be used to benchmark new stormwater projects in Detroit.

The key findings of the economic analysis were:

1. **GSI can be cost-competitive in certain instances**. The GSI projects in our sample were cost-competitive to their "gray", or traditional, counterparts in some cases. This was true when co-benefits were both included and excluded. Project costs (both initial and lifetime) varied greatly on a per-gallon basis, so we cannot say with certainty that green or gray projects are always more or less competitive. While the sample size was too small to make categorical claims about cost, this assessment can be strengthened over time and the specific instances can be examined in more detail as more projects are installed in Detroit.

2. **Standardized unit rate costs are needed to effectively compare across stormwater management practices and can inform future GSI projects**. As part of this analysis, we developed new unit rate ($/gallon/year) cost estimates. This standardized the performance (volume managed) and costs (pre-construction, construction, and operations and maintenance). These estimates can be used to benchmark future analyses and project designs.

3. **GSI provides positive additional benefits over the life of a project.** This was true for all of the private GSI projects in this analysis. As part of this analysis, we identified co-benefit values ($/gallon) for CSO reduction, avoided pollution, scenic benefit, flood risk reduction, and avoided stormwater volume. These can be used to help assess the full value of future stormwater management projects.

In conclusion, we recommend a series of actions and considerations for designers, policymakers, and funders and financers, as the use of GSI to manage Detroit's stormwater (as well as provide additional benefits) continues to expand across the city. These include:

- Considering GSI as a potential first-choice option early in the development process and considering a spectrum of best management practices
- Incorporating co-benefits into stormwater management decision-making, both for property owners and funders
- Leveraging GSI to access additional funding
- Reducing institutional barriers
- Continuing to add clarity, find common language, and reframe certain requirements
- Showcasing cost-effective future projects.

[1] Post Construction Stormwater Management Ordinance, https://detroitmi.gov/sites/detroitmi.localhost/files/2020-12/Ordinance%20with%20Cover%20-%20Post-Construction%20Stormwater%20Management%20-%20Approved%20Revision%20November%202020.pdf

II. The Need for Stormwater Infrastructure in Detroit

Detroit is a Great Lakes city and cultural center that sits between Lake St. Clair and Lake Erie on the Detroit River—a major recreational hub, a regionally significant ecosystem,[2] and one of the busiest waterways in the world. Detroit is home to over 670,000 people and many longstanding, vibrant communities. It is also a place at risk from the increased rainfall volumes and intensity expected to result from the changing climate. As such, stormwater management that can address increased rainfall, reduce downstream pollution, and support healthy communities will play a critical role in the future of Detroit and the surrounding region.

The Detroit River and one of its tributaries, the Rouge River, face significant ecological pressure from the adjacent urban environment. In 2021, the Great Lakes Water Authority (GLWA) recorded 41 CSO events, which released 5.9 billion gallons of untreated sewage into the Detroit and Rouge Rivers. That accounts for two-thirds of the untreated combined sewer overflow in the State of Michigan.[3]

Unmanaged stormwater can have harmful impacts before it ever hits the sewer system. Surface flooding is a regular occurrence across Detroit,[4] closing roads, flooding neighborhoods, and damaging homes and businesses. Residents are living with a legacy of aging infrastructure and impervious land left after decades of divestment. Impervious surface covers over 71 square miles of Detroit, or roughly 51% of its land area[5]. That is high for a city in Michigan, where all urban areas average just 31.5% impervious cover[6]. Two out of three Detroiters are impacted by urban flooding in their neighborhoods.[7] These floods come at a significant cost to property owners—in August of 2014, flooding from torrential rains resulted in $1.8 billion in direct damages.[8] This would be catastrophic anywhere, but even more so in Detroit, where the median household income is just half of what it is nationally.[9]

In compliance with their National Pollutant Discharge Elimination System Permit[10]—the localized state application of federal Clean Water Act regulations—the Detroit Water and Sewerage Department (DWSD) and GLWA have undertaken significant efforts to curtail CSOs, putting measures in place that control around 95% of the annual wet-weather volume generated in Detroit.[11]

However, TNC's analysis of the available data shows that, on average, Detroit's combined sewer system is flowing between 54%-75% full on a dry day. This leaves very limited space to carry runoff from wet weather events to the treatment plant.[12] Sanitary sewer use, inflow and infiltration resulting from leaky pipes, and backflow into the wastewater treatment plant make up that base flow, ultimately combining with stormwater runoff to trigger CSOs. Stormwater is not the only contributor

[2] https://www.sciencedirect.com/science/article/abs/pii/S0380133021001271?via%3Dihub
[3] Michigan Department of Environment, Great Lakes, and Energy 2021 CSO/SSO/RTB Annual Report, https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/CSO-SSO/2021-CSO-SSO-RTB-Annual-Report.pdf?rev=4ce3c7af7e834eeeb2d5103411e147b7
[4] Larson PS, Gronlund C, Thompson L, Sampson N, Washington R, Steis Thorsby J, Lyon N, Miller C. Recurrent Home Flooding in Detroit, MI 2012–2020: Results of a Household Survey. International Journal of Environmental Research and Public Health. 2021; 18(14):7659. https://doi.org/10.3390/ijerph18147659
[5] DWSD Post-Construction Stormwater Management Ordinance Fact Sheet, https://detroitmi.gov/sites/detroitmi.localhost/files/2020-12/PCSWMO%20Fact%20Sheet%20-%20Revised%20December%202020.pdf
[6] Nowak D, Greenfield E. Tree and impervious cover in the United States. Landscape and Urban Planning. 2012; 107, 21e30, https://doi.org/10.1016/j.landurbplan.2012.04.005.
[7] Sustainability Survey, Detroit Office of Sustainability, June 2018: https://courbanize.com/projects/sustainable-detroit/information
[8] United States Flood Loss Report—Water Year 2014, https://www.weather.gov/media/water/WY14%20Flood%20Loss%20Summary.pdf
[9] https://www.census.gov/quickfacts/fact/table/US,detroitcitymichigan/INC110220; $32,498 v. $64, 994
[10] NPDES Permit no. MI0022802, effective July 18, 2019
[11] Michigan Department of Environment, Great Lakes, and Energy 2021 CSO/SSO/RTB Annual Report, https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/CSO-SSO/2021-CSO-SSO-RTB-Annual-Report.pdf?rev=4ce3c7af7e834eeeb2d5103411e147b7
[12] Appendix A: Memorandum: Stormwater Contribution to CSO Overflows: To what degree can stormwater management reduce CSOs in Detroit?

to the combined system, but it is the most variable, making stormwater management a critical component of controlling CSOs.

While the dry weather flows in the sewer system do not fluctuate as widely or as frequently as wet weather flows, they are not static either, and these baseline pressures on the combined system will continue to grow. Detroit's population is expected to increase by 55,000 people between 2020 and 2045,[13] increasing demand on the sanitary system (more flushing toilets, draining sinks, showers, etc.). As infrastructure continues to age and deteriorate, reducing inflow and infiltration into the sewer system, or even maintaining the same rate of infill and infiltration, will continue to require maintenance and management.

There will also be increased need from the stormwater side. As the climate changes, extreme precipitation is expected to increase in the Great Lakes region, increasing the overall volume and peak flows of water that need to be managed.[14] Additionally, with Detroit's vacant land being redeveloped, more impervious area will be created, meaning less water is infiltrated or slowed, and more is running directly into the combined sewer.

With all these pressures combined, stormwater management—especially dispersed stormwater management that helps support healthy communities—will continue to be critical in Detroit for managing CSOs, improving downstream water quality, and reducing localized surface flooding.

III. The Opportunity to Leverage Stormwater Management

THE CONTEXT

A New Policy Landscape

Detroit has a set of existing policies to incentivize and regulate decentralized stormwater management.

1. **The drainage charge** (implemented 1975 and originally embedded in water bill, updated 2018 to align with impervious surface and appear as a standalone charge) assesses a stormwater fee to property owners commensurate with the impervious surface on their properties. This provides a mechanism for ensuring stormwater management costs are distributed amongst properties in proportion to their use of those services.[15]

2. **The Green Credit** (implemented October 2016) incentivizes property owners to install stormwater management to control their wet-weather runoff and reduce their dependence on the combined sewer system, by reducing their drainage charge accordingly.[16] This is applied through two forms of credit, volume credit (retention) and peak flow credit (detention), each of which can reduce a sewer bill by up to 40% for a maximum cumulative 80% reduction.

3. **The Post Construction Stormwater Management Ordinance (PCSWMO)** (implemented November 2018, updated November 2020) requires development with an area

[13] SEMCOG Population Estimates, https://semcog.org/population-estimates
[14] GLISA Extreme Precipitation, https://glisa.umich.edu/resources-tools/climate-impacts/extreme-precipitation/
[15] DWSD Drainage Charge, https://detroitmi.gov/departments/water-and-sewerage-department/dwsd-customer-service/drainage-charge
[16] DWSD Drainage Charge, https://detroitmi.gov/departments/water-and-sewerage-department/dwsd-customer-service/drainage-charge

> more than 0.5 acres (both new and re-development) to manage stormwater onsite. This ensures that overall stormwater runoff volumes are kept in check as new impervious surface is created.[17] Specific management requirements are determined by project size, but generally all projects in the combined sewer area must retain and detain stormwater on site to keep some of it out of the system completely and slow the flow of the rest.[18] Developers retain flexibility in exactly how they choose to manage that stormwater. DWSD allows for alternative compliance through a set of approved options including offsite compliance, fee-in lieu, and extended detention, but only in cases where these conditions cannot be met due to site constraints.[19]

The Green Credit is voluntary—whether property owners pursue it depends on whether they believe it provides enough return on the investment of installing stormwater management to be worthwhile. However, for property owners looking to build on or redevelop land at a scale large enough to trigger the PCSWMO, installing stormwater management is mandatory.

This shifts the question from "is it worth it for me to manage stormwater," to "what's the best way to manage my stormwater?" Developers are now looking for the most cost-effective means of meeting their regulatory stormwater management requirements. This means that the PCSWMO introduced a particularly strong leverage point for supporting sustainable development in Detroit: the case for incorporating nature-based GSI practices in a development only needs to be made against other traditional stormwater management strategies, not as a standalone return on investment.

This new framework provides an opportunity to help developers and their designers consider implementing GSI as a viable stormwater management approach. Within this framework, the right tools and information could encourage more projects to meet multiple community priorities—sustainability, climate resilience, improved community spaces, and more.

Open Space & Public Ownership

Detroit has a great deal of vacant land, with estimates ranging from 24 to 40 square miles.[20] Much of this vacant land is publicly owned. As of March 2023, the Detroit Land Bank held nearly ~72,600 residential parcels,[21] the Detroit Building Authority was actively marketing 51 commercial properties,[22] and additional properties were held by the Detroit Economic Growth Corporation (DEGC) and the City.[23]

Unlike other cities that are dealing with similar stormwater management challenges but lack available land, Detroit can address stormwater management challenges as these large vacant areas are designed and redeveloped. This provides an opportunity to incorporate stormwater management

[17] Post Construction Stormwater Management Ordinance, https://detroitmi.gov/sites/detroitmi.localhost/files/2020-12/Ordinance%20with%20Cover%20-%20Post-Construction%20Stormwater%20Management%20-%20Approved%20Revision%20November%202020.pdf
[18] See DWSD's PCSWMO Design Manual, Chapter 2, Regulatory Requirements for full details.
[19] The options for alternative compliance under the PCSWMO include: 1) Onsite mitigation, 2) Offsite mitigation, and 3) Fee In-Lieu. Onsite mitigation refers to extended detention. Offsite mitigation refers to building a practice on another site. Fee-In-Lieu refers to a one-time fee to the city.
[20] Social media is arguing about how much vacant land is in Detroit — and the number matters, https://www.freep.com/story/money/business/john-gallagher/2019/10/26/detroit-vacant-land/4056467002/
[21] DLBA Owned Properties, https://data.detroitmi.gov/datasets/detroitmi::dlba-owned-properties-1/explore?location=42.357375%2C-83.036875%2C16.40; Accessed 11/14/2022
[22] DBA Marketed Properties, https://summitcommercialllc.catylist.com/jsp/search/results.jsp?override=true&search2=true&propertyType=&subtype=&groupSuites=1#p=1,50|s=CITY,0|m=11,42.39296044819909,-83.1134615|c=search2:true;propertyType::subtype::groupSuites:1;|ac=StreetAddress,Keyword,Location:[],PropertyType,UseType,SalePrice,LeasePrice,Size,SaleLease|gs=1|h=|tl=Page%201|hid=2|; Accessed March 30, 2023.
[23] City Owned Properties, https://detroitmi.gov/government/mayors-office/properties/buy-publicly-owned-property

from the start of a site's design and construction process, and to ensure land is used in ways that not only serve developers but also meet the needs of the community.

A Moment in Time

The PCSWMO is a relatively new policy. It was adopted in November 2018 and updated in November 2020. The COVID-19 pandemic significantly delayed the pace of construction beginning in March of 2020, so there have been relatively few PCSWMO compliance projects (an estimated 12 as of December 2021) that have completed construction. But there are enough to learn from, and many more are in the design and construction pipeline (at least 49 more as of December 2021).

This is an ideal time to investigate the successes and challenges of these recent stormwater management projects in Detroit. Understanding the current views of the stormwater design community and the costs and benefits of existing projects will provide timely insight into how nature-based, vegetated GSI solutions could be deployed more effectively to meet the stormwater management needs in Detroit while also having a positive impact on the community.

OUR APPROACH

Given the need and opportunity around stormwater management in Detroit, The Nature Conservancy (TNC) set out to analyze a set of existing stormwater management projects. **Our hypothesis was that nature-based solutions were not being considered as often as they could or should be, due to perceptions that they are more expensive to design and construct and that they are harder to implement and manage over time.**

To test our hypothesis, we took a two-pronged approach. Specifically, we examined 1) the approaches and perceptions of stormwater management designers through a series of interviews with practitioners, and 2) the costs and benefits of a suite of existing stormwater management projects—both conventional gray infrastructure projects and projects that incorporated green, nature-based interventions—through an economic analysis.

IV. Stormwater Designer Perceptions

TNC conducted a series of conversations with stormwater practitioners, including architects, civil engineers, and landscape architects, that have incorporated stormwater management practices into development projects in Detroit.

Through these conversations with the design community, we aimed to better understand:

- Perceived and/or real barriers to GSI
- Current understanding of GSI
- Perceptions and understanding of Detroit's stormwater management policies and processes
- The types of stormwater management projects that are being designed and installed
- Trends in demand that designers see coming from developers

METHODS

Project Identification: Using a March 2021 list of PCSWMO compliance projects provided by DWSD, the stormwater management project inventory from the Detroit Stormwater Hub, and information gleaned from a series of informal conversations, we identified 93 relevant stormwater management projects. These 93 projects included those that were required to comply with the PCSWMO and those that were not, but that managed a roughly equivalent volume. They included both public and private sites, and they represented a variety of replicable practice types (e.g., bioretention, surface detention, and underground detention).

Designer Identification and Outreach: Using this project list, we looked through designer websites, news articles, and public records to identify over 50 associated design firms. We then narrowed down to firms who regularly worked locally and had multiple projects. This new list included firms with both green-leaning and gray-leaning portfolios. We then reached out to these companies to have conversations about their stormwater management experience and perspective.

Interviews: In total, we held conversations with 21 individuals across 11 different firms. These ranged from 45-60+ minutes. Some meetings were with a single individual, while some had multiple representatives from a single organization.

While all the interviewees were familiar with stormwater projects in Detroit, their experience with GSI varied and their portfolios included a very wide range of typologies including transit centers, housing, daycares, sports facilities, office buildings, campuses, industrial facilities, churches, parking garages, museums, apartments, and parks. Experience included public and private projects, but favored the private sector.

Compilation of Results: We distilled what we heard in these conversations into crosscutting themes, ultimately providing a set of insights about the true and perceived barriers to implementing GSI. These findings have been summarized as they pertain to Detroit, but many may also be applicable more broadly.

INSIGHTS

The following insights summarize perceived challenges expressed by the designers, as well as some of our observations about how those challenges could be addressed or further researched. At this stage of our research, we were listening to understand—whether these perceptions bear out in reality was not the focus of these conversations. Importantly, the perception that a barrier exists (even when it doesn't) can affect behavior just as much as an actual barrier.

Cost

Perception #1: GSI must make business sense

Designers believe that cost is the primary decision driver for developers when looking at stormwater management, with a minority seeking to achieve a competitive advantage through sustainability efforts or meet a social/moral obligation by using GSI. As a result, designers are inclined to be pragmatic and will only recommend GSI when they believe it makes financial sense.

The likeliness of this happening is decreased further by the perception that GSI requires more interaction and iterative feedback. Anything that adds time, adds cost—and the perception that design feedback from DWSD can add months of delay and tens of thousands of dollars in additional design and testing costs.

Our observations: Designers could benefit from tools and guidance that demonstrate cost-effectiveness and make the case for GSI to their clients. Streamlining GSI review and communicating this new process to developers would help encourage GSI.

Perception #2: Developers will target the minimum requirement

Designers generally believe that developers seek to either 1) avoid triggering the PCSWMO by implementing projects just under the threshold, or 2) comply for as little cost as possible. They can be agnostic about the practice type, or willing to pay DWSD's fee-in-lieu as an alternate compliance option, if it meets the requirements.

Our observations: This may be why offsite compliance, which adds complications through site identification and/or acquisition, and potential administrative burdens, is not more readily adopted as an alternate compliance option, while extended detention and fee-in-lieu seem to be more common when onsite stormwater retention cannot be attained.

Perception #3: GSI carries additional risk

Designers had heard concerns from developers about GSI carrying more risk than subsurface detention. These perceived risks are both intangible (e.g., uncertainty about permitting, performance, and long-term maintenance associated with early adoption) and direct (e.g., liability of having open water). They often rely on their designers to make the case that the risks of GSI are mitigated, shown to be minimal, or come with a significant value trade-off.

There is also a risk that the owner will not see a return on their investment—especially voluntary stormwater projects that are just for drainage charge credit, where owners are not seeing additional development value. Inconsistency in permitting and approval means unpredictable costs, and inconsistent application of the credit means inconsistent returns. In some cases, designers said they have submitted a project for credit and never heard back or had to change designs at a stage that added significant cost.

Our observations: While there are tangible risks that need to be mitigated (i.e., open water liability), the perceived risks around administrative difficulties and long-term maintenance and performance can likely be reduced or overcome through more visibility into successful projects, both locally and regionally. As DWSD continues to streamline processes and improve communication, perceived uncertainty around receiving credit should continue to decrease.

Perception #4: GSI projects generally require additional incentive

Most examples of GSI that our interviewees were familiar with had been implemented because of an additional incentive. Those incentives ranged from direct monetary assistance to alignment with a social mission. Examples include:

- Access to additional funding (e.g., GSI helped unlock public funds like housing or transportation funding, projects had pro bono support to put in GSI, projects had grants to put in GSI, etc.)
- Drainage charge credit (this was often cited as a conversation starter for GSI, but does not drive implementation on its own—credits will not usually cover costs)

- Moral imperative (organizations felt it was necessary to manage stormwater, or they wanted to improve their neighborhoods, or they had a corporate culture of sustainability).

Our observations: It would be valuable to continue to implement and highlight projects where GSI did not have additional funding incentives.

Perception #5: Consistency saves money

Open-ended policies, while seemingly leaving room for innovation, were also seen to introduce more bureaucratic review barriers and lead to delays and difficulties in permitting and approval. When designers run into scenarios where no guidance exists (i.e., GSI options beyond the examples provided in DWSD's Stormwater Management Design Manual) they feel that the challenges can be greater.

Our observations: DWSD provides design guidance for implementing effective and accepted GSI practices through its Stormwater Management Design Manual[24]. However, more templatized options and guidance could help designers save time without closing the door on innovation. This would reduce the need for each individual firm to overcome the learning curve on common, but not yet standardized scenarios.

Site

Perception #6: Detroit has difficult site conditions

There is a prevailing belief that site conditions make GSI difficult or impossible in Detroit—tight soils, high contamination, and limited site sizes are cited regularly as reasons that GSI does not make sense to install.

The cost-effectiveness of any individual stormwater management project depends on these site conditions, which makes it highly variable. Because of this, designers believe that there are a narrow set of conditions in which GSI is an appropriate and cost-effective solution. This cost variability paired with a lack of definitive information means that designers have differing opinions on whether GSI is generally a cost-effective option in Detroit.

Our observations: Clearer cases of cost-competitive GSI solutions could help to dispel the idea that GSI is rarely or never cost-effective.

Perception #7: Stormwater is just one competing priority for useable space

Decisions about site design must consider a variety of competing priorities, and stormwater management is just one of them. For example, Detroit has significant parking requirements for certain development typologies, which makes it difficult to find space to manage stormwater on the surface, driving practices underground. In many cases, developers want to use every inch of the site for a building, leaving no room for surface-level stormwater.

Our observations: There are likely a set of development typologies where the site is large enough and the other priorities don't outweigh the need for surface-level stormwater management.

[24] DWSD Stormwater Management Design Manual. https://detroitmi.gov/sites/detroitmi.localhost/files/2021-01/PCSWMO%20Design%20Manual%20December%202020%20-%20Compressed.pdf

Identifying those typologies could facilitate recognition of surface-level GSI as a viable option for stormwater management.

Process

Perception #8: Bureaucracy in Detroit is more challenging than in other cities

Designers shared that particularly onerous requirements and other barriers (e.g., lots of infiltration testing, high freeboard requirements, lack of recognition that phytoremediation can address contaminants, etc.) make it more difficult to implement GSI in Detroit compared to neighboring areas. They also mentioned that the plumbing code, when applied to GSI, had historically been a barrier to innovative stormwater design as it was designed for something else. These perceptions, whether true or not, may be keeping designers from recommending GSI.

Our observations: Any changes to these processes (such as the increased involvement of the Stormwater Management Group in interpreting plumbing codes for better applicability to GSI), corrections to misperceptions (such as Detroit's freeboard requirements matching surrounding municipalities), or clarifications of intention (such as why this level of infiltration testing is required) should be broadly communicated.

Perception #9: Designers can influence developers

Developers are generally understood to be seeking to either 1) avoid triggering the PCSWMO by implementing projects just under the threshold, or 2) asking their designers to comply for as little cost as possible. They trust their technical teams—architects, civil engineers, and landscape architects—to tell them how to do that.

Our observations: If these technical teams can effectively make the business case for GSI to their clients, it is likely to be adopted.

Perception #10: The course for stormwater management is set early in the design process

The decision of what stormwater management practices to use is heavily influenced by the site design and is often made before any interaction with the City. Project teams generally meet with DWSD after an initial plan for the practice type is already set and it is rarely changed after this point, especially if other permits are in progress already.

Our observations: Since the site design determines what land remains available for stormwater management, the earlier in the process that GSI is considered, the more likely it is to be integrated. Under the current process, designers need to be considering GSI prior to DWSD's influence for it to become a standard approach. As the process exists now, DWSD alone is not likely to influence designers and developers to implement GSI over other practice types.

Capacity & Understanding

Perception #11: Policy confusion persists

Several interviewees conflated the drainage charge, Green Credit, and PCSWMO. Without understanding the full implications of the different policies, designers may not always be providing their clients with optimal alternatives or fully taking advantage of incentives (e.g., they could be complying with the ordinance, but not applying for credit). Even when they do understand the differences, they see risk in building with the intention of getting the Green Credit due to a lack of certainty that the project will actually receive the credit.

Moreover, property owners do not always understand that PCSWMO compliance does not necessarily correspond with full Green Credit. Green Credit scales up with increased retention and detention, so some compliance options (such as extended detention) may lead to a project that is fully in compliance with the PCSWMO receiving a relatively small Green Credit.

In addition, the terminology used by firms did not always align with DWSD's usage (e.g., referring to the drainage charge as a "stormwater tax" instead of a "charge" or "fee"). This could add to frustration with the policies and undermine efforts to communicate about them.

Our observations: As trust and clarity is built over time, potentially through education and advocacy efforts, these confusions and frustrations are likely to decrease. In the absence of policy changes to address the differences between the ordinance and green credit, clarity around the terminology would aid in broader understanding.

Perception #12: "Green stormwater infrastructure" does not have a clear definition

There are a lot of different interpretations of what constitutes GSI. The designers we interviewed tended to see GSI on a spectrum rather than adhering to a firm definition—practices can be more or less "green." Many of their interpretations focused on outcomes (e.g., infiltration, heat reduction, and community benefits) while others were based on aesthetics (e.g., attractive vegetation and ponds).

Our observations: In the Stormwater Management Design Manual, DWSD defines GSI as "Stormwater Control Measures that divert runoff of rain and snowmelt from the sewer system while providing environmental, social, and economic benefits. GSI practices helps control the rate, volume and quality of drainage from impervious surfaces and help to maintain and restore natural hydrology by infiltrating, evapotranspiring, capturing, or using stormwater."[25]

The Detroit Stormwater Hub defines GSI as something that: "replicates natural systems to reduce runoff volume, filter pollutants, and cut down on flooding by slowing the movement of water into the combined sewer system and may channel it into the ground."[26]

Both of these definitions could be inclusive of subsurface practices that do not provide the human and biodiversity benefits associated with vegetated GSI. In other words, 'green' does not necessarily refer to vegetation in these definitions, as only a portion of the defined GSI practice types involve plants. Therefore, without a clear and common definition, there is potential for greenwashing. A clear definition of GSI that includes vegetation would not only help clarify what GSI is, but also help designers, the City, and third parties focus on the practices that convey the greatest benefits.

Perception #13: Integrated teams reduce barriers

The more integrated the civil engineering team and landscape architects are on a project, the more opportunity there is to install GSI. Working together helps avoid scenarios where the best

---

[25] DWSD Stormwater Management Design Manual, 1-4. https://detroitmi.gov/sites/detroitmi.localhost/files/2021-01/PCSWMO%20Design%20Manual%20December%202020%20-%20Compressed.pdf

[26] Detroit Stormwater Hub, https://detroitstormwater.org/faqs

stormwater management opportunities on a site are used for other things (e.g., the building is on the best soils for infiltration) and ensures that the landscaping is being thought of as part of the stormwater management instead of a primarily aesthetic layer that goes on afterward.

When the civil engineering teams alone design the stormwater management, they tend to rely on a handful of tried-and-true conventional solutions (detention ponds and underground storage) that do not carry the additional benefits of nature-based practices (scenic amenities, access to greenspace, biodiversity benefits, etc.)

Our observations: Facilitating conversations and knowledge-sharing across design specialties could help support earlier and more comprehensive consideration of GSI practices.

BRIGHT SPOTS & OPPORTUNITIES

Skills and capacity vary greatly across design firms. Some specialize in one aspect of project design and management and subcontract other tasks, while some offer start-to-finish services. This means it is unlikely that there will be a one-size-fits-all strategy for encouraging the more widespread uptake of GSI practices among designers.

However, we noted several trends among the project designers we interviewed that could support an increased use of GSI.

- **Developers understand that there are requirements:** Developers are aware of the PCSWMO and generally understand stormwater management is something they need to do, even if it's challenging. In some cases, they understand the broader responsibility of stormwater management to benefit the community and region.

- **Designers are pragmatic:** If they have information showing when and where GSI is the best option, they generally want to see that and incorporate it into their practice.

- **Designers see the additional value of GSI:** Designers mostly understand that GSI, especially vegetated GSI, has additional value beyond traditional solutions, although they sometimes struggle to make it work.

- **Designers have good rapport with DWSD's Stormwater Management Group (SMG)**: While any bureaucracy and review can be viewed as a burden, the designers generally felt that SMG was helpful to work with. They also noted that the team had made significant improvements over time.

- **Designers are hungry for information:** Designers are looking for information that shows cost comparisons, lifecycle costs, and return on investment of real projects—especially on more difficult sites. They want to be able to make the case for their clients as clearly and defensibly as possible.

- **There remains room to tell the broader story:** There was some desire for more information to help tell the story of how a single project supports the regional needs (e.g., CSOs). DWSD's efforts on this front were seen as helpful.

V. Costs and Benefits of Existing Stormwater Projects

GSI practices can be an effective component of addressing urban stormwater challenges such as surface flooding, CSOs, and poor water quality. Generally speaking, "green" practices are those that incorporate infiltration, evapotranspiration, and evaporation, although this definition is not rigid, and practices can have varying degrees of environmental and community benefit depending on the individual installation. These nature-based solutions can also improve air quality, reduce urban heat stress, provide recreational spaces, and foster healthier communities.

However, as we identified through the practitioner interviews outlined above, perceived barriers on the cost and complexity of implementing GSI leave some designers reluctant to recommend these sustainable solutions, and property owners reluctant to adopt them.

To test these assumptions, we explored the lifetime cost and benefits of implementing GSI solutions for non-residential properties in Detroit. Using data from a set of 14 existing projects, we modeled the stormwater management performance, standardized the cost estimations for different phases of construction and maintenance, monetized the public benefits, and estimated the economic impact.

This analysis aimed to answer the following questions:

1. How does the cost-effectiveness of existing GSI practices in Detroit compare to technically similar traditional site-scale infrastructure practices?

2. What conditions impact the cost-effectiveness of a given best management practice (BMP) most significantly? How sensitive is that cost-effectiveness to variation in those conditions?

3. How does that return on investment (ROI) change when including the value of triple-bottom-line benefits?

METHODS

Project Identification & Data Collection

This analysis focused on projects that could be broadly replicable and would have a significant stormwater management impact. Data collection took place through a four-step process:

1. **Creating a comprehensive stormwater management list.** Using data from the Detroit Stormwater Hub, a list of PCSWMO projects shared by DWSD, and others that we heard about through partner organizations, desktop research, media mentions, and word-of-mouth, we assembled a database of 331 stormwater projects in Detroit. These included projects that were complete as well as projects that were in progress.

2. **Setting inclusion criteria**. We narrowed down the full list into a set of relevant projects that:

    - *Were PCSWMO compliance projects or managed a similar volume of water* and could provide relevant examples for future PCSWMO projects. We set a rough minimum threshold of 0.28 MG of water managed annually. This was a conservatively estimated volumetric equivalent of the PCSWMO's 0.5-acre size threshold. In other words, it is the minimum volume that a project triggering the ordinance would be required to manage.

    - *Included BMPs that were broadly replicable across the city on many different sites*: Bioretention/bioswale, stormwater/constructed wetlands, surface detention (e.g., detention ponds), subsurface detention (e.g., doghouses), permeable pavement, and subsurface infiltration. Practices that relied on specific limited geographies, like direct discharge projects that require sites along the river, were excluded because of their limited applicability to future development.

    - *Were complete* to ensure we could get accurate cost and design data.

Project Identification Process

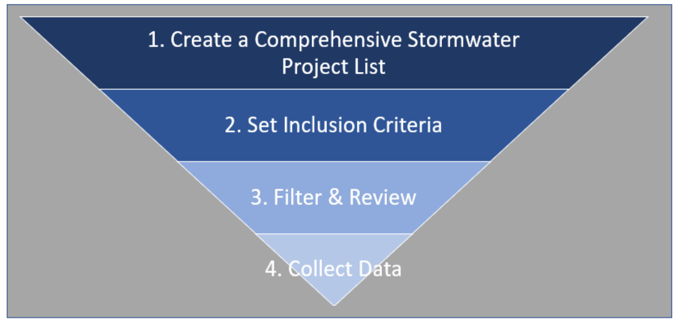


Figure 1: Project Identification Process

3. **Filtering the list and reviewing the remaining projects.** We conducted desktop research and drive-by site visits to fill any information gaps, primarily checking practice types and confirming projects were complete. Using our criteria and removing major outliers, we filtered the project list down to 31 relevant projects.

4. **Detailed data collection.** Permitted construction drawings and detailed budgets were required for each of the projects included in this analysis. These were provided by project owners and designers through an extensive outreach effort. In total, **14 projects provided the necessary data for the analysis**: 9 public and 5 private projects[27]. These included 8 bioretention, 2 bioretention/rain gardens, 1 permeable pavement, 1 stormwater wetland, 1 surface detention, and 1 subsurface detention project (Table 1).

[27] One of the projects was built on public land but installed by a private group with some intention of receiving green credit. Since the public projects were designed to manage road runoff, which would not achieve credit, that project has been classified as "private" for the purposes of this analysis.

Table 1: Estimated Project Costs for Pre-Construction, Construction, and Annual O&M Activities (2020 prices)

Project	Type	Vol. Managed (Gallons/year)		Pre-Construction Cost	Construction Cost	Annual O&M Cost
Project 1	Stormwater Wetland	8,500,000	*Overall*	$358,058	$961,911	$15,000
Private	*Highly Green*		*Per gallon*	$0.042	$0.113	$0.002
Project 2	Bioretention/Rain Garden	274,000	*Overall*	$2,510	$25,858	$336
Private	*Highly Green*		*Per gallon*	$0.009	$0.094	$0.001
Project 3	Bioretention	2,530,000	*Overall*	$54,657	$538,334	$10,528
Public	*Highly Green*		*Per gallon*	$0.022	$0.213	$0.004
Project 4	Bioretention	361,000	*Overall*	$9,549	$92,367	$1,408
Public	*Highly Green*		*Per gallon*	$0.026	$0.256	$0.004
Project 5	Bioretention	2,000,000	*Overall*	$42,396	$622,608	$10,410
Public	*Highly Green*		*Per gallon*	$0.021	$0.311	$0.005
Project 6	Bioretention	276,000	*Overall*	$9,864	$95,528	$1,467
Public	*Highly Green*		*Per gallon*	$0.036	$0.346	$0.005
Project 7	Bioretention	1,102,000	*Overall*	$43,632	$449,407	$8,331
Public	*Highly Green*		*Per gallon*	$0.040	$0.408	$0.008
Project 8	Bioretention/Rain Garden	1,050,000	*Overall*	$72,173	$743,382	$5,378
Private	*Highly Green*		*Per gallon*	$0.069	$0.708	$0.005
Project 9	Bioretention	2,100,000	*Overall*	$132,558	$1,519,909	$3,636
Public	*Highly Green*		*Per gallon*	$0.063	$0.724	$0.002
Project 10	Bioretention	430,000	*Overall*	$40,439	$470,727	$8,996
Public	*Highly Green*		*Per gallon*	$0.094	$1.095	$0.021
Project 11	Bioretention	157,000	*Overall*	$23,499	$209,413	$4,721
Public	*Highly Green*		*Per gallon*	$0.150	$1.334	$0.030
Project 12	Detention Basin	5,133,000	*Overall*	$6,129	$247,293	$7,136
Private	*Medium Green*		*Per gallon*	$0.001	$0.048	$0.001
Project 13	Permeable Pavement	481,000	*Overall*	$39,141	$656,807	$11,742
Public	*No Green*		*Per gallon*	$0.081	$1.366	$0.024
Project 14	Subsurface Detention	610,000	*Overall*	$21,897	$191,379	$4,096
Private	*No Green*		*Per gallon*	$0.036	$0.314	$0.007

Performance Standardization

To provide an "apples to apples" hydrologic comparison between the projects in this analysis, their performance needed to be modeled with an explicit, generally accepted method. Using the construction plans and stormwater calculations gathered in the data collection phase of the study, GEI Consultants performed hydrologic performance evaluations using the U.S. Environmental Protection Agency Storm Water Management Model (SWMM, v.5)[28]. The modeled results were compared to the performance evaluations and credit calculations provided in the original dataset. Monitoring of these sites would have provided a more accurate picture of performance, allowing for measurement of change over time, especially in planted systems where maturing root structures have the potential to change infiltration rates. However, this data was not available for the relatively new projects that were within the scope of this analysis, and practices were modelled as a means of comparison.

In some cases, the design data and/or the designer's calculations and their reported results were incomplete or did not contain backup calculations. In these instances, GEI estimated values from the information provided.

Runoff and hydraulic sub-routines in SWMM were used to simulate performance for all sites for discrete storm events impacting those sites (design storm events) and using precipitation and evapotranspiration data for one representative year (annual). All design and watershed inputs were identical for the design storm events and one-year continuous simulations, except for the rainfall, evapotranspiration, and date ranges. The continuous models ran for one year with hourly rainfall data from 2015 (33.3-inch annual total rainfall) and monthly average evapotranspiration data for Detroit (Table 1)[29]. The event models were used to simulate the design storm events specified in the original data, and to simulate the 100-year event for the crediting calculations.

The event models ran for 96 hours, with the total storm event distributed over the first 24 hours using an NRCS Type II distribution and with evapotranspiration assumed to be zero during the storm event. Drainage areas and percent impervious areas came from designer calculations and drawings, where available. Watershed infiltration was modeled using the Green-Ampt method. Infiltration rates were based on geotechnical reports or designer calculations, where available.

To help create a direct methodology for evaluating each project by BMP, GEI aimed to simplify each site model as much as possible. As part of that simplification process, they did not combine the low-impact development (LID), another term for GSI, subroutine in SWMM with explicit representation of hydraulics. Bioretention basins, rain gardens, and bioswale BMPs were all modeled as storage units with

Table 2: Average Daily Evapotranspiration SWMM Input for Detroit

Month	Average Monthly ET (in/day)	Total Monthly ET (in)
Jan	0.03	0.84
Feb	0.03	0.96
Mar	0.06	1.88
Apr	0.11	3.31
May	0.16	4.96
Jun	0.20	5.86
Jul	0.20	6.26
Aug	0.17	5.17
Sep	0.12	3.54
Oct	0.08	2.44
Nov	0.05	1.37
Dec	0.03	0.84
Total		37.43

[28] Technical Memorandum: Hydrologic Performance Evaluation of Detroit Green Stormwater Infrastructure, GEI Consultants, Dierks S, Giese E, Noye L, 2022
[29] From SWMM data, provided by GEI Consultants

seepage losses equivalent to the native soils present on the site. Underdrain features were represented as outlet orifices of the storage unit. Permeable paver BMPs were also modeled as storage units with appropriate volume adjustments using the porosity or void ratio of the stone as specified in the plan sets or details provided. Where plan sets specified a riser pipe or elevated overflow control, an additional node was used to represent the overflow structure for that storage unit. Storage curves for all BMPs were either from designer calculations, if available, or were measured from elevation contours on design drawings. Project 14 (subsurface detention) was the only site not modeled as a storage unit. Instead, the underground storage pipe was modeled as a conduit to more accurately represent the dynamic volume stored. Because the storage was a solid pipe, no exfiltration into the underlying soil was simulated.

Where sites had multiple BMPs that did not route to one another, each BMP was modeled using a separate drainage area (or "sub-basin") and storage unit. For example, Project 12 (detention basin) was modeled as "East" and "West" due to the drainage area being delineated as such on the plan set and the bioretention basins for the east and west regions being separate from one another. The multiple BMPs at Project 2, Project 10, and Project 5 (all bioretention) were each also modeled separately.

The Project 9 (bioretention) bioswales are connected either by underdrains or storm sewers but were modeled as one drainage area and as one storage unit. The two Project 7 (bioretention) bioswales were also modeled as one drainage area and one storage unit. While this simplification would lose some detail related to how each section of bioswale might perform individually, we felt it was appropriate to simulate the aggregate behavior for this level of analysis.

The Project 8 (bioretention) infiltration through the bioretention soil was simplified and represented as a direct input to the underground storage, which is consistent with the designer's calculation methods. On the other hand, the underdrain, simulated as an orifice, throttles outlet flows and allows for ponding to occur, so some of the time-delay behavior of seepage through the engineered soil is captured in this kind of model. Also, as a part of the simplification process, individual catch basins and pipes or underdrain routing site runoff to the BMP were not modeled. Runoff from the drainage area was specified to flow directly to the storage unit representing the BMP. Storm sewer infrastructure beyond the first node beyond the outlet of the BMP was also not modeled and it was assumed there was no backwater effect from the downstream storm or combined sewer.

For each of the modeled projects, this modelling provided:

- Volume detained (design storm event and annual)
- Volume retained (design storm event and annual)
- Volume credit estimate
- Peak flow credit estimate

Cost Estimation

To understand the cost-effectiveness of each BMP, a cost estimation was made using only those costs and benefits that would directly apply to the owner or developer of the project.

The cost analysis below is based on actual project estimates retrieved from local construction costs during the project year. The method is built upon 10 years of analyses initiated by Grand Valley State

University's (GVSU)[30][31]. The most recent study, titled *Benefit-Cost Analysis of Stormwater Green Infrastructure Practices for Grand Rapids, Michigan, USA,*[32] was adapted to a locally relevant context in a report led by the West Michigan Environmental Action Council (WMEAC) and produced for TNC, *Modeling the Business Case for Green Stormwater Infrastructure in Detroit, Michigan*[33]. The findings of that report were then further modified by TNC to answer the questions of this analysis. To compare projects across case studies, the Consumer Price Index from the Bureau of Labor Statistics was used to adjust for inflation and reflect all costs in 2020 dollars. [34] Capital cost estimations are based on data provided by participants and include products, services, and labor associated with pre-construction and construction activities. Reported pre-construction costs include design and engineering, testing, surveying, and insurance. Reported construction cost estimations include activities related to mobilization, excavation, utilities, fencing, landscaping, and site cleanup. Common with commercial construction projects, a 3% contingency is applied to the overall project cost to account for unforeseen construction costs. Annual operations and maintenance (O&M) costs are assumed to be 3% of project construction cost, unless otherwise provided.[35] Costs that were not associated with the stormwater management practices (i.e. recreational amenities) were excluded.

Drainage charges are based on the site's impervious area (pre-construction). Reductions in drainage charges can be achieved by reducing impervious surfaces and/or implementing GSI for Green Credit against the drainage charge.[36] For this analysis, the drainage charge reduction is estimated from the reduction of the base charge through removal of impervious areas post-construction, along with estimated Green Credits applied for peak flow and volume reduction practices. When the estimated drainage credits were modeled, in some cases, these models showed an outflow rate greater than what was allowable for the Green Credit. Since we knew that some practices were still receiving credits, they were estimated as a range for this analysis, with the higher bound not including that enforcement and the lower bound including it. To compare projects that were implemented over different time periods and estimated project cost spread across multiple years, all cost estimates were adjusted to reflect present values (Figure 2). The present value cost (PVC) reflects the "real" cost of the project and includes capital cost, lifetime O&M cost, and where applicable, opportunity cost of land estimated over 50 years. A 50-year infrastructure planning horizon was replicated based on GVSU's analysis for the City of Grand Rapids. To compare the net impacts on project cost over time, a 3.5% real discount rate was used for all present value calculations. This rate is appropriate for environmental projects with a lifespan of 30-75 years.[37] A cost of capital (5%) is included in

Figure 2: Formula Used for Calculation of Present Value Cost

$$PVC = \sum_{i=0}^{n} \left(\frac{Capital\ Cost_i}{(1+r)^i} + \frac{O\&M\ Cost_i}{(1+r)^i} + \frac{Opportunity\ Cost_i}{(1+r)^i} \right)$$

[30] Isely, E.S., P. Isely, S. Seedang, K. Mulder, K. Thompson, and A.D. Steinman (2010).Addressing the information gaps associated with valuing green infrastructure in West Michigan: INtegrated Valuation of Ecosystem Services Tool (INVEST). Journal of Great Lakes Research 36(3): 448-457.
[31] Isely, P., E.S. Isely, C. Hause, and A.D. Steinman (2018). A socioeconomic analysis of habitat restoration in the Muskegon Lake area of concern. Journal of Great Lakes Research 44(2): 330-339.
[32] Benefit-cost analysis of stormwater green infrastructure practices for Grand Rapids, Michigan, USA, Nordman, Isely, Isely, & Denning (2018) www.elsevier.com/ locate/jclepro
[33] Modeling the Business Case for Green Stormwater Infrastructure in Detroit, Michigan, Isely E, Viars S, Nordman E, Glupker C, Isely P (2022)
[34] CPI Index, All Urban Consumers, Bureau of Labor Statistics. https://www.bls.gov/cpi/data.htm
[35] 8 O&M for GSI at 5%: assumed for Grand Rapids, MI as reported in *Establishing a Stormwater Credit-Trading Program as an Off-Site Alternative for Compliance with Stormwater Management Requirements in Grand Rapids, Michigan,* American Rivers et al. *(2019).*
[36] Per the DWSD Guide to Drainage Charge Credits (2019), credits are determined based on criteria for effectiveness to reduce volume and peak flow characteristics of stormwater runoff. A property that removes impervious surfaces can reduce the property's drainage charge and it is not considered a drainage credit. (A Guide to Drainage Charge Credits, DWSD https://detroitmi.gov/sites/detroitmi.localhost/files/2019-06/A%20Guide%20to%20Drainage%20Charge%20Credits_0.pdf)
[37] Almansa, C., Martínez-Paz, J.M., 2011. What weight should be assigned to future environmental impacts? A probabilistic cost benefit analysis using recent advances on discounting. Sci. Total Environ. 409, 1305e1314. https://doi.org/10.1016/j.scitotenv.2010.12.004

construction and pre-construction costs over 50 years. Lifetime or cumulative O&M costs are based on estimates for year one, plus intermittent maintenance activities related to life-cycle cost for best management practices and low-impact developments retrieved from the Water Environment Resource Federation (WERF) and modeled over 50 years.[38]

The PVC includes an opportunity cost to reflect the value of foregoing income-producing land area to implement green infrastructure practices. The opportunity cost is applied to projects on properties that opted to implement GSI solutions in lieu of other profitable land use activities. Land values for private property were based on current listings for available commercial properties in October 2021 across Detroit.[39] An average price per square foot of land was estimated from real estate listings retrieved from properties in greater Detroit area and weighted based on property type: Commercial/Office/Retail, Multi-Family/Residential, Industrial, Parking Lots, or Public Land for Private Sale. The City of Detroit sells available parcels to private owners; therefore, the opportunity cost of land was also applied to public properties. The opportunity cost for public properties is based on current marketed properties in 2021 listed for sale by the Detroit Building Authority and include land zoned for commercial, industrial, and multi-family land use.[40] The opportunity cost of land is estimated using Thorsnes' (2002) hedonic analysis of open space preservation in the Grand Rapids, Michigan area and adjusted to reflect prices in 2020.[41]

Assigning Value to the Public Benefits

The benefits of using GSI for onsite stormwater management were valued using the benefit transfer technique. The research team built on the work done by Nordman et al. (2018) in Grand Rapids, Michigan. The team identified the following benefits stemming from GSI implementation, although not every GSI practice delivers the same suite of benefits: avoided CSOs, avoided water pollution (total suspended solids and phosphorus), flood risk reduction, avoided stormwater volume, and, in some cases, a scenic amenity (Tables 3,4). While in many cases, bioretention is considered to be a scenic amenity, for the purposes of this report, if it included that benefit it was considered a rain garden.

The values for avoided pollution, scenic amenity, flood risk reduction, and avoided stormwater volume were taken directly from the Nordman et al. (2018) Grand Rapids report and adjusted as necessary to 2020 US dollars and for differences in property and labor prices in Detroit.

Grand Rapids separated its stormwater and sanitary sewer systems, so Nordman et al. did not include avoided CSO discharges in their report. However, Detroit does have a combined stormwater and sanitary sewer system and is prone to CSO discharges. Therefore, this report

Table 3: Value of Ecosystem Services from Green Stormwater Infrastructure

Service	*Value ($/gal/year)*
Avoided CSO	$0.0354
Avoided pollution (TSS & P)	$0.0069
Scenic amenity	$0.0019
Flood risk reduction	$0.0008
Avoided stormwater volume	$0.0003

[38] Moeller, J., Pomeroy, C.A., 2009. BMP and LID Whole Life Cost Models: Version 2.0 https://www.waterrf.org/research/projects/bmp-and-lid-whole-life-cost-models-version-20

[39] Detroit Commercial Properties for Sale, CityFeet.com
[40] The City of Detroit markets properties through the Detroit Building Authority contracts with Summit Commercial to market certain properties.
[41] Thorsnes, P., 2002. The value of a suburban forest preserve: estimates from sales of vacant residential building lots. Land Econ. 78, 426e441. https://doi.org/10.3368/le.78.3.426

Table 4: Ecosystem Services Provided by the Different Types of Green Stormwater Infrastructure

GSI Practice	*Avoided CSO*	*Avoided pollution*	*Flood risk reduction*	*Avoided volume*	*Scenic amenity*
Rain garden / restored wetland	Yes	Yes	Yes	Yes	Yes
Bioretention	Yes	Yes	Yes	Yes	No
Detention / underground storage	Yes	No	Yes	No	No

does include a monetized value for CSO discharges. A benefit transfer approach was used to estimate the value of avoiding CSOs. Mourato et al. (2005) conducted a willingness-to-pay study of avoided CSO discharges in London, UK. They estimated the total willingness to pay to avoid 39 million cubic meters per year of CSO was £371.63 (2005). This volume was based on a conservative, minimal intervention scenario in which 80% of the storm events are captured. The willingness to pay was transferred to Detroit by adjusting for Detroit's lower household income ($30,894—54.4% of London's household income) and adjusting for inflation to 2020 US dollars.[42] The impact of a practice on CSO volume is likely overestimated here, because there is no model to determine exactly how the volume of stormwater managed by a single practice translates to reduced CSOs. However, the *value* of CSO reduction is likely underestimated, because the cited study investigated the value of capturing 80% of storms, while in Detroit, the percent of stormwater captured is much higher than that. Further research into the relationship between upstream management and downstream CSOs could help improve these estimates.

There are many other benefits provided beyond what was included in this analysis such as urban heat reduction, habitat, and health benefits of greenspace. Their exclusion here is not intended to indicate that they are not also important. In fact, they are an essential part of the value of GSI.

Economic Impact of Construction Spending

Separate from the costs and benefits to individual properties are the broader economic impacts. These may be important metrics for planners at a neighborhood or municipal scale.

Economic impact studies estimate total dollars, household earnings, and jobs generated in an economic region due to a new activity. The emphasis is often on what new money and how many jobs will come into the economy because of this new activity. For our study, this new activity is stormwater management infrastructure construction spending (both green and gray). The economic impact is estimated using the IMPLAN regional economic analysis software. This analysis software provides a way to measure the complete economic impact that an initial change in demand has on the local economy. These secondary effects come in two forms:

[42] Mourato, S., G. Atkinson, E. Ozdemiroglu, J. Newcombe, Y. de Garis. 2005. Does a cleaner Thames pass an economic appraisal? The value of reducing sewage overflows in the River Thames. Water International 30(2): 1174-183. https://www.tandfonline.com/doi/abs/10.1080/02508060508691858

1. **Indirect Effects:** Business-to-business purchases within the supply chain that stem from the initial direct spending. In other words, an increase in sales by businesses that are suppliers to restaurants, hotels, retail stores, etc.

2. **Induced Effects:** Increased economic activity by individuals (labor) in the area who received extra income due to the increase in direct spending.

IMPLAN reports economic impact in three ways:[43]

1. **Gross Output:** Gross output is the total economic activity, including the sum of intermediate inputs and the value they add to the final good or service. The intermediate inputs are the resources used in the production of final goods and services. It should be noted that gross output can be overstated if the intermediate inputs are used multiple times in the production of other goods and services.

2. **Labor Income:** Labor income measures the increases in wages, salaries, and proprietors' income as a result of the initial change in demand. This can also be stated as the increase in household income for every $1 change in demand.

3. **Value Added:** Value added represents the difference between total output and the cost of its intermediate inputs. Value added is equivalent to the industry's contribution to gross domestic product (GDP).[44]

FINDINGS

Capital Costs

Capital costs vary greatly: Across the fourteen projects in the sample, **capital costs ranged from $0.05 - $1.48/gallon**. Pre-construction costs ranged from $0.001-0.15/gallon; construction costs ranged from $0.048-1.37/gallon. With a sample size of fourteen projects, it is not possible to make statistically significant inferences about what factors drive those cost differences, but it is worth noting that there was no clear pattern regarding practice type or project size.

GSI can be cost-competitive: While there was no clear pattern that emerged to say which practices cost more, there are scenarios where green projects can likely be cost-competitive. The two non-vegetated practices we looked at (permeable pavement and subsurface detention) had capital costs between $0.34-1.44/gallon. While permeable pavement can allow for infiltration, which is considered "green" in many instances, we are including it among more traditional practices here because it does not provide evapotranspiration or greenspace benefits. The greener practices (wetland restoration and bioretention) had capital costs between $0.15-1.48/gallon. The cheapest project was a dry detention basin that incorporated surface level green space, at $0.049/gallon. *Note: This only includes costs. Comparisons that include benefits are included below.*

[43] Jobs created is not included in this analysis because the focus is on construction spending. The economic impact of construction spending only occurs during the construction phase of the project, therefore it does not generally create new jobs, but instead supports current jobs in the local economy.
[44] Jobs created is not included in this analysis because the focus is on construction spending. The economic impact of construction spending only occurs during the construction phase of the project, therefore it does not generally create new jobs, but instead supports current jobs in the local economy.

Present Value Costs

To get a better picture of the full cost to the property owner, the opportunity cost of the land and the lifetime operations and maintenance costs have been added in to provide present value costs. When looking at the costs from this perspective, the same findings appear to be true:

- **Lifetime costs vary greatly**, with present values ranging from $0.07 to $2.16/gal.
- **Green can be cost-competitive**—the dry detention basin remained the least costly project for property owners on a per-gallon basis ($0.07/gal PVC), with constructed wetlands the next lowest at $0.25/gal PVC.

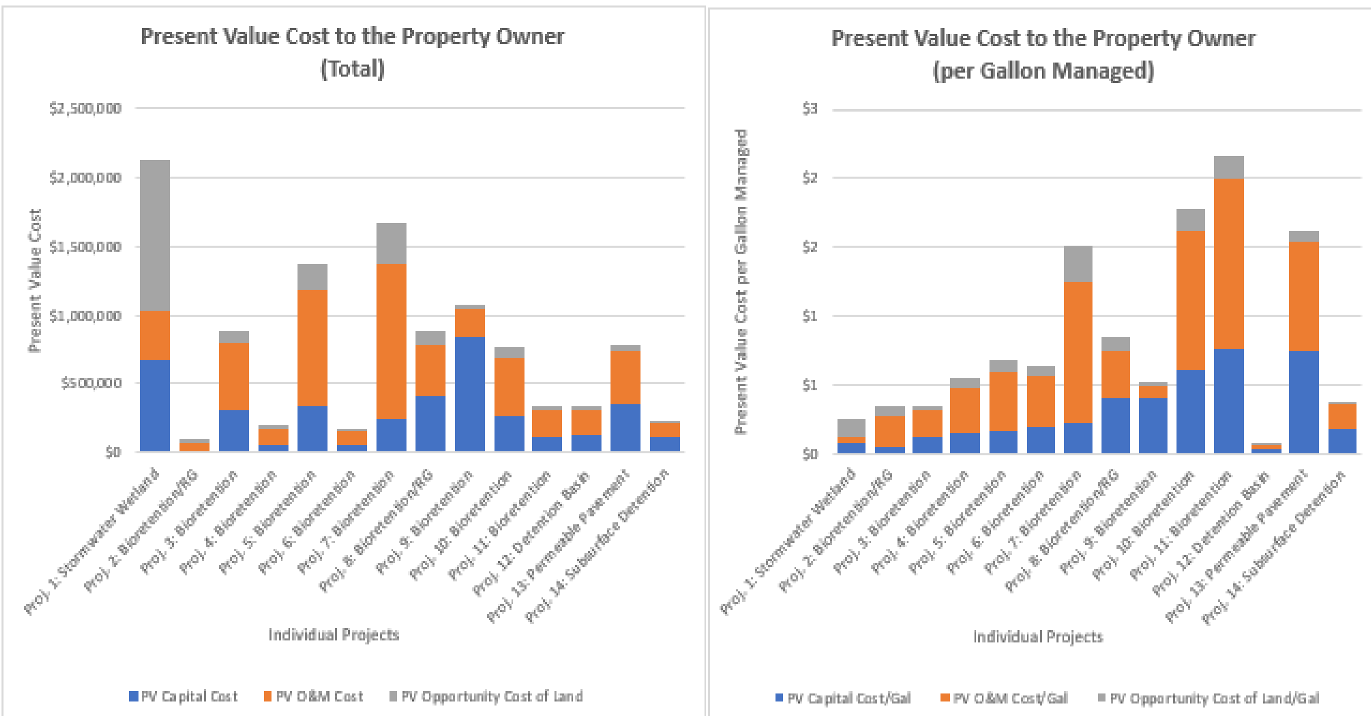


Figure 3: a) Present Value Cost to the Property Owner (total) and b) Present Value Cost to the Property Owner (per gallon)

Net Present Values

The Net Present Values (NPVs) have been calculated for the private projects in the analysis (Projects 1, 2, 8, 12, and 14). The only direct financial return is through the Green Credit program which gives a monetary incentive to manage onsite imperious area. Since the public projects were designed to manage offsite impervious area (e.g., roadways that do not accrue a charge) they do not provide an effective comparison or relevant examples for private developments when looking at this particular component. So, they have been left out of this section of the analysis.

NPVs were calculated in two ways:

1. NPV for the property owner:
   (PV Drainage Charge Reduction from Impervious removal + PV Green Credit) - (PV Capital Cost + PV O&M Cost + PV Opportunity Cost of Land)

2. NPV to the public (including property owners):
   (PV Co-Benefits) - (PV Capital Cost + PV O&M Cost + PV Opportunity Cost of Land)

The higher bound of green credit estimate ranges was used here, assuming that the outflow rate would be designed to achieve credit on future projects.

In two cases (Project 1 & Project 12) the practice provided a net benefit over the 50-year lifetime for the project. For Project 1, this is due to the large amount of impervious area removed, which reduced the base charge. For Project 12, it is likely because costs remained very low. All the private projects in this analysis created a positive net present value for the public.

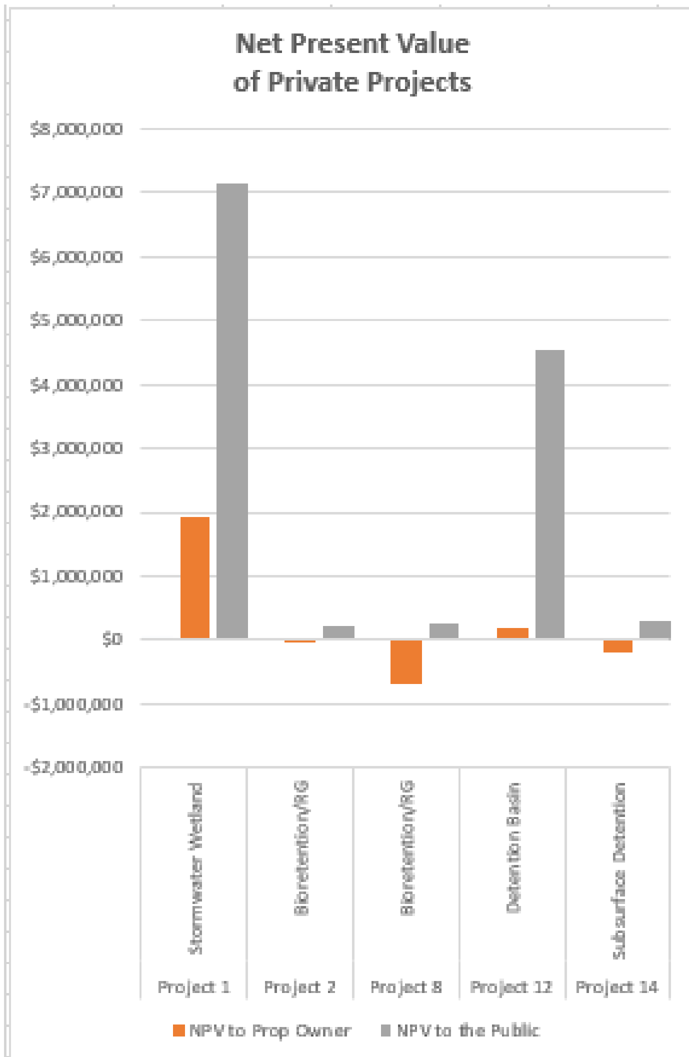


Figure 4: Net Present Value of Private Projects

Table 5: Project Costs, Returns, and Net Present Value

Project Costs, Returns, and Net Present Value

Project	Type	Vol. Managed (Gallons/year)		PV Capital Cost	PV O&M Cost	PV Opportunity Cost of Land	PV Cost	PV IA Removal	PV Credit	PV Return	NPV to Prop Owner	NPV to the Public
Project 1	Stormwater Wetland	8,500,000	*Overall*	($672,930)	($357,831)	($1,094,956)	**($2,125,717)**	$3,443,510	$610,209	**$4,053,719**	**$1,928,002**	**$7,160,240**
Private	*Highly Green*		*Per gallon*	(0.08)	(0.04)	(0.13)	**(0.25)**	0.41	0.07	**0.48**	**0.23**	**0.84**
Project 2	Bioretention/Rain Garden	274,000	*Overall*	($14,463)	($58,271)	($20,173)	**($92,907)**	$49,306	$26,945	**$76,250**	**($16,656)**	**$206,429**
Private	*Highly Green*		*Per gallon*	(0.05)	(0.21)	(0.07)	**(0.34)**	0.18	0.10	**0.28**	**(0.06)**	**0.75**
Project 3	Bioretention	2,530,000	*Overall*	($302,311)	($496,742)	($78,099)	**($877,152)**					
Public	*Highly Green*		*Per gallon*	(0.12)	(0.20)	(0.03)	**(0.35)**					
Project 4	Bioretention	361,000	*Overall*	($51,958)	($119,362)	($26,869)	**($198,189)**					
Public	*Highly Green*		*Per gallon*	(0.14)	(0.33)	(0.07)	**(0.55)**					
Project 5	Bioretention	2,000,000	*Overall*	($339,024)	($845,399)	($187,137)	**($1,371,560)**					
Public	*Highly Green*		*Per gallon*	(0.17)	(0.42)	(0.09)	**(0.69)**					
Project 6	Bioretention	276,000	*Overall*	($53,730)	($102,426)	($21,189)	**($177,345)**					
Public	*Highly Green*		*Per gallon*	(0.19)	(0.37)	(0.08)	**(0.64)**					
Project 7	Bioretention	1,102,000	*Overall*	($251,355)	($1,121,571)	($287,845)	**($1,660,771)**					
Public	*Highly Green*		*Per gallon*	(0.23)	(1.02)	(0.26)	**(1.51)**					
Project 8	Bioretention/Rain Garden	1,050,000	*Overall*	($415,777)	($370,517)	($98,085)	**($884,378)**	$31,556	$173,544	**$205,099**	**($679,279)**	**$262,711**
Private	*Highly Green*		*Per gallon*	(0.40)	(0.35)	(0.09)	**(0.84)**	0.03	0.17	**0.20**	**(0.65)**	**0.25**
Project 9	Bioretention	2,100,000	*Overall*	($842,441)	($201,920)	($36,395)	**($1,080,756)**					
Public	*Highly Green*		*Per gallon*	(0.40)	(0.10)	(0.02)	**(0.51)**					
Project 10	Bioretention	430,000	*Overall*	($260,596)	($432,310)	($69,170)	**($762,077)**					
Public	*Highly Green*		*Per gallon*	(0.61)	(1.01)	(0.16)	**(1.77)**					
Project 11	Bioretention	157,000	*Overall*	($118,740)	($193,943)	($26,082)	**($338,765)**					
Public	*Highly Green*		*Per gallon*	(0.76)	(1.24)	(0.17)	**(2.16)**					
Project 12	Detention Basin	5,133,000	*Overall*	($129,197)	($179,187)	($27,747)	**($336,130)**	$0	$524,225	**$524,225**	**$188,095**	**$4,523,526**
Private	*Medium Green*		*Per gallon*	(0.03)	(0.03)	(0.01)	**(0.07)**	0.00	0.10	**0.10**	**0.04**	**0.88**
Project 13	Permeable Pavement	481,000	*Overall*	($354,800)	($383,999)	($34,343)	**($773,141)**					
Public	*No Green*		*Per gallon*	(0.74)	(0.80)	(0.07)	**(1.61)**					
Project 14	Subsurface Detention	610,000	*Overall*	($108,730)	($108,430)	($3,772)	**($220,931)**	$0	$39,671	**$39,671**	**($181,260)**	**$314,584**
Private	*No Green*		*Per gallon*	(0.18)	(0.18)	(0.01)	**(0.36)**	0.00	0.07	**0.07**	**(0.30)**	**0.52**

Table 6: Estimated Economic Impact Per Dollar Spent

Net Construction Costs (Direct Effect)[45]	**Output**	**Earnings**	**Value-Added**
Per $100,000	$183,779	$164,903	$190,726
Per $1M	$1,837,792	$1,649,032	$1,907,257

The formula for estimating economic impact is as follows:
Economic Impact = Direct Effect + Indirect Effect + Induced Effect

The formula for estimating indirect and induced economic impact is as follows:
Indirect and Induced Impact = Economic Impact – Direct Effect

It should be stressed that this is an estimate of the economic impact. To arrive at a more accurate figure, a formal economic impact analysis should be conducted. This impact analysis will evaluate the direct impact and the corresponding indirect/induced impact on jobs, output, labor income, GDP, and tax (fiscal) revenue.

VI. Summary

This study was designed to examine: 1) the ongoing needs for stormwater management in Detroit, 2) the opportunity to leverage stormwater management into broader impact, 3) the approaches and perceptions of stormwater management designers, and 4) the costs and benefits of a suite of existing stormwater management projects. Our approach, which combined a detailed situation analysis, deep-dive interviews with stormwater designers, and an analysis of existing stormwater management projects, offers several novel lessons for designers, policy makers, funders and others looking to increase the adoption of GSI practices in Detroit.

Ongoing Needs for Stormwater Management

Detroit finds itself at a unique intersection of pressures: aging infrastructure, climate change, projected population growth, a large land base, and increasing development. In light of this, stormwater management, especially vegetated, dispersed stormwater management that helps support healthy communities, will continue to be critical in Detroit for managing CSOs, improving downstream water quality, and reducing localized surface flooding.

Opportunities to Leverage Stormwater Management

The City of Detroit has established a set of policies designed to incentivize and regulate decentralized stormwater management, including a drainage charge, a Green Credit, and a Post Construction Stormwater Management Ordinance. These policies, combined with opportunities for significant

[45] Construction costs should be adjusted to reflect for spending that occurs in the local region. This paper assumes 72% of the construction costs were spent locally.

public investment over the coming years through the Infrastructure Investment and Jobs Act[46] and Inflation Reduction Act[47], can significantly accelerate the installation of GSI, providing localized and downstream benefits. However, a suite of barriers and perceptions remain that may limit the use of GSI.

Approaches and Perceptions of Designers

In general, designers possess a high degree of awareness of and support for GSI, but remain limited by demand, cost, and a lack of clarity around various policies. Below, we highlight a series of recommendations for designers, policymakers, funders, and all interested parties, designed to overcome existing barriers. These include the need for both increased communication among developers, designers, and municipal government, as well as the inclusion of GSI consideration and design elements early in project development.

Costs and Benefits of Stormwater Management Projects

The primary question of the economic analysis was whether GSI was cost-competitive with traditional on-site stormwater management. While the sample size was too small to make categorical claims about cost—i.e., we can't say one practice type is always more or less expensive—the data does suggest that GSI cost is highly variable in Detroit and there are scenarios in which GSI can be a cost-effective alternative to gray infrastructure. This is particularly salient in Detroit where new development is compelled to install stormwater solutions through the Post Construction Stormwater Management Ordinance.

The new unit rate costs identified in this study can provide a basis for estimating future stormwater management project costs as new developments are designed and constructed in Detroit. This offers an advantage over the currently available cost data in two ways.

1) **These are local projects** that face local challenges including site conditions, administrative processes, and labor markets, and as such, they reflect local prices. Much of the previously available data comes from national or international databases which have much larger sample sizes, but less directly relevant costs than those in this analysis.

2) **The costs are meaningfully presented on a unit rate basis** (cost/gallon managed annually). This is a more nuanced way to look at unit costs than the more broadly available $/sf of the stormwater practice. Measuring cost by volume rather than by area replaces the previous proxy measurement with a more direct measure of performance, making it more scalable and more accurate as a prediction tool. The PCSWMO and Green Credit are related to volume managed, not practice area, so this puts costs in those relevant terms.

This research also provides localized methods for calculating the public benefits, something that was previously only available at other scales or for other geographies. The unit rate benefit valuation ($/gal) is a useful tool for measuring the public impact of stormwater management practices. Of course, there are other benefits that are not included in this valuation, and community input is critical for ensuring the actual benefits that any given set of people want to achieve, but this does provide a tool for coarse comparison of potential practices.

[46] https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/
[47] https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/

The research also shows that there is significant economic impact for every dollar spent on stormwater construction projects of any type. This could be useful for planners or developers who are interested in having a more significant positive impact on their neighborhoods.

RECOMMENDATIONS

A handful of recommendations have emerged from this research. They are categorized below by audience: designers, policymakers, funders and financers, and anyone working in stormwater management and GSI.

For Designers

- **Consider GSI at the outset**. PCSWMO projects that have the land available should always be exploring whether green is an option—often it can be cost-competitive, and more so if it is considered early, providing the broadest suite of opportunities on the site as well as a host of public benefits. Do not assume that green practices always require incentives.

- **Make additional benefits of GSI part of the pitch.** Connecting GSI to the broader suite of potential benefits will help make the case for GSI in scenarios where developers may otherwise be on the fence.

- **Consider hybrid projects when fully green projects are not an option**. There can be site conditions in Detroit that limit the implementation of fully green projects where the majority of water is managed through evaporation, evapotranspiration, and infiltration. However, there are often opportunities to implement components of these practices. For instance, if there are contaminated soils that preclude infiltration, dry detention can still have a surface level component with native plants that provides greenspace for people and habitat that supports biodiversity. Or, a practice that is space-limited could be designed for a hybrid surface level GSI and underground detention system to manage the requisite amount of stormwater. Even in difficult site conditions like these, green components can be included that help provide financial benefits to the property owners through increased Green Credit as well as benefits to the community.

- **Recommend GSI in any cases where it might help access additional funding:** Since GSI can be a cost-competitive option, additional funding and resources could tip the scales into making it more affordable. For example, to access Low Income Housing Tax Credit funds, developments are required to go through a grading system that awards points for stormwater management.

- **Showcase cost-effective future projects**. Compare new projects against the cost ranges presented here, and showcase projects that cost-effectively meet ordinance requirements.

For Policymakers

- **Continue to add clarity and communicate with designers.** Consistency and predictability help designers and private property owners make decisions. Suggested actions include:
    - Continue to develop and communicate consistency in **permitting and application of the Green Credit**.

- Develop consistent guidance for when GSI can be used on **brownfields**—and even leveraged for phytoremediation—to help encourage innovative solutions from designers.
- Communicate to designers what has **changed in the application of interpretation of the plumbing code and design manual**. Confusion from earlier processes seems to persist.
- Develop and distribute materials that clarify **how the PCSWMO and drainage credit interact**, e.g., how much credit would a minimum ordinance project achieve? How do you design ordinance projects to achieve maximum credit? This would help clear up existing confusion and potentially lead to some PCSWMO projects being built larger to qualify for credit.

- **Work to reduce institutional barriers from outside City departments.** Designers cited difficulties in working with DTE Energy on projects where stormwater needed to cross a right-of-way where there was a DTE Energy easement. Working to find replicable solutions to common problems like this could encourage more GSI.

- **Reframe the geotechnical testing requirements.** These were regularly cited as something that added significant time and cost. Designers also said that in Detroit, these tests are required earlier in the process than they are elsewhere. However, early and extensive testing has obvious benefits in understanding what is possible on a given site. Continuing to communicate these benefits may make the testing seem like less of a burden.

For Public and Private Funders and Financers

- **Incentivize vegetated projects to maximize co-benefits.** Project developers required to manage stormwater by the PCSWMO can comply while still failing to receive the full potential Green Credit or provide community benefit. These are good opportunities to leverage existing investments in stormwater management to put in better practices. Projects with co-benefits should be prioritized for public and private funding.

For Everyone

- **Work toward a common language.** Use a simple, regularly repeated definition of GSI that focuses on outcomes and reduces the risk of greenwashing. One approach would be to consider the "greenest" solutions to be vegetated GSI, or those that incorporate infiltration, evapotranspiration, and evaporation, and provide the co-benefits of greenspace.

RECOMMENDED FURTHER RESEARCH

- **Continued Cost/Benefit Analysis:** In the future, when more data are available, use the methods presented here to get statistically significant answers and better investigate which circumstances contribute most significantly to cost difference. Explaining and normalizing the variation between bioretention practices would be helpful in guiding future installations.

- **Identify core competing policies**: At the municipal and state level, there are host of policies that potentially act as barriers to GSI implementation (parking requirements, setbacks, plumbing code, brownfield requirements, etc.) Identifying and cataloging these would be a good first next step in figuring out how policy can be tweaked to streamline GSI installations in the city.

- **GSI longevity - monitored performance and maintenance costs:** While this analysis provided local data for a handful of projects, they were all relatively recent and relied on modelled performance. Heavily vegetated systems can change soil properties over time, potentially making GSI more effective as plantings mature. Research that includes multi-year local performance monitoring would be beneficial in understanding the true effectiveness of these systems at local and regional scales and help understand how they can change over time. Maintenance cost data over time would also be valuable, as these costs may change as practices mature, labor costs change, and local expertise grows.

- **GSI Liability:** One of the barriers cited was about liability of GSI versus beneath ground systems. Research into what the actual liability difference is in terms of cost would help inform future comparisons.

CONCLUSION

This report shows that there is potential for GSI to become a standard option for stormwater management in Detroit, as well as indicating some of the areas where continued advocacy, advice, and engagement could help achieve it.

The policies instituted by DWSD and the City Council have paved the way for GSI. They signal the public costs of stormwater management and provide an opportunity for property owners to comply with regulations while reducing their monthly bills.

Moreover, momentum around GSI is growing—the Detroit Stormwater Hub shows 267 projects managing runoff from over 830 acres of the city. Continuing to build on this progress by highlighting successes, learning from challenges, and removing and reducing barriers will help shift the culture toward GSI as a standard practice as significant redevelopment happens throughout the city.

This report suggests that GSI can be a cost-effective alternative to traditional gray infrastructure. Continuing to seek out and encourage cost-effective and technically effective GSI practices will build climate-smart solutions that improve communities, support clean water and biodiversity, and work for property owners. Doing so now, while significant redevelopment happens throughout the city is critical. The continued installation and investigation of these practices will help ensure that we get it right this time and develop social norms that support these solutions.

VII. Appendices

Appendix A: Memorandum: Stormwater Contribution to CSO Overflows: *To what degree can stormwater management reduce CSOs in Detroit?*

Draft Memo | SW Contribution to CSO Overflows

To what degree can stormwater management reduce CSOs in Detroit?

Research Scope

By definition and design, stormwater volume is combined with wastewater volume in a combined sewer system. Every system has a design capacity. When the capacity is exceeded (and sometimes otherwise), the excess combined flow is released to surface waters as a combined sewer overflow (CSO).

The relationship between stormwater management and CSOs has been modeled, but there is a great deal of uncertainty in these modeling results. Much of this uncertainty is attributed to the wide variety of antecedent conditions (e.g., how full is the system at any given time?), and the complicated hydraulics of wastewater conveyances, some of which are not well-characterized or known. This relationship between water volume going into the system, and the trigger for a CSO appears to be non-linear. In other words, if we remove one gallon of stormwater runoff (i.e., managed on site) it does not necessarily affect CSO activation nor does it reduce the activation volume by one gallon.

These relationships are particularly problematic in terms of seeing a return on investment from stormwater management aimed at CSO control. No one can argue that stormwater management isn't valuable, especially in Detroit where inland flooding is a concern. Over the last decade, Detroit, among many other cities has invested in green infrastructure as a set of techniques to manage stormwater runoff by naturalizing landscapes and making them both more permeable and retentive of rainfall or snowmelt. Likewise, many cities have engaged with green infrastructure as a sort of large-scale experiment. In this way, they've asked the question "does GSI control stormwater and CSOs?". As a part of meeting their permit terms, DWSD has invested in and assessed GSI in Detroit and is showing some important results that can aid in a mid-term correction. Consistent with work done around the nation and world, Detroit is finding that there are many factors as to why stormwater management does not yield an immediate, positive impact on CSO activation frequency and volume. This situation suggests a change in narrative around better defining how stormwater management (as GI or otherwise) can more directly improve on current wastewater system performance.

While it would be ideal to understand the relationship perfectly, that is outside the scope of TNC's current research. Instead, this memo is intended to define how much of the system's capacity is available for stormwater volume? This analysis is based on the gross capacities of the system and all data was extracted from GLWA's recently released *Flow Balance Analysis*[1] and *Wastewater Master Plan*[2].

[1] Great Lakes Water Authority. (March 2019). *Flow Balance Analysis & Results for Fiscal Year.*
[2] Great Lakes Water Authority. (June 2020). *Wastewater Master Plan.*

For discussion purposes only

Last Revision: 1/11/2021

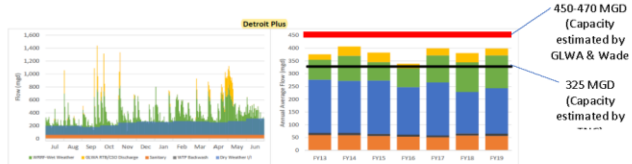
Estimating Detroit's Average Daily Dry Weather Flow & Impacts to Conveyance Capacity[3]

Initial TNC Estimate:

Based on seven years of data from the *2019 Flow Balance Analysis*[4], TNC estimated a **daily capacity of roughly 325 million gallons (MGD)** – see black line in *Detroit Plus Annual Average Flow* table below.

Updated Estimate from GLWA and Wade Trim:

TNC presented this estimate to GLWA and their consulting firm, Wade Trim. They came back with an estimated **daily capacity range of 450-470 MGD** in the Detroit combined sewer system – see red line in *Detroit Plus Annual Average Flow* table to the right.



FY2019 Monthly Statistics								
(MGD)	All Days	Dry Weather	Sanitary	WTP	DWII	WRRF-WW	RTB/CSO	Precip (inch)
July	250.85	198.99			133.55	50.71	1.14	2.12
August	284.38	199.19			133.75	71.22	13.96	2.46
September	368.69	180.44			115.00	139.62	48.63	5.31
October	377.93	203.53			138.09	138.04	36.36	4.16
November	423.64	247.77			182.33	147.80	28.07	3.18
December	330.12	264.79			199.35	64.83	0.50	2.35
January	361.15	257.64	56.74	8.71	192.19	98.52	5.00	1.14
February	461.00	272.95			207.50	187.36	0.69	1.55
March	399.21	265.29			199.84	112.48	21.44	2.93
April	552.64	251.91			186.47	222.94	77.79	4.78
May	575.19	271.42			205.98	220.41	83.36	4.41
June	403.21	312.12			246.68	90.37	0.72	2.81
Annual Avg	398.07	243.55			178.11	127.97	26.55	37.2

* Dry weather flow = sanitary + WTP Backwash + DWII; All Day flow = dry weather + wet weather + RTB/CSO

Historical Records								
(MGD)	All Days	Dry Weather	Sanitary	WTP	DWII	Wet Weather	RTB/CSO	Precip (inch)
FY2013	375.35	276.64	60.10	8.20	208.33	77.57	21.15	32.5
FY2014	406.03	271.85	59.24	8.95	203.66	97.88	36.29	31.6
FY2015	382.52	273.20	56.62	8.19	208.40	71.94	37.38	31.9
FY2016	338.87	247.34	54.03	7.51	185.80	73.91	17.62	28.0
4-Yr Avg	375.69	267.26	57.50	8.21	201.55	80.32	28.11	31.0
		71%	15%	2%	54%	21%	7%	
FY2017	399.29	265.88	51.18	7.58	207.11	105.74	27.67	38.5
FY2018	380.20	228.59	58.48	8.09	162.02	115.84	35.78	33.7
FY2019	398.07	243.55	56.74	8.71	178.11	127.97	26.55	37.2
		61%	14%	2%	45%	32%	7%	
3-Yr Avg	392.52	246.01	55.47	8.13	182.41	116.52	30.00	36.5
		63%	14%	2%	46%	30%	8%	

Meter Math: WRRF minus customer meters

CDM Smith 1/28/2020

Capacity Range:

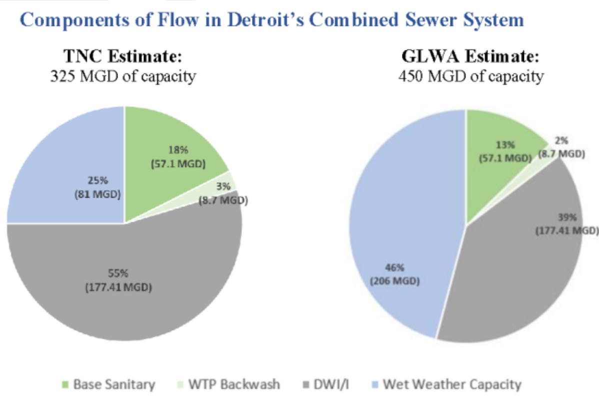
The analysis also indicates that there are three major components of daily dry weather flow:

1. Base Sanitary (Sanitary)
2. Wastewater Treatment Plant Backwash (WTP)
3. Dry Weather Inflow and Infiltration (DWII) including drinking water leakage

When these components are summed (see *Historical Records* table, FY 2019 Dry Weather) the **average daily flow during dry weather is approximately 243 MGD.**

Based on TNC's and GLWA's estimates, we find **that Detroit's combined sewer system is flowing between 54 - 75% capacity on an average dry day** (243 MGD base flow/325 MGD capacity & 243 MGD base flow/450 MGD capacity). **This leaves only 25 - 46% capacity** (81 - 206 MGD) **to manage wet weather events** (see *Components of Flow in Detroit's Combined Sewer System* pie charts to the right). This limitation acts as a ceiling on the potential relief offered by stormwater management BMPs and their potential contribution to CSO reduction.

Components of Flow in Detroit's Combined Sewer System



[3] These estimates include the "Detroit Plus" communities from the Flow Balance Report as they appear to be functionally part of the same system. These communities include Dearborn NE, Gross Pointe, Hamtramck, Harper Woods, Highland Park, Redford Township & Area 6, and Wayne County Area 3.

[4] Attachment 3. Member FY2019 Monthly and FY2013 - FY2019 Annual Flow Components – *Detroit Plus*

For discussion purposes only

Last Revision: 1/11/2021

Initial Findings

- **The system has very limited capacity to manage runoff generated from a majority of the existing impervious area - –** If Detroit's impervious area (IA) generated 1 inch of runoff, it would only take ~7% - 17% of the existing IA to fill the current average stormwater capacity of the combined sewer system.[5,6]

- **Maintaining and increasing the current system-wide wet weather capacity (25% - 46%) is critical to sustainably reduce CSOs –** Multiple factors could increase the flow contributions, potentially exacerbating CSOs even if adequate stormwater management practices are in place to manage the existing problem. For example, population growth could increase the base sanitary flow, increased elevations of groundwater table and river levels could add to WTP backwash or inflow and infiltration, deferred maintenance of the drinking water system could add to DWI/I, and increased rainfall intensity and duration could add to the need for additional wet weather capacity.

- **CSO reduction should not be used as the sole measure of success for GSI or other on-site stormwater management practices, and changes in wet weather system capacity would be a stronger measure of success –** Because wet weather flow is only one of the contributors to total system flow, measuring CSO reductions is not, in and of itself, an adequate measure of stormwater management success. All stormwater management practices add resiliency to the system, and green stormwater infrastructure in particular can produce a host of other co-benefits to the community.

- **Targeted investment in stormwater management is needed at a sewershed scale** – Recognizing that the data represents the systemwide average of the conveyance capacity, there is a need to better understand the capacity stressors at the sewershed scale. This would systematically relieve pressure on the combined system in a way that contributes a reduction in CSO event frequency and volumes.

Next Steps

We now have an initial estimated range of the maximum average volume of wet weather flow that Detroit's conveyance stormwater system can manage. That range is based on differing estimates of the system capacity as presented in GLWA's 2019 Flow balance Report. However, this memo does not go so far as to fully answer the question, "to what degree can stormwater management reduce CSOs in Detroit?"

Immediate next steps in answering this question would be to reconcile the difference between these two estimates to understand the actual average stormwater capacity of the system. Beyond that, there would be a significant amount of work to understand how the other contributing factors (system optimization efforts, etc.) interact with these peak flows to trigger CSO events.

[5] This is based on the assumption that one square mile of impervious area generates 17.23 MG of runoff from 1" of rainfall. So, 81 MG = 4.7 sq. mi. of IA and ; 81 MG = 4.7 sq. mi. of IA and 206 MG = 12 sq. mi. of IA or approximately 7% - 17% of the city's total IA (71 sq. mi.)

[6] "More than 71 square miles (roughly 51%) of Detroit is covered with paved and other hard surfaces" – Detroit Water and Sewerage Department. *Fact Sheet: Detroit Stormwater Management Regulations.*

For discussion purposes only

Last Revision: 1/11/2021

Appendix B: Detroit Stormwater Hub Project Map

Link to project map: https://detroitstormwater.org/projects

Screenshot taken June 29, 2023