MUSKEGON LAKE RESILIENCY PLAN

JANUARY 2017

Acknowledgements

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Cover photo taken by Nick Kroes, mostlymuskegon.com

MLWP Muskegon Lake Watershed Partnership

NOAA

City of North Muskegon

Muskegon — West Michigan's Shoreline City

Laketon Township

Muskegon County

WMSRDC West Michigan Shoreline Regional Development Commission

delta institute

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ACRONYMS

AOC - Area of Concern

AWRI - Annis Water Resources Institute

CIP - Capital Improvements Plan

CVTRS - City, Village, and Township Revenue Sharing

US EPA - United States Environmental Protection Agency

GVSU -Grand Valley State University

IBI - Index of Biological Integrity

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

MCPAC - Muskegon County Port Advisory Committee

MLWP - Muskegon Lake Watershed Partnership

MS4 - Municipal Separate Storm Sewer System

NPDES - National Pollutant Discharge Elimination System

NOAA - National Oceanic and Atmospheric Administration

NRCS - Natural Resources Conservation Service

PRP - Potentially Responsible Party

TSI - Trophic State Index

WMSRDC - West Michigan Shoreline Regional Development Commission

USACE - United States Army Corps of Engineers

USDA - United States Department of Agriculture

INTRODUCTION

Background

Over the past several decades, communities surrounding Muskegon Lake have invested significant effort and resources into restoration and are interested in shifting the focus toward protection and stewarding of healthy communities and ecosystems into the future. Jurisdictions that are responsible for planning and implementation of management decisions on the Muskegon Lake shoreline include Muskegon County and the coastal communities of the City of Muskegon, the City of North Muskegon, and Laketon Township, As part of the movement to rethink and shape the future of Muskegon Lake, Muskegon Lake Vision 2020 was a public input process developed to provide information and a platform for a unified vision to guide sustainable development and utilization of Muskegon Lake and its shoreline.

This plan builds on Muskegon Lake Vision 2020 Master Plan, as well as area land use, watershed management, and hazard mitigation plans. It provides local decision makers with a blueprint for incorporating resilience thinking and practices into ongoing and future programs, policies, and community discussions in ways that address social and ecological links and interactions and their role in resilience. While Muskegon Lake is part of a much larger Muskegon River watershed spanning jurisdictions beyond those located on Muskegon Lake shorelines, this plan is focused on assessing the resilience of the Muskegon Lake coastal communities and engaging shoreline stakeholders.

Why Resilience?

While there may be many definitions of **resilience**, the concept, which has gained much prominence in the past several decades, focuses on how to **build capacity to deal with unexpected change**.[1] A **resilience assessment** approach integrates social, cultural, and economic factors and looks at how people are part of and interact with the ecosystem. One of the main ways in which people depend on and interact with their environment is through their use of different ecosystem services, such as the water we use for cooking and drinking, shipping and navigation that support commerce activities in the region, regulation of the climate, and our cultural and recreational connections to ecosystems. A resilience assessment approach tries to investigate how these interacting systems of people and nature – or social-ecological systems – can best be managed to ensure a sustainable and resilient supply of the essential ecosystem services on which communities depend.

Traditional approaches to managing natural resources and community assets that assume a static model of the environment can make a system more vulnerable by concealing key system properties that may go unnoticed until it's too late. Likewise, actions that address problems one by one, as they arise may be successful in the short term, but they may also trigger interactions among the different components of a system that can come into play later. Piecemeal interventions do not prepare a system for dealing with ongoing change and future disruptions.

The resilience assessment approach employs **adaptive governance** as a main principle that recognizes cross-scale interactions and promotes collaboration across organizational levels. Governance structures, and, in turn, decisions made by communities, are based on both formal rules - laws, organized markets, property rights, and informal cultural practices - communal and familial social norms - that determine how people interact with the ecosystems around them. Adaptive governance emphasizes the capacity to adapt to changing conditions within society and ecosystems in ways that sustain ecosystem services. Characteristics of adaptive governance include experimentation, new policies, approaches to collaboration within and among agencies and stakeholders, new ways to promote flexibility, and new organizational structures. An adaptive approach to governance and management can enhance general resilience by encouraging flexibility, inclusiveness, diversity, and innovation. With the Muskegon Lake Vision 2020 Master Plan, the recovery of Muskegon Lake ecosystem, and shifting priorities focusing on healthy environmental and economic conditions, Muskegon Lake communities are well positioned to apply the resilience assessment approach and transform Muskegon Lake into a resilient, vibrant system into the future.

Goal

This plan will guide local governments in the development and adoption of climate adaptation and resilience strategies for the Muskegon Lake waterfront, ensuring that these strategies and principles are incorporated into future waterfront development, commercial port activities, and shoreline restoration work. It will also be used by shoreline landowners (public and private) to guide protection of valuable natural resources and physical recreational and commercial amenities in the face of changing conditions. Muskegon Lake ecology and community profiles have been described in detail in numerous documents (e.g. Muskegon Lake Remediation Action Plan, Muskegon County Hazard Mitigation Plan), therefore we are simply including a map to orient the reader and provide initial context for the plan's contents. Furthermore, there has been extensive work done to characterize natural resource issues, including sources, impacts, and strategies to address them. In addition, various municipal/county departments have their own plans to manage recreational assets, infrastructure, and economic development. This plan draws on the information contained in existing plans and reports, however, the main goal of the resilience plan and strategies presented within it is to better understand how valuable assets in and around Muskegon Lake function as a system, and how the existing plans and activities fit together. Ultimately, this is the basis for establishing system-wide processes that foster adaptive governance

[1] Stockholm Resilience Centre, 2014

and resilience of the Muskegon Lake as a functional ecosystem that supports a thriving community and sustainable economic development.

This plan will characterize assets and potential disturbances, assess vulnerabilities for the area, identify key management processes and barriers impacting resilience outcomes, and provide a roadmap for implementing resilience strategies and tracking progress, as shown in **Figure 1**. The recommended strategies presented in the plan are in the timeframe aligned with the typical planning cycles - over the 10 year horizon (2020-2030). The timeframe is defined for practical purposes to help align municipal and county planning cycles. In concert with the concept of resilience, the plan is also intended to help facilitate adaptive management - revisiting and revising goals and strategies over the 10 year span and beyond.

Figure 1. Resilience assessment process diagram.

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Figure 2. Map of the Muskegon Lake and surrounding area.

DEFINING THE MUSKEGON LAKE SYSTEM

A resilience assessment is the first phase of resilience planning and is needed to evaluate *what* is it that we want to be more resilient and what does it need to be *resilient to*. As such, resilience assessment begins with defining the social-ecological boundaries of the system, the main components of the system that are important to the community and corresponding issues of concern. In this plan, the geographic boundaries of the system are defined as the Muskegon Lake shoreline and the surrounding area (**Figure 2**). In this plan, we focus on this system and its components, however, it is important to keep in mind that any system is influenced by factors that lie both outside and within its boundaries spanning a range of scales, both in time and space. See p. 24 for an explanation of cross-scale interactions and examples of larger and smaller scale drivers that influence Muskegon Lake shoreline and its resilience.

Muskegon Lake Assets and Issues

The first step in a resilience assessment process is to define the system and identify the important components of the system. As part of the Muskegon Lake Vision 2020 development process, the community residents and stakeholders engaged in a series of discussions about the future of Muskegon Lake. The community identified valued assets and ecosystem services provided by Muskegon Lake, as well as stressors that may be impacting them. The assets prioritized comprise 4 main categories: natural resources (**Table 1A, Figure 3**), outdoor recreation (**Table 1B, Figure 4**), commerce and ports (**Table 1C, Figure 5**), and residential areas (**Table 1D, Figure 6**). The tables and maps below describe the attributes of each category in detail, list related issues, and provide information about related stakeholders and organizations involved in making management decisions. *Note: see the list of acronyms at the beginning of the document.*

Stakeholder meeting, Photo: WMSRDC.

Table 1A. Community identified natural resource assets for Muskegon Lake.

Natural Resources		
System Attributes (components/uses)	**Issues**	**Management & stakeholders**
• Fisheries (variety of species such as walleye, chinook, steelhead, sturgeon, yellow perch, large/smallmouth bass) • Fish and Wildlife Habitat (dunes, wetlands, benthos, littoral zone, state park land, parks and green space) • Aesthetics (surface water, green space) Water quality & infiltration (surface water, stormwater, groundwater)	• Water quality impairment (sediment, harmful and nuisance algal blooms, microbial pathogens, hypoxia) • Degradation and loss of habitat • Erosive/filled-in shoreline • Invasive Species – Aquatic & Vegetative • Industrial contamination • Lake bed alteration/degradation • Lack of connectivity • Lack of awareness	• Muskegon Lake Watershed Partnership and Area of Concern remediation partners • Monitoring and research (US EPA, MDEQ, MDNR, NOAA, GVSU, AWRI) • Stormwater Management (Muskegon Area Municipal Storm Water Committee MS4 Program, City of North Muskegon MS4 Program/Public Works Department) • Wetland restoration (WMSRDC, MDEQ, MDNR)



Baby Snapping Turtle near Muskegon Lake; Hawk near Ruddiman Creek; Photos taken by Nick Kroes, mostlymuskegon.com.
Muskegon Lake Shoreline, Photo: Delta Institute.

Figure 3. Map of natural resource assets for Muskegon Lake.

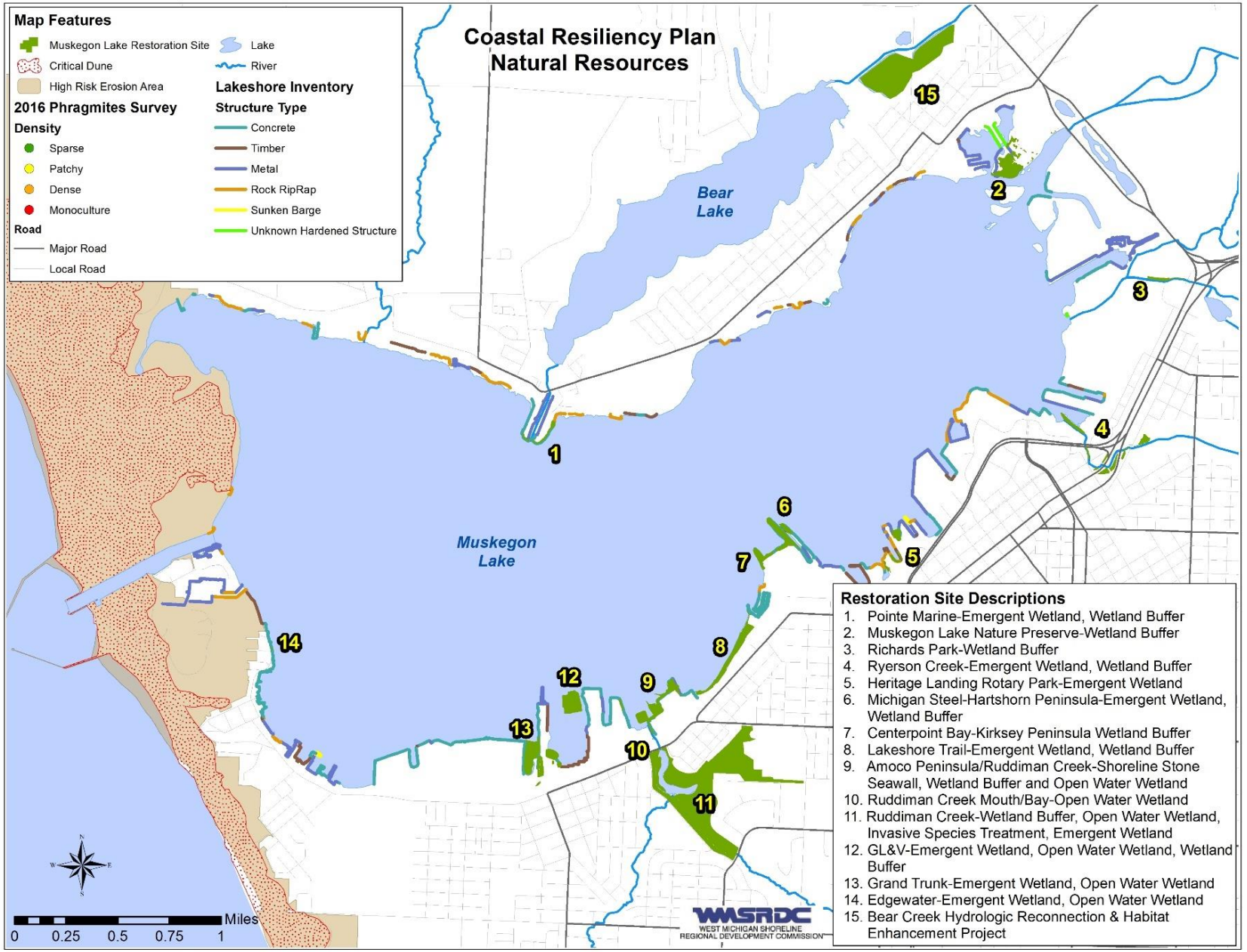


Table 1B. Community identified outdoor recreation assets for Muskegon Lake.

Outdoor Recreation		
System Attributes (components/uses)	**Issues**	**Management & stakeholders**
• Fishing (boat launches, fisheries) • Sailing & boating (water trail, boat launches, marinas, outfitters) • Swimming (beach) • Trails (state park, other parks, biking path) • Historical/cultural sites (lighthouses, historic ships, historic houses) • Birding and wildlife viewing	• Water quality impairments • Property damage • Degraded habitat • Lack of access • Lack of awareness • Loss of Habitat	• Park and beach management (Muskegon Planning, Zoning, & Recreation Department/North Muskegon Recreation Board/Laketon Township Parks and Recreation Department/Muskegon County Parks Department/MDNR) • Operation of boat launches/marinas (Hartshorn - municipal marina; others are privately owned and operated) • Fishing licenses (MDNR) • Tourist visitation (Muskegon County Convention and Visitors Bureau, Muskegon Lakeshore, Chamber of Commerce)

Norman F. Kruse Park, Photo: www.muskegon-mi.gov. Frauenthal Theater, Photo by Evan Witek, Muskegon Chronicle, MLive.com. Marina on Muskegon Lake, Photo: WMSRDC.

Figure 4. Map of outdoor recreation assets for Muskegon Lake.

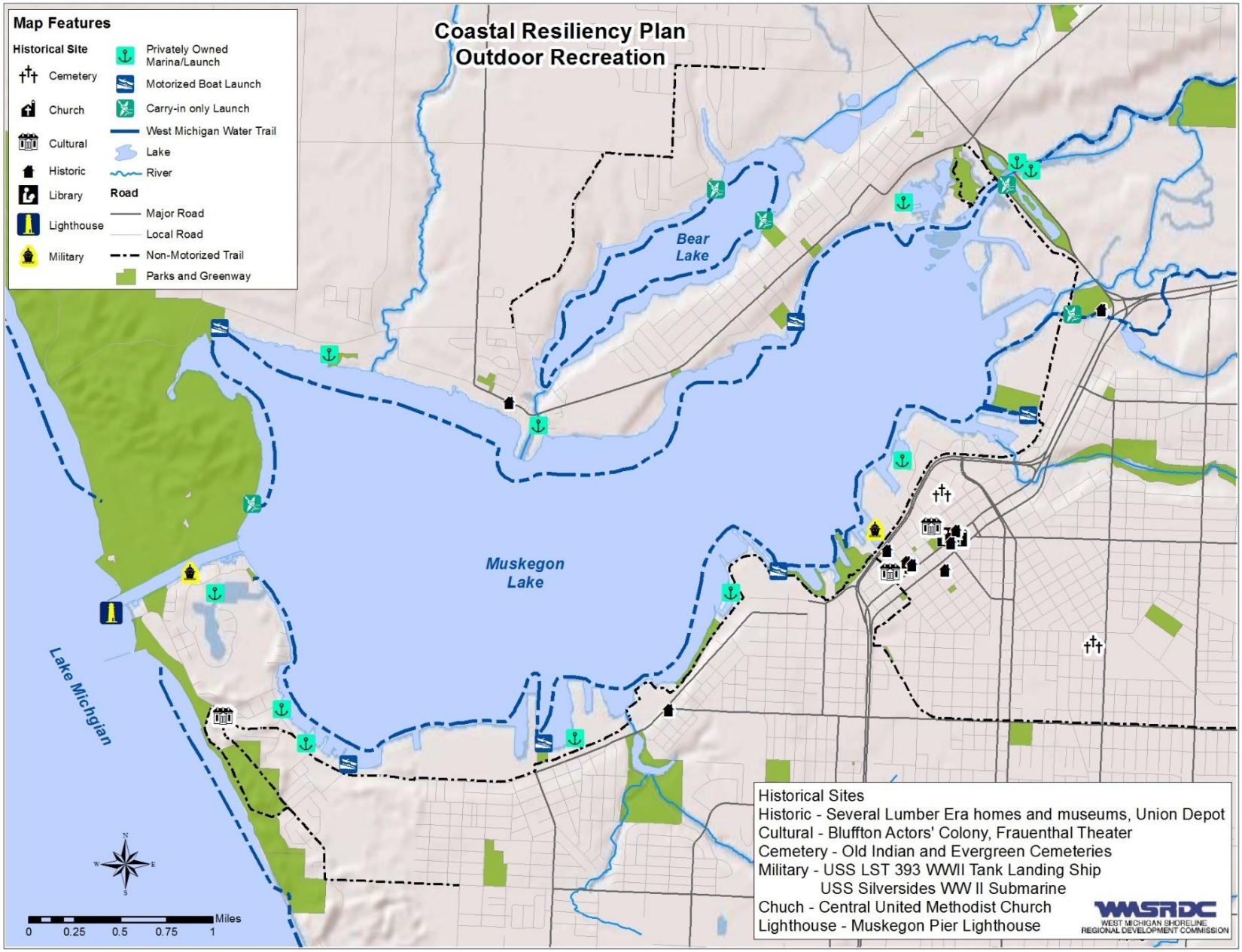


Table 1C. Community identified commerce and ports assets for Muskegon Lake.

Commerce and Ports		
System Attributes (components/uses)	**Issues**	**Management & stakeholders**
• Deep water port (port infrastructure, channel) • Industrial docks (cargo shipping of cement, rock, construction materials, salt, storage) • Commercial marinas (Cruises)	• Erosion • Property damage • Fluctuating water levels • Sustained low water levels • Commercial vs ecological interests are at possible odds with each other • Introduction of invasive species • Connectivity with transportation infrastructure	• Port revitalization (MCPAC) • Coal plant decommissioning (Consumers Energy) • Channel maintenance (USACE) • Port operations (property owners) • West Michigan Port Operators

Ice on Muskegon Lake, Photo taken by Nick Kroes, mostlymuskegon.com.

Freighter traveling in Muskegon Channel, By NOAA Great Lakes Environmental Research Laboratory (2977) via Wikimedia Commons.

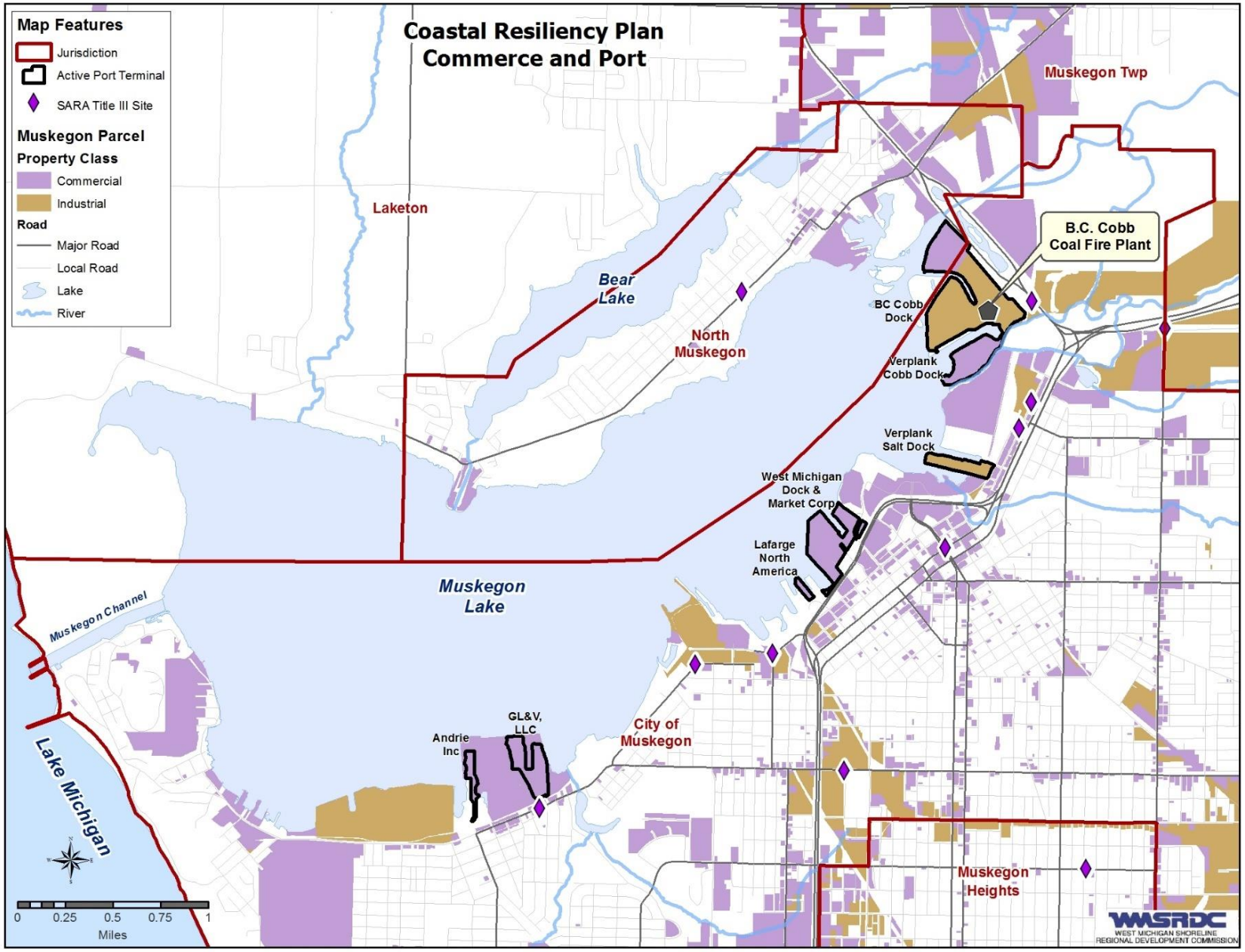

Coastal Resiliency Plan
Commerce and Port
Map Features
Jurisdiction
Active Port Terminal
SARA Title III Site
Muskegon Parcel
Property Class
Commercial
Industrial
Road
Major Road
Local Road
Lake
River
Muskegon Twp
Laketon
Bear Lake
North Muskegon
B.C. Cobb Coal Fire Plant
BC Cobb Dock
Verplank Cobb Dock
Verplank Salt Dock
West Michigan Dock & Market Corp
Lafarge North America
Muskegon Lake
Muskegon Channel
Lake Michigan
GL&V, LLC
Andrie Inc
City of Muskegon
Muskegon Heights
0 0.25 0.5 0.75 1
Miles
WMSRDC
WEST MICHIGAN SHORELINE REGIONAL DEVELOPMENT COMMISSION

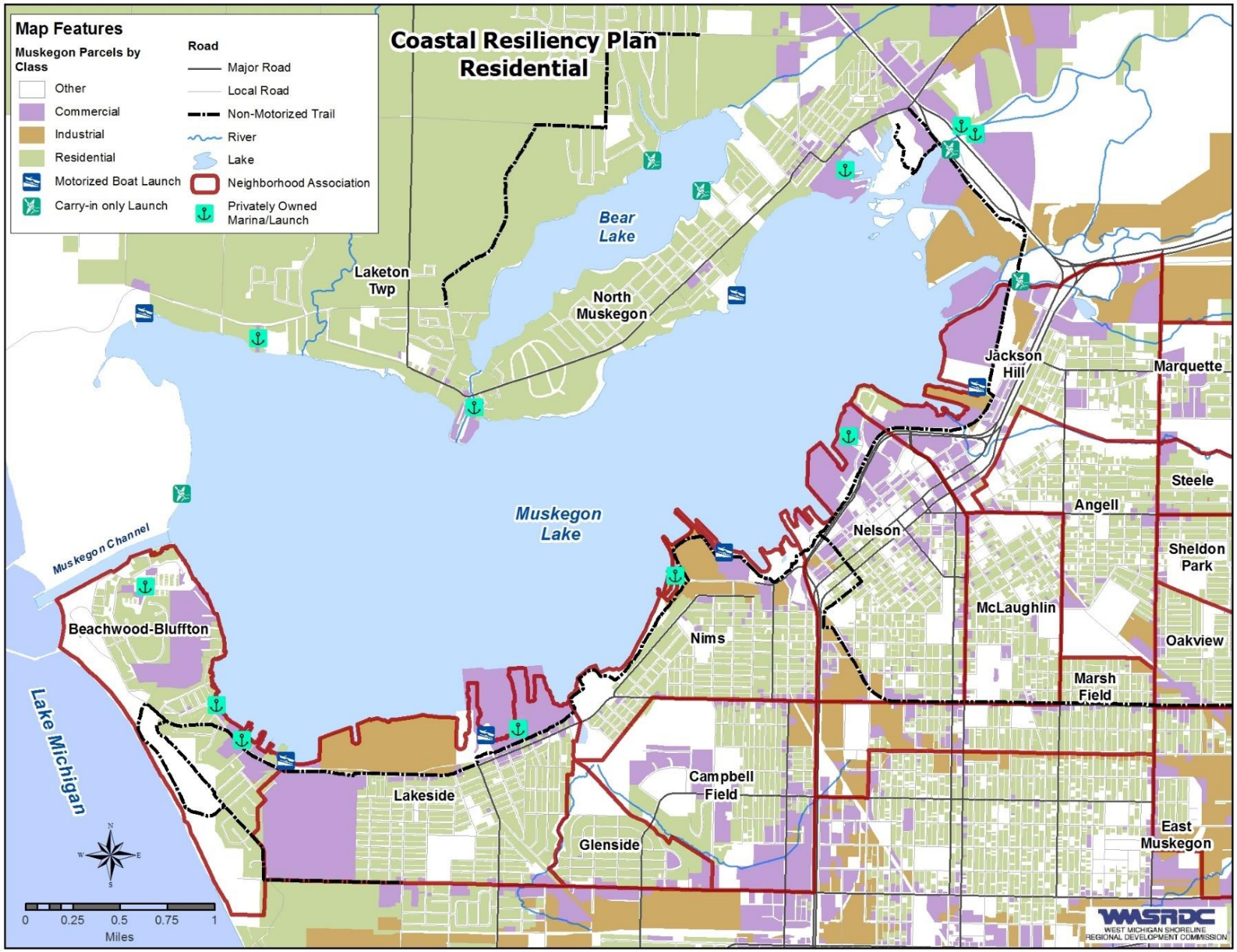
Table 1D. Community identified residential assets for Muskegon Lake.

Residential		
System Attributes (components/uses)	**Issues**	**Management & stakeholders**
• Property value (building structures, docks/boat launches, roads) • Quality of life (viewshed, proximity/access to waterfront) • Municipal sewer and private septic systems	• Water quality impairment • Property damage • Higher risk of exposure to waterfront associated hazards • Erosive shoreline • Lack of connectivity • Lack of consistency in setback regulations • Lack of awareness • Equity/access to water resources	• Zoning (Muskegon Planning, Zoning, & Recreation Department/North Muskegon Zoning Department/Laketon Township Planning and Zoning Department, Muskegon County Public Works Department) • Public Health Muskegon County • Redevelopment (municipal/private contractors) • Localized management (property owners)

Residential Boat Launch, Photo: Delta Institute.

Muskegon Shoreline at Night, Photo taken by Nick Kroes, mostlymuskegon.com.

Figure 6. Map of residential assets for Muskegon Lake.



Disturbances

The next step in a resilience assessment is to gain an understanding the types of disturbances that may impact each of the four types of assets in Muskegon Lake and disrupt the services they provide to the community. A **disturbance** can be thought of as anything that causes a disruption to a system. It is important to consider if and how the disturbances are managed currently, how the system responds to those disturbances, and distill lessons that can be applied to mitigating the impacts of the likely disturbances in the future.

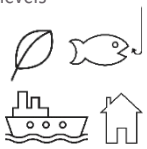
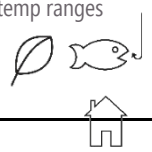
Disturbances can be ecological, like drought, introduction of invasive species, or floods, as well as socioeconomic, like recessions, new regulations, or a change in management. Furthermore, disturbances occur at different time scales, as a relatively discrete event or a more gradual or cumulative pressure on a system. Both ecological and socioeconomic disturbances are typically part of the natural variability of a social-ecological system and combinations of different types of disturbances may lead to interaction or compounding of impacts. Disturbances also shift over time and magnify the level of uncertainty about the system, which reinforces the need for adaptive governance in building resilience. See sidebar on this page for a brief discussion about uncertainty and how to think about it in the context of resilience assessment.

Table 2A-B describes disturbances that are likely to impact the Muskegon Lake assets, characterizes their impact, and the corresponding management structures in place. It should be noted that common barriers to effective management often stem from unnatural shoreline fill and composition, degraded habitat at shoreline edge, lack of formal and informal environmental education and financial support for environmental programs. The Appendix includes a more detailed characterization of each disturbance while the section on p. 24 gives examples of disturbances and system drivers at various scales.

UNCERTAINTY

Although this document does not directly evaluate uncertainty for the resilience assessment, it is important to consider how uncertainty relates to policy and management decisions. In the scientific realm, defining **uncertainty** means understanding how well something is known. The range of uncertainty in assessing vulnerability of a system is derived from a combination of factors that include uncertainty about exposure to a given disturbance (e.g. frequency and intensity of storms), how sensitive the system components are (e.g. extent of possible damage that may occur due to flooding), as well as the system's capacity to adapt (e.g. availability of resources to rebuild or retention capacity of a wetland). The ability to quantify uncertainty is a function of how well we understand and model interactions within social-ecological systems and at various scales, which are highly complex and dynamic. There have been significant advances in scientific community to quantify and reduce uncertainty and scientists have developed and adopted terms that consistently describe uncertainty about current situations and future outcomes to inform public policy.

Table 2A. Ecological Disturbances

Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure
Winter storms 	dunes/wetlands marinas/docks/ launches port infrastructure roads buildings historical sites	severe	Current management: hardened shorelines (riprap/retaining walls), seasonal measures such as dock de-icers/bubblers, or winter dock/boat/buoy removal; : repairs by public and private landowners; voluntary retrofit programs; insurance; reactive to address damage caused Barriers: Much of the shoreline is comprised of unnatural fill (historic sawmill debris, spent foundry sand and slag, broken concrete). Unconsolidated material presents technical complexities when engineering shoreline developments that withstand high water elevations, high winds and the forces of ice break up
Severe winds 	dunes marinas/docks/ launches port infrastructure roads buildings historical sites	severe	Current management: repairs by public and private landowners; voluntary retrofit programs; insurance; reactive management to address damage caused
Great Lakes water levels 	dunes/wetlands, other shoreline habitats aesthetics beach marinas/docks/ launches port infrastructure buildings	severe	Current management: repairs by public and private landowners, and competitive grant funds for post restoration monitoring management of shoreline habitat; during low levels, dredging of shipping channel by the USACE
Extreme temps, temp ranges 	fisheries, habitat, fishing quality of life	medium-severe	Current management: The Michigan Department of Natural Resources Fisheries Division is responsible for development of fisheries management plans. The National Oceanic and Atmospheric Administration designated Muskegon Lake as a Habitat Focus Area. The WMSRDC and MLWP implement habitat restoration projects to enhance biodiversity of native species; There are no direct management activities focused on adaptive management or routine maintenance of natural resources. Muskegon County Sustainability Office provides energy efficiency resources and incentives to potentially aid residents in dealing with extreme temperatures

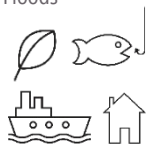
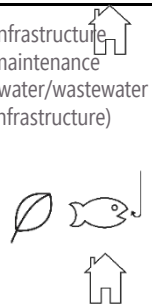
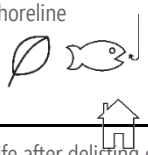
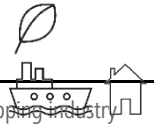
Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure
Floods 	wetlands, water quality marinas/docks/ launches swimming trails historical sites port infrastructure roads buildings sewer/septic systems quality of life historical sites	medium-severe; potentially catastro-phic (e.g. dam failures on Hardy/ Croton dams)	Current management: local - zoning ordinances (where you build), building codes (how you build), stormwater management permit (how you manage water after you build and maintain infrastructure), and Capital Improvement Plan (fund new infrastructure); yard/lawn management; upstream - dams on river flow; control of runoff in watershed, ag land; Effectiveness: minimal to partial due to weak standards in zoning / permitting allowing development in the floodplain area; Barriers: old infrastructure, public resistance, economic/cost concerns, resistance to regulation
Pollution loading: sediment nutrients pathogens chemicals 	water quality fisheries benthos fishing swimming port infrastructure quality of life	severe	Current management: industrial and municipal NPDES permits (what is discharged), MS4 stormwater management permit/illicit discharge elimination plan (what is discharged), voluntary implementation of agricultural best management practices upstream (USDA programs administered by USDA-NRCS, in conjunction with the Muskegon Conservation District and other conservation districts); legacy chemical contamination removal is conducted via implementation of remediation projects under MDEQ enforcement actions and voluntary AOC delisting cleanups (implemented by the U.S. Environmental Protection Agency in coordination with Muskegon Lake Watershed Partnership) Effectiveness: minimal to partial due to voluntary participation (rural nonpoint), site by site variation in implementation (remediation projects & stormwater management approaches) Barriers: increasing frequency and intensity of precipitation events likely to overwhelm the system; public education and controls lack connection to biological systems; limited local, state and federal resources for large-scale contaminated sediment remediation projects
Invasive species 	fisheries habitat water quality aesthetics port infrastructure fishing quality of life	medium-severe	Current management: enforcement of ballast water regulations (U.S. Coast Guard); strategy, planning, funding (MDNR, US EPA) and permitting and funding (MDEQ) for implementation of invasives control; coordination and outreach support for implementation (West Michigan Cooperative Invasive Species Management Area, Midwest Invasive Species Information Network, West Michigan Conservation Network, Muskegon Lake Watershed Partnership Habitat Committee); technical assistance and small scale implementation (Muskegon Conservation District strike teams, WMSRDC regional/multi-county planning and implementation), habitat restoration projects (local governments and environmental organizations) Effectiveness; minimal to progressing, however reactive Barriers: uncertainty related to impact of new species introductions; management costs, lack of political will to strengthen ballast regulation; multiple state agencies serve various roles in funding control projects.

Table 2B. Socioeconomic Disturbances

Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure

Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure
Hazardous materials spills (8 SARA Title III sites in Muskegon within a mile of shoreline) 	water quality fisheries habitat swimming property values quality of life	severe	Current management: Coast guard, DEQ, US EPA, PRPs, industry, Muskegon County Local Emergency Planning Committee, WMSRDC/Multi-County Hazard Mitigation Plans, WMSRDC/Multi-County Homeland Security Program Effectiveness: medium, varies site by site, reactive Barriers: site by site management, maintenance issues are not identified in time; lack of knowledge, cost
Infrastructure maintenance (water/wastewater infrastructure) 	fisheries habitat water quality aesthetics fishing swimming buildings roads sewer/septic systems quality of life	severe, either as primary event, or secondary consequence of storms and floods	Current management: The City of Muskegon Water Filtration Plant produces drinking water for the City of Muskegon and four surrounding communities; Muskegon County manages and operates the Muskegon County Wastewater Management System while local jurisdictions (City of Muskegon, City of North Muskegon and Laketon Township) Departments of Public Works are responsible for maintaining water and sewer infrastructure and hook ups to drinking water and wastewater systems. A Capital Improvements Plan (CIP) is the mechanism through which a community identifies, prioritizes, and establishes financing methods for needed public improvements such as new or improved treatment plants, water and sewer infrastructure, etc. Effectiveness: minimal to medium Barriers: lack of resources and sustainable political will
Shoreline development 	habitat water quality trails marinas/docks/ launches port infrastructure property values access to waterfront	potentially severe	Current management: local government through zoning and permitting (Michigan's Soil Erosion and Sedimentation Control Ordinance, Michigan's Shorelands Protection and Management permits), private landowner investments, brownfield redevelopment programs; Effectiveness: minimal to medium Barriers: complex soil structure/industrial brownfield shoreline properties, lack of sustainable political will to put in place setbacks, public access features, restrictions
Modified (hardened/filled) Shoreline 	habitat aesthetics water quality marinas/docks/ launches	severe	Current management: local government and private shoreline landowners; WMSRDC, GVSU AWRI and the MLWP plan, monitor and implement fill removal and shoreline softening/habitat restoration with grant funds through GLRI and NOAA. Effectiveness: minimal to medium Barriers: lack of resources to implement additional restoration projects and long-term maintenance is dependent upon local resources
Life after delisting of the AOC	fisheries water quality	medium	Current management: Muskegon Lake Watershed Partnership (MLWP) is a voluntary organization that receives natural resources planning and technical assistance through the WMSRDC, AWRI and other state and federal partners. Local governments and private sector

Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure
	habitat/benthos aesthetics property value		organizations voluntarily partner with the MLWP. Effectiveness: Post-restoration monitoring studies indicate improved aquatic habitat and potential for improved socioeconomic conditions. The WMSRDC and MLWP are committed to ongoing planning to improve water quality and natural resources into the future, beyond AOC delisting. Barriers: diminishing resources to implement additional restoration projects, maintain restored resources, and keep community engaged; delisting could be perceived as a "done deal"
Industrial facilities closings (Coal plant, Paper mill, and Steel mill closed) 	habitat aesthetics trails marinas property values	the facilities are closed, but decommissioning/redevelopment takes a long time	Current management: Consumers Energy owns the property, portions to be sold for redevelopment (January 2017), future land use/development currently unknown. Consumers Energy has commissioned at least 2 studies focused on redeveloping the site for commercial port activities including an End Use Study for the property that identified commercial port activity as the highest and best future use and the Economic and Fiscal Benefits of the Port of Muskegon Study to support potential future port development. Additional shoreline, brownfield properties have also become available for cleanup and redevelopment, including a former paper mill property and a steel company. The paper mill property was purchased for mixed use redevelopment and is being marketed as Windward Pointe. The Muskegon Lake Vision 2020 public input process identified the cleanup and redevelopment of the parcels as high priorities for the community. Effectiveness: uncertain due to the pending sale of two of the three properties Barriers: no community-wide consensus on how best to redevelop site and competing demand for shoreline use; public's perceived lack of transparency regarding redevelopment plans; lack of awareness

Disturbance	Components/ uses most affected	Magnitude of impact	Management Structure
Shifts in political climate (new regulations, changes in elected officials, etc.) 	habitat port infrastructure waterfront access	medium	Current management: campaigns, election cycles, and political appointees at state and local level Effectiveness: variable Barriers: differences in ideology/platform, leadership ability, erosion of trust in public institutions
Shipping industry changes 	port infrastructure waterfront access	medium	Current management: There are many activities related to port development and operation, including legislation and innovative business practices. The activities include the following: West Michigan stakeholders and the Detroit Port Authority worked with legislators from Muskegon to introduce an amendment to the existing Michigan Port Authority Act in 2016. The recommended language changes the definition of a port facility and allows for increased opportunities for public/private partnerships with port facility owners and operator, while providing additional protections to private property owners. The proposed legislation passed through the Michigan House of Representatives and is now in committee at the Michigan Senate. The Port of Muskegon Infrastructure & Organizational Analysis assessed the current transportation infrastructure in and around the port including water, roads, rail, and air as well as future capacity of the infrastructure and the potential of developing an organization to manage and/or market the port as a regional logistics hub. The completed study identified excess capacity in all four modes of transportation around the port. In addition, the study identified no current infrastructure improvements necessary to increase the amount of goods being moved through the port. However, the study did recommend additional infrastructure assessments including underwater structural analysis of existing seawalls and the establishment of an organization to be created by the County of Muskegon to promote and advocate for waterborne transportation and a regional logistics hub. A start-up short sea shipping company, Eco Ships, is in the process of securing customers in both West Michigan and the Milwaukee area and purchasing vessels to move goods across Lake Michigan between the ports of Milwaukee and Muskegon. The company is expecting to begin business in the spring of 2017. Muskegon County owns and manages the commercial port facility at Heritage Landing, accommodating Great Lakes cruise ships (the Pearl Mist). There is also a current effort to develop a food hub in downtown Muskegon with a focus around the port, supplying locally grown produce to area school, hospitals, and restaurants, and shipping across Lake Michigan to other interested markets. A pilot food hub shipping project is expected to start in the spring of 2017. Effectiveness: current port facility owners/operators have increased business over the past few years, making up for the tonnage lost by the closure of the BC Cobb Plant. However, there is still a desire by the community to increase and diversify the tonnage being moved through the Port of Muskegon. Barriers: potentially lack of coordination among stakeholders to develop and advance a shared vision of the Muskegon Port
Disturbance	**Components/ uses most affected**	**Magnitude of impact**	**Management Structure**
Energy prices 	port infrastructure commercial marinas quality of life	medium	Current management: the Muskegon County Sustainability Coordinator provides information about resources to assist with voluntary practices related to energy use reduction. Barriers: beyond the control of local jurisdictions

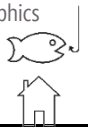
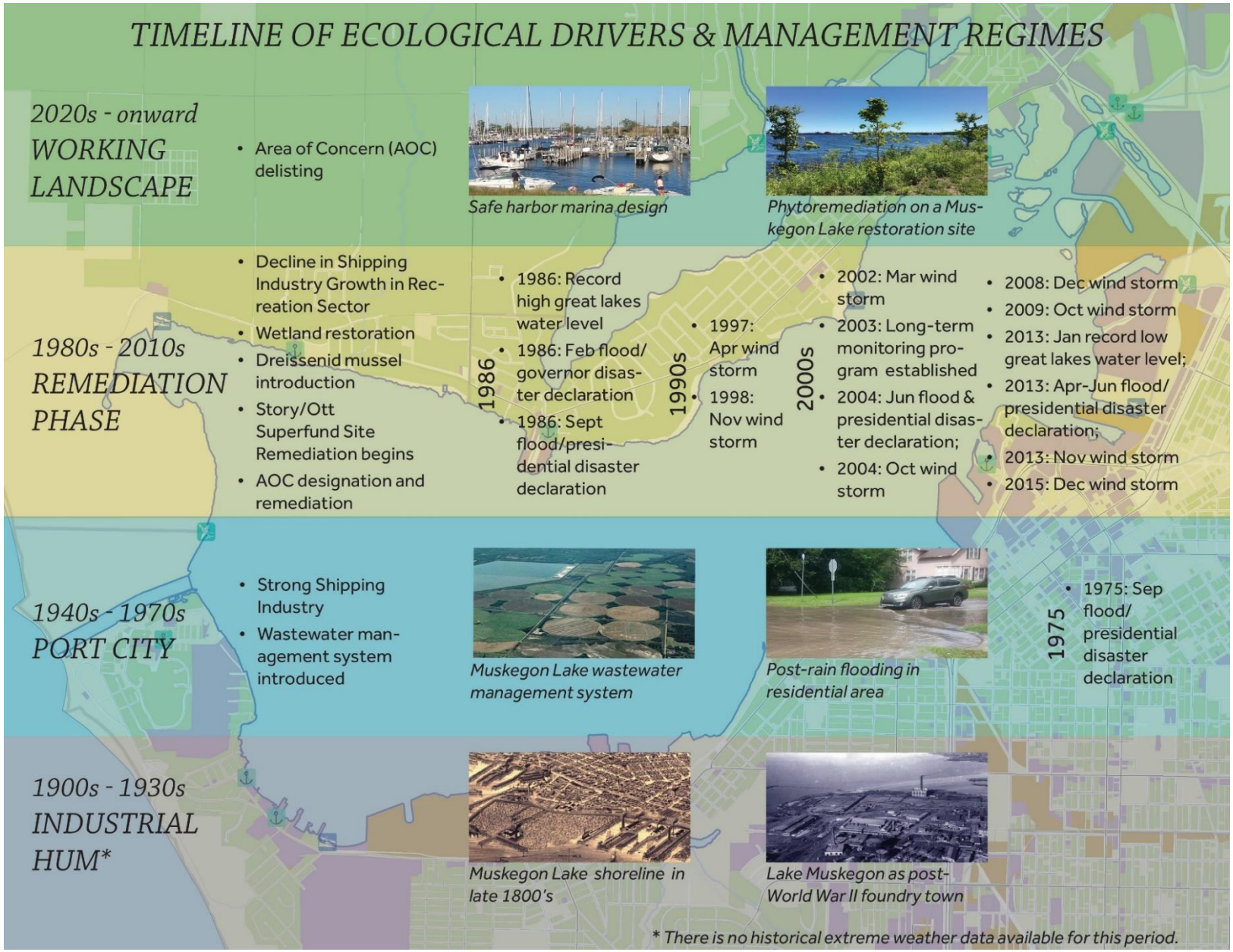
Shifting demographics 	access to waterfront property values marinas quality of life	medium	Current management: Local governments are improving access to water recreational amenities Barriers: Lack of coordination among the local jurisdictions to prioritize retrofits and recreational developments; Equitable geographic access for recreational use of the lake is not ensured for underserved residents

Figure 7. Timeline of Ecological Drivers and Management Regimes



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ASSESSING RESILIENCY

This section describes the linkages between the identified assets and disturbances. It will also identify the most vulnerable assets within the system. This is important to guide the development of resilience strategies and prioritize actions that will protect assets that are most vulnerable.

Vulnerabilities

This section looks at assets and the disturbances that impact them, how severe the impact is, and whether assets have the adaptive capacity to recover (**Figure 8**). Those that will experience severe impact and have lower adaptive capacity are more vulnerable and therefore should be prioritized for action.

Vulnerability Ranking		Sensitivity *impact on the system*				
High	Low-medium	low				high
Medium- high	Low	not affected	minimally affected	somewhat affected	largely affected	greatly affected
Medium	Opportunity					
low	not able		**Cultural/ historic sites**			
	minimally able			**Port; Industrial Docks**	**Fish and wildlife habitat;**	**Aesthetics**
Adaptive capacity *ability to accommodate or adjust in a beneficial way*	somewhat able			**Swimming; Fishing; Quality of life; Sewer/ septic systems**	**Property values**	**Fisheries; Water quality & ground water**
	mostly able		**Boating/ sailing; Commercial marinas; Trails**			
high	able					

Figure 8. Vulnerability ranking based on steering committee assessment.

Defining Resilience Goals

In order to build resilience in the Muskegon Lake system, stakeholders and organizations involved in making management decisions about the system for which resilience is sought, need to develop a deep understanding of the interdependencies and trade-offs between various system components, as well as a nuanced vision of what needs to be resilient and what it needs to be resilient to.

Through Muskegon Lake Vision 2020, communities have identified the valued assets and corresponding issues facing Muskegon Lake shoreline - these provide the guidance for resilience planning. The valued assets become the focal point of the resilience plan, i.e. what needs to be resilient.

> *This plan will guide local governments in the development of resilience strategies for the Muskegon Lake waterfront. It recommends a set of system wide and asset specific actionable strategies, that ultimately lay the groundwork for communities to grow their understanding of how to apply resilience principles and build on ideas in this plan to revisit and refine the resilience goals into the future relying on adaptive management to assess whether resilience targets are being met.*

Below is a brief list of existing programs and corresponding metrics used for tracking their progress. This will inform communities on how to leverage existing organizational resources and prioritize actions that enhance alignment rather than develop entirely new processes.

Ruddiman Creek. Photo taken by Nick Kroes, mostlymuskegon.com.

Natural Resources

System Attributes: Fisheries (variety of species such as walleye, chinook, steelhead, sturgeon, yellow perch, large/smallmouth bass); Fish and Wildlife Habitat (dunes, wetlands, benthos, littoral zones, state park land, parks and green space); Aesthetics (surface water, green space); Water quality & infiltration (surface water, groundwater)

Current plans/programs that have developed and/or utilized indicators for natural resource management in Muskegon Lake:

Muskegon Lake Area of Concern Remediation Action Plan[2] progress indicators:

- Fisheries - Index of Biological Integrity (IBI)
- Fish and Wildlife habitat/eutrophication - Secchi depth target; removal from Impaired waters list (also applies for water quality and aesthetics)
- Water quality - Trophic State Index (TSI); concentration targets for total phosphorus, Chlorophyll A;
- MDEQ 5 year stream/lake sampling program (Procedure 51);
- MDNR Fish Creel surveys;
- MDNR Michigan Community Health Program – Fish Consumption Advisories
- GVSU-AWRI Muskegon Lake Water Quality Monitoring Program

Michigan's City, Village, & Township Revenue Sharing/County Incentive Program (CVTRS)[3] progress indicators:

- Water quality - Trophic State Index (TSI), listed under the Quality of Life category (locations: M)
- Aesthetics - Acres of Public Park Per 1,000 Residents (locations: M, NM, L)

System Attributes: Fishing (boat launches, fisheries); Sailing & boating (water trail, boat launches, marinas, outfitters); Swimming (beach); Trails (state park, other parks, biking path); Historical/cultural sites (lighthouses, historic ships, historic houses); Birding & wildlife viewing

Current plans/programs that have developed and/or utilized indicators for outdoor recreation management in Muskegon Lake:

Outdoor Recreation

Michigan's City, Village, & Township Revenue Sharing/County Incentive Program (CVTRS) progress indicators:

- Parks - Acres of Public Park Per 1,000 Residents, listed under the Quality of Life category (locations: Muskegon (M), North Muskegon (NM), Laketon (L))
- Trails - Miles of sidewalks and non-motorized trails per mile of local roads swimming, listed under the Quality of Life category (locations: M, NM, L)
- Percent of general fund budget committed to arts, culture and recreation (location: NM, L)
- MDNR Fish Creel Surveys

Muskegon County Public Health Department – Beaches:

- In the event of a known sewage discharge or ongoing/chronic exceedance of body contact standards, a No-body contact advisory will be posted at public access sites.
- In the event of a single exceedance at a posted swimming beach, an advisory/flag will be uploaded at the State of Michigan Beach Monitoring Web Site [4]

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[2] Michigan Department of Environmental Quality. 2011. Stage 2 Remedial Action Plan Muskegon Lake Area of Concern http://www.muskegonlake.org/index.php?option=com_rubberdoc&view=category&id=66&Itemid=98

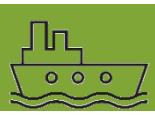
[3] http://www.muskegon-mi.gov/city-of-muskegon-dashboard/ (Muskegon); https://www.accessmygov.com/MunicipalDashboard/Performance?uid=1602 (North Muskegon); https://www.accessmygov.com/MunicipalDashboard/Performance?uid=1594 (Laketon)

- Per state regulations, all swimming beaches are to be posted as monitored or not. Local signs include the listed web site for further information.

System Attributes: Deep water port (port infrastructure, channel); Industrial docks (cargo shipping of cement, rock, construction materials, salt, storage); Commercial marinas (Cruises)

Current plans/programs that have developed and/or utilized indicators for shipping and port management in Muskegon Lake:

- There are currently no community established metrics to assess overall port performance nor its resilience. However, due to the closure of the Consumers Energy's B.C. Cobb coal-fired generating plant, the paper mill and the steel mill, there has been considerable discussion in the community on the future reuse of the sites and associated commercial and mixed-use activities. Considerations of



Commerce and Ports

resilience in those discussions should not be overlooked. Further recommendations are provided in the Strategies for Resilience section below.

System Attributes: Property Value (building structures, docks/boat launches, roads); Quality of life (viewshed, proximity/access to waterfront); Sewer/septic systems

Current plans/programs/rules that address residential management in Muskegon Lake:

Michigan's City, Village, & Township Revenue Sharing/County Incentive Program (CVTRS) progress indicators:

- Quality of Life/Waterfront access - Public and Freely Accessible Waterfront in Muskegon (location: M)
- Average age of critical infrastructure (years) (location: L)

Residential

[4] http://www.deq.state.mi.us/beach/

STRATEGIES FOR RESILIENCE

Basic Principles of Resilience and System Wide Strategies

Social and ecological resilience of a system is rooted in key principles that have been determined through careful scientific literature review and synthesis.[5] The seven principles are described below and offer guidance on opportunities to build and enhance the resilience of a system. Muskegon Lake system-wide recommendations are provided for communities to implement that advance the key principles of resilience.

Maintain diversity and redundancy - a system that is composed of a variety of species, habitat types, organizations and individual actors offers different pathways for responding to change and dealing with uncertainty. Furthermore, redundancy provides additional "coverage" because it allows for one component to compensate for others if they are disrupted, which is especially valuable if they respond in different ways to change and disturbances.

- Maintain ecological diversity by creating buffers around sensitive areas or building diversity and redundancy into governance systems by bringing in diverse sources of knowledge to support learning and innovation
- Identify system services or functions that have low redundancy and determine if and how it can be enhanced
- Focus less on maximizing efficiency and provide incentives that foster innovations and economic diversity

Manage connectivity - resilience of a system can be both enhanced and reduced by connectivity. A system that's well connected can withstand disturbances with more efficiency as is the case with maintaining biodiversity. However, an overly connected system can enhance the spread of a disturbance and impact more components, such as failure of communications equipment or electricity infrastructure. Applying this to the social aspect of resilience of the system means creating opportunities that strengthen networks between different community groups and organizations to increase information sharing and build trust.

- Map important components of the system to enhance understanding how and to what extent they interact with each other
- Use visualization tools and network analysis to reveal network structures, i.e. central nodes or sparsely connected areas that might be vulnerable
- Involve shoreline municipalities and a variety of organizations in the process. This will assist with making recreational sites more accessible to residents and support maintenance and/or development of habitat corridors

Manage slow variables and feedbacks - there are many ways in which all the components in the system are connected and it is important to consider the speed with which these connections may change the function of the system, potentially crossing a threshold that might lead to a different system configuration. Feedbacks are connections that can either reinforce or reduce change in the system. Slow variables include things like legal frameworks, cultural values, or land management changes that lead to increased runoff and impacts on water quality. The system should allow disturbances that permit the system to adjust to the changes.

- Identify key slow variables, feedbacks, and desired system functions and investing in monitoring programs that track key variables and set up governance structures that can respond to the monitoring information
    - Adopt consistent metrics for shoreline communities, e.g. Michigan's City, Village, & Township Revenue Sharing/County Incentive Program (CVTRS) progress indicators, ecological metrics defined in the Remedial Action Plan, Muskegon Lake Ecosystem Master Plan, NOAA Habitat Focus Area

[5] Biggs, Reinette, Maja Schlüter, Duan Biggs, Erin L. Bohensky, Shauna BurnSilver, Georgina Cundill, Vasilis Dakos, et al. 2012. "Toward Principles for Enhancing the Resilience of Ecosystem Services." *Annual Review of Environment and Resources* 37 (1): 421–48.

Implementation Plan and other indicators needed to assess progress toward making them more resilient
- Set thresholds for chosen metrics, e.g. trigger a formal meeting when certain metrics are exceeding set limits
- Track and evaluate public's and elected officials' environmental attitudes

Foster systems thinking - acknowledging the idea that social-ecological systems are complex with many interconnected components and dependencies is a critical first step in developing management actions that promote resilience. Recognizing complexity leads to accepting uncertainty and a variety of different viewpoints. An example of how adaptive systems thinking can be fostered is by setting up processes that allow for collaborations as well as assessment of intended and unintended consequences of various management scenarios.

- Leverage existing planning efforts to guide restoration, watershed, and land management - identify and prioritize actions that represent areas of overlap and alignment between watershed plans, hazard mitigation plans, remediation action plan, parks and recreation master plans, zoning ordinances, etc.; incorporate resilience concepts into development of new plans, projects, programs, or policies.

Encourage learning - efforts to increase the resilience of the system should be based on our understanding and knowledge of how the system functions. Because the system is evolving and changing, especially when encountering disturbances, learning and adaptive management are important mechanisms for ensuring we apply new insights and test new approaches to enhance resilience. In building resilience, communities can explore various ways to encourage learning, which include supporting long term monitoring of key components, engaging different stakeholders, and building networks and communities of practice.

- Broaden the problem definition by learning from multiple cultural and disciplinary perspectives and facilitating dialogue involving multiple groups of stakeholder - create a set of communication tools (factsheets about assets and resilience strategies to protect them) and continue to engage community stakeholders in discussions to become more familiar with concepts of resilience and refine resilience enhancing strategies;
- Apply adaptive management principles - set up a formal process to review and refine resilience strategies every 3 years;
- Ensure that a suitable social context for learning is established - host demonstration events or field visits for ongoing or completed restoration projects to highlight the impacts and resilience benefits.

Broaden participation - creating opportunities for broad engagement of different community stakeholders builds trust and a shared understanding of the system. Furthermore, it can help bring in knowledge or perspectives not addressed through the traditional scientific approach. It is important to structure participation in a way that doesn't create competition or conflict between stakeholders, by clarifying goals and roles, securing resources to facilitate effective participation and resolving imbalances in influence.

- Support community-wide formal and informal environmental education - host resilience themed workshops in the community and work with local schools to hold field trips and support place based environmental education, e.g. partner with West Michigan Great Lakes Stewardship Initiative in Muskegon, which is one of the regional hubs for the Great Lakes Stewardship Initiative working to make today's students effective environmental stewards. Other potential partnership and collaboration opportunities can leverage Muskegon area Leadership Academy and Muskegon Area Intermediate School District's Teacher/New Teacher In-Service programs.

Collaborate across institutions and jurisdictions - this principle for building resilience is focused on enhancing collaboration between different entities across different scales so that changes and disturbances can be addressed by

those who are best positioned to address them at that time. It also provides a basis for applying the remaining resilience principles that were described above.

- Provide an environment for leadership to emerge and for trust to develop
- Foster social networking that bridges communication and builds accountability among existing organizations
- Permit sufficient overlap in responsibility among organizations to allow redundancy in policy implementation

Resilience Strategies and Actions for Muskegon Lake

The aim of this plan is to identify specific strategies for building resilience for Muskegon Lake. It will support communities around Muskegon Lake in advancing the understanding of resilience and building a foundation to apply resilience concepts to current and future decisions about Muskegon Lake shoreline and surrounding areas. In return, these communities will be able to respond to changing conditions in the future. Muskegon Lake has undergone major shifts in management as well as ecosystem, economic, and cultural services it provides to residents. Like many port cities in the Great Lakes region, Muskegon is reimagining its waterfront. Although the transition from an industrial hub to a working landscape does not occur overnight and is driven by many factors within and outside of the system, communities around Muskegon Lake are currently well positioned to begin to turn the concepts of resilience into action. After decades of building environmental awareness, working out processes to guide remediation, and investing into restoring Muskegon Lake, there is a growing desire to continue to protect and enjoy the natural amenities Muskegon Lake offers as well as the economic activities that it supports. Building the foundation and taking key first steps toward a resilient Muskegon Lake will make the lake and communities that live on its shores move in stride with the changing ecological, social and economic conditions on the horizon.

Natural Resources	
Strategies	**Actions**
Continue to implement habitat restoration projects in particular those that enhance habitat connectivity;	Prioritize projects that restore shoreline to a more natural state offering protection from wave action, changing water levels and potential flooding during storms, while also helping manage runoff and creating habitat. Additional benefits include enhancing the viewshed and property values in the vicinity. Implement green infrastructure policies and projects
Implement watershed scale approaches	Seek Michigan's Natural Rivers designation for the Muskegon River - this could be used as an effective management tool as protective development standards are applied to private, as well as public lands within the Natural River district (400 feet on either side of a designated river) resulting in a seamless corridor of protected land. The Natural Rivers Program is implemented primarily through adoption of the Natural Rivers development standards into local zoning ordinances. Explore and where appropriate, utilize Farmland and Open Space Preservation Programs and USDA Natural Resources Conservation Service Programs to reduce pollution loading from upstream.
Outdoor Recreation	
Strategies	**Actions**
Diversify recreational offerings and retrofit to improve safety	Encourage recreation related businesses to expand the types of activities they offer in light of lengthening spring-summer-fall period and warmer winters with less snow; host workshops for the recreation and tourism sector representatives to discuss the issue of resilience and potential adaptation strategies Retrofit existing recreational infrastructure to protect from damage (see below) and ensure safety of recreational users
Increase residential access to and connectivity between waterfront recreational amenities	Create pedestrian bridges and greenways to lakefront to increase access to the waterfront and connect to the trail Implement bike sharing service, bike rental, and/or a lakefront trolley that enhances transportation around key recreational points around Muskegon Lake
Commerce and Ports	
Decisions about port redevelopment and viability of the shipping industry should seek solutions that result in acceptable outcomes in a wide range of possible scenarios	Use scenarios and simulations to explore consequences of alternative options because the shipping industry is particularly sensitive to fluctuations in water levels, which are projected to have increased variability in the Great Lakes Engage wide variety of stakeholders in scenario analysis

	Leverage existing or create opportunities for peer learning

Residential	
Strategies	**Actions**
Prevent development in sensitive areas;	Amend and implement zoning ordinances
Implement corrective measures to existing infrastructure to prevent damage from severe weather, both vegetative and built (In conjunction with Natural Resource Strategies)	Utilize green infrastructure to manage stormwater to reduce flooding with additional benefits to natural resources assets in terms of pollution loads and habitat (include voluntary green infrastructure opportunities in the MS4 stormwater Permit Post-Construction Stormwater Program and requirements in local stormwater ordinances) Develop an Urban and Community Forestry Plan to prevent wind damage - include wind fences and management practices to lessen frequency of fallen trees; integrate phytoremediation and biodiversity strategies for additional benefits to natural resource assets (Forestry staff at the Public Works Department & MDEQ Urban & Community Forestry Program) Ensure NPDES MS4 Stormwater Permit targets older infrastructure for maintenance and repairs (Illicit Discharge Elimination Plan); and considers projected rainfall data and adaptive management for long-term operation and maintenance (Post Construction Stormwater Runoff Program) Ensure local stormwater ordinances include resilience provisions such as: definition of a "Design Storm", "Storm Frequency", "Stormwater Management" in line with projected future precipitation and emphasizing Green Infrastructure controls, as well as implementing intermediate reassessments/revisions of the post construction maintenance plan. The ordinance adoption and implementation should be coupled with training and technical support to enhance effectiveness Retrofit/weatherize buildings - insulation/air-conditioning, floodproofing, securing of structures - create programs that incentivize and/or provide technical assistance to private property owners, recreational business owners, and prioritize retrofits for structures in more vulnerable areas.

CONCLUSION

The Muskegon Lake Resiliency Plan builds upon the demonstrated commitment of local government, businesses, and residents to environmental and social responsibility, and it marks a significant step forward in the process of building a more resilient Muskegon Lake for current and future residents. This plan applies the resilience assessment approach to key Muskegon Lake assets and attributes identified in the Muskegon Lake Vision 2020 Master Plan. Resilience assessment includes identifying and understanding major disturbances impacting Muskegon Lake, evaluating vulnerabilities, and laying the groundwork for crafting resilience strategies. This plan also outlines key principles of resilience in social-ecological systems and how they should be applied. One of the most important first steps is to enhance the communities' understanding of these principles and how to operationalize them.

Over the next several years, this plan will provide direction for how the City of Muskegon, the City of North Muskegon, and Laketon Township can incorporate resilience concepts into their ecological restoration, municipal planning, and economic development to create a system that is capable of responding to changing conditions and continue to provide valuable ecosystem services to the communities living around it. The West Michigan Shoreline Regional Development Commission will maintain oversight of this plan, facilitating actions that will make progress towards resilience goals and updating the plan as appropriate.

River Heron on Muskegon Lake. Photo taken by Nick Kroes, mostlymuskegon.com.

APPENDIX

Disturbances Data and Maps

Disturbance: brief description of the ecological or socioeconomic disturbance/disruption that impacts the system
Components/uses most affected: list of the system components (e.g. shipping infrastructure, beach, etc.) that are likely to be impacted by the disturbance
Magnitude of impact: assessment of the strength of the impact (e.g. severe, medium, low, variable, uncertain)
Frequency: how often the disturbance occurs; the answer can be precise, or give an estimate (e.g. approximately once a year); indicate also if the disturbance is episodic, periodic, continuous, and/or legacy if appropriate
Time for recovery: estimate the time scale the system needs to recover from the disturbance
Changes in past years/decades: indication of if/how the disturbance changes with time (e.g. increased frequency, difficult to predict, etc.)

Disturbance	Components/ uses most affected	Magnitude of impact	Frequency	Time for recovery	Changes in past years/decades
ECOLOGICAL					
Winter storms	dunes/wetlands marinas/docks/launches port infrastructure roads buildings historical sites	severe	once every couple of years	weeks/months for residential/infrastructure damage, seasonal for natural systems	this is a typical occurrence with potential increases in frequency/intensity
Severe winds	dunes marinas/docks/launches port infrastructure roads buildings historical sites	severe	coincide with thunderstorms approximately 1 per year, 1993-2005; most common Oct/Nov	weeks/months for residential/infrastructure damage, seasonal for natural systems	this a typical disturbance in the area, suspected increase in frequency of strong weather systems pushing wind from the east
Floods	wetlands, water quality marinas/docks/ launches swimming trails historical sites port infrastructure roads buildings sewer/septic systems quality of life historical sites	medium-severe; potentially catastro-phic (e.g. dam failures on Hardy/ Croton dams)	1 flood every 2 years over last 2 decades; 1 major flood 7-8 years over the last 4 decades (local, state, or federal disaster declaration)	months/years (rebuilding)	5.3% increase in number of annual days of precipitation greater than ½"; 1.67% increase in annual average precipitation (30 yr periods 1971-2000 and 1981-2010); may occur as a result of infrastructure failure since it's more likely to fail in the future
Great Lakes water levels	dunes/wetlands aesthetics beach marinas/docks/launches	severe	Cyclical; periods of major flooding/erosion due to high Great Lakes water have occurred approximately once per		long term average is predicted to slightly decrease, high seasonal/annual variability (shortened time frame with variability) remains

Disturbance	Components/ uses most affected	Magnitude of impact	Frequency	Time for recovery	Changes in past years/decades
	port infrastructure buildings		decade over last century; Record low Great Lakes water levels reached in January 2013; Record high water levels reached in 1986, near-record high reached in 2016		
Pollution loading: sediment nutrients pathogens chemicals	water quality fisheries benthos fishing swimming port infrastructure quality of life	severe	continuous from watershed inputs w/ seasonal patterns episodic from storms legacy from industrial	months/years (ecosystem processes, rebuilding, dredging)	island formations at causeway/mouth of the Muskegon river
Invasive species	fisheries, aquatic and terrestrial habitat, water quality aesthetics fishing	medium-severe	A dozen or more introductions of both, flora and fauna species have already occurred in the past 25-30 years, new introductions are difficult to predict, but are likely	potentially unrecoverable, management is costly	increased risk of new introductions, e.g. phragmites
Extreme temps, temp ranges	fisheries, habitat, fishing quality of life	medium-severe	heat waves/cold spells occur once/decade; shifts in temp ranges are occurring already and expected to continue long term	depending on length of extreme periods, recover for residents takes days/weeks; shifts in temperature ranges may be irreversible for flora/fauna	overall average temperature is expected to rise
SOCIOECONOMIC					
Shifts in political climate (new regulations, changes in elected officials, etc.)	habitat port infrastructure waterfront access	medium	changes may occur with each election cycle, as a rule every 2-4 years, but big swings are unlikely	potentially with each change in leadership, but difficult	uncertainty in impacts, CO and municipal level government tends to be blue, state level tends to be red
Shipping industry changes	port infrastructure	medium	supply/demand volatility	could be rapid or long term	large scale system, push for sustainable and efficient operations, adoption of new technology
Energy prices	port infrastructure commercial marinas	medium	driven by energy supply disruptions, record high prices in 2008	may lead to decrease in port activity or shift to a different modes of recreation	large scale disturbance can't be managed locally; retail price of electricity has been rising between 2004 and 2013, and has leveled off starting in 2014 for the industrial, residential and commercial sectors while the transportation sector has been

Disturbance	Components/ uses most affected	Magnitude of impact	Frequency	Time for recovery	Changes in past years/decades
					more volatile
Shifting demo-graphics	access towaterfront property values marinas quality of life	medium	gradual shift toward a higher median age	generational pattern, not something to recover from	growing demand for recreational opportunities; increased vulnerability to disasters and pollution exposure: from 1998 to 2014, travel and tourism employment went from 14% to 16% (Headwater Economics)
Hazardous materials spills (8 SARA Title III sites in Muskegon within a mile of shoreline)	water quality fisheries habitat swimming quality of life	severe	given industrial history, the likelihood of occurrence is high	weeks/months to contain, years to clean up	with increasing storm intensity, risk is increased for structural failure
Infrastructure maintenance (water/wastewat er infra-structure)	fisheries habitat water quality aesthetics fishing swimming buildings roads sewer/septic systems quality of life	severe, either as primary event, or secondary consequence of storms and floods	major sewage spill events occur regularly, 5 since 1982, the last one in 2007, In the 12-year period from 2000-2011, there were 47 sewer system overflows, or about four per year;	Some property damage may be permanent, and even though services may be restored within days/weeks, the costs for dealing with infrastructure failure are high natural systems may take months/years to recover	with increasing frequency/intensity of precipitation, and general degradation of infrastructure with time, the risk for failure is increasing. In Muskegon Co, spending on waste and sewerage infrastructure decreased by ~50% between 2007 ($70,000) and 2012 ($36,500) (Headwater Economics)
Shoreline development	habitat water quality trails marinas/docks/ launches property values access to waterfront	potentially severe	a continuous pressure to build more stuff within areas that are prone to erosion/sensitive	years/decades, may depend on new regulations or conservation initiatives	continuous challenge to balance economic interests with environmental protection
Modified (hardened/filled) Shoreline	habitat aesthetics water quality marinas/docks/ launches	severe	lake was filled and shoreline significantly modified beginning 20th century	years	recent push to restore and enhance natural resources, efforts underway to soften the shoreline
Life after delisting of the AOC	fisheries water quality habitat/benthos aesthetics property value	medium	remediation planning and implementation has gone on for decades with delisting target of 2019; projects are large scale, multi-year and progress is slow	years (in this case, the disturbance is "positive" as the delisting requires various ecological impairments removed and establishes metrics for assessing progress)	After delisting, the challenge will be to maintain interest and investment in natural resources protection after AOC designation is gone
Industrial	habitat	the plant is	one time occurrence	may take years to	high uncertainty in impacts,

Disturbance	Components/ uses most affected	Magnitude of impact	Frequency	Time for recovery	Changes in past years/decades
facilities closings (Coal plant, Paper mill, and Steel mill closed)	aesthetics trails marinas property values	not running, but decommissioning/redevelopment takes a long time		plan/fund/implement redevelopment	could help enhance natural resources, property values, and recreation, but needs to be remediated and in line with community priorities