# Planning for More Equitable Implementation of Flooding Infrastructure in Berrien County, MI and Milwaukee, WI

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# Executive Summary

Compound flooding, caused by a combination of heavy rainfall and high water levels, has become an increasingly urgent challenge for coastal communities on the Great Lakes as lake levels fluctuate and storms intensify due to climate change. This project addresses the socioeconomic impacts of compound flooding in the cities of Benton Harbor, Michigan, and Milwaukee, Wisconsin, both situated in low-lying watersheds near Lake Michigan. Building on current city planning efforts and technical modeling by other researchers, this project develops a series of recommendations for measures that states and municipalities can implement to reduce damage to infrastructure and livelihoods from flooding while enhancing socioeconomic equity.

This project is a partnership with Michigan Sea Grant, an organization committed to supporting flood mitigation efforts and community resilience in Benton Harbor. The goals of the project align with Michigan Sea Grant's efforts to reduce disparities and support healthy and safe Great Lakes communities. Wisconsin Sea Grant's involvement supports a similar partnership in Milwaukee. Drawing on stakeholder interviews, community engagement, and spatial analysis of social vulnerability indices such as the CDC Social Vulnerability Index (SVI), the report situates flood risk within the historical and socioeconomic contexts of Benton Harbor and Milwaukee.

This project and its methods were designed to unite technical, political, sociological, and community perspectives on compound flooding and paths to resilience. Combining experts' and community members' understanding of compound flooding in Benton Harbor and Milwaukee synthesizes relevant experience, preferences, and expertise on best practices for flooding resilience strategies. The team conducted a series of interviews with project leaders, city officials, and stakeholders in Benton Harbor and Milwaukee, culminating in a flood mitigation Stakeholder Advisory Board meeting in Benton Harbor. The team also conducted a series of informal conversations with community members. Depending on the length and type of the conversation, the team either coded or summarized the results to examine best practices for these sites. To address the distribution of social vulnerability in these communities, the researchers conducted a spatial and socioeconomic analysis that combined qualitative stakeholder interview data from community outreach with flood modeling and demographic information.

This project found that residents were most concerned about inundated roadways and backed-up drains, and many were interested in solutions that involved infrastructure improvements and more green space. Officials and experts highlighted the importance of educating residents about solutions, technical guidance, and shared best practices, while citing funding limitations and coordination challenges across jurisdictions as persistent obstacles. The cross-cutting recommendations drawn from these findings include re-aligning the valuation of cost-benefit analyses, adopting hybrid gray-green infrastructure strategies, and systematizing equity and planning for long-term maintenance. For Benton Harbor, the team identified a need to prioritize low-cost, high-visibility, publicly accessible spaces, including downtown roads, parks, and riverfronts. For Milwaukee, the team recommends improving equity and transparency in the planning process and strengthening community partnerships. The recommendations are further sorted into short-, medium-, and long-term implementation priorities and are grounded in stakeholder interests, socioeconomic inequities, and existing flood modeling.

# Introduction

Flooding is not only an environmental hazard, but it is also a social and economic issue that can disproportionately affect communities with limited financial and infrastructural resources. Research in environmental justice and hazard planning demonstrates that communities of color and low-income neighborhoods often experience greater exposure to environmental risks while receiving uneven protection through public infrastructure investment.[1] In the Great Lakes Basin (GLB), flooding has been identified as one of the primary climate-related hazards affecting coastal communities, as water level variability and extreme precipitation events intensify.[2]

Coastal cities are particularly vulnerable to compound flooding. Compound flooding refers to flooding driven by two or more interacting drivers, such as elevated lake levels, heavy rainfall, and high river discharge, that occur simultaneously or in close succession (Figure 1). In coastal Great Lakes systems, high lake levels can constrain river discharge and stormwater drainage, amplifying the impacts of intense precipitation events.[2]

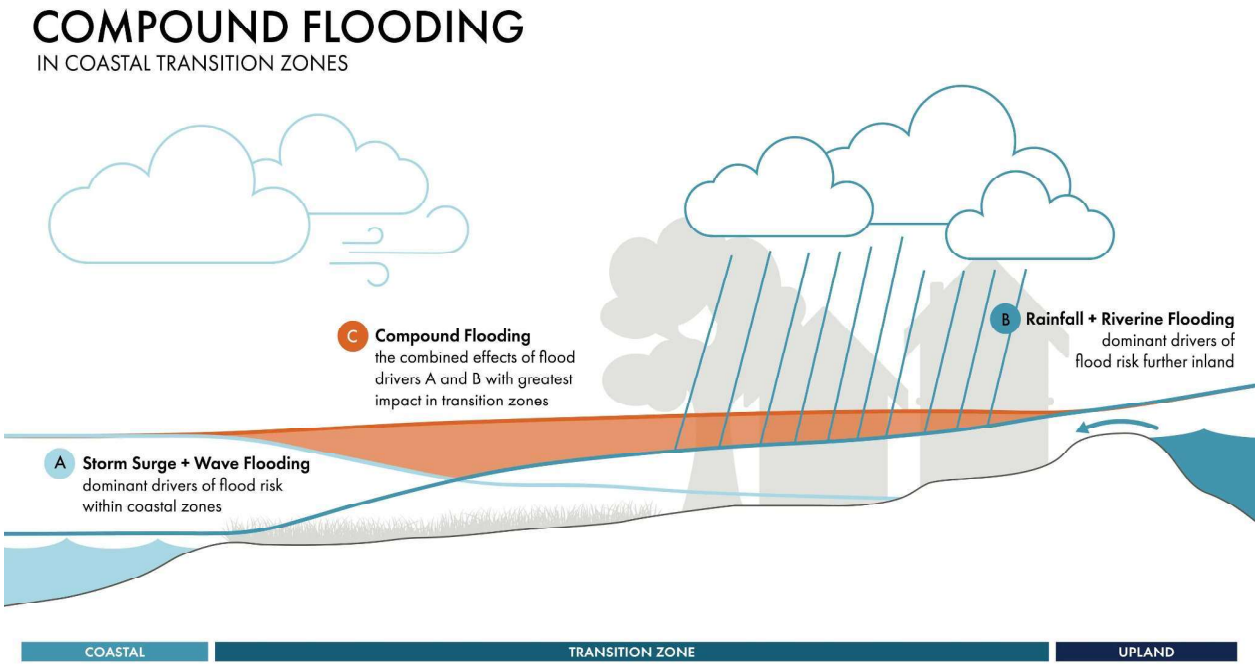



**Figure 1.** Compound flooding diagram from The Water Institute (2024).

Cities such as Benton Harbor in Berrien County, Michigan, and Milwaukee, Wisconsin, face increasing flood risk due to aging infrastructure, legacy land-use decisions, and changing hydrological conditions.[3] These risks are compounded in communities that have experienced industrial restructuring, population loss, and constrained municipal budgets over several decades. In such contexts, physical

flood exposure intersects with socioeconomic vulnerability, shaping both the severity of impacts and the capacity to recover.[2]

Current and previous work on flooding shaped the aims of this report. A 2022 U.S. Coastal Resilience Project Grant (USCRP) was awarded for the Development of a Probabilistic Compound Flood Hazard Assessment Tool and Evaluation of Countermeasures for Great Lakes Cities.[1] That project, led by University of Michigan researchers Dr. Jeremy Bricker and Benjamin Nelson-Mercer, models compound flooding in Berrien and Milwaukee counties through calibrated hydrological and hydraulic simulations of both historical and simulated storm events.

As part of the USCRP project, the researchers calibrated their hydrological and hydraulic models using historical meteorological data, observed water levels, and documented flood extents. Model validation incorporated Participatory Geographic Information Systems (PPGIS) mapping, in which community members identified experienced flood locations to refine flood extent estimates. Calibration of infiltration rates, used as a proxy for stormwater system performance, increased consistency between modeled and observed flood extents. The modeling framework then evaluated potential structural and nature-based green countermeasures, including floodwalls, levees, river widening, upstream storage, rain gardens, and coastal wetlands, and estimated reductions in expected annual damage over time.

Complementing this modeling effort, Dr. Diane Henshel at Indiana University developed a resilience guidance tool designed to help households and communities prepare for flood events before storms occur.[4] Her work draws on systems-based analysis and structured assessment methods to identify practical strategies that improve preparedness and adaptive capacity. Through focus groups and regional surveys across Southwest Michigan, this effort incorporated community-identified vulnerabilities and response priorities into a pre-disaster planning framework. Whereas the USCRP modeling initiative evaluates flood dynamics and infrastructure-scale countermeasures, Dr. Henshel's work emphasized anticipatory resilience and decision support at the household and community scale.

This report builds on existing assessments by centering on stakeholder perspectives, institutional constraints, and socioeconomic conditions to develop place-based flood mitigation recommendations. Rather than developing new hydrological models, this study examines how mitigation strategies can be implemented to reduce risk while advancing equity. Drawing on stakeholder interviews, community engagement, and spatial analysis of social vulnerability indices such as the Centers for Disease Control (CDC) Social Vulnerability Index (SVI), the report situates flood risk within the broader historical and socioeconomic contexts of Benton Harbor and Milwaukee.

[1] This document is not currently public as of April 2026.

Understanding the histories of Benton Harbor and Milwaukee is critical to ensuring successful flood mitigation that addresses both the environmental risks and the underlying social inequities that these communities continue to face. The disparities in how these cities, and specific areas in each town, experience and manage flooding are rooted in their histories. Their histories are shaped by racial segregation, industrial shifts, and policy decisions that have prioritized some communities while leaving others vulnerable.[1] Addressing compound flooding, therefore, requires attention to both hydrological dynamics and long-standing inequities embedded within the built environment. The following sections connect regional flood science with local contexts, moving from Great Lakes hydrology and infrastructure strategies to the historical and socioeconomic realities of Benton Harbor and Milwaukee. The report then draws on stakeholder input and spatial analysis to develop recommendations tailored to each site.

## *Hazard Exposure in the Great Lakes Region*

Historically, the water level range for most Great Lakes, excluding Lake Superior, has been 6.5 feet.[2] However, climate change is expected to bring both high and low lake level extremes that may surpass the historical record and increase the frequency and intensity of extreme weather events.[7] Regional modeling efforts demonstrate that these interacting drivers alter flood depths, spatial extent, and projected damage outcomes when evaluated together rather than independently. These findings underscore that compound flood events are dynamic and system-based rather than additive. Some researchers have also examined the potential relationship between declining lake ice cover and increased coastal erosion.[2] Reduced winter ice may expose shorelines to greater wave energy during storm events, which could heighten erosion and infrastructure vulnerability in certain nearshore areas.

While these physical dynamics are central to understanding flood risk, their impacts are shaped by social and infrastructural conditions. Redlining, a discriminatory housing practice institutionalized through federal mortgage lending policies in the mid-twentieth century, systematically restricted access to credit and investment in predominantly Black neighborhoods. Segregation and exclusionary land-use policies further concentrated marginalized communities in areas that often received fewer public resources and were less favorably located in terms of flood risk. Over time, infrastructure disinvestment, including deferred maintenance of stormwater systems, shoreline protections, and transportation networks, has contributed to uneven infrastructure performance across neighborhoods. These conditions are not only present in both Benton Harbor and Milwaukee but also extend throughout the GLB and beyond. Bringing a social dimension to the effects and mitigations of compound flooding offers an opportunity to address multiple conditions simultaneously.[3]

Research on hazard exposure and infrastructure provision demonstrates that communities of color and lower-income neighborhoods often face greater environmental risks while receiving unequal levels of protective investment.[1]

Climate adaptation scholarship further concludes that planning approaches relying heavily on property value-based cost-benefit analyses may reinforce existing spatial inequities by prioritizing areas with higher assessed market value.[8] Together, this indicates that flood vulnerability is shaped not only by physical land features, but by historical patterns of governance, resource allocation, and institutional capacity.

Several studies in the Great Lakes region and other regions are exploring the underlying mechanisms of compound flooding, and they emphasize that a well-developed understanding of these mechanisms is crucial for the development of equitable risk-mitigation strategies.[1] Compound flooding in the Great Lakes region, therefore, represents both a hydrological and institutional challenge. Effective adaptation and resilience strategies must account for interacting physical drivers as well as historically uneven infrastructure investment and planning decisions. In this context, resilience encompasses not only flood protection measures but also equitable allocation of resources, coordination across agencies, and the capacity of communities to prepare for, respond to, and recover from compound flood events.

## *Equity Disparity and Historically Underserved Communities*

Flooding disproportionately impacts low-income and minority communities, fueled by systemic disinvestment and inadequate infrastructure; thus, it is essential to consider equity throughout the mitigation planning process. Neighborhoods are not inherently vulnerable; rather, they occupy built environments shaped by planning policies, segregation, and long-term patterns of disinvestment.[1] Infrastructure condition, maintenance, and distribution are reflections of broader social and political processes.

Climate equity scholarship similarly emphasizes that mitigation and adaptation planning must account for structural inequities. There are three critical approaches to climate equity: recognizing marginalized groups, including them in planning processes, and distributing benefits and burdens, explored through the lens of social vulnerability and environmental justice.[8] Social vulnerability refers to how one's positionality (i.e., race and income status) influences or is influenced by access to resources before, during, and following a disaster.[1,6]

Historical planning practices play a central role in shaping contemporary vulnerability. Vulnerable neighborhoods often exist in built environments that have been historically underserved by local, state, and federal planning.1 Discriminatory housing policies and patterns of racial segregation, including redlining, limited investment in certain neighborhoods; these patterns have contributed to disparities in housing quality, municipal tax bases, and infrastructure maintenance.[6] Areas with higher proportions of Black residents were frequently designated as "hazardous," restricting access to credit and limiting public and private investment. Such policies contributed to segregated development patterns, reduced tax bases, and infrastructure systems in disrepair.[1]

Low-income and minority populations are placed at perpetual risk of flooding as they inherit housing and sewage systems with poor infrastructural integrity, which are often in more flood-prone areas.[1] Over time, neighborhood-level disinvestment has affected stormwater systems, sewer capacity, road conditions, and other forms of critical infrastructure that influence flood exposure and recovery outcomes.

Empirical research supports the link between infrastructure provision and hazard disparities, where infrastructure is described as a mechanism that can either mitigate environmental threats when adequately maintained or exacerbate exposure when degraded or under-resourced.[1] Unequal protection emerges not only from geographic proximity to hazards but also from uneven investment in protective systems such as stormwater networks, drainage capacity, and flood control measures.

An evaluation of national flood adaptation programs reveals that benefits, such as financial protection, are not evenly distributed across communities in the United States. Studies show that cumulative savings from flood insurance policies can be substantially higher in predominantly white communities than in communities of color.[14] Differences in mitigation investment, property valuation, and policy participation contribute to unequal long-term financial outcomes across racial groups.[14] These findings indicate that flood risk and recovery are mediated not only by hydrological conditions but also by institutional and market structures.

Within the Great Lakes Basin, spatial analyses of flood exposure and social vulnerability demonstrate that areas with higher concentrations of low-income and minority populations often overlap with zones of elevated flood risk.[6] When considered alongside research on unequal infrastructure provision and mitigation funding allocation, these findings indicate that flood exposure and recovery capacity are shaped by both hydrological conditions and historical planning and investment decisions.[1,8] Therefore, equity disparities in flood risk are rooted in structural conditions embedded within land use policy, infrastructure investment, and funding mechanisms. Effective mitigation planning, therefore, requires attention to infrastructure conditions, funding eligibility criteria, and community participation, in addition to hydrological modeling and hazard assessment.

## *Gray and Green Infrastructure*

Flood mitigation strategies generally fall into two categories, traditional gray and green, yet both are typically implemented with the intention of reducing the social and economic burden of climate change impacts.[3] Gray infrastructure includes stormwater infrastructure, storm surge barriers, levees, and seawalls, while green infrastructure includes measures such as permeable pavement, detention/retention ponds, and rain gardens.

Gray infrastructure is typically designed around defined performance thresholds to rapidly convey water away from developed areas or prevent water from entering

protected zones.[9] When properly designed and maintained, these systems can provide reliable protection against high-intensity rainfall and storm surge events and can reduce direct exposure to floodwaters. Large-scale structural interventions may be particularly important in densely developed areas where space constraints limit alternative options. Given their impermeable nature, hardened countermeasures can also exacerbate the negative impacts of flooding, and the forecast of increased storm intensity raises concerns.[10] In some cases, gray infrastructure neglects the underlying mechanisms and thus simply relocates the problem. For example, sea walls can cause coastal erosion along coastlines near them.[11] Moreover, structural systems can be expensive to construct and maintain, may have long design lifespans that reduce adaptability, and may transfer risk spatially if not carefully integrated within watershed-scale planning frameworks.[3]

Green infrastructure approaches are designed to slow and store stormwater closer to its source by mimicking natural hydrological processes, thereby reducing runoff and removing contaminants. Empirical studies of green infrastructure have demonstrated its ability to deliver valuable co-benefits, such as reducing peak runoff volumes during moderate precipitation events and improving water quality through filtration and nutrient retention.[9] Survey data from the American Society of Landscape Architects indicate that green infrastructure projects frequently reduce or maintain comparable overall costs relative to traditional stormwater approaches when lifecycle considerations are included.[12] At the same time, studies also identify performance constraints: infiltration-based systems may be less effective under extreme rainfall intensity, prolonged saturation, or high groundwater conditions, particularly in regions experiencing elevated lake levels.[2] Other challenges with green infrastructure implementation surround their suitability for predicted precipitation intensity, as well as the lack of necessary space in densely populated regions.[3] Decision-makers, such as city planners or politicians, often misperceive green infrastructure as less cost-effective or riskier than gray infrastructure, in part due to a lack of public knowledge of green infrastructure.[7]

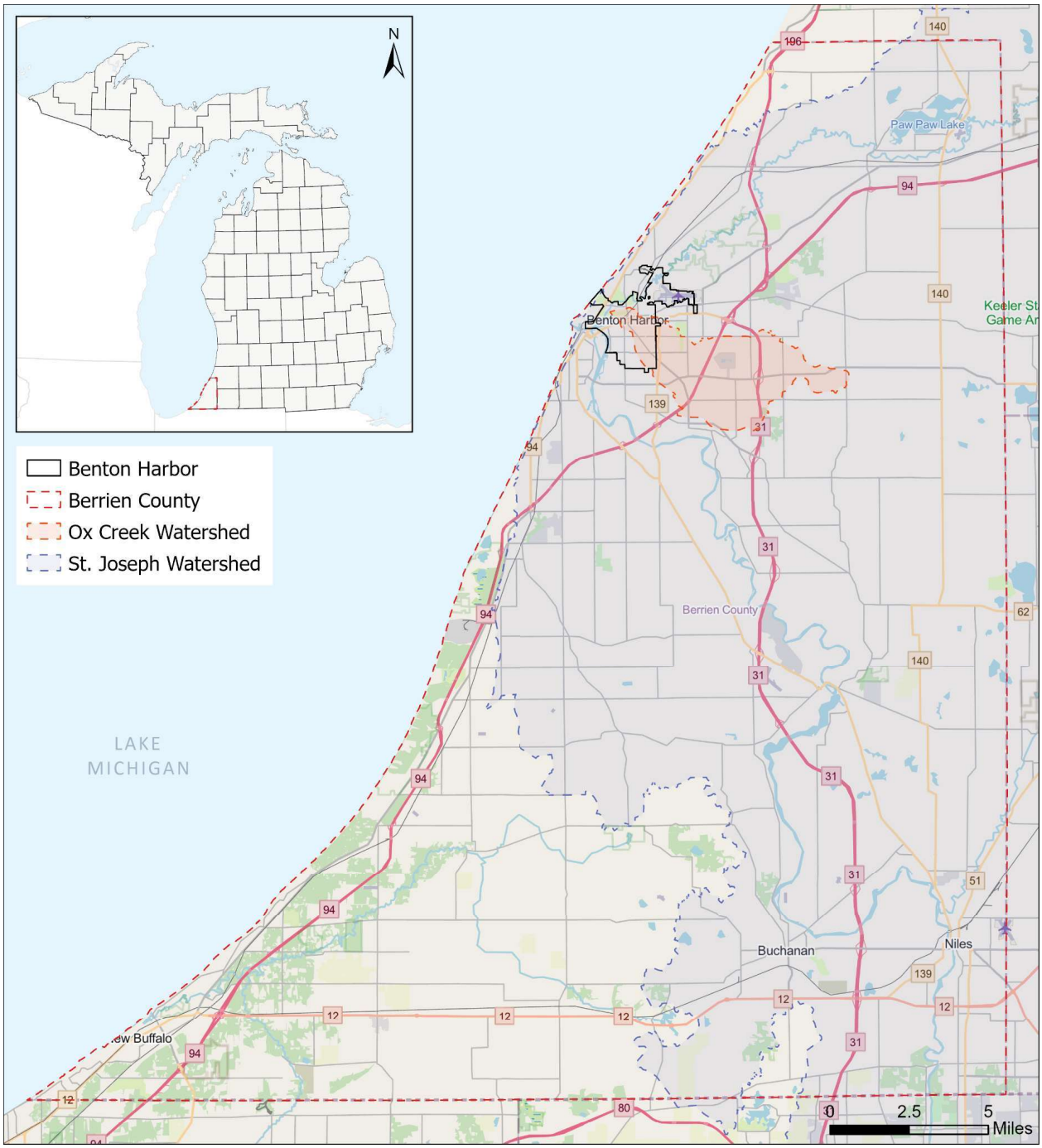
Under compound flooding conditions, infrastructure performance may be affected by interacting and intertwined drivers. Modeling conducted under the USCRP project demonstrates that simultaneous high lake levels, elevated river discharge, and heavy precipitation can alter flood depths and spatial distribution, rather than in single-driver scenarios. In such contexts, gravity-driven gray systems may experience reduced discharge capacity when downstream water levels are elevated, while infiltration-dependent green infrastructure may be constrained by saturated soils or elevated groundwater tables.[2] This suggests that infrastructure performance under compound scenarios should be evaluated based on combined stressors rather than on isolated events such as rainfall.

Infrastructure decisions also carry governance and equity implications. Large structural projects often require substantial upfront capital investment and long-term maintenance commitments, frequently relying on federal funding mechanisms tied to projected economic damages avoided.[3] Research on unequal

protection indicates that reliance on property value–based cost–benefit analysis may prioritize areas with higher assessed market value, potentially reinforcing existing sociospatial inequities in hazard protection.[1,8] Conversely, distributed green infrastructure investments may require sustained coordination across municipal departments and ongoing maintenance at smaller spatial scales, which can present implementation challenges in fiscally constrained jurisdictions.[9]

Though the application of green infrastructure has been growing in the U.S. over the past two decades, there are contexts in which relying solely on either approach becomes limiting. This suggests that investment in approaches combining nature-based and gray infrastructure may be most effective.[11,13] Rather than assuming inherent superiority of one strategy, several studies recommend evaluating infrastructure portfolios based on lifecycle costs, maintenance feasibility, performance under compound stressors, and alignment with equity objectives.[3,8] In practice, many jurisdictions consider integrated strategies that combine structural and nature-based measures to balance reliability, flexibility, and long-term resilience.[2]

## *Berrien County and Benton Harbor, Michigan*




(a)




(b)

**Figure 2.** (a) Reference map of Berrien County; (b) Reference map of Benton Harbor. State polygon data from Esri Training Services (2018); Ox Creek Watershed data from Jill Plescher/Southwest Michigan Planning Commission (2023); Great Lakes polygon data from Michigan State University Online ArcGIS via Great Lakes Aquatic Habitat Framework (2024); City polygon data from U.S. Census Bureau (2025); St. Joseph Watershed polygon data from Michigan Department of Environment, Great Lakes, and Energy (2026); County polygon data from Michigan GIS Open Data (2026).

The city of Benton Harbor is situated in Berrien County (Figure 2), in southwest Michigan along the eastern shoreline of Lake Michigan. The county contains a mix of rural townships, small cities, and coastal communities shaped by agriculture, manufacturing, and lake-based tourism. Its hydrology is defined by multiple river systems that discharge into Lake Michigan, including the St. Joseph River watershed, which drains a large multi-state basin before entering the lake. Variability in Lake Michigan water levels and precipitation patterns affects river discharge capacity throughout the county, particularly in low-lying areas near river mouths.

Benton Harbor sits on low-lying marshland at the confluence of three rivers: the Ox Creek, the Paw Paw River, and the St. Joseph River, which drains into Lake Michigan. When total or regional water levels in Lake Michigan are high, river levels rise as well. When high water levels are combined with precipitation, compound flooding becomes a frequent threat. According to the Total Maximum Daily Load report for Ox Creek, developed as required under the federal Clean Water Act, Ox Creek has one of the fastest flash-flood times in the state.[15] The report attributes this elevated flashiness in part to land cover characteristics, urban development, and reduced infiltration. Parts of the creek in Benton Township have been paved over, and parts of the floodplain and a local canal that leads from the St. Joseph River into downtown Benton Harbor have also been developed, leading to limited water drainage.[16]

According to the 2020 Census, Benton Harbor currently has a population of just under 9,000 residents, approximately 80% of whom identify as Black.[17] Michigan overall has a 14.1% Black population among 10,127,884 residents as of July 2025.[17] Additionally, the 2020 Census states that 41.9% of Benton Harbor's population lives below the poverty line, with a median household income of $29,652 compared to $72,875 for the state of Michigan. Benton Harbor has a crime rate 3.5 times higher than the national average.[18]

This demographic profile reflects a significant transformation over several decades from its early prosperity, largely shaped by historical economic shifts, racial segregation, and urban policy decisions, including urban renewal and attempts to recapture the city's industrial past. These indicators reflect long-term economic restructuring and population change over several decades and are relevant to municipal fiscal capacity and service provision. Established in 1891, Benton Harbor emerged alongside its neighboring city, St. Joseph. Initially, Benton Harbor experienced explosive growth and prosperity, largely driven by its robust industrial base, strategic geographic position near major transportation routes, and railroad connections.[19] In the 1960s, the U.S. Census data reported that Benton Harbor had a population of 19,136, its historical high. Early economic activity included fruit farming, carpentry, electrical infrastructure development, and trade via a locally founded steamship company, which facilitated commerce and visitor exchange with major cities such as Chicago.[19]

However, after World War II, Benton Harbor faced substantial economic downturns marked by rapid declines in manufacturing. Whirlpool Corporation, a major industrial employer headquartered in Benton Harbor, significantly reduced its local operations during this period, exacerbating unemployment and economic instability.[20] The period between 1965 and 1975 saw the closure of at least 69 local businesses in Benton Harbor, further accelerating economic decline.[21] In the 1970s, a predominantly Black neighborhood of workers known as "The Flats" was demolished in the name of urban renewal policies, and its residents moved into White neighborhoods.[22] This forced integration, combined with economic struggles, declining schools, and increased crime, heightened racial tensions and led to white flight, dramatically reshaping Benton Harbor's demographic and social landscape.[22] During this decade, an overwhelming number of White families relocated away from Benton Harbor, contributing to stark racial segregation and socio-economic disparities that persist today. This contributed to the economic decline that continued into the late 20th and early 21st centuries.

By the early 2000s, multiple revitalization efforts had already stalled, and major businesses had closed, triggering widespread community frustration.[21] Leading up to this period, efforts were made to entice developers and traffic to Benton Harbor, but these attempts failed, and the new infrastructure was abandoned.[22] Tensions culminated in public unrest and riots in 2003, reflecting profound dissatisfaction with city management, policing practices, and perceived neglect by authorities.[23] The State of Michigan imposed an emergency management system on Benton Harbor from 2010 to 2012, focusing primarily on fiscal responsibility and tourism-oriented development.[22] However, the actions of the emergency manager only increased tensions in a municipal government as the emergency managers stripped assets such as water and land service and city pensions from a city that was already suffering from instability due to a high staff turnover rate and gutted municipal infrastructure to balance the budget.[22]

Benton Harbor's environmental challenges have further complicated its situation, largely due to the cost and logistical challenges of addressing aging industrial infrastructure that needs to be remediated or replaced, such as the Benton Harbor water pipes, which recently underwent the removal and replacement of lead pipes. The city's industrial past has led to the presence of industrial contaminants in Ox Creek and the Paw Paw River, and the need to remediate brownfield sites that contain asbestos and some PCP (pentachlorophenol) within the city–a prohibitively expensive process–before they can be redeveloped.[24] Much of the money to address these issues must come from external grants or developers.

Public health and infrastructure challenges have also shaped Benton Harbor in recent years. The Benton Harbor Drinking Water Study documents exceedances of the EPA Lead and Copper Rule action level in municipal water samples and identifies aging service lines and distribution system components as contributing factors.[25] The report describes sampling conducted in 2021 that detected elevated lead concentrations in residential tap water, prompting expanded monitoring, corrosion control adjustments, and accelerated lead service line replacement

efforts.[25] The study further notes that legacy infrastructure, including older housing stock and historical pipe materials, increased the complexity and cost of remediation.[25] State and federal emergency funding was mobilized to support bottled water distribution, filter provision, and large-scale service line replacement, underscoring the financial burden associated with deferred infrastructure maintenance in a fiscally constrained municipality.[25] These conditions illustrate the intersection of environmental exposure, infrastructure age, and municipal capacity.

In light of these challenges, efforts to improve the local ecosystem and reduce climate hazards are underway. Benton Harbor's Ox Creek Revitalization Plan is a product of a broader, collaborative initiative coordinated by the Southwest Michigan Planning Commission and the city of Benton Harbor. This initiative brings together local governments, community organizations, and other stakeholders to address flooding and water quality issues in Benton Harbor. The plan outlines nature-based solutions and green infrastructure strategies to improve stormwater management, reduce pollutant loads, and restore habitat connectivity. These efforts reflect the partnership's commitment to equitable, community-driven approaches and align with Michigan Sea Grant's mission to build climate resilience while promoting social and economic equity.

In addition to addressing environmental concerns, the city has undertaken efforts to attract new development, which have met with some success but have also evoked concerns among residents. Recent development projects, notably the Harbor Shores golf course, which opened in 2010, have sparked intense debates over gentrification and public access. This extensive $500 million project, partly built on Benton Harbor public land at Jean Klock Beach and on portions of previously industrial and public land, has raised critical concerns about equity and the displacement of longtime residents.[22] The development includes a golf course, residential units, and hospitality amenities intended to attract tourism and stimulate economic growth. While these developments offer economic potential through tourism, these advantages have not been equitably distributed within the existing Benton Harbor community, further highlighting stark disparities and continued socio-economic divides.[22]

The city's history shapes the problems it grapples with today. Trade and manufacturing, once the city's predominant economic forces, have declined since the 1970s, and the city now faces a smaller tax base, legacy contamination, and a history of governmental disarray. Despite these setbacks, the City of Benton Harbor is now undertaking efforts to restore public green space, attract economic development, and protect against environmental hazards such as pollution and flooding.

## *Milwaukee, Wisconsin*

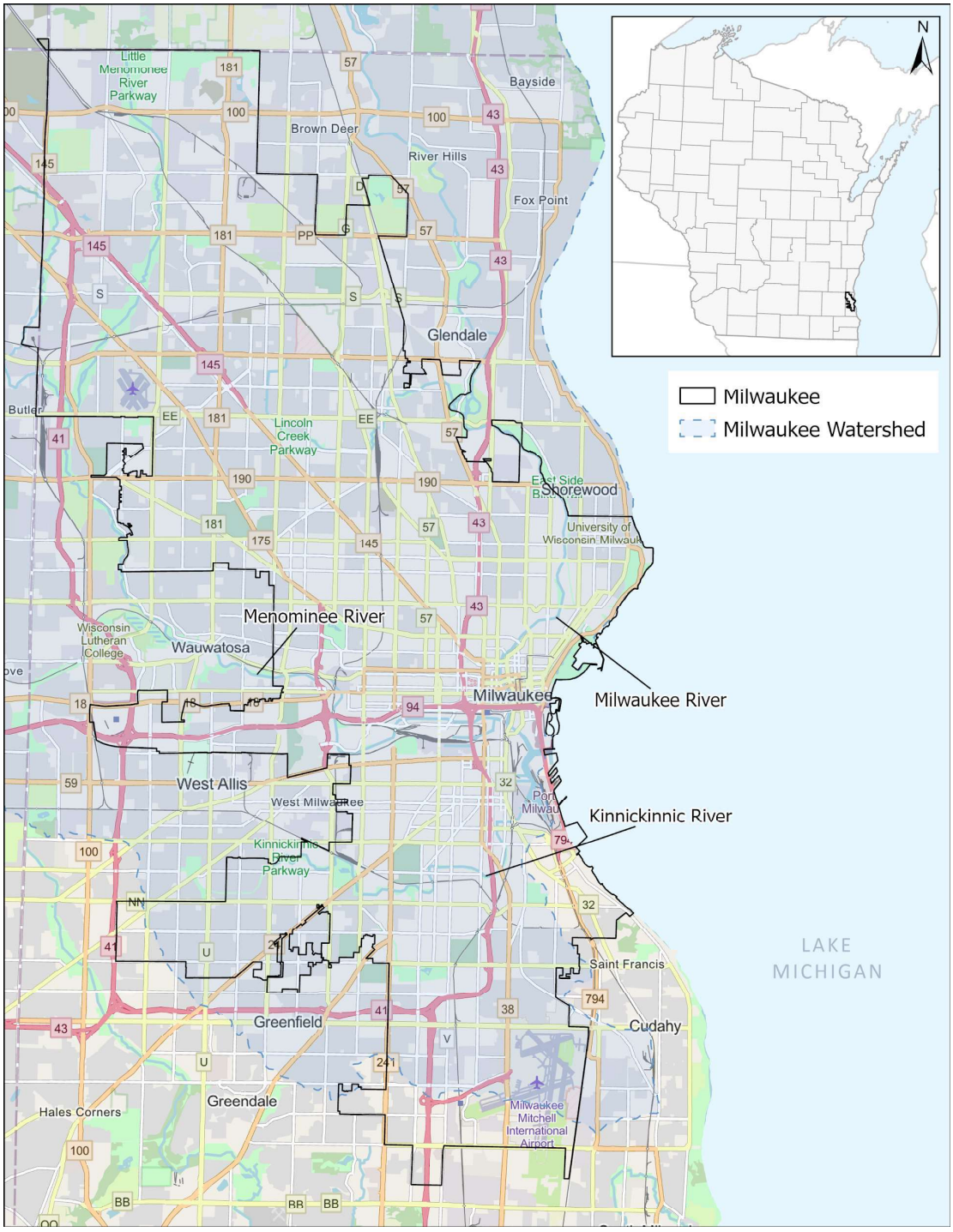



**Figure 3.** Reference map of Milwaukee. County polygon data from Wisconsin Department of Natural Resources (2017); State polygon data from Esri Training Services (2018); City polygon data from the U.S. Census Bureau (2025). Watershed polygon data from Wisconsin Department of Natural Resources (2024); Great Lakes polygon data from Michigan State University Online ArcGIS via Great Lakes Aquatic Habitat Framework (2024).

Milwaukee, Wisconsin, lies on the western shore of Lake Michigan (Figure 3) and was built around a low-lying harbor, which is crucial to its importance as a shipping and manufacturing hub. Milwaukee's ability to easily host a protected harbor is provided by its lowland position at the confluence of the Milwaukee and Kinnickinnic Rivers. First founded in the 1830s, several industries flocked to Milwaukee, including flour milling, meat processing, tanning, and brewing, shortly followed by iron and steel production and related heavy industry.[26]

The city's urban evolution, particularly from 1880 to 1910, transformed Milwaukee from farmland into an industrial hub, and the population grew quickly, fueled by an influx of workers. Neighborhoods primarily occupied by working-class immigrants often suffered delays in essential urban services like sewers, paved streets, and water mains, whereas wealthier areas benefited from timely infrastructure development.[26] In 1910, Milwaukee had the twelfth largest population of any American city, was tied with New York City for the largest percentage of immigrant workers, and had the second-largest percentage of the male workforce engaged in manufacturing, just behind Detroit.[27]

Like Benton Harbor, Milwaukee experienced economic decline after WWII, and tensions in the city, exacerbated by discriminatory policies, led Milwaukee to become one of America's most racially segregated cities.[28] Such socioeconomically stratified urban planning laid the foundation for persistent inequalities that are visible today. According to the 2020 census, Milwaukee has an estimated population of 561,385, with a diverse racial composition: approximately 36.5% of residents identify as White alone, 38.6% as Black alone, 4.8% as Asian, and 20.7% as Hispanic or Latino. The city has an average household income of $51,888, compared to $77,485 for the state of Wisconsin.[29]

Black communities in Milwaukee face significant challenges, highlighted by Wisconsin holding the nation's highest incarceration rate for Black residents, and more than half of Black men in their 30s to 40s in Milwaukee County have served time.[30] This disparity is deeply rooted in historical policies like redlining, involving discriminatory practices by government agencies and financial institutions that systematically denied mortgage loans, insurance, and other financial services to neighborhoods with significant minority populations.[31] These neighborhoods were often labeled as "hazardous" or "undesirable" for investment, predominantly affecting Black and Latino communities, which perpetuated stark differences in wealth, homeownership, and overall quality of life. In Milwaukee, industrial pollutants, such as lead and airborne toxins, linger and are more prevalent in low-income neighborhoods near industrial plants.[32] PFAS chemicals have been found in waterways, and the city is currently working on a method to quantify and address the contaminants.[33]

These systemic and infrastructural inequities exacerbate the impacts of climate change-related hazards. The City of Milwaukee acknowledges flooding as one of the top three significant climate hazards that are expected to worsen over the next few decades.[34] In its planning efforts, the city also acknowledges the value of equity

and the need to address the harms caused by historical redlining and neglect, and particularly the need for equitable distribution as Milwaukee invests in infrastructural improvements to fight climate hazards. Flooding is no exception to this pattern, and a 2024 mapping project reveals that many neighborhoods with high social vulnerability in Milwaukee are prone to flooding: approximately 47,800 residents live in areas that are identified as having both high social vulnerability and high flood exposure.[35] Between 2000 and 2018, the Milwaukee Metropolitan Sewerage Department estimates that 12 storms produced significant flooding and cost millions in damages, and in August of 2025,[36] a two-day storm caused record rainfall and flooding across the city, exceeding the city's 5.14 billion-gallon flood overflow capacity by nearly two billion gallons and causing drain backups in over a thousand homes.[37]

Most of the city's flood planning is managed by the Milwaukee Metropolitan Sewerage Department (MMSD). MMSD has developed a strategic plan for integrated watershed management for the six watersheds within its service area.[33] Flood management projects are already underway, with an emphasis on green infrastructure and restoring paved waterways. MMSD has developed detailed analyses of management options, such as the Kinnickinnic River Flood Management Plan, published in 2017, which outlines 14 mitigation options for seven waterways along the river.[38] Though this particular plan includes public involvement, it does not address how considerations of equity may vary between mitigation options.

Both the City of Milwaukee and MMSD recognize the importance of partnerships with other local organizations.[34] MMSD has established a green infrastructure plan in partnership with ECO, the City of Milwaukee's Environmental Collaboration Office, and has established the Fresh Coast Guardians as a centralized partnership with residents who seek to protect Milwaukee's watersheds, through which MMSD encourages citizens to get involved in planning efforts and install their own green infrastructure projects.[33] These plans and collaborative efforts lay the groundwork for future planning and equity efforts.

Historically, many urban waterways in Milwaukee were straightened, cleared, and lined with concrete, exacerbating flash flooding and ecological degradation. The city relied on a large underground storm sewer system, which has since been difficult to maintain and expand.[39] Since the early 2000s, Milwaukee has pivoted from this gray infrastructure-based approach to stormwater management to a green infrastructure approach guided by MMSD. The City has actively implemented urban green infrastructure and nature-based solutions, such as rain gardens and bioswales, designed to capture stormwater runoff, naturally filter pollutants, and reduce stress on municipal sewer systems.[35] Other strategies, such as green roofs, permeable pavements, and wetland restoration, are also critical measures Milwaukee has implemented. Despite these comprehensive strategies, the distribution of urban green infrastructure in Milwaukee remains uneven. Historically underserved neighborhoods continue to experience disparities in

access to these vital environmental improvements, emphasizing the necessity for equitable and inclusive planning in future urban development initiatives.[35]

Milwaukee and Benton Harbor, despite their differing population sizes, resemble each other in several key ways. For example, both are located on low-lying river systems near Lake Michigan, and both are home to minority populations that have experienced historical disinvestment. Both are still recovering from the loss of industry and population in the 1960s and 70s. These contextual similarities enable comparison of potential flood mitigation strategies going forward.

## *Project Significance*

This project aligns with and enhances Michigan Sea Grant's (MISG) mission to support healthy, sustainable, and accessible Great Lakes ecosystems and communities that depend on them. MISG's cooperative work with the National Oceanic and Atmospheric Administration (NOAA) provides the public with access to science-based information about Michigan's coasts and the Great Lakes. MISG's work in Benton Harbor and Wisconsin Sea Grant's work in Milwaukee, including this project, fall within a long-term NOAA effort to help communities make informed decisions rooted in the most widely accepted scientific and environmental practices to improve coastal resilience.

MISG's efforts to focus on underserved communities are emphasized in its selection of Berrien County for an analysis of flooding risk and mitigation. This parallels WISG's existing work in Milwaukee. These Great Lakes communities face increasing flood risks due to climate change, aging infrastructure, and systemic disinvestment. While NOAA and other researchers provide essential forecasting and modeling resources, this project ensures that the data is accessible and actionable for local decision-makers, particularly in underserved communities.

This project builds on previous flood risk and infrastructure assessments conducted in the region, including efforts by state and local agencies, academic institutions, and nonprofits. However, unlike existing models that often prioritize engineering solutions without fully accounting for social vulnerability, this project goes further by introducing an integrated framework that combines physical flood risk with socioeconomic equity in decision-making. The key differentiators of the research approach include:

- Assessing equity in flooding infrastructure investments by mapping risk in historically marginalized neighborhoods and analyzing whether mitigation measures are equitably distributed.
- Bridging the gap between data and community action by making flood projections more accessible and actionable for local leaders and residents.
- Prioritizing green infrastructure solutions that reduce environmental harm while offering long-term resilience benefits as desired by the community.

- Engaging local stakeholders directly to ensure that the solutions recommended are both feasible and aligned with community needs, avoiding top-down decision-making that has historically neglected vulnerable populations.

By building on past work and deepening its scope, this project ensures that flood mitigation efforts not only protect communities physically but also address long-standing systemic inequities in infrastructure investment.

The methodologies and frameworks developed in this project will have implications beyond the Great Lakes region. Coastal communities face similar challenges of balancing flood mitigation with social equity. This project provides a replicable model for assessing and implementing equitable flood resilience strategies.

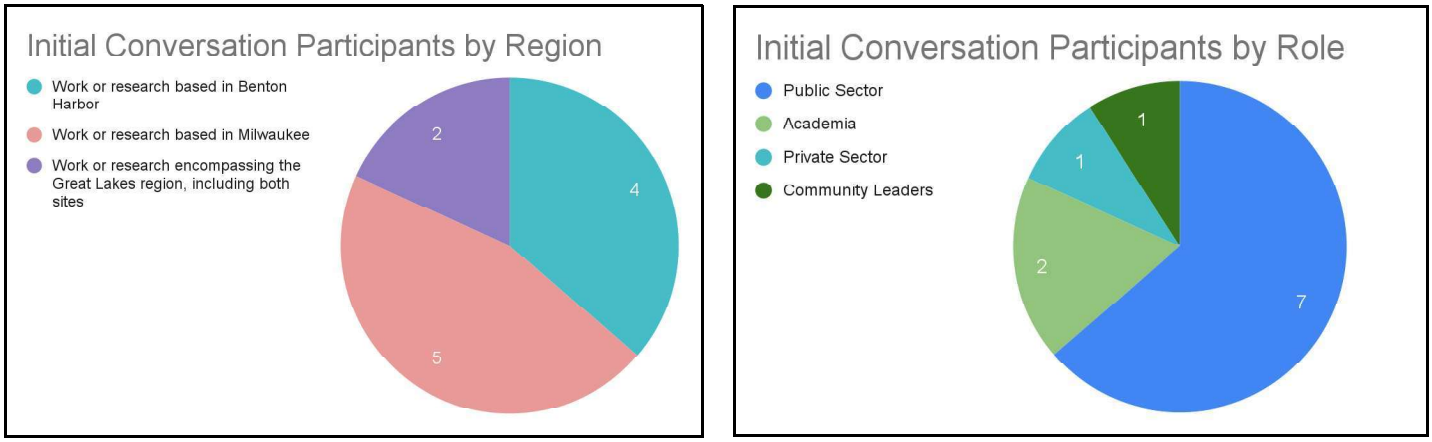
More broadly, this initiative contributes to the fields of environmental justice and climate adaptation by demonstrating how participatory research, probabilistic modeling, and policy engagement can be combined to pursue equitable flood resilience planning. The community engagement strategies used in this project can be applied to other climate resilience efforts, ensuring that underserved populations are not disproportionately affected by climate change. Understanding future flooding and storm scenarios, the effectiveness of various flooding countermeasures, and the optimal placement of flooding infrastructure to reduce vulnerability will help cities along Lake Michigan better prepare all their residents for future climate realities.

# Methods

## *Initial Stakeholder Conversations*

Between March and April of 2025, the research team conducted 11 initial stakeholder conversations. In several cases, team members conducted these conversations in conjunction with a University of Michigan PhD student, who currently works with a Berrien County stakeholder on a participatory GIS project in both Benton Harbor and Milwaukee. Stakeholders were identified through existing MISG and University of Michigan connections and contacted via email.

During these conversations, one to three team members spoke informally with a stakeholder actively working on flood mitigation or adjacent projects in Benton Harbor and Milwaukee. These stakeholders included researchers, city planners, nonprofit leaders, and project managers (Figure 4). While the conversations were informal, they loosely followed a conversation protocol (Appendix A) designed to gather guiding information on: the nature of their role; key areas of concern; flooding impacts; the extent of public input in decision-making; potential resources for a literature review; and potential local leaders, experts, and community members for the semi-structured interviews that followed.




(a) (b)

**Figure 4.** (a) Breakdown of initial conversation participants by region; (b) Breakdown of initial conversation participants by role.

During each conversation, one team member took detailed notes. The notetakers then summarized these notes in alignment with the initial conversation protocol and extracted recurring themes. Finally, the team compiled the shared names and contact information into a spreadsheet. This method of gathering potential interviewees, known as snowball sampling, was also used during the semi-structured interviews. Keeping the recurring conversation themes in mind, the team then crafted semi-structured interview protocols and a plan for further community outreach.

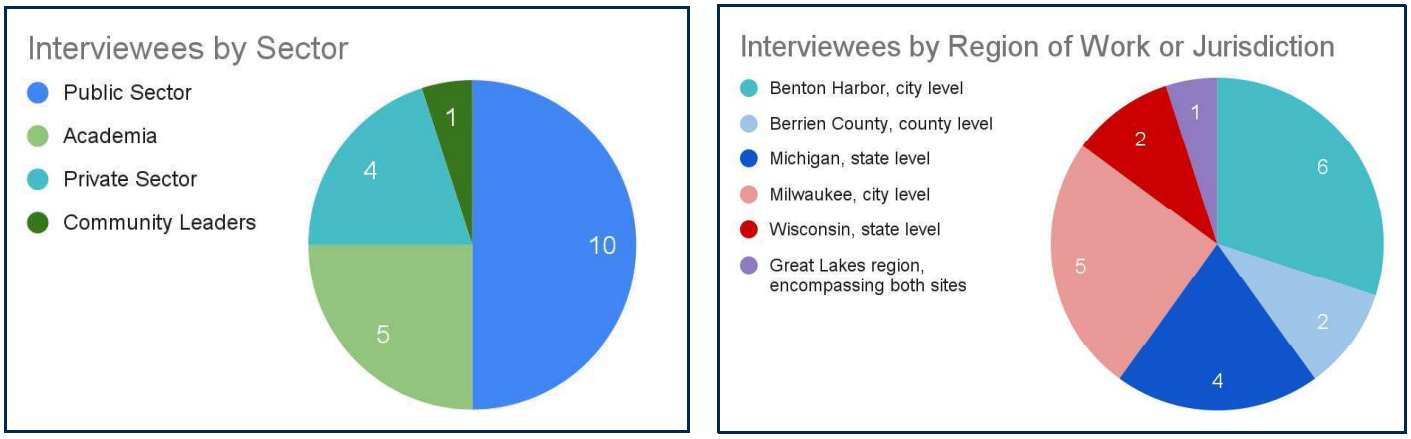
## *Semi-structured Interviews*

The research team conducted 20 interviews with a broader range of city planners, nonprofit leaders, researchers, engineers, and others involved in flood mitigation or adjacent urban planning projects, or with specialized knowledge of the project sites. Some of these participants were also stakeholders with whom the team held an initial conversation and/or are residents of the city whose work involves planning or water management. The goal of these interviews was to gather a large range of expert perspectives on flood mitigation options, past community engagement outcomes, and the technical concerns and ongoing mitigation efforts in Berrien County and Milwaukee.

Reaching out to stakeholders began with an interview request, followed by additional emails, including initial outreach and follow-ups as needed. Snowball sampling yielded 54 potential interviewees. Of these 54, team members interviewed 20 via Zoom. Five people declined to participate, and 29 did not respond to an interview request or follow-up.

Of these 20 respondents, 10 worked in the public sector, 5 had an academic background in flooding mitigation or related issues, 4 worked in relevant areas of the private sector, such as engineering, and 1 led a community organization

working on local flooding issues. Twelve individuals were based in Michigan, including both Berrien County and Benton Harbor; seven were based in Wisconsin, including five based in Milwaukee; and one worked throughout the broader Great Lakes region (Figure 5).




(a) (b)

**Figure 5.** (a) Breakdown of interviewees (respondents) by sector; (b) Breakdown of interviewees (respondents) by region of work or jurisdiction.

Before conducting the interviews, the project obtained an exempt status from the University of Michigan's Health Sciences and Behavioral Sciences Institutional Review Board.[2] The interviews were roughly 1 hour in length, conducted with 1 to 2 team members at a time, and audio was recorded with the respondents' prior consent. The interviews followed a script to provide comparable data regardless of background (Appendix B). In general, the interviewers asked participants about their roles, top priorities for flood mitigation, preferred mitigation methods, existing and potential barriers to flood mitigation, community engagement methods, and their definition of equity in this context (Appendix B).

The team generated transcripts from each interview recording using the software Rev and cleaned them by having two team members manually correct any words or phrases misunderstood by the software. Team members then imported these transcripts into the qualitative coding software Dedoose. Each transcript was carefully coded by one to two members, then later reviewed and, if necessary, edited by another two team members.

A few of the parent codes within the codebook are inspired by the work of former School for the Environment and Sustainability (SEAS) Master's student, Abigail Merolle, whose research resulted in a set of codes surrounding coastal flooding in Lake Michigan communities.[40] The alterations to her codebook include questions specific to urban areas and codes relating to community outreach. The final codebook encompasses infrastructure and environmental conditions that can impact flooding, damages, and disruptions that occurred due to flooding, and the

[2] https://hrpp.umich.edu/irb-health-sciences-and-behavioral-sciences-hsbs/

sites on which they occurred, as well as mitigation techniques that interviewees preferred or knew to be preferred by community members, and the planning techniques and challenges surrounding flood mitigation (Appendix C). Code counts reflect the frequency with which codes were applied across interviews and indicate relative salience and emphasis rather than statistical prevalence or causal weight. The analysis focuses on how flooding is understood, experienced, and acted upon by practitioners operating within distinct historical, ecological, and governance contexts.

## *Site Visits and Community Outreach*

The team traveled to Benton Harbor four times over the course of the project. Each visit had a different purpose (see Table 1), with the overarching goal of informing recommendations for Benton Harbor and advancing inclusivity through stakeholder and community member engagement.

The original plan was to use a survey to maximize participation, and the team proceeded with this approach during the first three visits. However, the survey response rate was very low, and the approach soon pivoted to informal conversations with community members (Appendix D), with the intention that face-to-face interactions would encourage them to share their experiences.

**Table 1.** Site visits, dates, and purpose(s) (excluding the Berrien County Stakeholder Advisory Board meeting).

| Event | Date | Purpose(s) |
|---|---|---|
| Ox Creek Earth Day Clean-Up | April 26, 2025 | • Remove litter from Hall Park with community members<br>• Collect responses on the physical survey<br>• Connect with local leader Dane Rasmussen<br>• View Hall Park renovation progress<br>• Speak informally with community members |
| Benton Harbor Farmers Market | July 30, 2025 | • Hand out QR code for virtual survey<br>• Speak informally with community members<br>• Connect with local leader Deidre Fields |
| The Mindset Show with Ricky Hill | August 22, 2025 | • Share the project's significance and goals with local leader, Ricky Hill, and listeners<br>• Promote virtual survey |

| | | |
|---|---|---|
| (Radio Show) | | |
| All Things Wellness | September 27, 2025 | • Set up and volunteer with Deidre Fields<br>• Speak informally with community members |

Questions for community members covered four categories: residents' concerns about flooding; residents' non-flooding-related concerns; what they want to see from future flooding interventions; and what they most appreciate about Benton Harbor. Team members spoke with five individuals in a semi-structured format, covering these topics, though two more said they had not experienced or knew little about local flooding issues (Appendix D). The interview site was a community center in Benton Heights, near Highland Ave and Fair Ave, which falls within Census Tract 22. This tract is 93% African American and in the 94th percentile for sensitive population and socioeconomic risk factors, according to Michigan EJ Screen. Team members approached event attendees in pairs and captured detailed notes on their responses. Due to the low number of participants and the informal nature of the conversations, a formal coding process was not applied. Instead, the team created a summary of the notes and again extracted recurring themes, with a focus on existing flooding issues and desired countermeasures (i.e., infrastructure).

### *Berrien County Stakeholder Advisory Board Meeting*

As the interview process concluded, the team convened a half-day hybrid meeting with the Berrien County Stakeholder Advisory Board for Coastal Resiliency and stakeholders from Milwaukee in August of 2025 at the Benton Harbor Public Library. The team created a scheduling poll on the Doodle platform, which was shared with stakeholders via email in mid-June.

The team coordinated the event and, with the client and faculty advisor, designed a detailed agenda. This meeting provided the team with an opportunity to share summer research updates and to receive feedback from 18 researchers, developers, and local policymakers who have been professionally involved in flood mitigation efforts in their respective regions for years.

The team began the meeting by posing the query "How might you define equity in flooding mitigation?" to the stakeholders and asking them to share and discuss their definitions. Team members took notes of the ten discussion points raised by the six stakeholders who elected to answer the prompt. Later analysis incorporated the points they raised into the analysis and recommendations. For example, one stakeholder noted that cost-benefit analyses used to evaluate flood risk often skew the risk and, thus, the need for intervention for high-value properties; the team incorporated this information as a factor in the flood risk assessment.

The meeting also included an interactive activity in which the stakeholders were split into small groups, rotated across stations with each of the example countermeasures (Figure 6), and spent 10 minutes writing down pros and cons and generating alternative ideas. The countermeasures included constructing a levee in downtown Benton Harbor, widening Ox Creek, and creating diversions in the creek to allow water to flow during high-flow periods, among others. Their input enabled the researchers to understand the significant benefits and concerns that those most involved in flood mitigation efforts perceived regarding a subset of potential flood countermeasures, and helped inform the final recommendations.

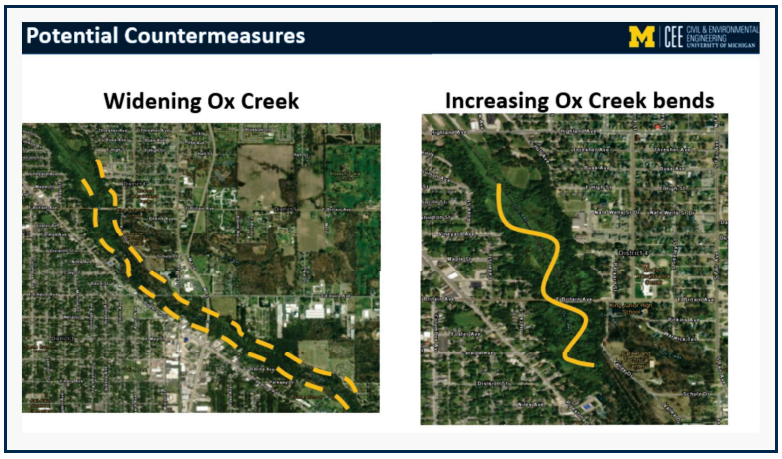



**Figure 6.** Example of proposed countermeasure. Courtesy of Benjamin Nelson-Mercer (2025).

## *Spatial and Socioeconomic Analysis*

The spatial and socioeconomic analysis combined qualitative stakeholder interview data gained from the community outreach with flood modeling and demographic information. This analysis was designed to address the equity component of flood mitigation recommendations. In a geographic context, equity is the distribution of benefits and hazards, explored through the lens of social vulnerability and environmental justice.[8] Flooding vulnerability, as assessed by the Federal Emergency Management Agency's (FEMA) risk factors, contributes to vulnerability from redlining and disinvestment in the majority Black Census Tracts. In the process of gathering qualitative comments on flood risk, the team asked community members about specific locations of flooding and incorporated these areas of interest into this analysis. This gives the geospatial analysis grounding in the community's input as a measure of equity. Social vulnerability data sources were also overlaid with the flood model created by Benjamin Nelson-Mercer to identify areas with high flood risk and high inequity.[3]

The analysis utilized established indices, including the Centers for Disease Control's Social Vulnerability Index (SVI), Michigan Environmental Justice

[3] Data sources: CDC/ATSDR SVI (2022), FEMA Flood Risk CRCI (2024), and the MRLC impervious surface gradient (2024) to identify vulnerability and were both of which are prone to.

Screening Tool (MiEJScreen), and FEMA Community Resilience Challenges Index (FEMA CRCI), which draw from multiple indicators and average percentile ranks to yield a final vulnerability score. These indices provide context for the socioeconomic conditions in Berrien and Milwaukee counties. After examining the individual components of demographic data and various factors, the SVI effectively captured inequities across the study sites. Tract-level demographic data accounts for the variability in vulnerability across counties and illustrates neighborhood-specific dynamics in Benton Harbor, St. Joseph, and Milwaukee.

### *Benton Harbor*

Census Tracts split Benton Harbor city and township into 10 subdivisions, allowing for more thorough and accurate neighborhood analysis than zip-code or county-level data (Figure 7). These tracts were used for identifying vulnerability and overlaid with flood modeling. Tracts 3 and 4 face high levels of vulnerability by most measures, in addition to bordering the St. Joseph River and containing Ox Creek, which both face pronounced flooding.

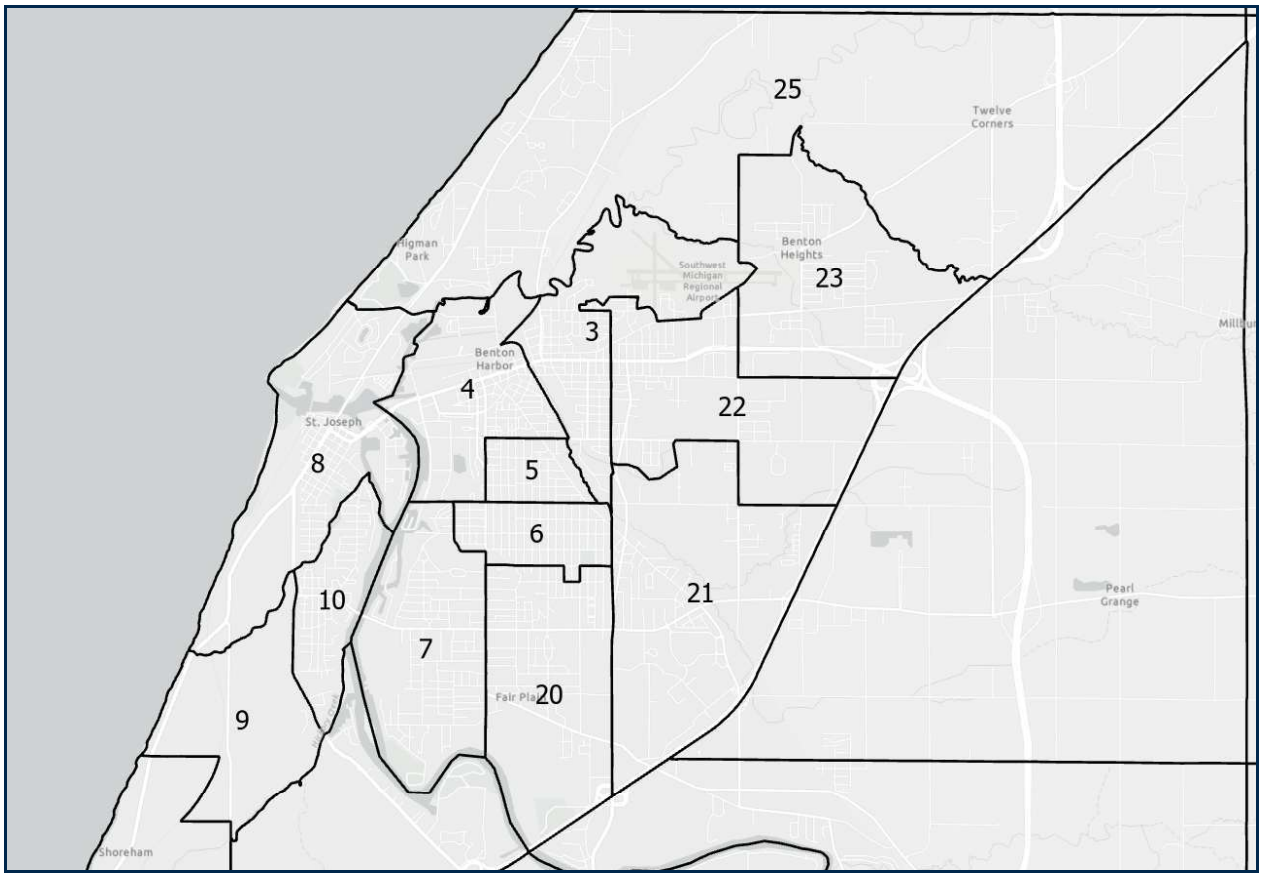



**Figure 7.** Map of Benton Harbor and St. Joseph Census Tracts. Census tract polygon data from the U.S. Census Bureau (2000).

### *St. Joseph and Greater Berrien County*

Other tracts within the county have a low SVI, low flooding risk, or both. When sorted by SVI, 10 of the 53 tracts in the county are in the top 25th percentile for vulnerability, considered “high” by CDC SVI measures. 7 of these tracts are in Benton Harbor, including the top 6 most vulnerable. Census Tracts 8, 9, and 10 comprise St. Joseph, and all rank in the lowest 30th percentile for social vulnerability. These SVI values reinforce a setting of extreme social inequity throughout the county.

### *Milwaukee*

Milwaukee County contains 301 Census Tracts. Stakeholders spoke of the difficulty of working with large community data sets, given the city's size. A short list of 10 vulnerable tracts was identified using the highest rankings (SVI > 0.97) in aggregate vulnerability indices (Figure 8). Detailed information on the history of redlining in Milwaukee and its ongoing effects on socioeconomic conditions is available.[41] Areas with present-day high vulnerability correlate with those marked Hazardous or Declining on a 1938 redlining map. Neighborhoods in the near-central south side, including Mitchell Street (Tract 167), Muskego Way (169), Burnham Park (170), and Lincoln Village (175), all fall within formerly redlined areas. This information was combined with insights from stakeholder interviews about compound flooding. Vulnerabilities and needs for investment on and around the Kinnickinnic River are reflected in current city priorities.

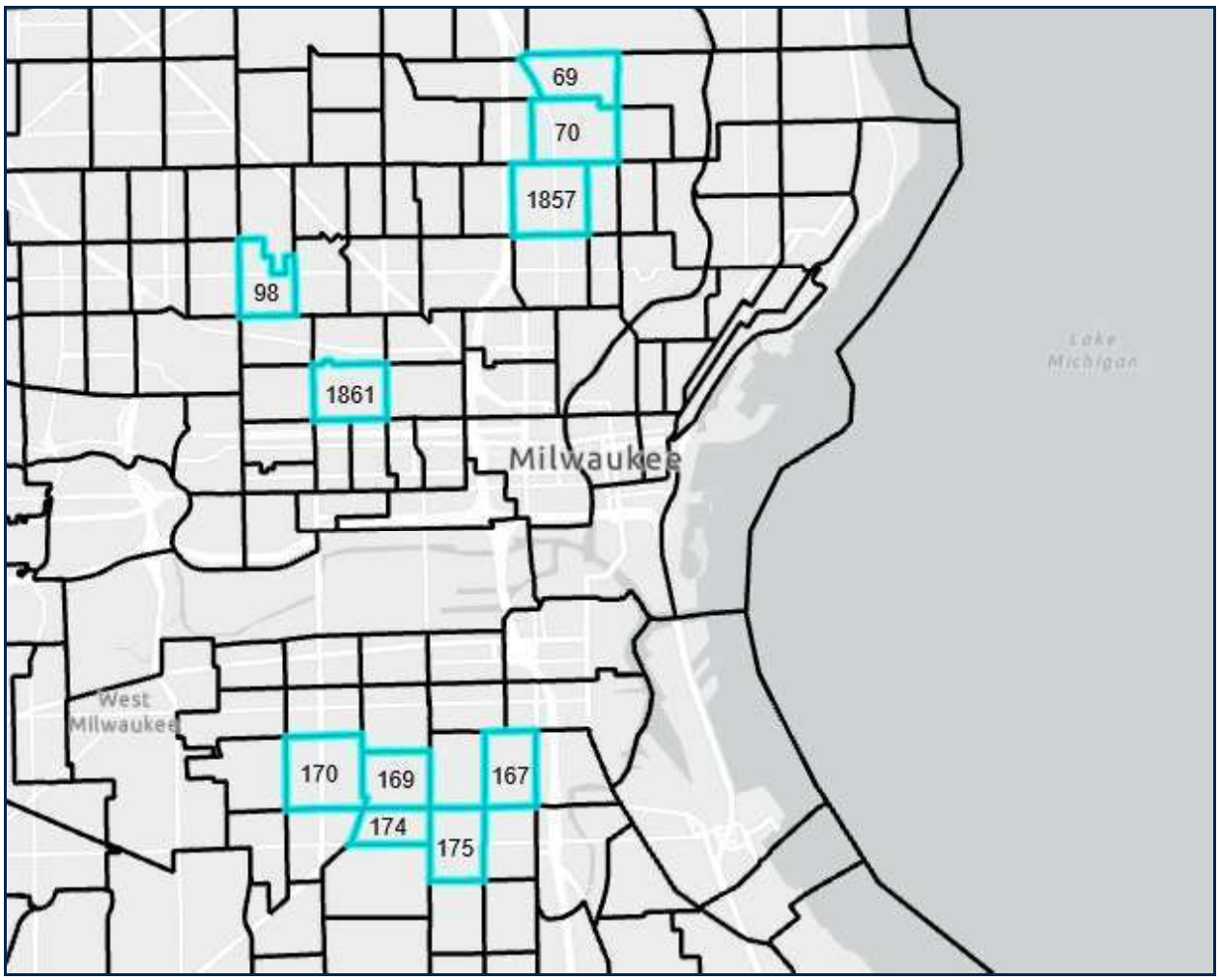



**Figure 8.** Map of highlighted Milwaukee Census Tracts, based on the highest 2022 CDC ATSDR SVI scores (>97th percentile). Census tract polygon data from the U.S. Census Bureau (2000).

Researchers at the CDC developed the Social Vulnerability Index (SVI) using census data.[42] The SVI combines 16 indicators into four themes: socioeconomic status, household characteristics, racial and ethnic minority status, and housing type/transportation. SVI is calculated by converting each data point to a percentile rank (Rank) and dividing by population (N). Normalizing each factor to a scale of 1-100 based on percentiles and averaging the factors results in a unitless SVI between 0 and 1. A low SVI ranges from 0-0.25, low-medium from 0.25-0.50, medium-high from 0.5-0.75, and high from 0.75-1.0, with the highest scores correlating with the greatest vulnerability. The 2022 SVI for Berrien County was 0.6338.[43] For Milwaukee, the SVI was 0.8276.

Key indicators for this analysis included housing burden, residents below the poverty level, racial or ethnic minorities, and the percentage of impervious surfaces. Social vulnerability indicators, including the percentage below the poverty line and housing burden, were higher in Benton Harbor than in St. Joseph

and in surrounding Berrien County tracts. In Milwaukee, a history of redlining has exacerbated disinvestment and inequality. Analysis of tracts aimed to capture the conditions in these two settings and examine how they interacted with flooding risk. Overlaying SVI with flood modeling and impervious surfaces identified hotspots of flood risk and cumulative vulnerability. These hotspots inform the area-specific recommendations for flood mitigation. Taken together, a tract-level analysis informed siting priorities for infrastructure projects that address flooding and alleviate vulnerabilities associated with the greatest climate risks.

# Findings

## *Semi-Structured Interviews*

### *Environmental Causes of Flooding*

**Great Lakes cycle (20 mentions)**

Respondents most frequently mentioned the Great Lakes water-level cycle as a significant environmental driver, framing flooding as a long-term and structurally embedded cyclical condition rather than a series of isolated storm events. Interviewees consistently describe elevated lake levels as a background stressor that reduces drainage efficiency, increases backwater effects, and magnifies precipitation impacts. Several respondents emphasize that recent lake levels fall outside historical norms, attributing increased variability and persistence of high-water conditions to climate change. Flooding is therefore understood as a compound phenomenon in which rainfall interacts with lake-level conditions rather than acting independently.

> *"When you have record high lake levels, you've given the flooding a running head start."*

**Lakeshore Conditions (14 mentions)**

Respondents discussed lakeshore-related flooding primarily in relation to hardened shorelines, aging protective infrastructure, and dense coastal development. Shoreline exposure and hard infrastructure along the coast were commonly identified as sources of erosion, overtopping, and backwater effects. Emphasizing the use of parks and natural spaces along the lakeshore was intended to improve compatibility with flood-prone areas, rather than eliminating flooding.

**Highland/Lowland topography (11 mentions)**

Respondents mentioned elevation as a determinant of where flooding concentrates within both cities. Respondents emphasized that low-lying neighborhoods (including much of Benton Harbor) function as de facto collection points for surface runoff and groundwater, particularly during prolonged wet periods.

**Riverside (9 mentions)**

Respondents identified riversides as areas developed to accommodate industrialization and shipping channels. Respondents mentioned that this industrialized riverside has been degraded by years of neglect and misuse. The riverbanks are eroding, creating a bottleneck and increasing the risk of flooding.

**Groundwater (7 mentions)**

The cities have areas built on wetlands with high groundwater tables. In these areas, respondents mentioned how the ground is spongy and areas with concrete experience flooding when it rains. One respondent expressed frustration that during significant rain events, "there is nowhere for that water to go."

**Floodplain (5 mentions)**

Houses and businesses are built on floodplains. This makes them especially vulnerable to flooding. Respondents explained that much of Benton Harbor's downtown is in a FEMA-designated floodplain.

### *Types of Flooding Impacts*

**Infrastructural impacts (27 mentions)**

Respondents most frequently mentioned infrastructural damage as a significant impact, encompassing roads, culverts, storm drains, and public utilities. Respondents emphasized that much of the existing infrastructure is aging and was not designed to accommodate current hydrological conditions, leading to repeated failures and escalating maintenance costs.

> *"You never want to have asphalt near water because [it] just crumbles and cracks and doesn't do well with exposure to freezing and thawing."*

**Mobility disruptions (13 mentions)**

Respondents discussed road closures, detours, delayed emergency response, and reduced access to essential services. These disruptions were described as particularly consequential for residents without flexible transportation options.

**Economic impacts (9 mentions)**

Respondents mentioned economic consequences in relation to small businesses and property owners in flood-prone areas, including repair costs, business interruptions, and declining property values. One respondent described the high cost of running pumps to keep water away from building foundations.

**Other impacts (10 mentions)**

Respondents identified environmental degradation, increased disease risks from mosquitoes, loss of recreational space, and heightened safety risks as secondary but compounding effects of flooding.

### *Flood Mitigation Planning Techniques and Barriers*

**Technique: Education and best practice (54 mentions)**

Respondents most frequently mentioned education and communication as an important best practice. Respondents describe a range of activities, including public input sessions, information-sharing across organizations, and outreach intended to communicate flood risks and mitigation options to residents. Respondents noted that flood mitigation knowledge is unevenly distributed across institutions, stakeholders, and residents. Several respondents described increasing public awareness as a necessary condition for informed decision-making, as well as building trust and transparency with residents who have experienced repeated flooding without visible improvements.

**Barrier: Funding constraints (49 mentions)**

Respondents repeatedly mentioned funding as one of the most significant barriers to planning. Interviewees referred to challenges associated with securing external funding, navigating grant application requirements, and aligning available resources with project needs. Several respondents noted that funding timelines are frequently misaligned with flood events, leading to delayed responses or missed mitigation opportunities. Costs borne by private property owners were also raised as a concern, particularly in areas where mitigation measures require easements, property retrofits, or long-term maintenance commitments.

> *"The money is limited in local governments, and it's increasingly from federal funding. The further away you get from the time of that flooding event happening, the harder it is to have that be a priority."*

**Barrier: Government coordination (46 mentions)**

Respondents repeatedly mentioned coordinating across levels of government as a determinant of the feasibility and pace of flood mitigation projects. Respondents described overlapping jurisdictions, unclear lines of authority, and inconsistent priorities between municipal, county, state, and federal agencies. In some cases, respondents pointed to conflicts between local mitigation plans and state-level regulatory frameworks, while others noted difficulties synchronizing capital improvement schedules across agencies. These coordination challenges became administrative obstacles and factors that influence which projects advance and which stall, particularly when responsibilities for funding, permitting, and long-term maintenance are distributed across institutions.

*"[MMSD] is not allowed to spend money on recreational amenities for the community and it's not able to utilize tax dollars to fund those kinds of projects, but can work with others to do that. 'How do we expand this? How do we bring in more partners on these projects?'"*

**Technique: Community-based decision-making (32 mentions)**

Respondents referenced a variety of engagement practices, including public meetings and outreach initiatives. Respondents emphasized the importance of incorporating resident knowledge, lived experience, and priorities into mitigation planning, noting that community input can improve project design and legitimacy. Advocacy was frequently described as a core function of local organizations, where residents have expressed frustration with top-down planning processes. Several respondents also acknowledged challenges in translating community input into implementable projects, citing constraints related to funding eligibility, technical feasibility, and regulatory requirements.

*"We may think green infrastructure and rain gardens are great, but what if you take out the playground or the grass field that's really valued by the community? Flood mitigation is felt during the flooding times, but then the other 99% of the time the soccer field's gone and you've taken away an asset from the community. It's really about understanding where it is that there's space to do flood mitigation, and what are the things the community wants to see, and making sure that that's built into the solutions."*

### *Flood Mitigation Implementation Barriers*

**Human resources (18 mentions)**

Respondents described limited staffing capacity as a recurring constraint, affecting agencies' and organizations' ability to apply for grants, manage projects, and sustain community engagement. Interviewees noted that flood mitigation work is often added onto existing responsibilities, limiting long-term planning capacity.

*"[MMSD] had an EPA grant [and] full-time resilience ambassador doing targeted at-home outreach, talking about different city resources and stormwater management. Unfortunately, the grant got canceled and we had to lay [them] off."*

**Property ownership conflicts (15 mentions)**

Respondents mentioned issues with public vs. private property ownership in contexts where flood mitigation measures intersect with privately owned land. Interviewees described challenges related to access, permissions, and responsibility, but did not consistently attribute them to specific actors or policy failures.

*"[In Milwaukee], you can't just replace the port with a wetland and say, 'Yay, nature-based solution.' I think [mitigation] would start with making sure that the assets there that have been identified, maybe dock walls to be raised and things like that can be brought up as needs for resilience for that industrial facility to keep functioning."*

**Upstream–downstream dynamics (11 mentions)**

Respondents emphasized that stormwater does not respect jurisdictional boundaries, noting that upstream development and infrastructure decisions can exacerbate downstream flooding. These dynamics were particularly salient in discussions of watershed-scale planning and inter-municipal coordination.

**Limited infrastructural availability (8 mentions)**

References to infrastructural availability focused on the physical constraints of existing systems, including space limitations and the condition of aging infrastructure, as factors that shape which mitigation measures are feasible.

## *Site Visits and Community Outreach*

Based on the five informal conversations with community members (Table 2), it was confirmed that flooding may not be the foremost issue on some residents' minds. Among non-flooding-related issues, two residents were concerned about gentrification and the growing divide between downtown Benton Harbor and the residential areas beyond Main Street: development, they explained, sharply stopped in predominantly Black residential areas and created a divide between parks and spaces designed for Black residents and predominantly White visitors. Another community member remarked that many residents wanted the safety of children to be of high priority for the city and the community. Lastly, one resident explained that they were concerned about a pervasive political attitude that tended to stop new ideas without due consideration or alternative solutions, which they referred to as "stopping politics".

Residents were asked what they like most about living in Benton Harbor. The most common answer was that there is a lot to do and a lot going on. In addition, one resident appreciated Benton Harbor's affordability, and one loved the close-knit community of families and youth who all know one another.

The major flooding concerns are transportation issues and backed-up drains. Key areas of transportation concern included Colfax Road and Blossom Road, where residents reported they could not drive through standing water on the roadways, which sometimes lingered for days after heavy rain. Backed-up pipes and sewers were of even greater concern, and the majority of community participants were concerned about water lingering in the stormwater system and backing up into people's homes. One participant noted that the lack of flood insurance was an issue

for many families, and another indicated that there were few trusted sources of help or funding available if homes or basements flooded.

Community members had a wealth of ideas about what they wanted to see from the city's flood mitigation efforts. The two most commonly recurring themes were improvements to infrastructure and more green space. Residents hoped to see drains, sewers, and streets repaired and kept clean, and for trash to be kept out of the streets, drains, and waterways. One suggested a basement waterproofing program to help close the gap in available assistance for residential flooding. All participants showed interest in parks and green spaces, including community gardens, flowers, rain gardens, a water park, and safe parks for children. One resident suggested hosting more events and increasing attendance at local parks. Other topics of interest included rain barrels, community composting, reducing trash, and removing tree roots that can damage sidewalks and infrastructure.

**Table 2.** A summary of community members' responses to informal conversations.

| Non-Flooding Concerns | Flooding Concerns | Potential Improvements | Best Attributes of Benton Harbor |
|---|---|---|---|
| Gentrification, tourist/resident division at Main Street and in public spaces<br><br>Safety for children<br><br>"Stopping politics" that dismisses new ideas for urban improvement | Standing water and impassable roadways<br><br>Backed-up drains and sewers<br><br>Flooding in basements<br><br>Limited funding, insurance, and trusted help for residential flooding | Streets, drains, and sewers repaired and kept clean<br><br>Green space, parks, rain gardens, and outdoor events<br><br>Basement waterproofing program<br><br>Trash and overgrowth management | Lots of events and recreational opportunities<br><br>Close-knit community of families and youth<br><br>Affordability |

## *Berrien County Stakeholder Advisory Board Meeting*

Stakeholders' answers to the question of equity largely fell into two categories: the well-being of community members and funding/financial concerns. The discussion began with one participant pointing out that equitable flood mitigation should be implemented so that mitigation measures do not shift hazards from one group or community to another. Stakeholders also pointed to the inequitable distribution of existing hazards, such as impermeable pavements that increase flood risk. Furthermore, the discussion turned to the distribution of a community's resources among residents' time, attention, and immediate priorities. Equitable flood mitigation in low-income communities, stakeholders indicated, is implemented in a social environment in which residents' primary concern is

making ends meet, with limited time and mental energy available to participate in municipal planning.

The other part of the equity discussion focused on funding concerns. Several stakeholders pointed out that traditional cost-benefit analyses assign higher value—and thus greater benefit from financing and assistance in the event of damage from climate hazards—to higher-value properties. This skews the benefit of assistance toward higher-income landowners. Statistical calculations of cost, another participant suggested, fail to account for the intrinsic emotional value of a home, regardless of its monetary value. Stakeholders identified a disconnect between some of these unintuitive calculations of value and actual policy outcomes, wondering aloud how methods of turning equity into policy can be developed and advanced.

The pros, cons, and suggestions generated by stakeholders during the activity are summarized in Table 3. Countermeasures that are considered to be "in a priority area for the public," reflect a few hundred responses (up until August 14, 2025) to a University of Michigan researcher's ongoing crowdsource survey that asked residents of the county to identify parcels on a map in which they had ever seen flooding occur.

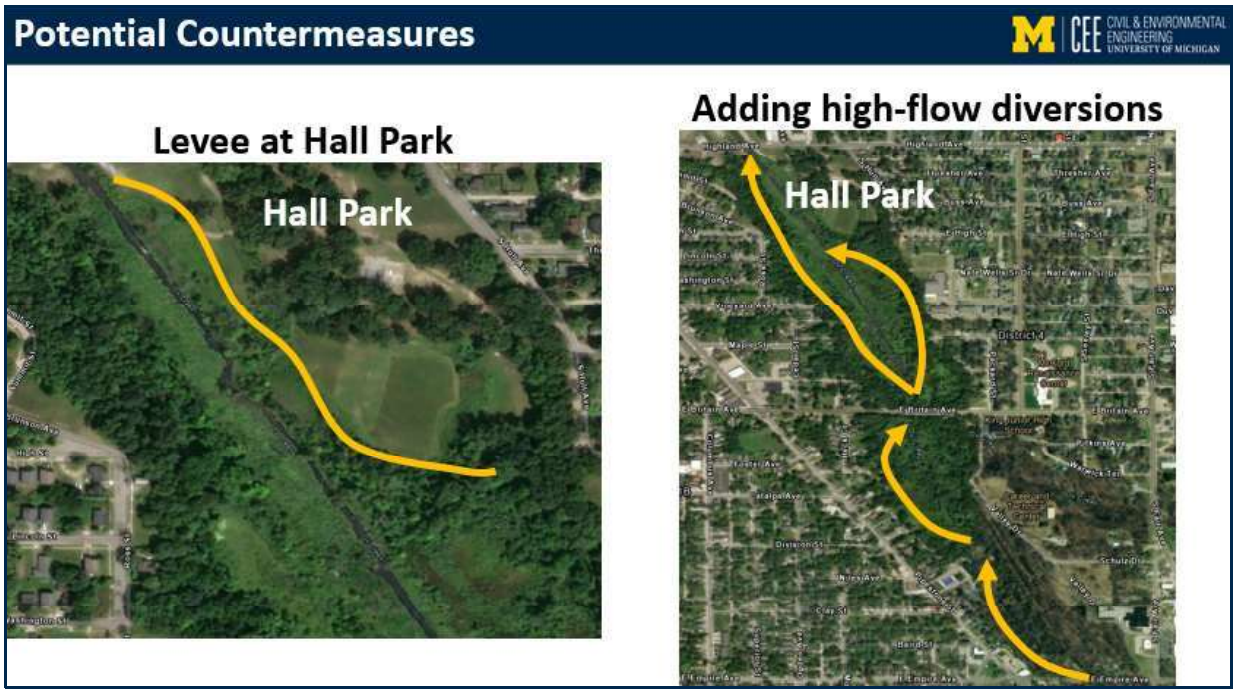



**Figure 9.** Two of the four proposed countermeasures along Ox Creek and near Hall Park. Courtesy of Benjamin Nelson-Mercer (2025).

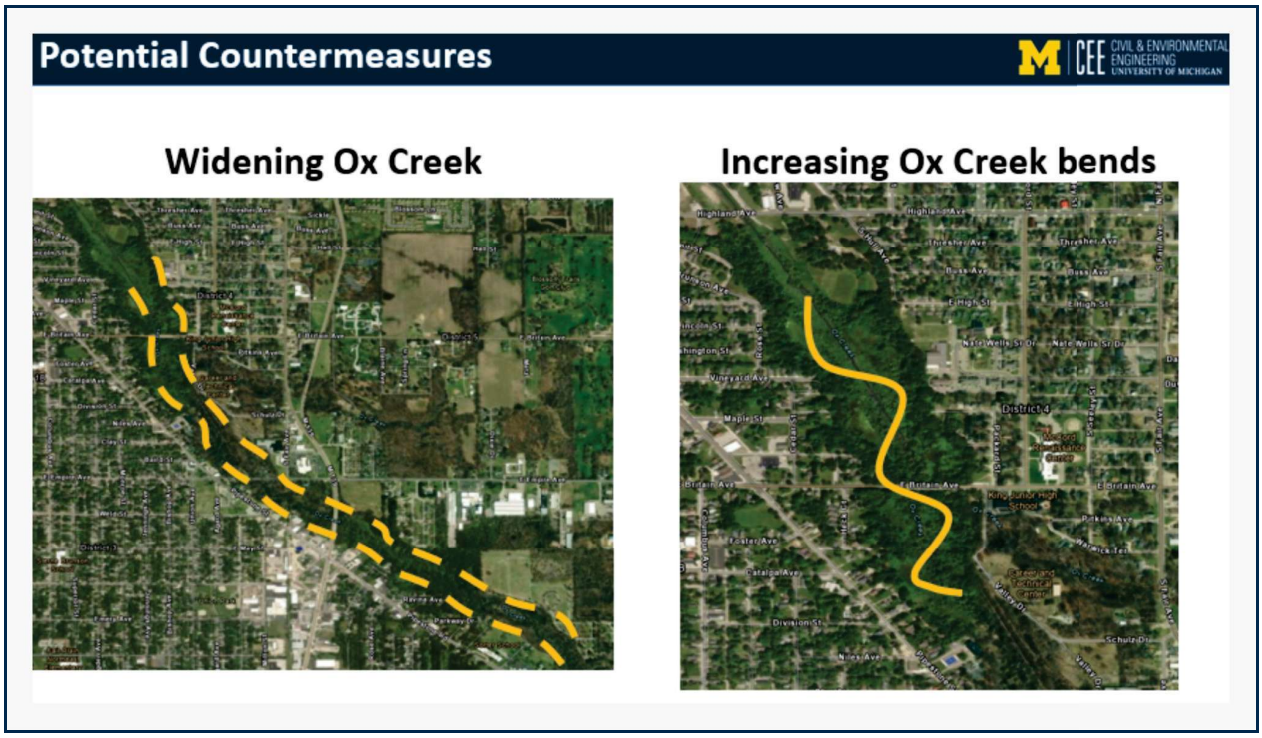



**Figure 10.** Two of the four proposed countermeasures along Ox Creek and near Hall Park. Courtesy of Benjamin Nelson-Mercer (2025).

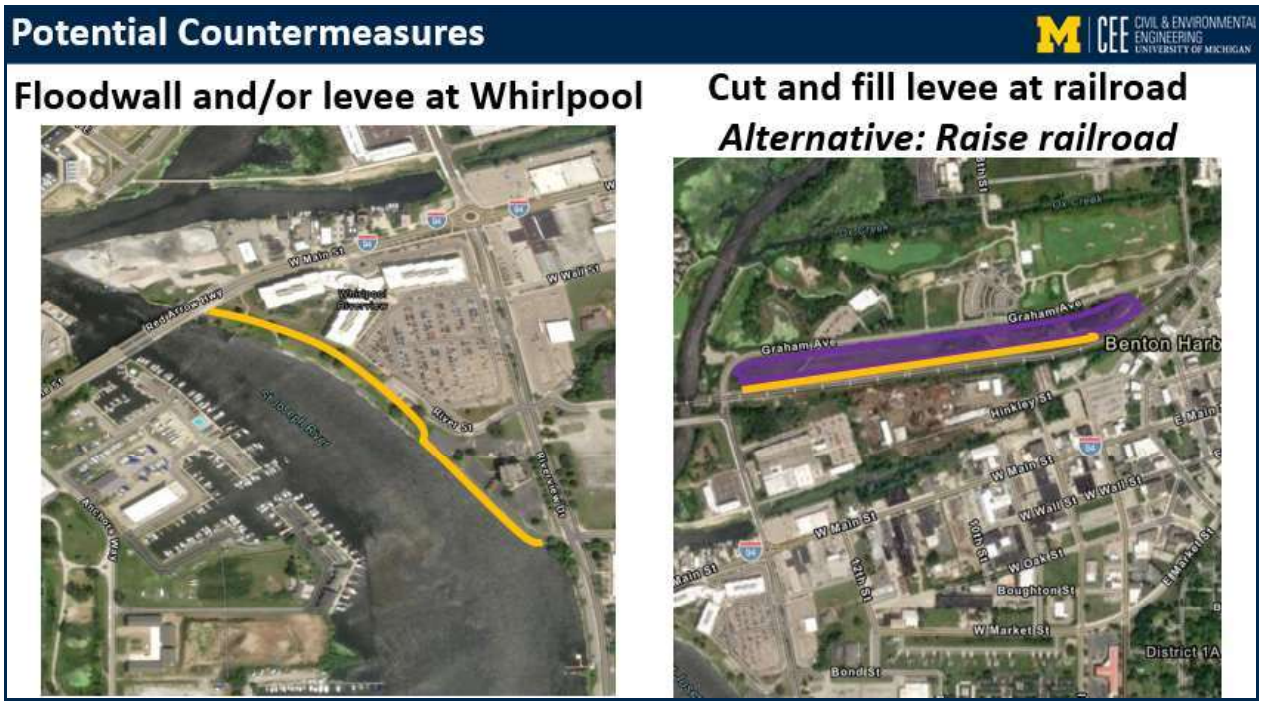



**Figure 11.** Two of the four proposed countermeasures along Main Street and Riverview Drive. Courtesy of Benjamin Nelson-Mercer (2025).

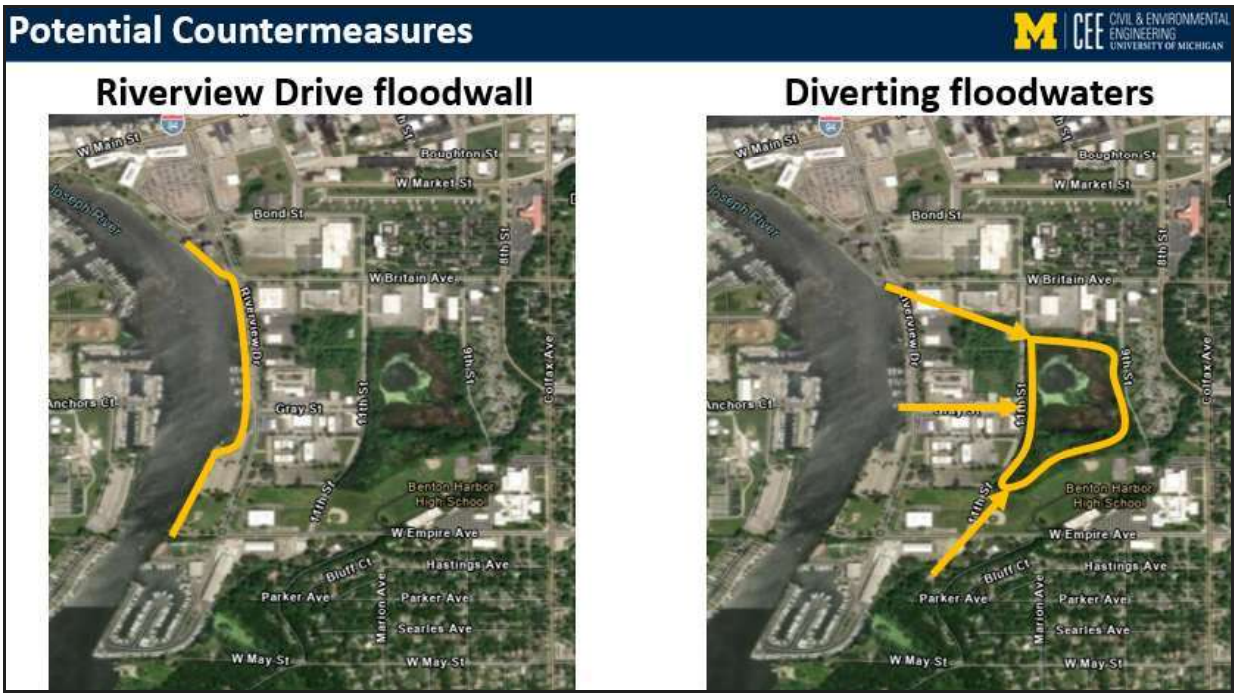



**Figure 12.** Two proposed countermeasures along Main Street and Riverview Drive. Courtesy of Benjamin Nelson-Mercer (2025).

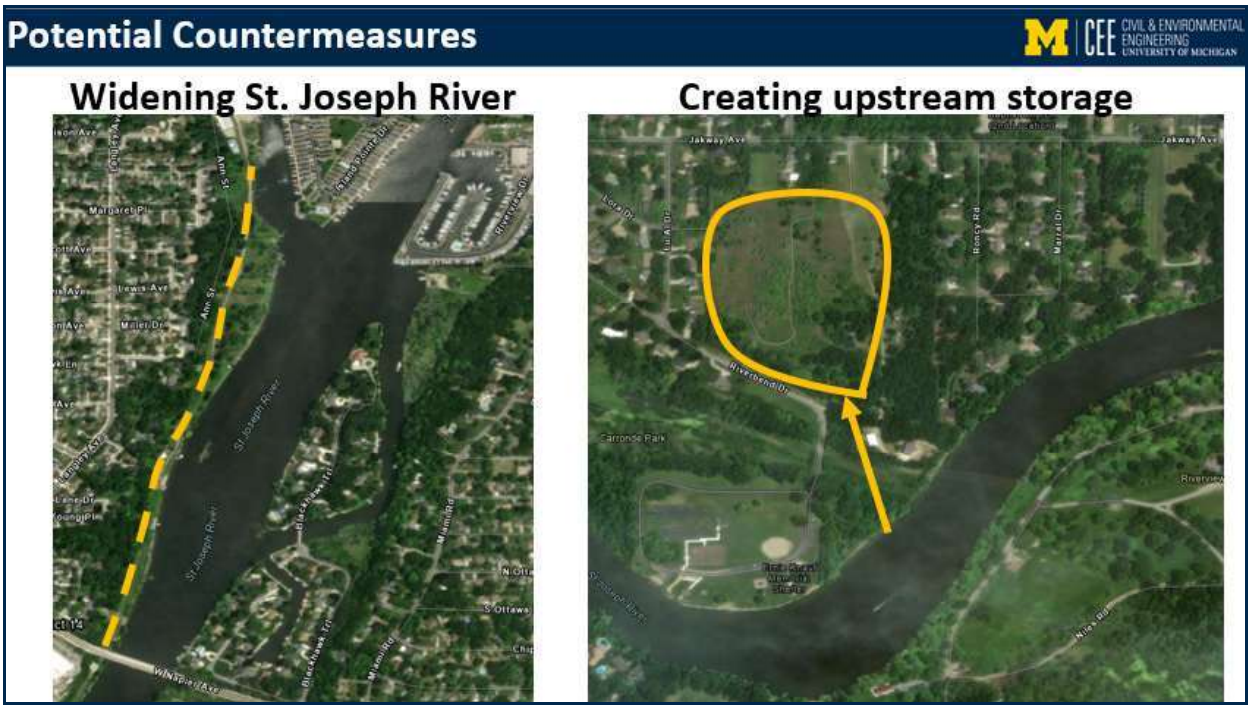



**Figure 13.** Two proposed countermeasures along and near the St. Joseph River. Courtesy of Benjamin Nelson-Mercer (2025).

**Table 3.** A summary of stakeholders' input regarding the proposed countermeasures during the Stakeholder Advisory Board meeting.

| Ox Creek/Hall Park | | |
|---|---|---|
| *Proposed Intervention* | *Pros* | *Cons* |
| Levee at Hall Park<br><br>(Figure 9) | • Anticipated to preserve the ball field<br>• Likely to be seen to work<br>• In a priority area for the public | • Impacts on creek views<br>• Might be unsightly<br>• Might decrease public access |
| High-flow diversions in Ox Creek<br><br>(Figure 9) | • Protects surrounding neighborhoods<br>• In a priority area for the public | • High flow might cause perceived concern.<br>• Could increase flows downstream |
| Widening Ox Creek<br><br>(Figure 10) | • May alleviate downstream issues in Hall Park | • Anticipated to be costly.<br>• Does not directly protect against floods like a levee or floodway<br>• Politically challenging<br>• Disrupts habitats<br>• Mobilizes contaminants in soil from farm runoff, plating company |
| Increasing Ox Creek bends<br><br>(Figure 10) | • Curvilinear elements are often seen as aesthetically pleasing<br>• Potential habitat benefits<br>• Can be a park | • Anticipated to be costly.<br>• Does not directly protect against floods like a levee or floodway.<br>• May impact planned trails |
| Main Street and Riverview Drive | | |
| Riverview Drive floodwall<br><br>(Figure 11) | • Likely to be seen to work<br>• In a priority area for the public | • May not be aesthetically pleasing<br>• May limit public access to the river<br>• Potential impacts on fishing and habitats<br>• Anticipated to be costly |

| | | |
|---|---|---|
| Diverting floodwaters to the 11th St. retention pond<br><br>(Figure 11) | • In a priority area for the public<br>• Maybe willing landowners | • Unclear drainage route<br>• Bisects existing infrastructure<br>• Anticipated to be costly |
| Floodwall or levee at Whirlpool<br><br>(Figure 12) | • Potential for a BH mural on the wall or along the walking path | • Some may see protecting Whirlpool's property as the company's responsibility<br>• Not a public priority.<br>• Does not help with clogged storm drain issues<br>• Doesn't help in cases of pluvial or lake level flooding<br>• Might be unsightly<br>• Potential negative ecological impacts<br>• Anticipated to be costly |
| Cut and fill levee at the railroad<br><br>(Figure 12) | | • Anticipated to be costly<br>• Not a public priority |
| St. Joseph River/Other | | |
| Widening St. Joe River (Figure 13) | • Could reduce flows downstream | • Not in a priority area for the public<br>• May not be willing landowners<br>• Anticipated to be costly. |
| Creating upstream storage (Figure 13) | • Appears to have fewer impediments to connecting to the river<br>• Could reduce flows downstream | • Not in a priority area for the public<br>• May not be willing landowners<br>• Anticipated to be costly |

| Suggestions | |
|---|---|
| • Preserve more existing open areas | • Enhance ship canal to take water |

| | |
|---|---|
| • Develop a program similar to ECO Neighborhoods to address upstream[4]<br>• Countermeasure(s) for high water table flooding & upstream | • Change/update building codes<br>• Build on higher elevations<br>• Create more permeable surfaces |

With only diagrams and short descriptions to work from, stakeholders did not coalesce around an unequivocal favorite mitigation method(s). Instead, they identified the major benefits and concerns that they associated with certain types of mitigation measures and the areas in which they were proposed. The potential for high cost was a major concern for several measures, and a few participants offered insight into public priorities based on their own knowledge. Other leading concerns included aesthetic value, feasibility, and potential negative ecological impacts, such as the release of contaminated sediments. Feasibility concerns included both the ease of physically implementing the measure and working through political barriers, such as potentially reluctant landowners or perceived favoritism toward the Whirlpool Corporation, which is headquartered in Benton Harbor and is the largest and most influential employer in the area.

On the other hand, the most attractive solutions were methods with high predicted feasibility, located in areas of high public priority, and capable of providing co-benefits such as aesthetic value or park space. Hall Park, Riverview Drive, and 11th Street near the high school were identified as high-priority areas. However, none of the proposed mitigation measures stood out to stakeholders as lower-cost from their own perceptions of city planning, which indicated to the team that lower-cost alternative methods should be considered in addition to the hypothetical measures suggested during the meeting.

## *Spatial and Socioeconomic Analysis*

### *Benton Harbor*

Benton Harbor Census Tracts 4 and 21 exhibit high SVI percentiles, both above 98% (Table 4; Figure 14). Berrien County is included by way of reference to illustrate the relatively lower burden in the rest of the county. Tracts 3, 4, and 22 also have high percentile scores for percentage of residents below the poverty line (>98th) and racial/ethnic minority status (90th).[44]

[4] https://city.milwaukee.gov/ECO-Neighborhoods-Initiative-

| Area | FEMA Flood Risk CRCI | CDC ATSDR SVI |
|---|---|---|
| Tract 21 | 95 | 0.9894 |
| Tract 4 | 98 | 0.9876 |
| Tract 22 | 97 | 0.9638 |
| Tract 3 | 96 | 0.9044 |
| Tract 23 | 77 | 0.8898 |
| Tract 20 | 77 | 0.8535 |
| Tract 5 | 83 | 0.7694 |
| Tract 25 | 72 | 0.6963 |
| Tract 6 | 96 | 0.6785 |
| Berrien County | 52 | 0.6338 |
| Tract 7 | 68 | 0.5572 |

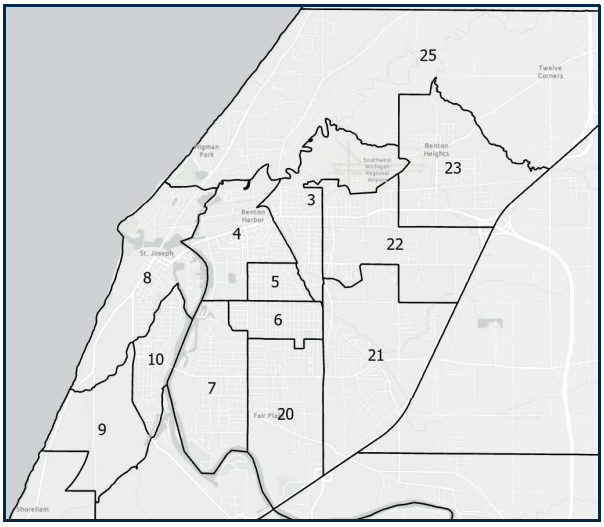



**Table 4 and Figure 14.** Census Tracts in Benton Harbor sorted by 2022 CDC ATSDR Social Vulnerability score (SVI).

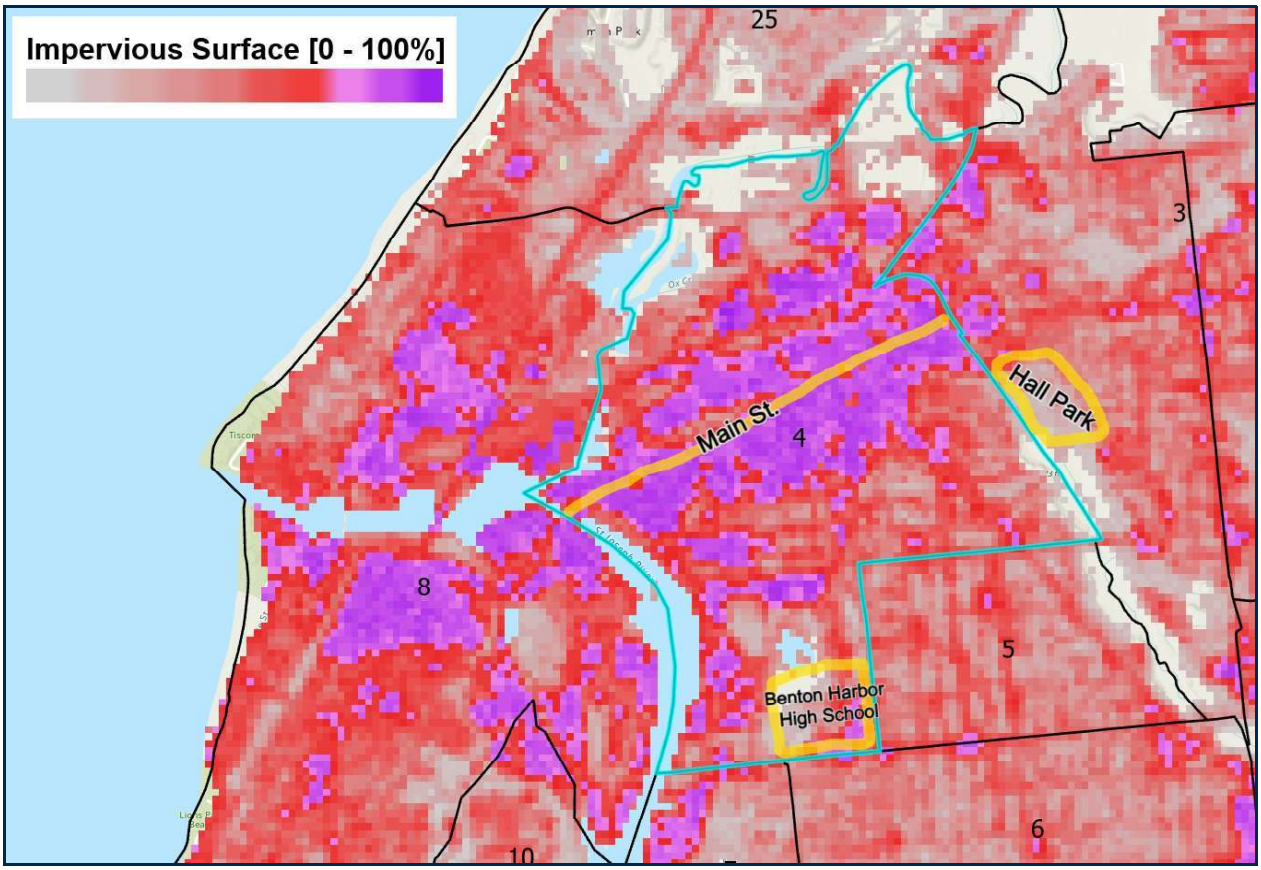



**Figure 15.** Benton Harbor impervious surface gradient, with Tract 4 and Main St., Hall Park, and Benton Harbor High School highlighted. Impervious surface gradient data from Multi-Resolution Land Characteristics Consortium (2024). Census tract polygon data from the U.S. Census Bureau (2000).

Coupled with FEMA Flood risk percentile values and the Nelson-Mercer flood model, Tracts 3, 4, 21, and 22 all face a cumulative vulnerability that can be addressed by flooding mitigation strategies. Impervious surfaces contribute to compound flooding throughout, and Tract 4 is highlighted in Figure 15 for its extensive built environment along West Main Street.

Stakeholders involved in infrastructure and governance mentioned an anticipated reconstruction of the M-139 road (forming the border between Tracts 3 and 21/22) and its anticipated realignment. This could be an opportunity to offset some of the expected flooding in these high-vulnerability neighborhoods. Revitalization of the east bank of the St. Joseph River south of the Whirlpool facilities was also mentioned by stakeholders. The area around Benton Harbor High School in the southern corner of tract 4 was also identified for potential resilience planning at the Stakeholder Advisory Board meeting (Figure 16). Current efforts by City Administration and the Ox Creek Coalition to revitalize the corridor address both runoff from permeable surfaces and resident preferences.

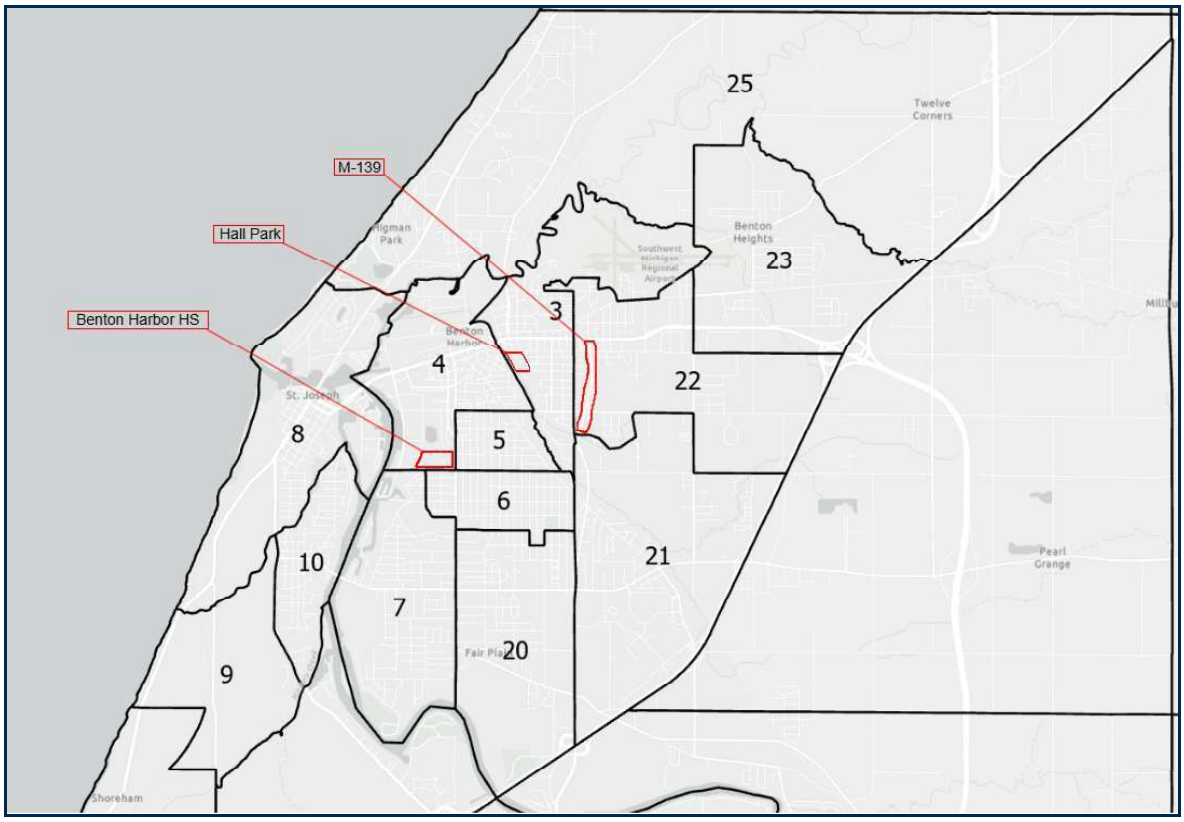



**Figure 16**. Three priority areas within high-vulnerability Census Tracts 3, 4, and 22. Left to right: Benton Harbor High School, Hall Park, M-139. Census tract polygon data from the U.S. Census Bureau (2000).

### *St. Joseph and Greater Berrien County*

St. Joseph and Berrien County are included separately in Table 5 to highlight the contrasting vulnerabilities of these communities. While flood risk remains a threat, especially when impervious surfaces are taken into account, the notion of cumulative vulnerability is not supported by the data. Examining the percentage of residents with incomes below the poverty line shows that no tract in St. Joseph is below the 44th percentile, underscoring the city's greater economic stability and opportunities (Table 5). Stakeholders confirmed that the flooding resilience needs in most residential areas are lower than those in Benton Harbor.

At large, the county exhibits lower climate-hazard risks and cumulative vulnerabilities than Benton Harbor. Some stakeholders expressed interest in improving countywide emergency preparedness for flooding events along the St. Joseph River in inland areas such as Royalton Township and Batchelor's Island.

**Table 5.** St. Joseph city Census Tracts with FEMA percentiles for flood risk (1-100) and CDC Social Vulnerability (0-1). FEMA CRCI data is from the 2024 American Community Survey. SVI scores are from the 2022 American Community Survey.

| Area | FEMA Flood Risk CRCI | CDC ATSDR SVI |
|---|---|---|
| Tract 8.01 | 45 | 0.2087 |
| Tract 8.02 | 26 | 0.0933 |
| Tract 9 | 23 | 0.2971 |
| Tract 10 | 14 | 0.0477 |
| Berrien County | 52 | 0.6338 |

### *Milwaukee*

The most vulnerable tracts in Milwaukee by SVI are consistently in historically Black neighborhoods with a history of redlining and segregation. The south end neighborhoods, particularly tracts 174 and 175, have high percentiles for housing cost burden (>95), residents below the poverty line (>97%), and racial/ethnic minority status (>91). The highest ten SVI tracts for Milwaukee appear in Table 6 and are highlighted in Figure 17.

**Table 6.** Milwaukee Census Tracts with FEMA CRCI percentiles for flood risk (1-100) and CDC Social Vulnerability (0-1). FEMA CRCI data is from the 2024 American Community Survey. SVI scores are from the 2022 American Community Survey.

| Area | FEMA Flood Risk CRCI | CDC ATSDR SVI |
|---|---|---|
| Tract 175 | 90 | 0.9918 |
| Tract 1861 | 98 | 0.9918 |
| Tract 167 | 90 | 0.9913 |
| Tract 70 | 94 | 0.985 |
| Tract 98 | 95 | 0.9822 |
| Tract 157 | 98 | 0.9815 |
| Tract 170 | 92 | 0.9812 |
| Tract 174 | 92 | 0.9761 |
| Tract 69 | 89 | 0.9751 |
| Tract 1857 | 98 | 0.9709 |
| Tract 169 | 86 | 0.9707 |
| Milwaukee County | 60 | 0.8276 |

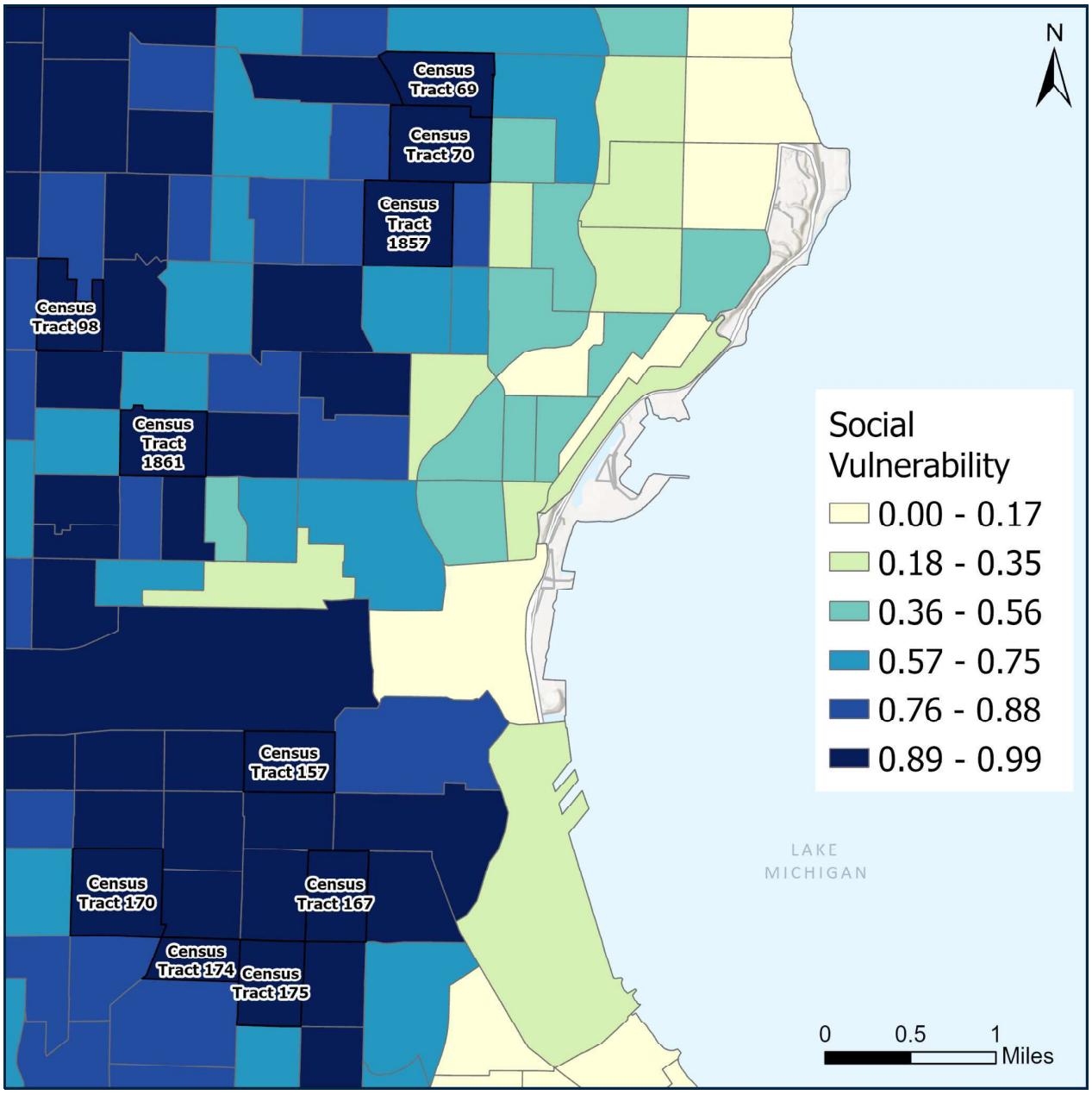



**Figure 17.** 2022 CDC ATSDRSVI values in Milwaukee County, with the top 10 highest tracts highlighted. Census tract polygon data from the U.S. Census Bureau (2000).

Milwaukee has high percentages of impervious surfaces throughout the city, including the harbor, downtown, and the south end and northern neighborhoods, where the 10 identified socially vulnerable tracts are situated. Compound flooding risk is high in Milwaukee due to the direct coastal setting and substantial built-up environment (Figure 18).

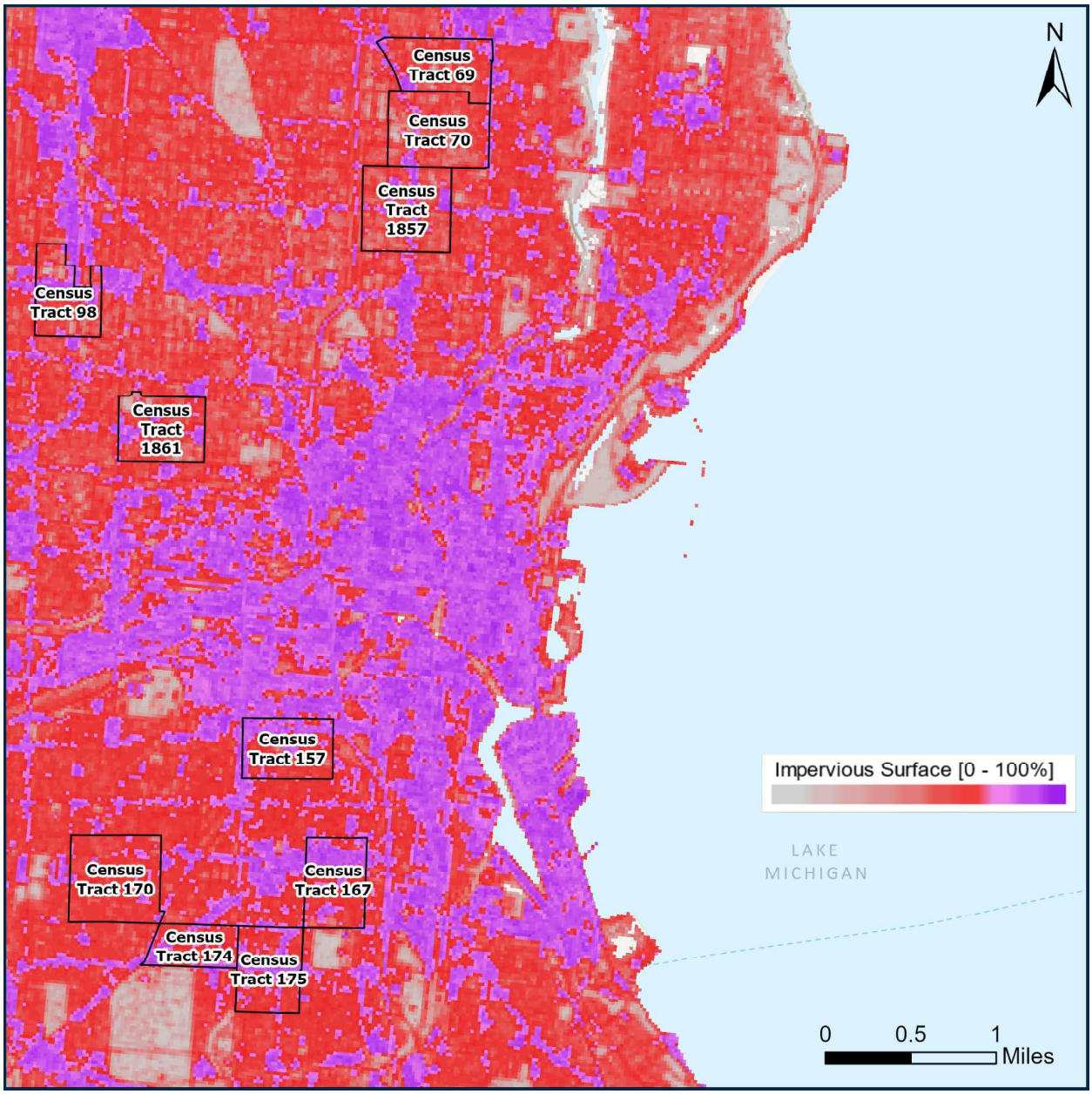



**Figure 18.** Milwaukee's impervious surface gradient with overlaid high-SVI Census Tracts. Impervious surface gradient data from Multi-Resolution Land Characteristics Consortium (2024).

### *Key Takeaways*

These findings point to a consistent pattern in how flooding is understood and managed in Benton Harbor and Milwaukee. Interviewees repeatedly framed flooding as a compound condition shaped by long-term hydrological dynamics, historical land-use decisions, and the limits of existing infrastructure systems. Elevated Great Lakes water levels provide the broader hydrological context within which more localized factors, such as topography, groundwater conditions, and river corridors, shape where flooding concentrates and how it persists.

The impacts most frequently emphasized across interviews were those affecting physical infrastructure and mobility. Recurrent damage to roads, stormwater systems, and public utilities was described as both a symptom of flooding and a factor that amplifies future vulnerability, as aging systems struggle under changing conditions. Mobility and economic disruptions were similarly framed as consequential not only because of immediate inconvenience, but because of their implications for access to emergency services, employment, businesses, and daily activities. While other impacts were discussed less frequently, they were often presented as compounding effects that accumulate over time rather than as isolated losses tied to individual events.

The planning and implementation dimensions of flooding reveal a parallel set of reinforcing constraints. Interviewees consistently highlighted the importance of education, technical guidance, and shared best practices, suggesting that flood mitigation is viewed as an ongoing learning process rather than a one-time engineering challenge. At the same time, funding limitations and coordination challenges across jurisdictions were described as persistent obstacles that shape what types of projects are feasible and where they can be implemented.

In Benton Harbor, site-specific impacts were frequently tied to Ox Creek and adjacent residential blocks, where repeated flooding disproportionately affects low-income and marginalized communities in older neighborhoods with limited municipal capacity. Respondents described consistent flooding in the downtown area, specifically Main Street in Riverview Drive and the business loop for I-94, where infrastructural damage and mobility disruptions exacerbate existing socioeconomic stressors, limiting residents' capacity to recover between events. These areas align with SVI values, indicating higher risks and burdens.

In Milwaukee, infrastructural and mobility impacts were often framed at the corridor or system scale, affecting downtown roads, transit routes, and shore-adjacent public spaces. Flooding impacts were more frequently linked to commercial districts, transportation networks, and marginalized communities, including northwestern Milwaukee. Milwaukee Interviewees emphasized the interaction between river systems and highly engineered stormwater networks in Milwaukee. Lakeshore conditions in Milwaukee were often linked to transportation corridors, public amenities, and critical infrastructure located immediately inland from the shoreline. Respondents highlighted how upstream inflows and constrained conveyance interact with elevated lake levels to produce flooding far from the immediate shoreline. The socioeconomic analysis illustrates the scope of the equity concerns and highlights areas that could be prioritized for investments addressing both flooding and social vulnerability.

Overall, these findings do not suggest a single causal pathway or uniform experience of flooding across the two cities. Instead, they indicate that similar environmental drivers and planning challenges manifest differently depending on local context, infrastructure legacies, and governance arrangements. The alignment between environmental conditions, experienced impacts, and institutional barriers

underscores the need for flood mitigation approaches that account for long-term hydrological variability while remaining attentive to place-specific constraints and capacities.

# Recommendations

## *Cross-Cutting*

### *Re-align Valuation of Cost-benefit Analyses*

Flood mitigation decisions should move beyond property-value-based cost–benefit analysis and explicitly incorporate social vulnerability factors such as income, renter status, housing burden, and access to transportation. Traditional prioritization frameworks tend to favor higher-value properties, which can systematically disadvantage low-income and historically marginalized communities despite high levels of flood exposure.[14] Incorporating equity-focused indicators into prioritization processes would better align infrastructure investment with community need and risk, rather than solely with economic value.

Stakeholder input emphasized that the emotional, cultural, and social value of homes and neighborhoods is not captured by conventional valuation methods. This was a resonant sentiment from residents in Benton Heights to community organizations in the south end of Milwaukee. Integrating social vulnerability metrics into project ranking and funding decisions can help ensure that flood mitigation investments reduce disparities rather than reinforce them.

**Potential Benefits**

- Directs resources toward communities with the greatest need and vulnerability
- Reduces inequities in flood risk and recovery capacity
- Improves transparency and defensibility of prioritization decisions
- Aligns flood mitigation with environmental justice and climate equity goals

**Potential Barriers**

- Requires changes to existing prioritization frameworks and evaluation criteria
- Equity metrics may be perceived as subjective or politically contentious
- Data limitations or resolution issues may complicate implementation

### *Adopt Hybrid Gray-Green Infrastructure Strategies*

Flood mitigation strategies should pair green infrastructure and nature-based solutions with targeted gray infrastructure to address compound flooding while providing social and ecological co-benefits. As discussed in the literature and

background sections of this report, reliance on either green or gray infrastructure alone can be limiting: gray infrastructure may shift flood risk or lock communities into inflexible, high-cost systems, while green infrastructure alone may be insufficient to manage large storm events or high water levels. Hybrid approaches offer a more adaptive pathway that balances risk reduction, environmental performance, and community benefits.

Building on these lessons, municipalities across the study sites should pursue hybrid strategies that are tailored to feasibility, capacity, and community priorities. Milwaukee's experience demonstrates the value of integrating green infrastructure into broader flood management systems, while also highlighting the continued need for structural interventions along the Kinnickinnic River and in inland areas at risk of compound flooding, such as Harambee, Metcalfe Park, and North Division.

**Potential Benefits**

- Improves effectiveness across a range of storm intensities and lake-level conditions
- Reduces risk of maladaptation and unintended consequences
- Provides ecological, recreational, and aesthetic co-benefits
- Supports more flexible and adaptive flood management systems

**Potential Barriers**

- Hybrid designs can increase planning and design complexity
- Higher upfront coordination and technical expertise may be required
- Green infrastructure may require ongoing maintenance to remain effective
- Funding programs may favor single-solution project types

### *Systematize Equity in Planning Processes*

Community engagement in flood mitigation planning should be ongoing, accessible, and institutionally supported rather than episodic or project-specific. Stakeholder interviews and community outreach indicated that one-time meetings or short public comment periods are insufficient to build trust or meaningfully incorporate resident knowledge into decision-making. In contrast, partnerships with trusted local leaders and community-based organizations, such as neighborhood groups and stewardship programs, have demonstrated greater success in sustaining participation and fostering dialogue between residents and agencies. Collaboration was evident from discussions with leaders from community-based organizations.

Municipalities could support ongoing engagement by dedicating funding streams to community-based resilience initiatives, such as the FloodWise Great Lakes South Central Project, which aims to integrate the voices of historically underrepresented communities into stormwater vulnerability assessments. Resilience hubs such as Green Tech Station, neighborhood stewardship programs

such as Sixteenth Street Community Health Centers, or small grants for local organizations facilitating outreach are all potential avenues. Engagement opportunities should be held in familiar, accessible locations (e.g., community centers, schools, libraries, parks), advertised through multiple channels, and scheduled at varying times to accommodate different work schedules. Creating regular "meet your decision-maker" events and maintaining clear feedback portals can further strengthen two-way communication and demonstrate how community input informs project selection and design.

**Potential Benefits**

- Builds long-term trust between residents and implementing agencies
- Improves the relevance and effectiveness of flood mitigation decisions
- Increases participation from historically underrepresented groups
- Strengthens institutional accountability and transparency

**Potential Barriers**

- Requires sustained funding and staff capacity
- Community fatigue may occur if engagement does not lead to visible outcomes
- Coordinating across agencies and organizations can be challenging
- Measuring the impact of engagement efforts can be difficult

### *Plan for Long-Term Maintenance and Capacity Restraints*

Flood mitigation strategies and investments should be evaluated not only for upfront capital costs, but also for long-term operations, maintenance, and administrative capacity. Even well-intentioned investments can reinforce inequities over time if they impose maintenance burdens that exceed a municipality's fiscal or staffing capacity. This gap can pass the burden onto those in the neighborhood willing to volunteer their time. As a result, equity-focused prioritization must extend beyond project selection to include long-term feasibility and sustainability.

Stakeholders emphasized that communities like Benton Harbor and Milwaukee, with limited tax bases, staffing, or institutional capacity, are often least able to maintain complex infrastructure systems. This is true for Benton Harbor, despite facing some of the highest flood risk in the county. Benton Harbor and Milwaukee city management, incorporating capacity-based considerations, such as municipal revenue, staffing levels, or local economic contribution, into funding and cost-sharing frameworks, could help prevent inequitable outcomes. For example, the choice of the mitigation strategy should depend on the community's maintenance capacity. It could be structured on sliding scales, payment plans, rather than requiring uniform matches across jurisdictions. Designing flood mitigation programs with long-term support mechanisms can help ensure that investments remain effective and equitable over time.

**Potential Benefits**

- Prevents infrastructure failure due to insufficient maintenance capacity
- Aligns flood mitigation investments with long-term equity goals
- Reduces risk of burdening low-capacity communities with unsustainable obligations
- Encourages durable, realistic project selection and design

**Potential Barriers**

- May require restructuring existing funding and cost-share programs
- Capacity-based contributions could face political or legal resistance
- Long-term maintenance needs are often difficult to quantify upfront
- Requires coordination across funding agencies and jurisdictions

## *Berrien County and Benton Harbor*

### *Prioritize Low-Cost, High-Visibility Flood Mitigation Measures*

Given Benton Harbor's limited municipal capacity, history of disinvestment, and desire from community members for visible, near-term improvements, place-specific flood mitigation strategies should prioritize interventions that are feasible, incremental, and responsive to locally identified needs. Addressing inequity specific to Benton Harbor's demographic history and geographic setting should be central in mitigation efforts.

Near-term investments should focus on storm sewer maintenance, targeted parcel- or block-scale green infrastructure, and neighborhood-scale upkeep that directly address community-identified flooding concerns such as backed-up drains, sewer overflows, and impassable roadways. Planned Ox Creek community clean-up and stewardship events further present opportunities to pair physical maintenance with outreach and education that strengthen community norms around litter prevention, drainage protection, and environmental stewardship. These events also provide residents with the opportunity to interact with and bring their concerns to elected and appointed officials who can follow up on resident requests. Such interaction may facilitate trust-building and generate goodwill between residents and the local government.

Community-based green infrastructure programs can be effective when residents are supported through technical assistance, access to materials, and long-term maintenance guidance, e.g., local and state revolving funds. These models suggest that the city of Benton Harbor could pursue a localized version of neighborhood-scale green infrastructure or stewardship initiatives, similar in spirit to Milwaukee's ECO Neighborhood-style programs, which aim to build a neighborhood's climate resilience through collaborative climate education, planning, and action that is supported by local expertise and resources and guided by Milwaukee's Climate and Equity Plan.

Prioritizing highly visible, lower-cost actions can reduce immediate flood risk while simultaneously building public trust and demonstrating municipal commitment to historically underserved neighborhoods. In Benton Harbor, these include residential areas in the floodplain directly south of W. Main Street between the St. Joseph River and Ox Creek (Census Tract 4), and the neighborhoods east of Ox Creek, south of the airport, and west of M-139 (Census Tract 3). Benton Heights (Census Tract 22) also faces cumulative burdens beyond flood risk through disinvestment, low incomes, and low employment. The Nelson-Mercer flood model highlights the risk to Main Street, Riverview Drive, and Ox Creek. Field visits offered opportunities to engage with all three communities, and residents expressed an interest in seeing more investment from city and regional initiatives. One resident spoke about community-led public gatherings in Hall Park, which illustrate the importance of the space and the potential to revitalize areas around Ox Creek through visible, participatory climate resilience programs. Restored wetlands and rain gardens along Ox Creek could mitigate flood risk. The northwest corner of the park is at the same elevation as the river and could be a potential site for renovation for public access and use. Success stories from Milwaukee's recent past emphasize that community members want opportunities to engage with restored floodplains through participatory programming.

**Potential Benefits**

- Reduces localized flooding and sewer backups in high-priority areas
- Produces visible improvements that strengthen public trust in municipal action
- Builds community stewardship and environmental awareness
- Requires lower upfront capital than large gray infrastructure projects
- Can be implemented incrementally and scaled over time

**Potential Barriers**

- Ongoing maintenance requirements may strain limited municipal capacity
- Effectiveness depends on sustained community engagement and participation
- Benefits may be localized and insufficient to address large-scale flooding alone
- Securing consistent funding for small projects can be challenging, with funders being hesitant to take on the risk

### *Focus Investments in Publicly Accessible Priority Areas*

Flood mitigation projects in publicly accessible and community-valued locations, such as Hall Park and Riverview Drive, can provide meaningful risk reduction while also delivering social and recreational benefits. Community members identified these areas as important gathering spaces and expressed appreciation for their role in supporting recreation, neighborhood identity, and quality of life. Although residents may be more sensitive to physical changes in these highly

visible locations, this concern can be addressed through early and transparent engagement, including community forums after work hours, social media, and radio outreach that emphasize how projects will protect and enhance valued spaces rather than detract from them. Outreach should continue after projects to assess effectiveness.

Input from the Berrien County Stakeholder Advisory Board further suggests that projects in these areas are more likely to be perceived as functional public investments compared to interventions located on private or industrial property. Stakeholders noted that the proposed measures in Hall Park and along Riverview Drive were considered high-priority areas for the public, with the potential to deliver co-benefits, including park improvements, aesthetic enhancements, and walking paths, alongside flood mitigation. Riverview Drive could benefit from a restored floodplain with more vegetation and permeable pavement, which municipalities could facilitate by revitalizing areas along the St. Joseph River. These areas would benefit the residential areas east of Riverview Drive and south of Main Street. Focusing investments in these visible, shared spaces can therefore increase the likelihood of public support while advancing both resilience and community well-being.

**Potential Benefits**

- Reduces flood risk in areas of great public concern
- Provides recreational, aesthetic, and social co-benefits
- Increases public visibility of municipal investment
- Strengthens the legitimacy and political feasibility of projects
- Creates opportunities for community engagement and stewardship

**Potential Barriers**

- Higher public scrutiny and sensitivity to design changes
- Potential concerns about temporary construction disruptions
- May require additional design effort to ensure accessibility and aesthetics

## *Milwaukee*

### *Embed Equity into Green Infrastructure Siting*

Milwaukee should move beyond citywide green infrastructure targets and explicitly prioritize investments in neighborhoods with high social vulnerability and documented flood exposure. Milwaukee stakeholders described successful prior collaborations on the Kinnickinnic River south of downtown Milwaukee and an interest in developing projects farther downriver. Redlined neighborhoods with present high vulnerability, such as Harambee and Riverwest (west of the Milwaukee River and north of North Ave), could benefit from green infrastructure such as rain gardens and permeable pavement to address inland compound flooding. Investing in accessible public use areas along Milwaukee's rivers will increase support and

address inequity. Although the city and MMSD have made substantial progress in implementing green infrastructure and nature-based solutions, their distribution remains uneven, and high-vulnerability neighborhoods continue to experience disproportionate flood risk. Integrating Social Vulnerability Index (SVI) and flood-health vulnerability mapping into MMSD's project selection and capital planning processes would help ensure that future investments directly address these persistent disparities.

Milwaukee's extensive data infrastructure and established watershed-scale planning framework position the city to operationalize equity-based siting criteria in ways that many communities cannot. Formalizing this approach would align flood mitigation investments with the city's stated climate and equity goals while improving transparency and accountability in decision-making.

**Potential Benefits**

- Directs resources toward communities with the greatest need and risk
- Reduces inequities in flood exposure and associated health impacts
- Increases transparency and consistency in project selection
- Strengthens alignment between climate, equity, and stormwater planning

**Potential Barriers**

- May require changes to existing planning workflows and evaluation criteria
- Could face political resistance from neighborhoods accustomed to receiving investments
- Data gaps or resolution limits may complicate fine-scale prioritization
- Equity-based siting alone does not address long-term maintenance disparities

### *Evaluate Equity Tradeoffs Among Flood Mitigation Options*

Flood mitigation planning should include a comparative evaluation of equity outcomes across alternative mitigation options, rather than focusing solely on hydraulic performance or cost. Milwaukee and MMSD have developed detailed watershed-scale plans and management analyses that assess the technical feasibility and limitations of a wide range of flood mitigation strategies. However, these documents generally do not compare how different options may distribute outcomes across neighborhoods, for example, which areas receive the greatest reductions in flood exposure, which experience construction disruptions, and which retain residual risk.

Incorporating equity analysis, such as evaluating which neighborhoods benefit, which may experience construction impacts, and which may face residual risk, would strengthen existing planning frameworks and help ensure that mitigation strategies advance both flood resilience and social equity. Building this analysis into MMSD's existing planning and alternatives-evaluation processes would

represent an incremental but meaningful shift toward more equitable decision-making.

**Potential Benefits**

- Improves understanding of who benefits and who bears costs under different mitigation options
- Supports the selection of mitigation options that reduce inequities in exposure, maintenance burden, construction impacts, and residual risk across neighborhoods
- Increases transparency and defensibility of planning decisions
- Aligns technical planning with Milwaukee's stated climate and equity goals

**Potential Barriers**

- Requires additional data integration and analytical capacity
- May lengthen planning and alternatives-evaluation timelines
- Could surface politically sensitive tradeoffs between neighborhoods

### *Strengthen Community Partnerships Beyond Project Implementation*

Milwaukee should expand partnerships with community organizations to support the long-term maintenance, monitoring, and stewardship of green infrastructure, rather than limiting collaboration to project design and installation. Stakeholders emphasized that while partnerships are central to Milwaukee's flood mitigation efforts, sustaining these relationships over time can be challenging, particularly as organizations' funding cycles, staffing, and priorities shift. Strengthening long-term collaboration can help ensure that green infrastructure continues to function as intended while reinforcing trust between communities and implementing agencies.

Milwaukee could broaden its partner base by engaging neighborhood associations, watershed groups, faith-based organizations, and environmental justice organizations that have existing relationships within high-vulnerability neighborhoods. These partnerships can be formed through neighborhood cleanups of rain gardens, learning and caring for the gardens, and citizen science programs. When partnerships are lost or change over time, agencies should proactively identify alternative partners and maintain continuity through standardized stewardship agreements, training resources, and clear communication channels. Embedding partnership maintenance into program design, rather than treating it as an informal activity, would improve both infrastructure performance and equity outcomes.

**Potential Benefits**

- Improves long-term performance and maintenance of green infrastructure
- Builds sustained community trust and ownership
- Expands local capacity for monitoring and stewardship

- Reduces burden on municipal staff

**Potential Barriers**

- Requires staff time and resources to manage relationships
- Community organizations may face their own capacity constraints
- Partner turnover can disrupt continuity
- Formalizing partnerships may introduce administrative complexity

### *Improve Transparency in Flood Mitigation Decision-Making*

Milwaukee should improve transparency around how flood mitigation projects are selected, funded, and sited, including how equity considerations are incorporated into these decisions. Currently, the Milwaukee Department of Public Works chooses projects based on 'community needs' but does not state if equity is considered. Stakeholders and community members expressed uncertainty about why some neighborhoods receive investments while others do not, contributing to perceptions of inequitable treatment even when technical justifications exist. Clear, accessible communication about decision-making processes can demystify planning and strengthen public trust, encouraging community participation in future projects.

Public-facing dashboards, annual summary reports, or community forums that link equity indicators (e.g., SVI, flood-health vulnerability) to investment decisions could support accountability and allow residents to track progress over time. Making this information available in plain language and multiple formats would further enhance accessibility.

**Potential Benefits**

- Increases public understanding of flood mitigation planning
- Reduces perceptions of favoritism or inequitable investment
- Strengthens the accountability of implementing agencies
- Builds trust between residents and decision-makers

**Potential Barriers**

- Requires staff time and technical capacity to maintain public-facing tools
- Risk of misinterpretation of complex data without adequate explanation
- Potential political sensitivity around revealing tradeoffs
- Need for coordination across agencies and departments

## *Prioritization*

Unless otherwise stated, recommendations are stated for both Berrien County and Milwaukee.

### *Short Term Actions (0-3 years): Building Trust and Addressing Immediate Risk*

Low-cost, maintenance-oriented interventions can reduce flooding impacts while demonstrating visible progress.

**Most Readily Trackable Recommendations**

- Prioritize low-cost, high-visibility flood mitigation measures
- Systematize equity in planning processes
- Foster community partnerships beyond project implementation by establishing routine collaboration (e.g., meetings, workshops, post-project evaluation)

**Example Metrics**

- Number of storm sewer maintenance activities or drain cleanings in high-SVI neighborhoods
- Number and location of small-scale green infrastructure installations
- Participation rates in engagement or stewardship events
- Number of active community partnerships or stewardship agreements

### *Medium-Term Actions (3-10 Years): Expanding Capacity and Targeted Investment*

As institutional capacity grows, municipalities can scale up green infrastructure and formalize equity-based frameworks.

**Most Readily Trackable Recommendations**

- Prioritize high-SVI Census Tracts or neighborhoods for maintenance, drainage improvements, and small-scale mitigation projects (Benton Harbor, St. Joseph, Berrien County)
- Prioritize high-SVI Census Tracts when allocating funding for major flood mitigation projects (Milwaukee)
- Embed equity into green infrastructure siting
- Evaluate equity concerns among flood mitigation options

**Example Metrics**

- Percentage of projects evaluated using equity-based criteria
- Share of flood mitigation funding allocated to high-SVI neighborhoods
- Number of plans or capital programs that include explicit equity analyses
- Documentation of equity tradeoff evaluations in alternatives analyses

### *Long-Term (10+ Years): Projects and Systemic Change*

Large-scale infrastructure investments should proceed only once equity criteria, funding stability, maintenance capacity, and equity reports are secured.

**Most Readily Trackable Recommendations**

- Adopt hybrid gray–green infrastructure strategies
- Plan for long-term maintenance and capacity constraints

**Example Metrics**

- Proportion of major projects that include both green and gray components
- Long-term operations and maintenance funding secured for flood mitigation assets
- Demonstrated reductions in flood exposure in high-SVI neighborhoods

# Limitations

## *Methods*

Throughout this project, the research team encountered a few logistical issues that may limit the results. The greatest potential effect comes from a low rate of community responses, which led to changes to the methodology. Other potential limiting factors include fewer opportunities to engage with the Milwaukee community and stakeholders, as well as gaps in spatial data availability.

During the initial scoping phase of this project, the research team decided to use a survey to gather perspectives from as many community members as possible. The team distributed the survey link and physical copies during spring and summer community events, but received very few responses. Because of this, the team elected in August to draw community members' perspectives and preferences from informal face-to-face conversations. This proved to be a more effective method; however, it was limited by time constraints due to the methodological shift, which ultimately resulted in fewer opportunities for interaction and a much more limited number of participants than anticipated.

Further, there were more opportunities to engage with stakeholders and community members in Benton Harbor than in Milwaukee. This was in part due to geographic proximity, as the team was based in Michigan. This project also sought to work with, rather than against, the work done by MMSD and WISG in the past few years, much of which has been through the community input process and is already in the implementation phase. Instead, the team corresponded with WISG leadership to determine where input from this project would be most beneficial, which narrowed the range of data sources.

Finally, spatial data cannot be viewed as a complete representation of the community or its needs. Berrien County-wide data will not accurately reflect the vulnerability on the ground in Benton Harbor. The Census Tract divisions offer specific detail at a level closer to a neighborhood, with relatively recent data. These lines may not accurately represent how people live, make community, or define their needs.

### *Implementation*

Due to constraints on the scope of this project, some barriers to implementation for specific recommendations may not be addressed in the research. It remains possible that unforeseen site-specific barriers may arise during the implementation of flood mitigation measures on the ground, including political, technical, and funding constraints.

Political barriers may arise from pushback from landowners in response to changes near their properties, or from organizational constraints during implementation, such as disagreement among decision-makers. Technical barriers may arise during implementation as well, for example, a geological feature changing conditions on the intervention site. In addition, while the recommendations are designed for cost-effectiveness, the scope of this project cannot predict how federal and municipal funding may change in the future.

Implementation efforts should also be scrutinized for site-specific challenges to equity; for example, an intervention that shifts flooding damages from one property to another. The recommendations are centered on equitable flood mitigation measures, but decision-makers should keep in mind that new challenges may arise over time. All of these limitations are considered during the implementation process.

# Conclusion

As compound flooding worsens due to climate change, it becomes imperative that local governments rise to the challenge of upgrading, replacing, or expanding aging flood mitigation measures. In Milwaukee and Benton Harbor, this challenge is complicated by a legacy of disinvestment and historical infrastructure solutions, such as the paving of waterways and now-defunct underground stormwater systems, that no longer serve the community.

However, efforts are already underway to reduce the risk of flooding-related damage, and this project provides additional recommendations grounded in an equity-focused approach. In Milwaukee, MMSD is spearheading a renovation of urban river corridors that incorporates stream daylighting, green infrastructure, and community education and outreach. In Benton Harbor, flood mitigation measures overlap with efforts to restore community gathering spaces and

pedestrian connectivity as officials work to improve Hall Park, expand trail systems, and create development opportunities.

This research expands on those efforts. Drawing on the expertise of local project leaders, city officials, and community members, the recommendations use local context and equity considerations to meet the needs of these coastal communities. The research team recommends low-cost, high-visibility measures, green and hybrid infrastructure solutions, and planning for future maintenance needs and environmental changes, among others. The recommendations are chosen to meet the needs of the community, provide co-benefits such as green space and recreation, and build capacity for maintenance, future mitigation efforts, and community partnerships. In addition, the team provides recommendations for maintaining equity through community engagement and partnerships to further procedural equity and alleviate burdens on residents as these measures are planned and implemented. Centering equity helps bridge the gap between municipalities' actions and community members' needs and supports Michigan Sea Grant's efforts to reduce disparities and support healthy, safe Great Lakes communities.

We intend for these findings to assist with the implementation process, and the implementation of flood mitigation measures will, in turn, provide valuable services to Milwaukee and Benton Harbor. This research has illustrated the many incredible community members, stakeholders, and policymakers whose efforts are pushing back against climate hazards and strengthening these cities. Through their tireless work, these communities are on the path to greater equity and resilience.

# Appendices

### *Appendix A: Initial Stakeholder Conversation Protocol*

Introductory Script:
We are a team of graduate students at the University of Michigan working with Mike Shriberg and Michigan Sea Grant to develop recommendations for flood mitigation techniques, focusing on the types and placements that yield the greatest benefit to the surrounding community. We will build on previous technical flood modeling efforts, using community engagement to ensure that mitigation efforts are synchronized with community needs. We would greatly appreciate your advice and expertise so that the outcome of our work addresses stakeholders' questions and aligns with the project's broader scope. We would also love to know if there are any data needs of yours we can address.

Introductory

1. Tell us a bit about your role in the work on flooding mitigation in [...] (add Benton Harbor or Milwaukee).
    a. How long have you been involved?
    b. How does flooding impact your community (where and who is affected)?
    c. Within your community, who is involved with flood mitigation/prevention? What is your decision-making process for this?
        i. In the discussion on the decision-making process, gauge interest in public input.

Project Plan

1. We've done a literature review and read [...]. In your opinion, what are the key resources that we should be aware of and/or find to inform our work?
2. We'll be doing interviews and focus groups with community members. Who would you prioritize talking to? What key questions do you think we should ask?
3. Are there any on-the-ground sites in the [...] project area(s) that strike you as particularly important?
4. As a project component, we are developing a survey and mapping tool to gather community members' experiences with flooding and their flood-prevention priorities. Would this community feedback be helpful to people working on flood-prevention measures in your city? How?
    a. What other questions could we ask the community that might be useful for decision-makers?

Next Steps

1. In your opinion, who else would be a good person to contact during the scoping phase?
    a. Do you have contact information for these people that you can share with us?
2. If we have any other questions, can we reach out to you by email?

### *Appendix B: Semi-Structured Local Official and Expert Interview Protocol*

Introductory Script:
Hello. [*Begin with individual introductions*]. We are part of a team of graduate students at the University of Michigan's School for Environment and Sustainability, working with Michigan Sea Grant to develop recommendations to alleviate flooding and improve public amenities in two coastal Great Lakes communities—specifically, Berrien County and Benton Harbor, Michigan, and Milwaukee, Wisconsin. Thank you for taking the time to participate in this interview.

This interview will not result in your name being shared outside the research team, which consists of us, our University of Michigan faculty advisor, and our client at Michigan Sea Grant. All results will be reported in aggregate or without any identifying information. If you would like to stop the interview or skip a question, you are welcome to do so at any time. With those caveats in mind, do we have your permission to record this conversation so our research team can review it?
[ *Begin recording, if agreed upon* - or - *prepare for detailed note-taking.* ]

Introduction and Personal/Professional Experience
Let's start with you sharing a little bit about yourself.

1. What is your current role, and what is your primary geographic area of interest?
    a. Are you a resident of [...]?
        i. (If they are a resident) How long have you been?

Now we'd like to move on to identifying key challenges related to flooding in [...].

2. Overall, what do you see as the ongoing challenges [...] faces with flooding?
    a. Where and who is primarily impacted?
        i. (If they did not mention their own experience) If you feel comfortable sharing, how have you been impacted?
3. As [role], please tell us about the work that has been done surrounding flooding mitigation, and/or related concerns, in [...] that you have been and are currently involved with
    a. (If they did not mention their background or motivations) How and why did you get involved?
    b. (If they did not mention time) How long have you been involved?

Flood Mitigation and Desired Outcomes
[ *Thank them for sharing, and transition naturally to the following questions.* ]

1. What do you see as the top priority for flood mitigation in [...]?
    a. (If they did not share already) What is the worst flooding that you have seen? When/where/under what conditions?
        i. (If they did not share already) What were the impacts?
    b. With more (unlimited) resources, what would be your ideal scenario for mitigating flooding and its impacts?
        i. (If they did not share about related aspects) What benefits would be provided to the community as a result of successful flooding mitigation? (e.g., increased job or recreational opportunities)
2. What kind of mitigation infrastructure or measures (e.g., floodwalls, detention basins, floodways, shoreline restoration, improvements to city storm drains, water pumps in prone locations, etc.) do you think have been the most effective, or would be the most effective, given your experience? Why?
    a. (If relevant) Are there any places in particular that would especially benefit from one of these methods?

3. Under what conditions do you favor gray infrastructure over green infrastructure, and vice versa? What has worked better?
4. Based on your experience, what do you see as the key barriers to implementing or enacting flood mitigation measures?
    a. *(If they did not mention vulnerability or being underserved)* Based on your experience, how do you define equity in flooding mitigation? What do you see as the key barriers to achieving it?

Survey Development and Receiving Community Feedback
[ *Thank them for sharing, and transition naturally to the following questions.* ]
We plan to develop and distribute a survey to community members later in the summer to learn more about the impacts of flooding, desired mitigation measures, and the outcomes of successful flooding mitigation.

1. Based on your experience, what methods for receiving community feedback (e.g., community forums, interviews, surveys) have received the most engagement from community members in [...]? [ *e.g., Ox Creek Revitalization Plan goals and iterations were based, in part, on community feedback.* ]
    a. (If they did not mention specific types of response) Have community members expressed concerns that project plans and progress do not address their needs or that they are not involved in the planning process as much as they would like?
        i. (If yes) How has that been addressed, if it has?

Gathering Potential Interviewees, Relevant Literature, and Next Steps
[ *Thank them for sharing, and transition naturally to the following questions.* ]

1. Are there any other local officials or experts that we should reach out to for an interview?
    a. (If yes) Would you be willing and able to share their contact information with our team?

We understand that meaningful community involvement and engagement as students is crucial to providing feasible recommendations. [ *Mention if we spoke to any already (e.g., April 26th) and may need contact information.* ]

2. Are there any community members that we should reach out to for an interview?
    a. (If yes) Would you be willing and able to share their contact information with our team?
3. Our team is conducting a literature review, and we have read [*Describe materials relevant to them (e.g., municipal master plans, watershed plans, etc.)*]. Are there any other essential resources that we should be aware of to inform our work?
4. Given the current progress in implementing flood infrastructure in [...], how do you see our final recommendations report and efforts over the next year best informing the work you do?
5. If we have any further questions, could our team reach out to you via email?

[ *End recording.* ]

Thank you again for your time and engagement. [ *End with a thoughtful, natural goodbye.* ]
[ *End meeting, and ensure the conversion process is successful.* ]

*Appendix C: Codebook and Code Counts*

| Code | Description | Count |
|---|---|---|
| **Environmental Conditions** | **Parent Code** | |
| **GL Cycle** | Participant comments on the cyclical nature of Great Lakes water levels and the implications for communities and flood management. Any mention of the cyclical nature of the Great Lakes and how that can play into flood mitigation and management. | 20 |
| **Groundwater Table** | Participant mentions groundwater table or inundation and its impact on flooding or flood risk. | 7 |
| **Highland/Lowland Areas** | Participant mentions flooding variation due to land elevation. | 11 |
| **Lakeshore** | Participant describes beach or lakeshore development zones that vary with rising and falling water levels. | 14 |
| **Riverside** | Participant describes the river shoreline and its impacts on flooding or flood risk. | 9 |
| **Floodplain** | Participant describes flooding due to siting in the floodplain. | 5 |
| **Equity** | **Parent Code** | |
| **Management Equity** | Participant raises equity issues related to flood mitigation/management. | 23 |
| **Public Access** | Participant discusses issues of public access to the water/nature/public amenities. Restrictions or advancements of access for any reason. | 9 |
| **Existing Infrastructure** | **Parent Code** | |
| **BH Downtown Area** | Participant discusses flooding in the Benton Harbor downtown area, including Main Street, Colfax, Riverview, and the area in front of Whirlpool HQ. | 23 |
| **BH Old Canal** | Participant discusses flooding in and around the old shipping canal in Benton Harbor. | 4 |
| **Hall Park** | Participant discusses flooding in and around Hall Park. | 6 |

| | | |
|---|---|---|
| **St. Joseph Township** | Participant discusses flooding in St. Joseph Township. | 1 |
| **MWK Downtown Area** | Participant discusses flooding in downtown Milwaukee. | 0 |
| **MWK Lakeshore Infrastructure** | Participant discusses flooding and its impacts on Milwaukee shoreline infrastructure. | 7 |
| **Ox Creek** | Participant discusses flooding in and around Ox Creek. | 14 |
| **Stormwater Management** | Participant describes existing stormwater management infrastructure and strategies. | 24 |
| **Flood Impacts** | **Parent Code** | |
| **Economic** | Participant describes the economic hardships the community experienced as a result of flooding. Mentions of financial difficulties faced by a community as a whole or by community members —for example, community income suffering from fewer vacationers and business owners suffering from inaccessibility to their shops —would both fall under this code. | 9 |
| **Infrastructural** | Participant expresses concern about the existing infrastructure affected by flood damage. Mentions of damaged infrastructure in past flood events, fear of infrastructure damage in future events, and measures taken to protect infrastructure. | 27 |
| **Mobility** | Participant discusses impaired mobility throughout the community due to flooding—mention of impaired mobility in the community. | 13 |
| **Other Impacts** | Participant mentions flooding impacts that do not fit neatly into any of the other codes. | 10 |
| **Site-Specific** | Participant mentions a specific flood site. Mentions a particular site where flooding has been observed. | 7 |
| **Mitigation Techniques** | **Parent Code** | |
| **Accommodating Water Tables** | Participant describes the water cycle and the lake/river/watershed's pattern (decadal timelines) and advocates for building infrastructure with the watershed's cycle in mind. | 4 |

| | | |
|---|---|---|
| **Current/Previous** | Participant describes current or previous mitigation techniques—any description of what the community is doing or has done to deal with flooding. | 27 |
| **Green Infrastructure** | Participant supports green or nature-based mitigation techniques. | 61 |
| **Green Infrastructure Challenges** | Participant describes barriers to green infrastructure. | 15 |
| **Gray Infrastructure** | Participant describes or is in support of gray or infrastructure-based mitigation techniques. | 19 |
| **Situation-Based** | Participant believes the choice between green and gray infrastructure should be based on the specific situation or location. | 15 |
| **Planning** | **Parent Code** | |
| **Community-Based Decision-Making** | Participant believes communities should make their own decisions, even if those decisions are not aligned with neighboring communities. Participant advocates for decisions to be made within communities. | 32 |
| **Education/Best Practices** | Participant describes or expresses the need for educational outreach as part of flood mitigation tactics and/or represents the development of best practices as a part of education. Description of education, outreach, and/or best practices as a part of resilient coastline management and/or flood mitigation. | 54 |
| **Failed Management** | Participant describes a case in which a management decision did not meet the desired goals, resulting in negative flood impacts. Mentions of previous policy and management decisions that had negative consequences, including but not limited to total or partial physical failure or poor community acceptance. | 4 |
| **Funding** | Participant identifies funding issues as a barrier to coastal management/flood mitigation. Any mention of financing as a factor in flood mitigation includes, but is not limited to: difficulty accessing funding, insufficient staff to manage/apply for funding, or too much funding (i.e., not being able to operate efficiently). | 49 |

| | | |
|---|---|---|
| **Gov't Coordination** | Participant identifies coordination among local, state, and federal governments as a barrier to coastal management and flood mitigation. | 46 |
| **Human Resources** | Participant describes labor or expertise needed to address flooding. | 18 |
| **Limited Infrastructural Availability** | Participant discusses the lack of availability (land spaces, feasibility, aging structures, etc) for necessary mitigation measures or infrastructural improvements to take place. | 8 |
| **Private vs. Public Property** | Participant comments on tensions that exist among private property owners and the public, those relationships, or decisions made to protect private property that affect public land. Any mention of the tensions that exist between private land owners, the state, or the public. | 15 |
| **Upstream/Downstream** | Participant discusses the upstream/downstream dynamics. Any mention of upstream events impacting downstream events, especially outside the city's jurisdiction. | 11 |
| **Role** | **Parent Code** | |
| **Academia** | Participant works in academia. | 5 |
| **Community Leader** | Participant is recognized as a community leader. | 1 |
| **Private Sector** | Participant works in the private sector. | 4 |
| **Public Sector** | Participant works in the public sector. | 11 |
| **Community Engagement Techniques** | **Parent Code** | |
| **Addressing Grievances** | Participant describes techniques for addressing community grievances. | 12 |
| **Food** | Participant stresses the importance of food as a community engagement tool. | 4 |
| **In-Person Conversation** | Participant stresses the importance of in-person conversation as a community engagement technique. | 11 |

### *Appendix D: Community Member Conversation Protocol*

Introductory Script:
Hello. We are part of a team of graduate students at the U-M developing recommendations to address flooding in Benton Harbor. Some strategies include reconstructing existing structures in the floodplain with additional vegetation and removing concrete.
We are seeking public input on what flooding [people] have experienced, and what solutions are preferred. We won't share your personal information outside our team. Do we have your permission to take notes?

[ *Prepare for detailed note-taking.* ]

1. What types of problems with standing water or flooding have you experienced in Benton Harbor?
2. Have you made any changes or upgrades to your home/car/etc, to prepare for or manage flooding? If so, are they effective, and what made you pick those solutions?
3. What would you like to see the city do about flooding issues?
4. Some strategies to prevent damage from flooding involve putting a park, trail, or other natural space in the floodplain – instead of buildings or gray infrastructure – that allows the space to flood on occasion. If that were done in Benton Harbor, what kinds of green spaces would you like to see?
    a. What kind of green space/outdoor recreation facilities would you use?

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