Advancing Stormwater Management at Marinas in the Great Lakes
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The Advancing Stormwater Management at Marinas in the Great Lakes project is now final, with four green infrastructure (GI) projects constructed at four marinas in Michigan, Ohio, and Wisconsin. The installed GI projects, monitored for their water quality improvement benefits, represented a proof of concept that enhanced communications and outreach surrounding implementation of GI at marinas. The following report summarizes project activities, accomplishments, challenges and solutions. Michigan Sea Grant compiled information from each state project manager to create a comprehensive narrative of our work during the project period.

Introduction

The purpose of this project was to help build momentum around onsite stormwater management at Great Lakes marinas by developing an online toolkit and demonstrating the benefits of GI via on-the-ground installation projects. The project team worked with an established network of Clean Marina programs in the Great Lakes region that were able to share information, innovations, and outcomes of the project with marina and boating communities. The primary intent of this project was to change behaviors and attitudes about green infrastructure, increase adoption of these types of practices, and address stormwater runoff in the Great Lakes watershed. The specific goals of this project were to:

- Increase adoption of innovative green infrastructure design at marinas in the Great Lakes.
- Increase the number of marinas comfortable with and able to share peer-to-peer lessons about green infrastructure.
- Develop data to justify including or excluding GI in Clean Marina Program checklists – based on both water quality and hydrologic performance at marinas.
- Create a prioritized list of GI practices to simplify the stormwater BMP selection processes for marinas and contractors across a range of investment levels.
- Improve marina resiliency by increasing the capacity to capture stormwater, improve water quality, and reduce flooding on site.
- Collaborate within the Great Lakes Clean Marina Network to increase resources for Great Lakes marinas that will have a systemic impact.
- Increase awareness to the boating community about the impact of their actions on water quality.

This project included public and private marinas on Lakes Superior, Michigan, Huron, and Erie. These marinas typically have limited access to financial and institutional resources for implementing innovative approaches to reduce impacts of stormwater runoff at their sites. Marinas lack the time, financial resources, or expert knowledge to review the multitude of available GI practices, test them and decide which will work best for their site. This project evaluated a set of GI practices that address stormwater management for performance, practicality, cost, and aesthetics, and then developed a streamlined list of GI practices best suited for each marina.

This project resulted in four on-the-ground installations as summarized below:

1. ***Barker's Island Marina, Superior, Wisconsin.*** In May 2021, the team installed a constructed wetland (~9,000 square foot) at this private marina located on city-owned property, to capture and treat stormwater runoff from 96,000 square feet of maintenance building and paved service area. Locally sourced, native wetland wildflowers, grasses, sedges, and shrubs were planted following construction. Fencing was necessary to deter geese during the first growing season. Integrated Pest Management, including invasive plant removals and plant replacement, was conducted three times throughout the growing season in 2021, 2022, and 2023. The treatment wetland was constructed as a two-pond system with the dynamic nature of Great Lakes water levels in mind. The first pond was designed to be a wetland at all times and received all the runoff and most of the sediment. The second pond acts like a wetland when lake levels are high, but acts more like a bio-infiltration basin during low-water years. For most small, frequent rains there may be little or no flow out of the second pond. Over time, two distinct plant communities should develop in each of the ponds because of the differences in hydrology. In addition, stormwater improvements were also completed for a retention pond located on the north side of the marina to mitigate flooding and ice formation in the parking lot and capture sediment. The improvements have resulted in improved public safety and water quality entering Lake Superior.

2. ***Edward C. Grace Memorial Harbor Marina, Elk Rapids, Michigan.*** This public "grant-in-aid" marina on Village land treated one low industrial drainage area with one bioretention cell. The Village of Elk Rapids has partnered with The Watershed Center Grand Traverse Bay to install green infrastructure practices throughout the village with the goal of reducing stormwater volume and its effects on water quality in Grand Traverse Bay. These projects included bioretention cells (BRCs) and rain gardens, which are shallow stormwater basins that use soil and vegetation to capture and treat runoff. In 2020, several rain gardens were installed along River Street and a BRC was installed near the main pavilion at the west side of the Edward C. Grace Memorial Harbor using a variety of funding sources. Additionally, a rain garden was installed in the upper parking lot of the harbor using Sea Grant funding.

3. ***Charlevoix, Michigan, Municipal Boat Launch.*** At the Charlevoix boat launch, two bioretention cells (BRCs) – a type of shallow stormwater basin that uses soil and vegetation to capture and treat runoff – were installed in the downhill islands of the parking lot. This lot receives daily use by boaters using the public access boat launch in Charlevoix. This parking lot is also used to store snow during winter months, which means there's a lot of accumulated sediment and the associated heavy metals, as well as sand and deicing salts from "dirty" that accumulates on city streets as a result of snow plowing.

4. ***Holiday Harbor Marina, Huron, Ohio.*** At this marina, two side-by-side infiltrating GI practices were installed to address stormwater runoff from a parking lot, including a traditional bioretention cell and a high rate biofiltration cell. The projects were installed in a nearshore, traditionally mowed grass area between the parking lot and the waterway. Runoff from the parking lot and surrounding area include stormwater from the marina office building, service yard, and maintenance shop. An asphalt curb was installed such that two, similarly sized sub-watersheds were established, enabling the practices to be compared side-by-side for water quality and quantity impacts. While still treating the same amount of stormwater, the high rate biofiltration cell is much smaller than the traditional bioretention cell due to the high infiltration rate of its media. The research carried out on the performance of these systems will provide insight as to how the novel high rate biofiltration compares to traditional bioretention. Local, native, low-maintenance plants were utilized in both treatment practices, and signage is to be placed near the parking lot as this location is in a highly visible area in the marina.

Although the installations were successful, this project highlighted the need to understand an individual marina's unique site requirements and how difficult it may be for marinas to implement green infrastructure projects, even with support. For example, Barker's Island Marina has a naturally high water table that causes flooding at the marina during high water level years. Since the elevation difference between the paved service area and water table is small, infiltration-based green infrastructure practices, such as bioretention or tree box filters, were not practical. Without the willingness of the marina owner and city to allow GI placement in an underutilized area of the property, site conditions could have prevented the success of an installation at this marina. At Holiday Harbor Marina, the staff had significant limitations in funding and time that precluded a rigorous long-term maintenance schedule. The project team worked with the local soil and water conservation district and marina staff to develop a project that was informed by nearby GI performance and executed a realistic and achievable path forward for the landowner. As a result plantings were simplified from a diverse variety of plants to just two plants known for low maintenance, minimizing the number of plants the marina staff had to train to upkeep.

In the end, this project: 1) developed a set of educational resources geared to stormwater management at marinas including development of a decision support tool to identify appropriate marina GI practices; 2) supported marinas in working with contractors to design and implement GI practices at four Great Lakes marinas; 3) monitored the effects of the GI practice on water quality; and 4) installed educational signage at each GI installation to encourage public understanding and support of these efforts.

Most importantly, the project team now has a better understanding of the needs of marinas to ensure successful expansion of green infrastructure practices at these types of facilities. The report outlines the lessons learned, successes, failures, and challenges. For more information about this project: https://www.michiganseagrant.org/cmst/

How We Changed the Great Lakes

The primary intent of this project was to change behaviors and attitudes about green infrastructure, increase adoption of these types of practices, and address stormwater runoff in the Great Lakes watershed. One unanticipated benefit of this work included the connections that were forged between the various parties involved, including Sea Grant extension staff, staff at participating marinas, and local organizations and government near project sites. This section outlines how this project: changed attitudes about green infrastructure; increased adoption of these types of practices; and addressed stormwater runoff in the Great Lakes watershed.

Changed Attitudes

- Successfully installed GI practices tailored to the marina environment and improved water quality in collaboration with many on-the-ground partners that will help encourage similar applications.
- Promoted the success of the projects through numerous presentations, social media, video, and tours to answer questions, share lessons learned, and help educate interested parties on the benefits of GI.
- Developed outreach materials for the Great Lakes Clean Marina Network and others who will share this information with their networks.
- Guided village and city managers on how to talk with long-time marina slip-renters about the value of green stormwater treatment.
- Led marina managers to speak to peers and others about green infrastructure practices in a positive light - that it is possible to conceive and execute these practices for a marina.
- Adapted traditional green infrastructure terminology into simplified terms that was ground-truthed by marina managers so it was less intimidating to understand.

Increased Adoption

- Developed a public-private model that brought together funding, university, agency and local expertise, and education and outreach to support the installation of four GI practices and additional stormwater improvements at private marinas along the Great Lakes.
- Developed a Clean Marina Stormwater Toolkit that provides marinas, Clean Marina Programs, and other marina-related stakeholders resources to learn about, visualize, and build GI.
- Actively engaged four marinas in three states across the Great Lakes in the selection, development, and installation of GI such that these businesses can provide peer-to-peer knowledge transfer about these innovative stormwater management approaches into the future.
- Developed and implemented workshops, presentations, and GI practices used as demonstrations to encourage further adoption of these practices and technologies.

Reduced Stormwater Impacts

In addition to changing attitudes and increasing adoption, we also measured the real, on-the-ground impacts of the GI installations. Data show these GI installations resulted in the flow of cleaner stormwater to the Great Lakes. In the end, the project resulted in building a total of 4 BRCs, 1 high rate biofiltration cell (HRBF), 1 treatment wetland, and 1 retrofitted retention pond. Both hydrologic and water quality monitoring were carried out for each practice to quantify the benefits provided by each GI practice. The OSU team quantified hydrology using direct field measurements through flumes, weirs, or pipes or indirectly using curve number and rational method calculations based on precipitation data. Water quality samples were collected during storm events to compare concentrations of pollutants in stormwater entering (control) and leaving (treatment) the GI practices.

The GI practices all provided hydrologic improvements both in terms of volume reduction and peak flow mitigation. As shown in Table 1, the practices that performed best at volume reduction were the North BRC in Charlevoix, Michigan; the pond in Superior, Wisconsin; and the BRC in Huron, Ohio. Although the wetland in Superior provided the least degree of volume reduction, 34% is considered high for a treatment wetland. This degree of treatment was likely provided by the sandy soils underlying this site that promoted infiltration. All practices provided a high degree of peak flow mitigation. The HRBF in Huron provided the least amount of peak flow mitigation at 79%, but this is expected based on the design of this system which promotes high flow rates through the filter. The high flow rate capacity of the HRBF is the reason this practice can be designed with such a small footprint. At sites where square footage for stormwater control measures is limited, HRBFs provide an option that conserves space while allowing for treatment of stormwater.

Table 1. Hydrologic performance of each practice.

Site	Huron, OH	Huron, OH	Elk Rapids, MI	Charlevoix, MI	Charlevoix, MI	Superior, WI	Superior, WI
Practice	HRBF	BRC	BRC	North BRC	South BRC	Wetland	Pond
Volume Reduction (%)	62	74	44	100	38	34	85
Peak Flow Reduction (%)	79	97	97	100	97	98	99

Although GI practices can not impact water levels of the Great Lakes, the hydrologic performance of these practices is important. Higher peak-flow rates equate to higher erosive force, which can cause property damage and increased pollutant transport. Additionally, reducing stormwater volumes reduces pollutant loading rates. Comparing inflow and outflow pollutant loads allows us to determine what percentage of pollutants entering GI practices has been reduced (Table 2).

The pollutants measured for this project can be put into three main categories: sediment, nutrients, and heavy metals. It should be noted that due to the high infiltration rate and large stormwater capacity of the pond in Superior, there were only two stormwater samples collected from the pond outlet. Therefore, the results from that site are statistically weak. Similarly, there were no effluent samples collected for the North BRC in Charlevoix, which is why this practice is not listed in Table 2. The results reported for water quality performance in this report are reported as percent annual pollutant loads, which can be misleading when concentrations are already low. For instance, although it appears the performance of the BRC in Elk Rapids is not as high as the others, this watershed was relatively clean compared to the others; when pollutant concentrations are already low, they can approach irreducible concentrations where they cannot be reduced further. These results will be noted throughout this section to provide greater explanation.

The mechanisms for sediment removal rely primarily on reducing the flow of water. All of the practices featured rock forebays, which add roughness and cause water to slow down and drop out sediment. This type of flow reduction was also carried out by using rock weirs and vegetation in the wetland. In BRCs, the mulch layer on top of the engineered media mixture provided sediment removal after the forebay. Sediment is an important pollutant when it comes to water quality management because other pollutants can adsorb – or stick – to sediment grains and hitch a ride into waterways. On the whole, these practices performed quite well at sediment removal. The Elk Rapids BRC had the lowest sediment load reduction, but this was also the cleanest watershed regarding sediment so there was less sediment to be removed.

Regarding nutrients, several nitrogen species were measured, including: total ammonical nitrogen (TAN); nitrate-nitrite (NO_2-NO_3); total Kjheldal nitrogen (TKN); total organic nitrogen (TON); and total nitrogen (TN). Significant reductions between influent and effluent loads were provided by the Huron BRC for TAN, the wetland for NO_2-NO_3, and the HRBF for TN. Both TKN and TON are particulate nitrogen species. All practices provided removal of TKN and TON which is likely due to the effective TSS removal by the practices. The BRCs in Elk Rapids and Charlevoix released NO_2-NO_3 however these changes were not statistically significant. Stormwater samples were analyzed for orthophosphate (OP), particle bound phosphorus (PBP), and total phosphorus (TP). Similar to TKN and TON, PBP is particulate phosphorus. PBP was removed by all practices because TSS removal was high. There was no statistically significant change between influent and effluent OP for any of the practices.

Table 2. Annual pollutant load reductions (%) performed by each stormwater practice

Pollutant	Huron, OH	Huron, OH	Elk Rapids, MI	Charlevoix, MI	Superior, WI	Superior, WI
	HRBF	BRC	BRC	South BRC	Wetland	Pond**
Total Suspended Solids	81*	99*	55	97	96*	98
Total Ammonical Nitrogen	52	93*	71	62	86*	94
Nitrate-Nitrite	58	89	-199	59	87*	91
Total Kjeldahl Nitrogen	52	85*	11	79	82*	92
Total Organic Nitrogen	52	83*	-3	81	81*	91
Total Nitrogen	54	87*	-16	75	85*	92
Particle Bound Phosphorus	67*	92*	53	85	90*	96

Orthophosphate	45	90*	-28	-4	84*	98
Total Phosphorus	65*	92*	43	6	90*	96
Cadmium	36	87*	8	60	82*	98
Chromium	66*	90*	-22	59	87*	98
Copper	60*	97*	-4	93	91*	99
Lead	66	97*	72	92	94*	99
Zinc	67	96*	57	94	92*	97

*Marked values indicate statistically significant differences between the influent and effluent annual pollutant loads (kg/ha/year)

**The pond in Superior, WI did not have enough samples to perform statistical analyses for significant differences between influent and effluent annual pollutant loads

Heavy metals at marinas are generated by boat maintenance. These metals are toxic to wildlife and are especially harmful to invertebrates. Stormwater samples were analyzed for cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn) and loading rates of each varied between practices. Loading rates of cadmium and chromium were low for all marinas and were reduced but not by a significant amount. Loading rates of copper, lead, and zinc were elevated for the sites in Huron and Superior, specifically near the HRBF and wetland where boat maintenance is more prevalent. Fortunately, these practices provided good removal of these heavy metals. Increases in the percentage of metals shown in Table 2 is not cause for concern as the influent loading rates in these instances are quite low, and the increases in annual load are negligible.

Overall, the green infrastructure practices constructed for this project reduced annual pollutant loads from the marinas. The BRCs, HRBF, wetland, and pond performed best at removing sediment (TSS) and sediment-bound pollutants like TKN, TON, PBP, Cu, Pb, and Zn making them especially effective GI options for marinas where boat maintenance occurs, that is, those with elevated loads of Cu, Pb, and Zn compared to parking lots with only car and daily boat parking. This project serves to show that GI can reduce heavy metals entering the Great Lakes from marinas. In turn, these pollutant reductions will reduce the harmful impact heavy metals can have on biodiversity. These practices will continue to provide water quality benefits for decades to come given that they are properly maintained.

Where We Fell Short

Throughout the course of the project, which spanned from 2019 to 2024 and included multiple extensions and several changes, the team ran into a variety of issues that reduced efficiency and effectiveness.

- The initial proposal plan was to utilize the EPA Stormwater Calculator to inform the Decision Support Tool. The team quickly realized the effort needed to work with the EPA Stormwater Calculator at each site could be better spent by instead developing a more user-friendly decision support tool catered to a marina owner and not a stormwater professional. As such, the team worked with local, state, and regional stormwater professionals to develop the “Clean Marina Stormwater Toolkit” meant to summarize what green infrastructure is, how it could be utilized in a marina setting, and some basic parameters that could help inform a marina's decision on which GI practice to choose (i.e. space needed, cost, maintenance, etc.).

- One subcontractor in Michigan, while having some experience in GI, was not experienced with optimal plant selection, installation, and guidance for village maintenance staff for plant maintenance.
- Lack of communications with Michigan sites caused confusion among those who would maintain the constructed GI. This led to rain gardens not being maintained properly, confusion about what the constructed practices were among locals and slip-renters, and disappointment over the loss of trees in the parking lot islands in Charlevoix amongst locals.
- Insufficient stormwater samples were collected at a few of the constructed practices.
- We ran into several construction delays, which perhaps may not have been avoided but should have been considered in overall planning.
- The process for selection and design of GI practices with the Barker's Island marina took considerably longer than anticipated due to complexity of project, number of partners involved, and unforeseen circumstances that arose such as local permitting issues. The Wisconsin Coastal Management has played a key role in overcoming these challenges of managing the Wisconsin project.
- The project teams experienced some challenges with site selection and identification of appropriate GI options because of unpredictable weather, high lake levels, and changes in marina staff. The challenges were overcome by engaging with new partners and staff to get them vested in the project and waiting for a more appropriate time to conduct site visits.

How We Would Do Things Differently

There are several aspects of the project the team agrees could be improved, including expanding and improving outreach to better engage stakeholders in order to streamline implementation. In addition, ensuring funding was sufficient for the project goals and maintenance and increasing sampling for more robust results would have further strengthened this project. .

Outreach

- Reach out to boaters and other stakeholders near the project site at the beginning of the project. Ensure sufficient staff capacity for communications with local leaders and communities.
- Increase site visits and tours. These are especially informative as they provide an on-the-ground experience to a variety of audiences with the practice and can include the marina owner's perspective on the project.
- It is important to work with marina owners and other people who know the site and can help with finding the best design and placement for signage. This process worked extremely well when coordinated by Sea Grant staff that is familiar with the area and known to the marinas and owners.

Funding

- Modify research goals to ensure sufficient funding is available to pay volunteers who collect stormwater samples so it will be a higher priority for them.
- Marinas may be limited in the types of GI available given constraints of their site (e.g., real estate, high water table, contaminated soils, etc.). This project helped demonstrate how smaller, high-flow systems provide similar performance to traditional systems.
- The sites were more complex than expected because of the number of partners and activities needed. These complexities include local and state permitting requirements, re-paving of the site, moving fuel tanks, and pipe placement under a road. The amount of time it took to coordinate the different aspects of the projects, finalize design plans, and navigate university processes while accounting for appropriate construction seasons, ultimately led to construction being delayed. Lessons learned – it takes a lot of time and consistent communication to coordinate these activities among diverse partners. Local partners are critical to the implementation of these kinds of projects.

Sampling

- The number of paired water quality samples was limited by precipitation events of sufficient size to produce outflow. A careful balance must be struck between ensuring high performance of systems while also allowing for sample collection to achieve research goals. Modifications to sampling plans such as adding a mid-point sample collection in the wetland could have been implemented initially to ensure data collection goals were met.

Things That Changed Over the Course of the Project

The COVID-19 pandemic created many challenges for the project, causing the project to be extended and delaying the construction of practices. Most prominently, it caused a delay in design and construction of the installations at the Ohio marina. The team, however, was able to complete design and complete contracts with a construction firm during the fall of 2021 and were ready to construct once COVID restrictions were relaxed. In addition, there were long lead times on several sensors required for monitoring, which affected monitoring schedules. In addition, high Great Lakes water levels were a significant challenge in the design phase of the projects due to limited differences between the ground surface elevations and water tables. The practice at Barker's Island Marina was designed to accommodate varying hydrologic conditions and will hopefully be resilient to varying lake levels over time.

What the Team Learned in Creating its Products

Of greatest importance,the team learned how critical the need was for a high level collaboration with local groups to implement the GI practices and create tools and outreach materials that are suitable for their needs. The project team worked with many local organizations, including: Erie County Soil and Water Conservation District; Old Woman Creek National Estuarine Research Reserve; Grand Traverse Bay Watershed Center; Michigan Department of Natural Resources – Charlevoix Fisheries; Green Elk Rapids; Drummond Carpenter Engineering; Wisconsin Department of Natural Resources; and Lake Superior National Estuarine Research Reserve as well as local governments included the City of Superior, City of Charlevoix, and the Village of Elk Rapids.

This high level of collaboration was critical to ensuring successful installation at each marina. For example, the Barker's Island Marina project would not have been possible without the collaboration of the marina and City of Superior staff. The marina owner helped to coordinate timing of the re-paving and regrading of the capture area, worked closely with the OSU engineering team in the design phase, and privately funded raising of the fuel tank. All of these were necessary to direct stormwater away from Lake Superior and into the practice. In addition, the marina owner and City of Superior staff both provided input into the design, which ultimately helped preserve a grove full of birch trees adjacent to the practice. The City of Superior also bid and oversaw construction of the practice which was critical for successful installation. Staff from Lake Superior National Estuarine Research Reserve played a key role in monitoring. Each organization and individual gained knowledge and respect as to one another's role and expertise throughout the project, ultimately leveraging that expertise to achieve an on-the-ground success story that - without this level of collaboration - may have likely failed.

Contributions to Stormwater Management Research

An important finding from this project was better understanding of the loading rates of stormwater runoff pollutants at marinas. Findings showed concentrations of heavy metals were dependent on land usage. Marinas areas with more boat maintenance had the highest loading rates of copper, lead, and zinc. The HRBF and the wetland and pond in Superior receive stormwater from boat maintenance areas and levels of copper, lead, and zinc were highest for these areas. Both the Elk Rapids and Charlevoix parking lots, which are not used for boat maintenance, produced heavy metals loads similar to a typical parking lot.

These findings suggest that stormwater control measures that reduce heavy metal pollutant loads should be prioritized at marinas where boat maintenance occurs. Of the BRCs studied, the Huron BRC provided the greatest treatment for heavy metals. This practice was one of the larger BRCs in terms of water quality volume and provided the most stormwater volume reduction and peak flow mitigation. The wetland also provided good reductions to heavy metal pollutant loads.

Although flooding isn't a concern at Great Lakes marinas, the hydrologic findings of this work are relevant to inland sites where flooding is of concern. This study provided context for the relative stormwater volume reduction and peak flow mitigation of a BRC and HRBF. Additionally, there is little research on infiltrating wetlands and wet ponds so the findings regarding stormwater volume and peak flow reductions will be a novel contribution to stormwater research. Another novel component of this research is that many of the GI practices were designed with shallow cross sections due to the high water tables at marinas. Better understanding the performance of these shallow, undersized GI practices will provide more insight as to the application of GI in coastal areas and areas with high water tables. The results from this study will help inform the current body of research regarding the sizing of BRCs based on their underlying soil type.

Table 3. Area-normalized, annual pollutant loading rates of heavy metals for each practice (kg/ha/year).

Pollutant	HRBF	BRC	ER	S	WL	PD
Copper	0.58	0.13	0.003	0.06	0.49	1.33
Lead	0.044	0.006	0.003	0.015	0.026	0.15
Zinc	0.15	0.06	0.003	0.14	0.25	0.28
TSS	1084	223	38	166	93	226

Another important topic in green infrastructure research is the amount of compost used in engineered BRC media mixtures. Because the BRCs in Michigan had a different media composition than that of the Huron BRC, this information will help to better understand how percent compost in media impacts nutrient reductions or leaching. The media of the BRCs in Michigan contained more compost and these systems ultimately leached OP. This finding is especially important in places where nutrient management is a key component to stormwater management such as in Ohio.

How Deliverables Were Received by Intended Audiences

We conducted a needs assessment to better understand coastal marinas' interests and concerns for implementing GI at their properties. Members of the project team from Michigan, Ohio, and Wisconsin solicited input from marina owners and operators at their respective state clean marina workshops, site visits, conferences, and meetings. Data were gathered via a written survey between January and March 2019. In total, 12 marinas participated, including 4 marinas from each participating state. Responses were aggregated (using descriptive coding where necessary) and reported both quantitatively and qualitatively.

Of the twelve respondents, (nine marinas indicated they were willing to have GI practices installed at their properties. The three marinas that stated “no” or “uncertain” said they were concerned about the cost associated with installation, maintenance, and upkeep. Providing an economic assessment that outlines the costs and justifies the investment, providing educational information on what types of GI practices exist, and having resources to educate the public were three tools marinas wanted. Marina owners were also interested in information and training on the long-term effects and maintenance costs of GI installation and wanted to know what it is and why it was worth doing. Marina owners said the cost of assessing which GI works for their property, implementing the GI practice, and maintaining the GI were their biggest challenges. Receiving support to find and secure funding was mentioned by marina owners in responses to several of the survey questions.

We tested several green infrastructure calculators to collect site-specific information to use during this project or, potentially, for inclusion in the green marinas toolkit to be used by marina managers or those working with them. Unfortunately, the team was unable to find one that helped marinas in making decisions on improving the quality of stormwater running off their sites using cost as a variable. Ultimately, the team developed a decision support matrix specifically streamlined and designed to help marinas identify the most suitable GI practice based on their industry-specific needs. Characteristics such as size of the practice (as many marinas have very little room to expand), depth (due to high water table); resiliency to ice and flooding (due to fluctuating water levels); maintenance (due to limited staff and resources as a private business); and of course, cost (to give an idea of what GI practices could be realistic for their situation) were examined and assembled in an easy-to-understand way. This "calculator" is meant to be a tool utilized by trained Clean Marina coordinators to help marinas access more substantial stormwater information once they have narrowed down appropriate GI practices for their site.

In addition, the team provided fact sheets that included detailed case studies summarizing the projects and the effects of the GIs (based on monitoring data); accessible site schematics and signs for use on site at the marinas; content on the dedicated website; and a video. These items are all being used by the marinas to help promote public education and to help increase the adoption of GI at these sites. They also provide resources for the marinas, including a guide to green infrastructure, an outline of funding opportunities, and other information.

Who is Using the Deliverables

Project deliverables have been shared with marina industry professionals, outreach professionals, and stormwater experts across the Great Lakes. Initial feedback has indicated that these user groups each have specific but tangible applications for the Clean Marina Stormwater Toolkit and the GI case studies:

- Marina Industry Professionals are using the toolkit to increase understanding of GI, find others implementing these practices, and using the matrix to decide which GI practice might work for them.
- Outreach Professionals are using the toolkit as a relevant, easy-to-understand resource to educate their clientele about stormwater.
- Stormwater Professionals are referencing the toolkit as a model for making stormwater education more accessible to non-stormwater professionals, using the installation and monitoring outcomes to inform the adaptation of GI in nearshore areas across the Great Lakes.

In addition, each marina wanted to see their monitoring results. They are using these results to ensure ongoing maintenance of their sites. Limited studies exist on stormwater quality from marinas; this work will provide important insights for how marina activities such as boat maintenance impact water quality.

Team's Current Perspective on What These Taught Us

In addition to the high need for collaboration with local groups required for implementation of these types of projects, we also learned good outreach and communication from the outset of the project is critical. This communication includes being strategic about our rationale and message when it comes to the public, and that simple is better in terms of vocabulary and guidance for this group of stakeholders (marinas).

We also need to make sure sites are compatible with GI installation prior to spending time and resources on design plans and implementation. Finally, we need to engage the end user early and often and have a point of contact who will stay in touch with them after the project is over. This will help identify issues early on and help assure landowner's "buy-in" over the long term.

Summarize and Assess Big Victories, Failures, and Changes During the Project
The project aimed to promote GI adoption at Great Lakes marinas to address stormwater runoff. The team collaborated with Clean Marina programs, leading to on-the-ground installations in Wisconsin, Michigan, and Ohio. The following summarizes the successes, failures, and changes.

Big Victories:

- Successful installation of tailored GI practices at marinas, improving water quality and demonstrating the feasibility of such projects.
- Increased adoption of GI practices among marinas, facilitated by public-private partnerships and educational outreach efforts.
- Real, measurable reduction in stormwater impacts through the implementation of GI practices, including the reduction of pollutants like sediment, nutrients, and heavy metals entering the Great Lakes.
- Development of educational resources, including a Clean Marina Stormwater Toolkit and decision support tools, aiding marinas in selecting and implementing appropriate GI practices.
- Collaboration with local organizations and government bodies, fostering relationships that were crucial for successful project implementation.

Failures:

- Issues with subcontractors and lack of communication in certain areas resulted in maintenance and construction problems, affecting project outcomes.
- Construction delays, permit issues, and unforeseen circumstances slowed down progress at some marinas, highlighting the need for better planning and coordination.
- Insufficient sampling in some cases limited the thoroughness of the assessment of GI practice effectiveness, suggesting the need for improved monitoring strategies.
- Challenges with site selection and design arose due to unpredictable weather, high lake levels, and changes in marina staff, underscoring the importance of flexibility and adaptability in project management.

Changes:

- Adaptation to challenges brought about by the COVID-19 pandemic, including project extensions and delays in construction schedules.
- Insights gained into stormwater management research, particularly regarding pollutant loading rates, performance of different GI practices, and the importance of collaboration with local groups.
- Improved understanding of marina owners' needs and interests through needs assessments, informing the development of tailored outreach materials and decision support tools.

- Utilization of project deliverables by marina industry professionals, outreach professionals, and stormwater experts across the Great Lakes, indicating the relevance and usefulness of the resources created.

Overall, the project achieved significant successes in promoting the adoption of green infrastructure practices among marinas in the Great Lakes region and reducing stormwater impacts on water quality. However, it also faced challenges such as delays, communication issues, and sampling limitations that affected project efficiency and effectiveness. Moving forward, lessons learned from these experiences can inform future projects, emphasizing the importance of thorough planning, effective communication, and collaboration with local stakeholders to ensure successful outcomes in stormwater management initiatives.

What Will Happen Next Because of Our Work

The team hopes that these marinas will serve as stewards for more widespread adoption and innovation of these practices. Additionally, the project leveraged partnerships between the state Clean Marina programs and their respective marinas to support the projects and ongoing maintenance of the installed practices. Clean Marina programs have a unique educational role and relationship that they develop with their respective marinas, therefore there is a built model for outreach and oversight that is leveraged for this project.