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Great Lakes Water Levels

INTEGRATED ASSESSMENT REPORT

FEBRUARY 2018

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For more information on this project, please go to: http://graham.umich.edu/emopps/water-levels

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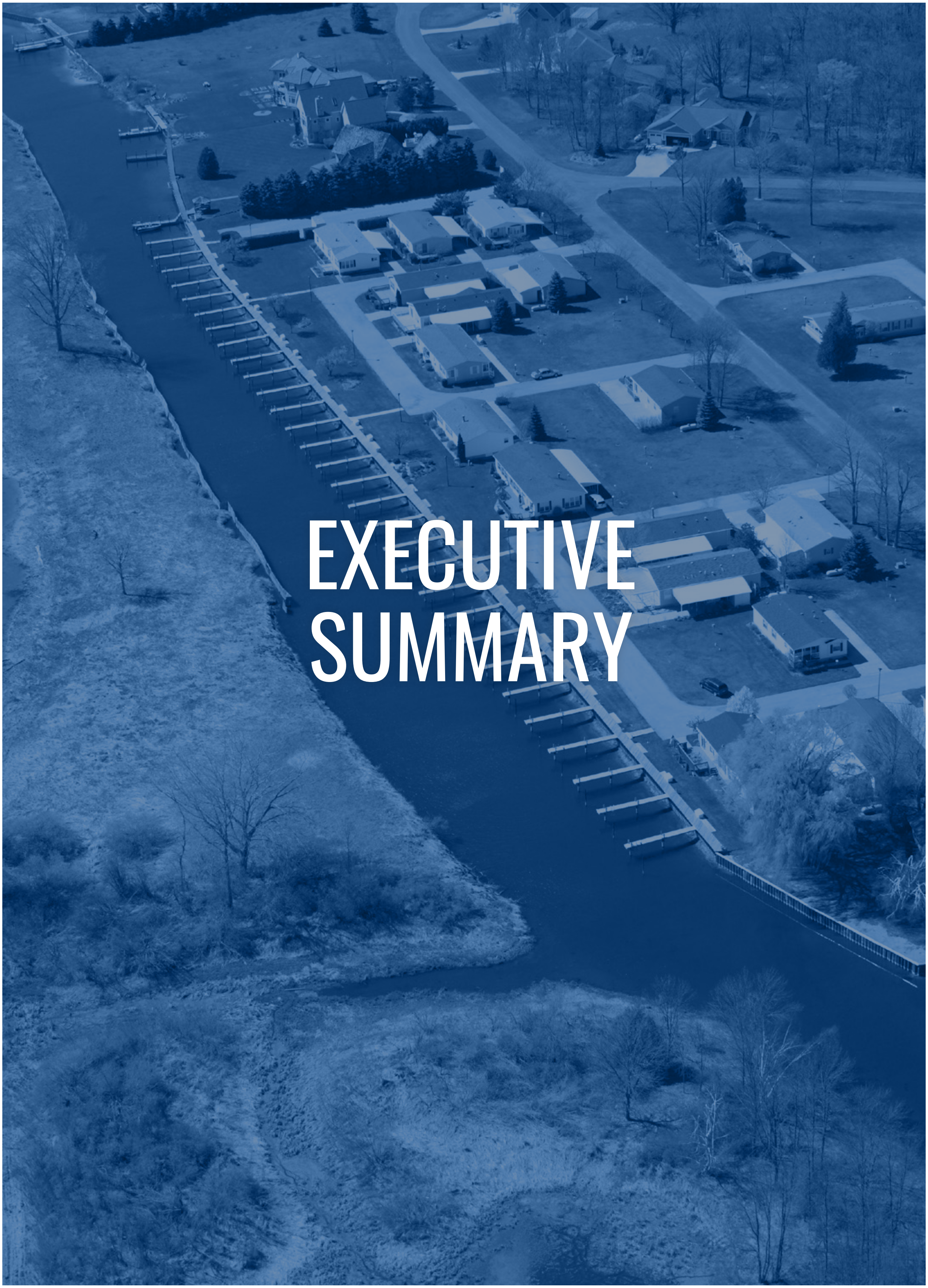
LIST OF ACRONYMS/ ABBREVIATIONS

ABCA	Ausable Bayfield Conservation Authority
BMP	Best management practice
CA	Conservation Authority
GIA	Glacial isostatic adjustment
GIS	Geographic information systems
GLASI	Great Lakes Agricultural Stewardship Initiative
GLERL	Great Lakes Environmental Research Laboratory
GPMC	Goderich Port Management Corporation
GTB	Grand Traverse Band of Ottawa and Chippewa Indians
HCWPSC	Huron County Water Protection Steering Committee
IA	Integrated Assessment
IJC	International Joint Commission
IUGLS	International Upper Great Lakes Study
LHCCC	Lake Huron Centre for Coastal Conservation
LID	Low impact development
LTBB	Little Traverse Bay Bands of Odawa Indians
MVCA	Maitland Valley Conservation Authority
NID	Neighborhood Improvement District
NOAA	National Oceanic and Atmospheric Administration
USACE	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY



Great Lakes water levels have been much in the news over the last few years. After a decade of downward trends, water levels on Lakes Michigan and Huron reached historic low levels in January 2013.[1] Then during 2013 and 2014 the same lakes came close to setting another record as they experienced the second-largest gain over a 24-month period since water levels began to be recorded.[2,3] Water levels since then have remained above the long-term recorded average, and the U.S. Army Corps of Engineers (USACE) official outlook forecasts continued trends higher in 2018.[4]

These recent changes in water levels and the nearly century of data showing cyclical water level fluctuations underscore the dynamic nature of the Great Lakes system. Many of the large and diverse group of interests connected to the lakes are accustomed to dealing with, and may even depend upon, a certain degree of water level change. However, water level conditions outside the range experienced more recently as well as uncertainty in future water levels can present significant challenges for individuals, businesses, and communities living with the lakes in the present.

Variation across the Great Lakes in terms of existing water level regulation, degree of observed change, and shoreline uses makes the question of how best to deal with changing water levels particularly challenging. Therefore, there is a need to explore alternative strategies for mitigating the harm and maximizing the benefits of water level variation in the Great Lakes. International Joint Commission (IJC) reference studies over the last three decades have identified various options that could help the region adapt to water level changes.[5] Some of these options, such as shoreline management, stand in contrast to lake-wide water level control structures in that they are inherently site-specific, and thus allow different localities to address impacts and issues specific to their geography, development, and shoreline uses. In practice, however, location-specific shoreline management and policy options have not been widely adopted throughout the region. A major challenge in implementation, in addition to variability and uncertainty in water levels, is determining the appropriate integrated mix of options that take into consideration local conditions, multiple objectives, and jurisdictional constraints.

Overcoming these obstacles requires a new approach that emphasizes creative solutions and engagement with decision-makers, and that couples place-based work with a broader regional perspective. It should build upon existing efforts, bring in best-available science, and recognize the dynamic nature of the Great Lakes system made more evident by the recent reversal in water level trends. To help decision makers address the challenges and opportunities posed by Great Lakes water level variability, the University of Michigan's Graham Sustainability Institute initiated the Great Lakes Water Levels Integrated Assessment (IA).[6]

PURPOSE

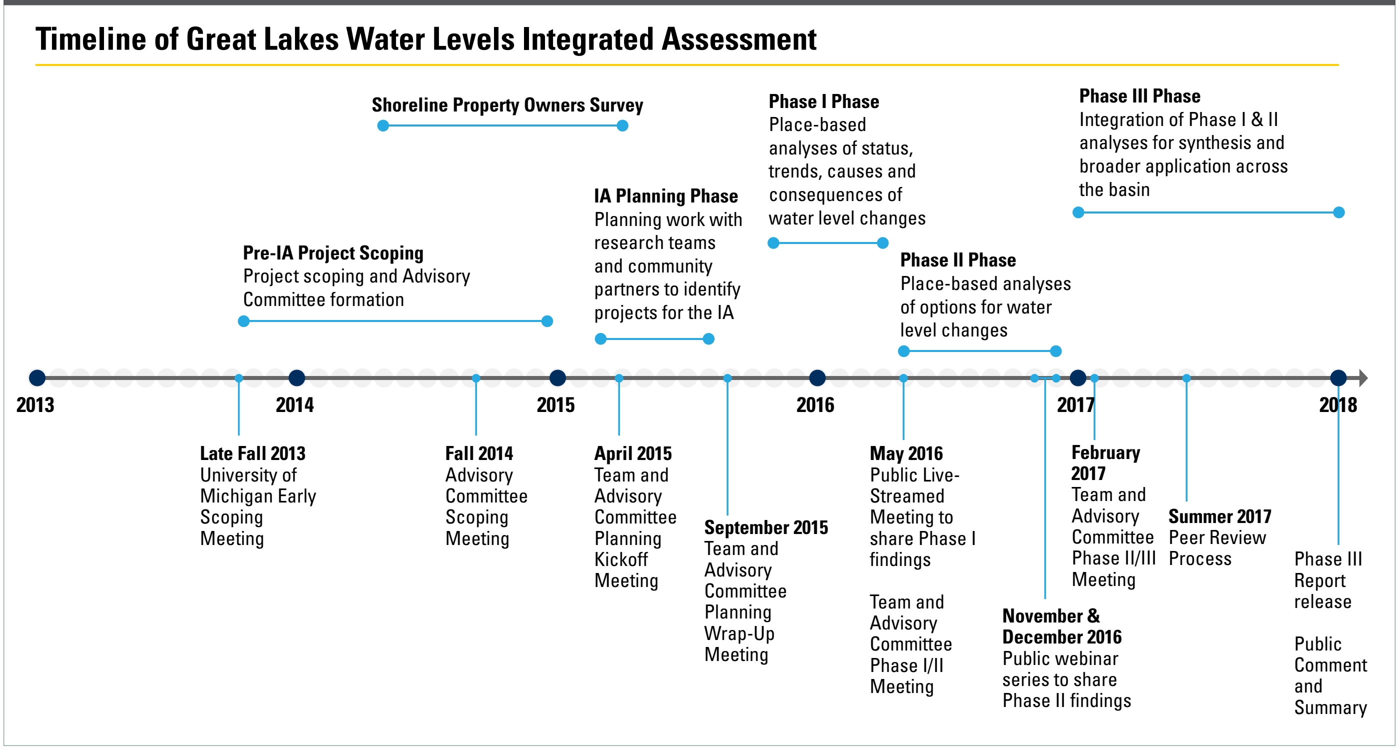
The purpose of the IA has been to develop information, tools, and partnerships to help decision makers address the challenges and opportunities posed by variability in Great Lakes water levels. The IA aimed to transform extensive existing research about water levels, flows, and impacts into practical, adaptive strategies to address issues facing shoreline property owners and managers. The IA was informed by a binational advisory committee,[7] who provided input and advice reflecting the views of key stakeholder groups. To focus the work, the following guiding question was developed in consultation with the advisory committee:

> *What environmentally, socially, politically, and economically feasible policy options and management actions can people, businesses, and governments implement in order to adapt to current and future variability in Great Lakes water levels?*

To respond to the question, the IA focused on Lakes Michigan and Huron and took both a place-based and regional approach. Place-based teams collaborated with specific communities to assess specific, integrated, and feasible options related to water level variability. This report integrates and builds upon the local projects to demonstrate variation and similarities among the communities' needs and identify insights for the basin more broadly.

The project adopted an IA approach as the organizing framework. IA is a deliberative process where experts summarize and synthesize existing scientific data and information to guide decision making. By engaging representatives from a wide range of impacted sectors and perspectives on a given issue, IAs collaboratively define problems, address diverse perspectives, use and share best-available information, and establish partnerships with the goal of analyzing options for making positive change.[8]

Figure 1: IA Timeline



PROCESS

The IA was divided into three phases. The first two phases were focused on specific localities. During Phase I, teams used existing data and information to develop an overview synthesis report on the status, trends, causes, and consequences of changing water levels as they relate to the key issues in the community they were working with. Each report then outlined the future research and planning each group intended to complete, whether that involved further community outreach, ordinance drafting, or geological mapping. Results from this work were shared at a public meeting (in person and live streamed) in May of 2016[9] and posted to the project website.[6]

In Phase II the research teams worked in collaboration with their partners to identify and analyze viable policies and adaptive actions that meet local objectives. Phase II reports outlined the full findings of each group. These included the options proposed by communities and researchers, the feedback to those options, and the challenges and opportunities of each option. Each group also presented webinars on their findings, which generated widespread public participation and feedback.[10]

This Phase III report seeks to integrate the findings of each group regarding the unique challenges and opportunities faced by each community to identify opportunities for the region. While relying primarily on material from the previous IA phases, the report also includes additional material to support findings and clarify topics of relevance. The hope is that this report can inform communities facing similar situations as to how to approach water level variability, given the environmental, social, political, and economic characteristics of their community.

IA TEAMS

Wisconsin Team

David Hart of Wisconsin Sea Grant headed a team of researchers from Wisconsin Sea Grant, the University of Wisconsin-Madison, and the University of Wisconsin-Milwaukee.

This team focused on communities along the shore of Lake Michigan located immediately north of the city of Milwaukee, Wisconsin in Milwaukee and Ozaukee counties, with a primary focus on the influence of changing water levels on coastal bluff erosion. Their goals were to synthesize existing resources and to engage community residents and officials in discussions about their hopes and concerns around the future of their coastal bluffs. Through several public meetings and stakeholder interviews, the team developed a wide range of options for addressing these challenges, and gauged community feedback to these options.

In addition to partners at the local and county level, the team coordinated with regional and state organizations and agencies working on coastal issues, such as the Southeastern Wisconsin Regional Planning Commission and Wisconsin Coastal Management Program, Department of Natural Resources, and Division of Emergency Management.

Ontario Team

Lynne Peterson, a local government and integrated policy consultant, led a team including researchers from the University of Toronto's Ecological Modelling Lab, Environment and Climate Change Canada, and University of Guelph, a former municipal chief administrative officer and a former

Figure 2: Map of the IA place-based projects

Ontario municipal finance and planning policy expert.

The team focused on Huron County, Ontario with 100 kilometers (62 miles) of shoreline along Lake Huron, and worked directly with the Huron County Water Protection Steering Committee. The team's goals were to review issues arising from both low and high water level extremes on Lake Huron and to identify regulatory and non-regulatory options for living with water level variability for review by Huron County, local municipalities, conservation authorities, non-profit organizations, harbor organizations, local residents, and businesses.

Through a series of workshops, presentations, and additional discussions with key stakeholders, the team developed a series of policy and adaptive management proposals. In addition to the Water Protection Steering Committee, key participants were the Lake Huron Centre for Coastal Conservation, the Ausable-Bayfield Conservation Authority, the Maitland Valley Conservation Authority, the Bluewater Shoreline Residents Association, and the Ashfield-Colborne Lakefront Association.

Southern Michigan Team

Richard Norton of the University of Michigan Taubman School of Architecture and Urban Planning led a team of researchers from the University of Michigan, Michigan Technological University, and the non-profit planning and community development firm LIAA.

The team worked directly with of the City of Grand Haven and Grand Haven Charter Township along the southern Michigan shore of Lake Michigan. The team sought to build on previous land use planning efforts and to identify options for actually implementing master plans or shoreland area management plans.

Northern Michigan Team

Frank Marsik of the University of Michigan College of Engineering led researchers from the University of Michigan and Michigan State University. This team developed a collaborative approach to work directly with the Little Traverse Bay Bands of Odawa Indians (LTBB) and the Grand Traverse Band of Ottawa and Chippewa Indians (GTB). The LTBB and GTB have reservation lands in the northwest lower peninsula of Michigan along Lake Michigan, as well as hunting, fishing, and gathering rights within a larger area spanning the upper and lower peninsulas of Michigan and Lakes Michigan-Huron and Superior.

The team sought to facilitate the integration of western science approaches and Indigenous Traditional Knowledge approaches into the consideration of climate change effects on lake levels in Tribal plans.

WATER LEVEL VARIABILITY & DIVERSE INTERESTS

Great Lakes Water Budgets

Many factors influence Great Lakes water levels, including precipitation, evaporation, run-off, water flow through connecting channels, diversions into and out of the system, consumptive water use, dredging, and water level regulation. Air temperature, wind, and vertical movement of the earth's crust also factor in.[15,16] A water budget is a concept that describes the relationship between inputs and outputs of water through a region, and it can help to clarify the causes of long-term fluctuations in water levels. When inputs (precipitation, runoff, groundwater, inflows from upstream, and diversions in) exceed the outputs (evaporation, outflow from the lake, diversions out) for a significant period of time, lake level rises. While the concept is simple, understanding the water balance still continues to be a scientific challenge and requires ongoing analyses.

The three main factors affecting water levels are precipitation, runoff, and evaporation.[15] Human factors also influence water levels in the Great Lakes, although to a much lesser degree than natural factors. Diversions bring water into and take water out of the lakes, although the net effect is a small input to the system, as the combined average amount of water diverted into Lake Superior at Ogoki and Long Lac is greater than the combined amount of diversions out of the Great Lakes Basin.[17] To put these in perspective, over the period of 1953-2010, precipitation added an average of 3,100 cubic meters of water per second (CMS) to Lakes Michigan and Huron and evaporation removed 2,700 CMS, while the Ogaki and Log Lac diversions added 160 CMS to the system and the Illinois diversion removed 90 CMS.[17] Additional human influences play even more limited roles in influencing water levels. For example, general consumptive uses, reflecting varied purposes, have little effect on overall water levels.[18]

BOX: IMAGES FROM THE PLACE-BASED PROJECT TEAMS

Figure 3: Photograph illustrating coastal bluffs within the Wisconsin project area[11]

The image shows both unarmored and armored shoreline.

Figure 5: Photograph of residential development along the shoreline in the City of Grand Haven, Michigan within the Southern Michigan project area[13]

Figure 4: Map illustrating the high proportion of properties facing erosion failure risks in a stretch of shoreline within the Ontario project area[12]

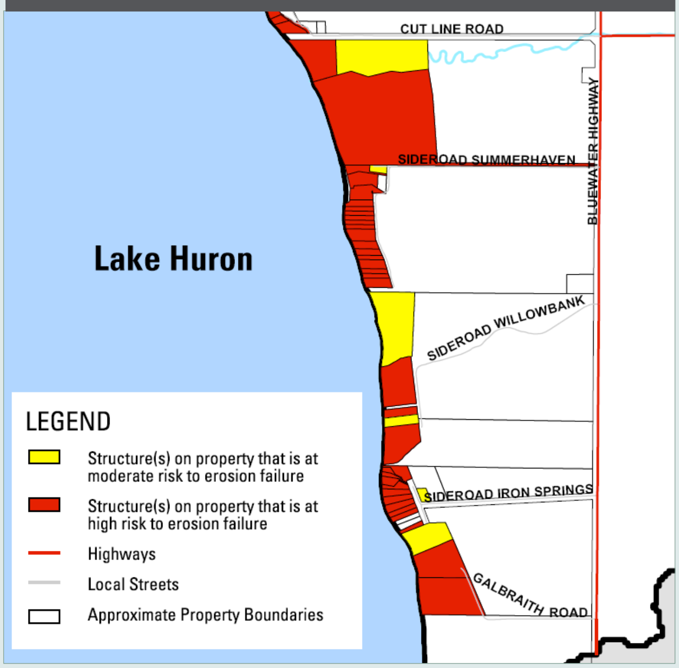
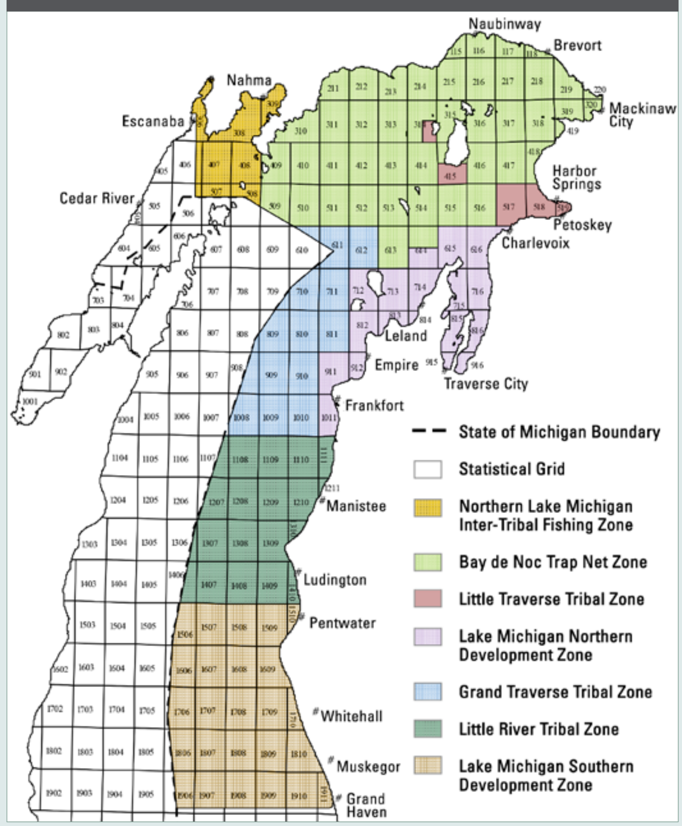


Figure 6: Map of 2000 Consent Decree Tribal commercial fishing zones that were considered by the Northern Michigan project team[14]



2000 Consent Decree

Federal court order that represents a negotiated agreement between the U.S., the State of Michigan, and five Native American Tribes, which details how fishing in the 1836 Treaty waters will be allocated, managed, and regulated through 2020.

The IJC provides oversight at three control structures that impact international water levels and flows on the Great Lakes and St. Lawrence River. These are located in the St. Marys River, Niagara River, and St. Lawrence River, near the outlets of Lake Superior, Lake Erie, and Lake Ontario, respectively.[19]

Changes Over Time

The combination of the Great Lakes' large size and small outflow channels results in a largely self-regulating system that tends to buffer changes and keep lake levels within typical ranges over long periods. It also means that extremely high or low levels and flows can persist for a considerable time after the factors that caused them have changed.[20]

The magnitude of water level changes varies depending on the lake and the time scale considered. Over the course of a year water levels typically vary approximately 30-50 centimeters (cm) or 12-20 inches. Over longer time scales, monthly water levels range from about 60-90 cm (2-3 feet) above or below the long-term averages for the month.[21] The historical range of recorded annual average water levels on Lakes Michigan and Huron, for instance, is close to 2 meters (6.5 feet).[22]

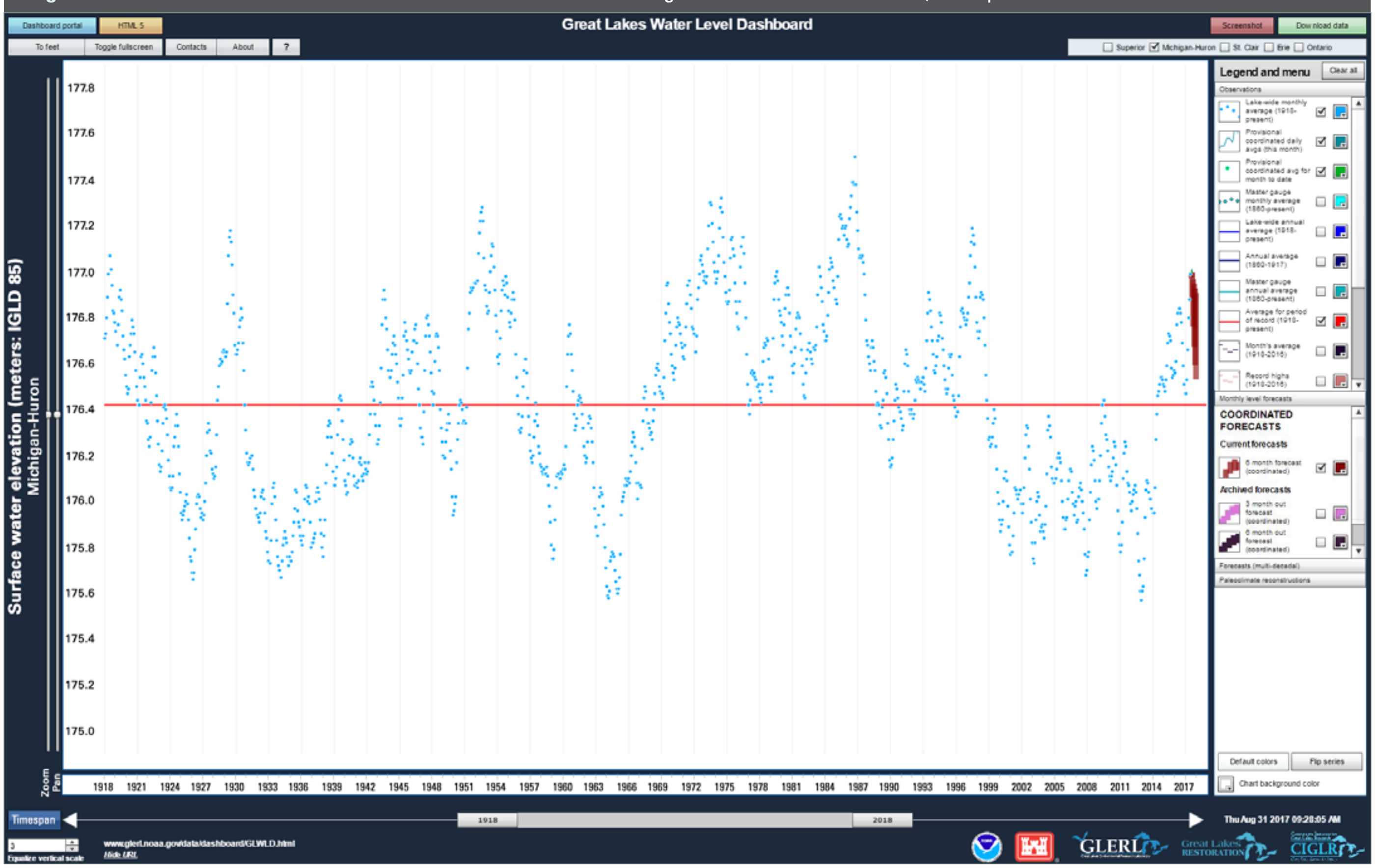
Regular seasonal changes in water levels are caused by corresponding seasonal patterns in the various inputs to and outflows from the system, with annual minimum water levels occurring in the winter and annual maximum water levels in the late spring.

Continuing high or low water supply conditions contribute to larger long-term fluctuations. Several-year periods of high or low levels are a normal feature of Great Lakes water levels dynamics, but they are very difficult to predict. Review of long-term water levels on Lakes Michigan and Huron from 1918 to the present (Figure 7) reveals periods of lows in the 1920s, mid-1930s, mid-1960s, and 2000s to 2013, with periods of highs in the early 1950s, early 1970s, mid-1980s, and mid-1990s. While they may be difficult to predict, extreme lake levels are not an unusual phenomenon.

Another factor affecting water levels over time is glacial isostatic adjustment (GIA), which is the ongoing movement of the earth's crust as it rebounds following the retreat of the glaciers at the end of the last ice age. GIA is effectively tilting the basin southward over time, and as a result, affecting how water levels changes are experienced across the region; falling water levels will be more prominent in northern areas, and rising water levels will be greater in southern areas.[20]

Climate change poses additional challenges to understanding and adapting to fluctuating Great Lakes water levels. In its extensive analysis of climate impacts on future water levels, the International Upper Great Lakes Study by IJC concluded that "lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range. While lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered."[20]

Figure 7: GLERL Great Lakes Water Level Dashboard – Lakes Michigan and Huron water levels, 1918-present [3]



Blue dots denote monthly lakewide average water levels from 1918-present. The solid red line shows the long-term average from 1918-2016. The USACE 6-month forecast is shown as dark red probability bands on the far right. Accessed August 3, 2017.

Shoreline Property Owners and Managers

A large and diverse group of interests are affected by and connected to the lakes—through their business or livelihoods, recreation, infrastructure, and values—even if they don't live immediately along their shores.

This IA focuses primarily on issues facing shoreline property owners and managers. As of 2012 an estimated 93,400 properties along the upper Great Lakes shorelines and connecting channels, and projections suggest that most of the Lake Michigan and Huron shorelines will be developed as residential in the next 50 years.[20]

Property owners often have preferences for water levels at their particular location. Depending on physical characteristics of a specific location, this group can experience negative impacts from both high and low water levels. Since the 1950s the most prevalent negative impacts during high water levels have been damages to land and structures from storm-related flood and erosion damage, as well as bluff and beach erosion; loss of beach access as beaches are narrowed or eliminated; and the related socio-economic impacts. In areas where boats are the primary means of access to the water (such as rocky coastal environments in Georgian Bay, sheltered embayments, and drowned rivermouth areas like Saugatuck, Michigan), low water levels may result in more difficult and costly use of or access to property. In other areas, low water levels may provide a wider more attractive beach for recreation. It is worth noting that water level changes in the opposite direction bring corresponding positive benefits. Moreover, coastal zone interests may also experience, directly or indirectly, the effects on other interests—whether related to water quality, the economy, infrastructure, ecosystems or recreation.

OPTIONS FOR WATER LEVEL VARIABILITY

There exists a wide array of options that communities and shoreline property owners can implement in order to adapt to current and future variability in Great Lakes water levels. Many of these options are not new. Going back decades, the IJC and others have completed extensive studies identifying and assessing options around Great Lakes water level fluctuations. One key challenge, as those studies noted, is identifying and tailoring the suite of options according to unique local conditions and interests.

As described briefly, during Phase II of the IA, the four place-based research teams proposed and assessed a variety of options and strategies for their partner communities to consider. To support other communities and interest groups in thinking through ways to approach variable water levels, this chapter organizes and explores the options the teams considered during their Phase II work.

The options are grouped into four broad categories that include the most common options among the teams:

- **Planning and Coordination**
- **Shoreline Stabilization**
- **Land Use and Shoreline Management Policies**
- **Education and Outreach**

Subcategories are listed below. The full report provides additional descriptions and select detailed examples of these options as analyzed by the research groups.

The IA does not seek to duplicate previous reports that comprehensively enumerate potential options, nor does it provide detailed technical guidance or analyses of the options. Rather, it aims to organize examples from the Phase II place-based work to illustrate what select options might look like and highlight some of the associated challenges or opportunities to be considered. For a full list of the options generated during Phase II refer to Appendix A of the full report.

Lastly, this IA recognizes that no single measure will be sufficient. Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political and legal factors. In addition, even these suites of options cannot completely eliminate potential negative impacts of water level fluctuations. They do, however, have the potential to address specific issues and to assist communities and interests in adapting to and living with variability.

Planning and Coordination

The Adaptive Management Plan for the IJC reiterated that "no one agency manages the issues associated with water level impacts and, therefore, a more intensive level of collaboration is needed than has been seen to date on the issue."[23] Not surprisingly, coordination emerged as an important theme for all four IA teams. Given the place-based nature of the projects, many of the options for coordination that the teams explored are focused more locally, addressing opportunities among and within jurisdictions, and among different organizations and individuals. The teams looked at options across these subcategories:

- **Coordinating among jurisdictions**
- **Working with other partners**
- **Planning across departments**
- **Coordinating funding**
- **Collaborating with neighbors**

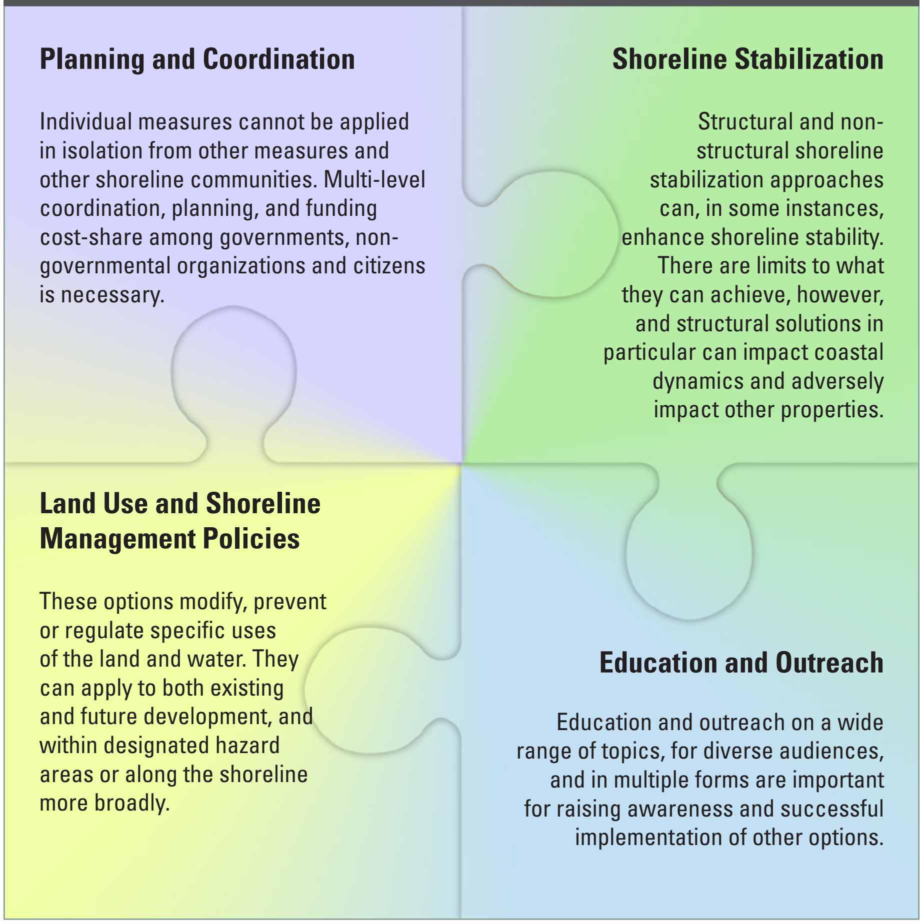
Shoreline Stabilization and Protection

Another category of response options the teams addressed is direct modification of the shoreline to reduce erosion and improve stability. This includes:

- **Structural approaches**
- **Non-structural approaches**
- **Gray-green infrastructure**

Where the shoreline has already been developed intensively, structural shore protection may be considered the only

Figure 8: Categories of water level variability response options explored through the IA



Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political and legal factors. The categories of response options here are often interrelated, and they do not represent a comprehensive list of options. Rather, they represent the most common options identified by the place-based teams during Phase II of the IA.

available option. It is important, however, to recognize the limits of this approach. Even well-designed stabilization structures may still adversely affect adjacent property as well as shoreline areas a considerable distance away, often leading to an ongoing cycle of more armoring, more erosion, and more armoring—with impacts increasing with the shore hardening.

Approaches using plants, rather than hard construction materials, can also serve to reinforce the soil, improve water drainage, prevent erosion and dewater wet soils. There are limits to these approaches as well; where there is ongoing toe erosion, these measures can only enhance stability in the short-term, and over the medium to long-term they have no effect on changing the recession rate.[24]

Land Use and Shoreline Management Policies

This category of options includes those focused on modifying, preventing or regulating specific uses of the land and water. These options can affect both existing and future development, and they can apply within designated hazards areas along the shoreline or more broadly. The report divides these into two subcategories. The first discusses land use planning and development requirements, while the second looks at options related to permitting processes more generally. What unites these options is a primary reliance on regulations or other mandatory requirements.

- **Land use planning and development requirements**
- **Permitting**

Examples within these related to setbacks, stormwater management and soil erosion control, ordinance review procedures, permitting requirements, and public notice and comment processes.

Outreach and Education

All of the place-based IA teams explored options related to outreach and education, but the topics addressed, audiences targeted, and forms of the outreach resources or tools varied based on the needs of the given community. The teams considered a range of opportunities, including;

- **Keeping property owners informed**
- **Engaging youth**
- **Providing resources and engagement opportunities**
- **Mapping and visualization**

Other Topics

Other approaches included in the report include emergency planning; construction standards; acquisition, conservation and relocation strategies; and real estate disclosure.

Takeaways

Although described separately, the categories of response measures and the specific options described within them are often interrelated. For instance, planning and coordination are important for most of the options in the other categories, from considering structural or non-structural approaches to aligning and funding outreach efforts. Education and outreach approaches are important for building support for and implementing potential regulations or incentives, while land use and permitting requirements may affect the need and ability to pursue different stabilization approaches. The complex, multi-level governance system in the basin ensures that jurisdictional considerations are unavoidable for many options.

As mentioned previously, no single measure will be sufficient. The place-based IA teams identified ranges of opportunities for their partner communities to consider, and there are additional options beyond those discussed here. In general terms, however, living with Great Lakes water level variability will require a combination of approaches that seek to prevent negative impacts, mitigate the effects of unavoidable negative impacts, respond to emergency impacts, and on the positive side, capitalize on the benefits associated with inevitable changes.

OVERARCHING THEMES

While the primary focus of the IA was to identify place-based adaptive strategies and options for water level variability in the Great Lakes, several common themes can be identified when examining the work of the research teams. These themes are reminders of conditions that may be critical for the success of any suite of strategies, or overall approach to identifying strategies, that a community takes.

Capacity

At the local level, capacity is variable, and efforts should be cognizant of capacity needs and develop strategies to meet them. As noted previously, while a significant amount of data and information are available on a range of water level issues it can require a substantial amount of work and expertise to convert those resources into actionable items at the local level. A good understanding of capacity can also provide insights on where partnerships can be particularly useful.

Context

When implementing policy options, context matters. Significant effort is needed to move general policy recommendations to locally-specific adaptive management strategies.

Jurisdiction

It is critical to understand the relevant authorities for decision making, particularly when multiple authorities (local, state, provincial, etc.) are involved, as is often the case with the Great Lakes resource issues.

Key Institutions

Efforts should be made to identify and engage critical partners and key institutions. Depending on the context, a key institution may be a property owners association, a local community organization, or a planning commission. Determining how to best apply limited resources and time can hinge on engaging key institutions.

Public Input

To find acceptable solutions, it is critical to solicit input from stakeholders, and competing perspectives should be sought out in a thoughtful manner. How stakeholder input is conducted can be as influential to an outcome as the methods of data collection and analysis. The work of all four of the research teams provides important insights on the value of and approaches to this engagement.

Uncertainty

Although uncertainty may be unavoidable to a certain extent, it need not preclude action. Tools such as scenario planning or approaches like adaptive management can help to develop and refine adaptive approaches in light of incomplete information.

PUBLIC PERCEPTION, INFORMATION, AND ENGAGEMENT

This overall study, as well as the four-placed based teams' work, recognizes that public perception of the issue of water levels, along with the validity of approaches to address the issue, is critical for adaptation to current and future Great Lakes water level variability. The diversity of views among the many interests in the region who are affected differently by water levels views can contribute to lack of agreement as to what the problem even is, let alone approaches for addressing it.

Access to information can help build understanding and acceptance, and all four teams included educational strategies in their analyses. Yet, while better information is important, it is not necessarily sufficient. It is important to remember that perceptions of risk among the public and technical experts often vary. Research emphasizes that neither groups' assessment is right or wrong, but instead they evaluate risks using different criteria. Moreover, coastal homeowners' decisions are also affected by values, beliefs, personal and property attributes, social norms, and other factors. These situations where parties disagree about an issue or misunderstand each other's perspective call for more engaged forms of public participation so that parties feel that their concerns are heard.

LIMITATIONS

Prior to the start of the IA, much discussion on this topic was focused on control measures to address concerns about low water levels in Lakes Michigan and Huron.[25] Now with higher overall levels, the discussion in some areas has focused to increasing the flow of water, particularly with respect to Lake Ontario.[26,27] While important discussions, water level regulation approaches are outside the focus of a place-based analysis of adaptive strategies. Moreover, the relatively quick change in the public discourse around water levels—from a focus on lows to highs—during just the course of this project underscores the dynamic nature of the Great Lakes system and the rationale for this IA's focus on variable water levels.

The scope of the IA was further bounded both geographically and topically, with a focus on Lakes Michigan and Huron and issues facing primarily shoreline property owners and managers. As a result, there are certainly topics of concern that are not addressed by the work of the teams and this report. However, it is the hope of this project that many of the topics that are addressed in the report, as well as the approaches taken by the teams, will have relevance to other Lake Michigan and Huron communities and communities along Lakes Superior, Erie, and Ontario.

Lastly, the assessment does not provide detailed technical guidance or effectiveness analyses, nor did it involve implementation funding for the place-based teams. Certainly both technical and financial resources are critical to successful adaptation, and in the case of the latter, some of the options addressed in the report aim to meet those needs.

NEXT STEPS

Although this project concludes, efforts around adaptation to water levels continue. It is our hope that the place-based work will inform local decision-making and that this Phase III report will assist other communities' thinking around options to consider.

A goal of this IA is that its engagement efforts would help to sustain work around the issue after the project ends. In the past, interest has peaked around periods of particularly high or low levels, but diminished when trends reversed. The framing of the issue around variability, rather than just highs or lows, reflects the dynamics of the lakes, uncertainty around the effects of climate change, and a desire to improve resilience over the long term.

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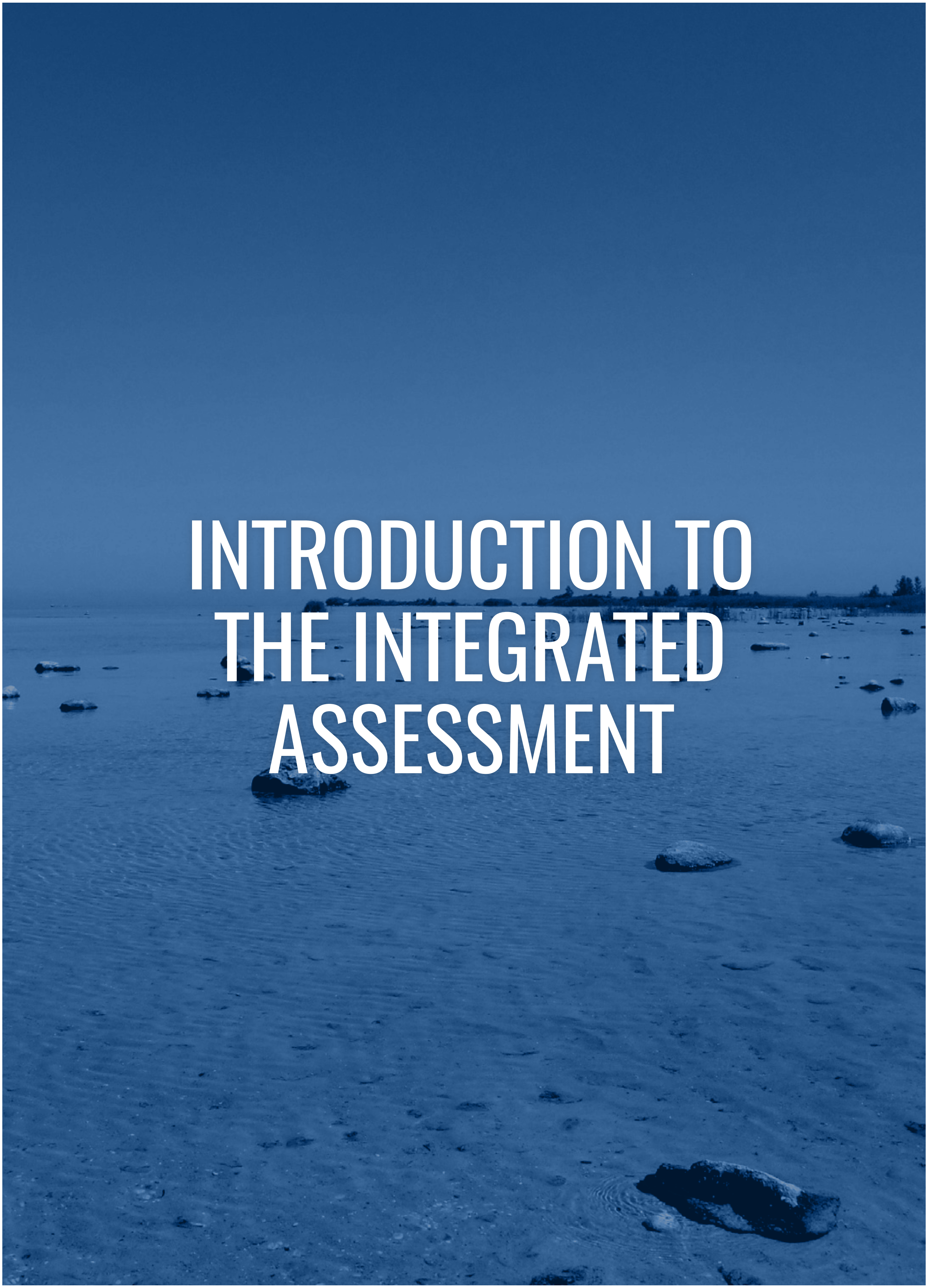


INTRODUCTION TO THE INTEGRATED ASSESSMENT

CHAPTER 1

Great Lakes water levels have been much in the news over the last few years. After a decade of downward trends, water levels on Lakes Michigan and Huron reached historic low levels in January 2013.[1] Then during 2013 and 2014 the same lakes came close to setting another record as they experienced the second-largest gain over a 24-month period since water levels began to be recorded.[2,3] Water levels since then have remained above the long-term recorded average, and the U.S. Army Corps of Engineers (USACE) official outlook forecasts continued trends higher in 2018.[4]

These recent changes in water levels and the nearly century of data showing cyclical water level fluctuations underscore the dynamic nature of the Great Lakes system. Many of the large and diverse group of interests connected to the lakes are accustomed to dealing with, and may even depend upon, a certain degree of water level change. However, water level conditions outside the range experienced more recently as well as uncertainty in future water levels can present significant challenges for individuals, businesses, and communities living with the lakes in the present.

Variation across the Great Lakes in terms of existing water level regulation, degree of observed change, and shoreline uses makes the question of how best to deal with changing water levels particularly challenging. In response to low water trends in the 2000s, some have called for water level restoration structures that would raise the water levels on Lakes Michigan and Huron. On April 26, 2013, in an unprecedented non-unanimous report, the International Joint Commission (IJC) recommended to the U.S. and Canadian governments that they consider further studies to investigate options for building structures to raise the level of Lake Michigan-Huron up to 25 centimeters (9.8 inches). At the time, this measure would have provided relief to many shoreline residents and businesses in areas struggling with the impacts of low lake levels. However, it also would adversely affect other interests in the region, cause a mix of environmental benefits and harms, and require financing from the U.S. and Canadian governments and an extremely extensive planning, design and environmental review process,[5] after which the permits to build the project could still be denied.

Therefore, there is a need to explore alternative strategies for mitigating the harm and maximizing the benefits of water level variation in the Great Lakes. IJC reference studies over the last three decades have identified various options that could help the region adapt to water level changes.[6] Some of these options, such as shoreline management, stand in contrast to lake-wide water level control structures in that they are inherently site-specific, and thus allow different localities to address impacts and issues specific to their geography, development, and shoreline uses. In practice, however, there are many location-specific shoreline management and policy options that have not been widely adopted throughout the region. A major challenge in implementation, in addition to variability and uncertainty in water levels, is determining the appropriate integrated mix of options that take into consideration local conditions, multiple objectives, and jurisdictional constraints.

Overcoming these obstacles requires a new approach that emphasizes creative solutions and engagement with decision-makers, and that couples place-based work with a broader regional perspective. It should build upon existing efforts, bring in best-available science, and recognize the dynamic nature of the Great Lakes system made more evident by the recent reversal in water level

BOX 1:1 – THE NEED FOR LAND USE AND SHORELINE MANAGEMENT OPTIONS

Over the last 60 years, the IJC has completed extensive studies of options to alleviate the impacts of high and low water levels across the Great Lakes – St. Lawrence River system. These studies have considered both structural lake level regulation options and non-structural measures.

A consistent finding has been that shoreline use and management approaches are necessary to affect the impacts of extreme water levels. Shoreline management and use approaches are described in IJC reports, most notably the 1993 Levels Reference study,[6] and provide a key framing for the approaches considered in this IA.

[i] Of the 5 members of the commission, the U.S. Chair chose not to sign the report due to concerns about insufficient emphasis on climate change and the need to pursue adaptive management strategies, as well as what she called "false hopes" that structures would be sufficient to relieve the negative impacts of low water levels. http://www.ijc.org/files/publications/IUGLS-IJC-Report-Feb-12-2013-15-April-20132.pdf

trends. To help decision makers address the challenges and opportunities posed by Great Lakes water level variability, the University of Michigan's Graham Sustainability Institute initiated the Great Lakes Water Levels Integrated Assessment (IA).[7]

PURPOSE

The purpose of the IA has been to develop information, tools, and partnerships to help decision makers address the challenges and opportunities posed by variability in Great Lakes water levels. The IA identified and evaluated environmentally, politically, socially, and economically feasible adaptive actions, and this analysis of options will contribute to advancing adaptive strategies that protect the ecological integrity, economic stability, and cultural values of the region. These strategies are also intended to support the notion of living with variability and address the uncertainties of an evolving future associated with climate change and the potential for extreme water levels and associated impacts.

Guiding Question

The IA aimed to transform extensive existing research about water levels, flows, and impacts into practical, adaptive strategies to address issues facing shoreline property owners and managers. The IA was informed by a binational advisory committee,[8] who provided input and advice reflecting the views of key stakeholder groups. To focus the work, the following guiding question was developed in consultation with the advisory committee:

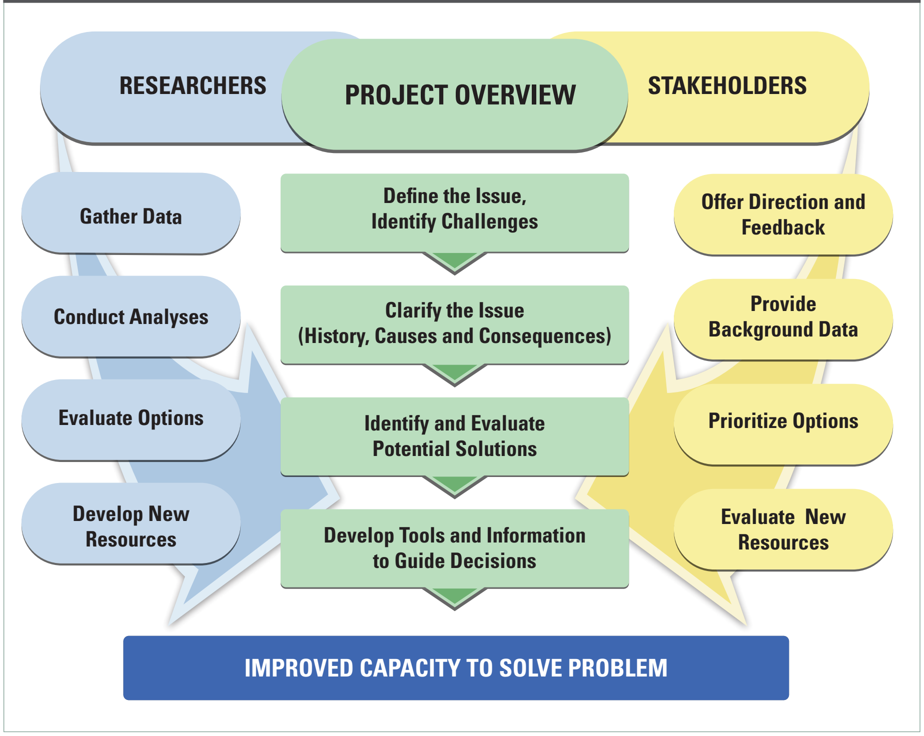
What environmentally, socially, politically, and economically feasible policy options and management actions can people, businesses, and governments implement in order to adapt to current and future variability in Great Lakes water levels?

Scope

To respond to the question, the IA focused on Lakes Michigan and Huron and took both a place-based and regional approach. As described later, the IA's primary work focused on specific communities, which allowed the research teams to engage local stakeholders to assess specific, integrated, and feasible options to meet local objectives related to water level variability. This report integrates and builds upon the work of the local projects to demonstrate variation and similarities among the communities' needs and identify insights for the basin more broadly.

The place-based projects are not representative of the full range of water level-related issues facing Great Lakes coastal communities. Locations were selected through an open proposal process based on their appropriateness for the IA, which required interested researchers and local stakeholders willing to participate in the process, sufficient available data to enable an analysis of options, and, in this case, known issues related to water levels and competing shoreline objectives that would require integrated solutions. Effort was also made to ensure representation in both the U.S. and Canada. While not exhaustive, the IA covers a range of issues relevant to other Great Lakes coastal communities.

Figure 1.1: IA process



An IA combines sound science and collaboration with diverse stakeholders to reframe a key issue and develop feasible solutions that promote environmental and economic sustainability.

WHAT IA MEANS

This project adopted an IA approach as the organizing framework. IA is a deliberative process where experts summarize and synthesize existing scientific data and information to guide decision making. By engaging representatives from a wide range of impacted sectors and perspectives on a given issue, IAs collaboratively define problems, address diverse perspectives, use and share best-available information, and establish partnerships with the goal of analyzing options for making positive change.

The IA process is flexible but typically includes the following iterative steps to promote relevance and credibility:

1. define the policy-relevant issue/challenge,
2. document status and trends, and describe the causes and consequences of the issue,
3. identify and evaluate potential solutions,
4. evaluate the likely environmental, social, and economic outcomes and uncertainty of each option,

5. develop tools and information to guide decisions, and
6. produce an analysis of strategies and policy options informed by stakeholder input.[9-11] Figure 1.1 illustrates how both technical experts and engaged stakeholders contribute to the process.

The IA process aimed to be transparent and inclusive, involving stakeholders representing a wide range of perspectives on water level issues. Following the "honest broker" approach, the assessment considered options without predetermined conclusions and compared and evaluated a suite of options, rather than a single recommended approach.[12]

PROCESS

Request for Proposals

Following the project scoping work done in consultation with the advisory committee and after a planning period phase, a request for proposals was sent out in September of 2015. The Graham Institute, with additional support from the Michigan Coastal Zone Management Program and National Oceanic and Atmospheric Administration (NOAA), then funded four research teams to investigate how communities on the Great Lakes are and could respond to actual and potential water level changes.[7, 8] This report synthesizes the findings of these place-based teams, outlining the problems faced by each community, the options each community might implement, and how likely these options are to successfully address the underlying issues each community faces.

Phases I, II, III

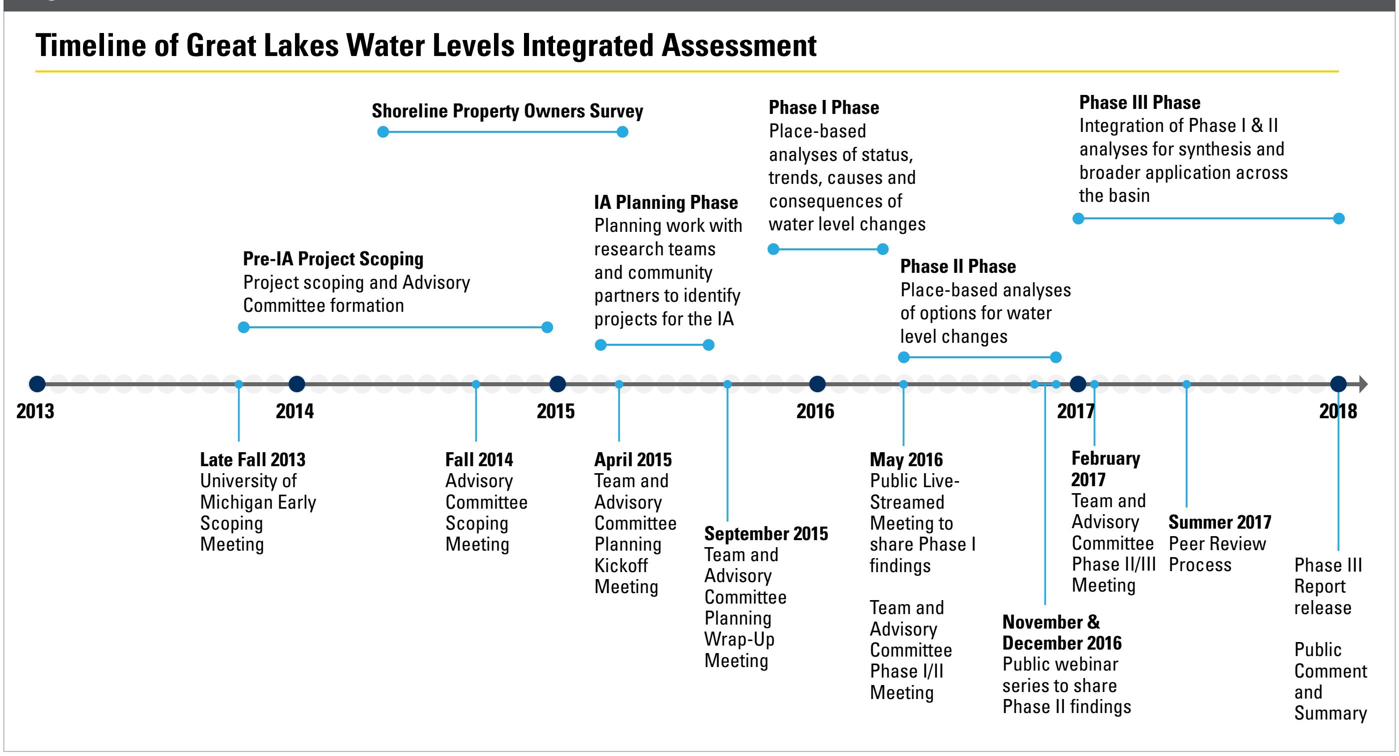
The IA was divided into three phases. The first two phases were focused on specific localities. During Phase I, research teams used existing data and information to develop an overview synthesis report on the status, trends, causes, and consequences of changing water levels as they relate to the key issues in the community they were working with. Each report then outlined the future research and planning each group intended to complete, whether that involved further community outreach, ordinance drafting, or geological mapping. Results from this work were shared at a public meeting (in person and live streamed) in May of 2016[13] and posted to the project website.[7]

In Phase II, the teams worked in collaboration with their partners to identify and analyze viable policies and adaptive actions that meet local objectives. Phase II reports outlined the full findings of each group. These included the options proposed by communities and researchers, the feedback to those options, and the challenges and opportunities of each option.[7] Each group also presented webinars on their findings, which generated widespread public participation and feedback.[14]

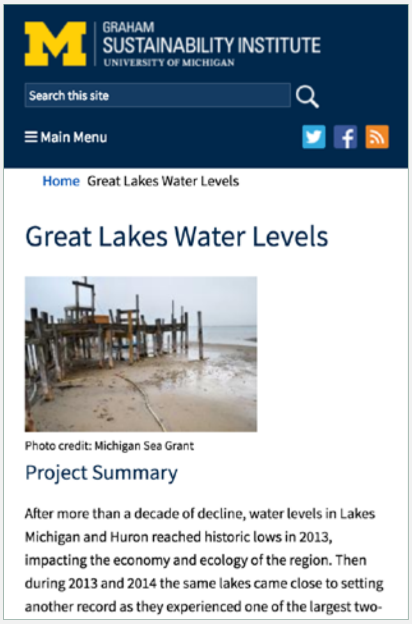
This Phase III report seeks to integrate the findings of each group regarding the unique challenges and opportunities faced by each community to identify opportunities for the region. While relying primarily on material from the previous IA phases, the report also includes additional material to support findings and clarify topics of relevance. The hope is that this report can inform communities facing similar situations as to how to approach water level variability, given the environmental, social, political, and economic characteristics of their community. Refer to Figure 1.2 for a timeline of the IA.

This chapter continues with a brief outline of each group of researchers, and what each

Figure 1.2: IA Timeline



KEY RESOURCE



Great Lakes Water Levels IA Project Webpage

http://graham.umich.edu/emopps/water-levels

This report and additional information about the IA, including the Phase I and Phase II reports, webinar recordings, and other resources are accessible on the Graham Sustainability Institute website.

set out to accomplish. Chapter 2 explores the dynamic nature of the Great Lakes system, including factors that create variable water levels and the diverse interests affected by them. Chapter 3 provides more detail on the IA approach, and adaptation planning more generally, as well as how each research team approached devising and assessing options for dealing with water level variability. Chapter 4 outlines various options proposed and assessed by each research team. These options are grouped into four categories:

- **Planning and Coordination**
- **Shoreline Stabilization**
- **Land Use and Shoreline Management Policies**
- **Education and Outreach**

Examples of these options, as analyzed by the research teams, are provided. Chapter 5 concludes the report by identifying several common themes identified in the work of the research teams and a discussion of the limitations of the IA.

Integrated Assessment Teams

WISCONSIN TEAM

David Hart of Wisconsin Sea Grant headed a team of researchers from Wisconsin Sea Grant, the University of Wisconsin-Madison, and the University of Wisconsin-Milwaukee.

This team focused on communities along the shore of Lake Michigan located immediately north of the city of Milwaukee, Wisconsin in Milwaukee and Ozaukee counties, with a primary focus on the influence of changing water levels on coastal bluff erosion. Their goals were to synthesize existing resources and to engage community residents and officials in discussions about their hopes and concerns around the future of their coastal bluffs. Through several public meetings and stakeholder interviews, the team developed a wide range of options for addressing these challenges, and gauged community feedback to these options.

In addition to partners at the local and county level, the team coordinated with regional and state organizations and agencies working on coastal issues, such as the Southeastern Wisconsin Regional Planning Commission and Wisconsin Coastal Management Program, Department of Natural Resources, and Division of Emergency Management.

ONTARIO TEAM

Lynne Peterson, a local government and integrated policy consultant, led a team including researchers from the University of Toronto's Ecological Modelling Lab, Environment and Climate Change Canada, and University of Guelph, a former municipal chief administrative officer and a former Ontario municipal finance and planning policy expert.

The team focused on Huron County, Ontario with 100 kilometers (62 miles) of shoreline along Lake Huron, and worked directly with the Huron County Water Protection Steering Committee. The team's goals were to review issues arising from both low and high water level extremes on Lake Huron and to identify regulatory and non-regulatory options for living with water level variability for review by Huron County, local municipalities, conservation authorities, non-profit organizations, harbor organizations, local residents, and businesses. Through a series of workshops, presentations, and additional

Figure 1.3: Map of the IA place-based projects

discussions with key stakeholders, the team developed a series of policy and adaptive management proposals. In addition to the Water Protection Steering Committee, key participants were the Lake Huron Centre for Coastal Conservation, the Ausable-Bayfield Conservation Authority, the Maitland Valley Conservation Authority, the Bluewater Shoreline Residents Association, and the Ashfield-Colborne Lakefront Association.

SOUTHERN MICHIGAN TEAM

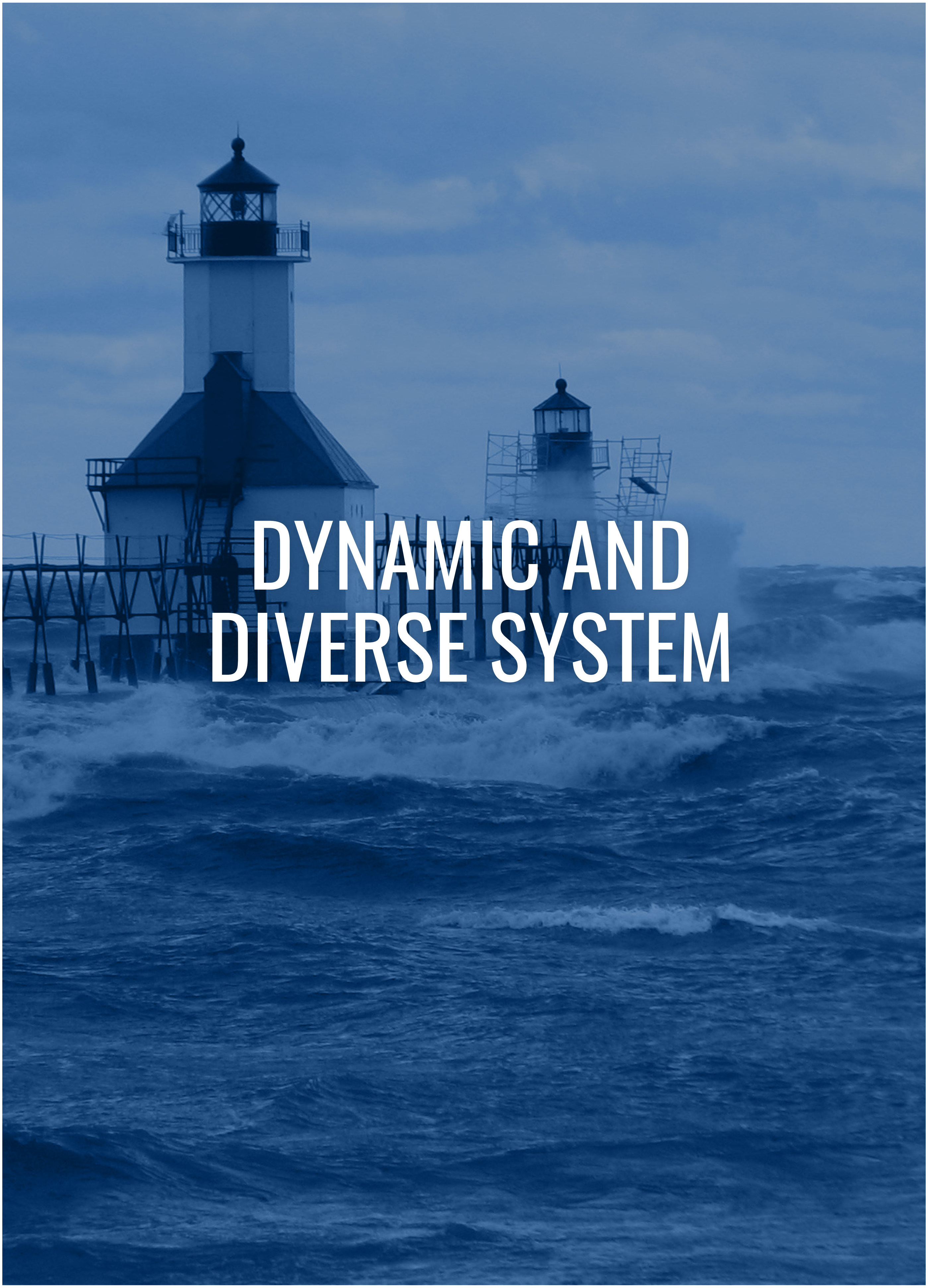
Richard Norton of the University of Michigan Taubman School of Architecture and Urban Planning led a team of researchers from the University of Michigan, Michigan Technological University, and the non-profit planning and community development firm LIAA.

The team worked directly with the City of Grand Haven and Grand Haven Charter Township along the southern Michigan shore of Lake Michigan. The team sought to build on previous land use planning efforts and to identify options for actually implementing master plans or shoreland area management plans.

NORTHERN MICHIGAN TEAM

Frank Marsik of the University of Michigan College of Engineering led researchers from the University of Michigan and Michigan State University. This team developed a collaborative approach to work directly with the Little Traverse Bay Bands of Odawa Indians and the Grand Traverse Band of Ottawa and Chippewa Indians, both of whom have reservation lands in the northwest lower peninsula of Michigan along Lake Michigan, as well as hunting, fishing, and gathering rights within a larger area spanning the upper and lower peninsulas of Michigan and Lakes Michigan-Huron and Superior.

The team sought to facilitate the integration of western science approaches and Indigenous Traditional Knowledge approaches into the consideration of climate change effects on lake levels in Tribal plans.



DYNAMIC AND DIVERSE SYSTEM

CHAPTER 2

The Great Lakes are highly dynamic natural systems that shape the ecology, culture, and economy of the region. The total U.S. and Canadian Great Lakes shoreline extends just over 17,700 kilometers (10,000 miles)[15] and includes a diverse array of ecosystems and land use types. Water levels on the Great Lakes exhibit fluctuations on time scales from hours to centuries as the result of various natural and anthropogenic factors, as well as long-term climate changes. Significantly, these changing water levels are occurring within the complex and varied physical, political, social, and economic context of the Great Lakes Basin, and can pose potentially significant impacts on a variety of shoreline types, communities, and interests throughout the region.

This chapter provides an overview of the factors affecting water levels in the Great lakes, the diverse interest groups affected by water levels, and the types of impacts—positive and negative—that this variability poses for shoreline communities in particular.

WATER LEVEL VARIABILITY

Great Lakes Water Budgets

Many factors influence Great Lakes water levels, including precipitation, evaporation, run-off, water flow through connecting channels, diversions into and out of the system, consumptive water use, dredging, and water level regulation. Air temperature, wind, and vertical movement of the earth's crust also factor in.[16,17]

A water budget is a concept that describes the relationship between inputs and outputs of water through a region, and it can help to clarify the causes of long-term fluctuations in water levels. When inputs (precipitation, runoff, groundwater, inflows from upstream, and diversions in) exceed the outputs (evaporation, outflow from the lake, diversions out) for a significant period of time, lake level rises. While the concept is simple, understanding the water balance still continues to be a scientific challenge and requires ongoing analyses.

The three main factors affecting water levels are precipitation, runoff, and evaporation.[16] Overlake precipitation contributes directly to total Great Lakes water supply while precipitation that falls over the land goes through various phases of the hydrologic cycle and eventually contributes to the lakes as runoff. In contrast, overlake evaporation, which peaks between late fall and early winter,[18] removes water from the lakes.

There are challenges associated with measuring each of these factors, particularly overlake evaporation. The International

Figure 2.1: Water budgets of the Great Lakes[18]

Values are shown in thousands of cubic meters per second (CMS). Averages for evaporation (e), precipitation (p), runoff (r), and artificial diversions, over the period of 1953-2010, are shown for each lake and connecting channel. Figure modified by the Graham Sustainability Institute from original, used with permission by Michigan Sea Grant. NOAA-Great Lakes Environmental Research Laboratory (GLERL) Hydrometerological database. Not to scale.

Upper Great Lakes Study addressed these challenges and concluded that "despite these uncertainties, it is clear that lake evaporation is increasing and likely will increase for the foreseeable future, likely due to the lack of ice-cover, increasing surface water temperatures and wind speeds. Analysis indicates that in the Lake Michigan-Huron basin, this increased evaporation is being largely offset by increases in local precipitation."[19]

Human factors also influence water levels in the Great Lakes, although to a much lesser degree than natural factors. Diversions bring water into and take water out of the lakes, although the net effect is a small input to the system, as the combined average amount of water diverted into Lake Superior at Ogoki and Long Lac is greater than the combined amount of diversions out of the Great Lakes Basin.[18] To put these in perspective, over the period of 1953-2010, precipitation added an average of 3,100 cubic meters of water per second (CMS) to Lakes Michigan and Huron and evaporation removed 2,700 CMS, while the Ogaki and Long Lac diversions added 160 CMS to the system and the Illinois diversion removed 90 CMS.[18] Additional human influences play even more limited roles in influencing water levels. For example, general consumptive uses, reflecting varied purposes, have little effect on overall water levels.[20]

The IJC provides oversight at three control structures that impact international water levels and flows on the Great Lakes and St. Lawrence River. These are located in the St. Marys River, Niagara River, and St. Lawrence River, near the outlets of Lake Superior, Lake Erie, and Lake Ontario, respectively.[21] International control boards established by the IJC are responsible for overseeing water levels and managing different control works.[22-24] Outflows from Lake Superior and Lake Ontario are established on a regular basis in accordance with the respective current regulation plans (referred to as Plan 2012 and Plan 2014) and IJC Orders of Approval. The regulation of Lake Superior influences the whole Great Lakes system; however, regulation of Lake Ontario has no impact on the upper lakes because of the difference in elevation at Niagara Falls.

Changes Over Time

The combination of the Great Lakes' large size and small outflow channels results in a largely self-regulating system that tends to buffer changes and keep lake levels within typical ranges over long periods. It also means that extremely high or low levels and flows can persist for a considerable time after the factors that caused them have changed.[19]

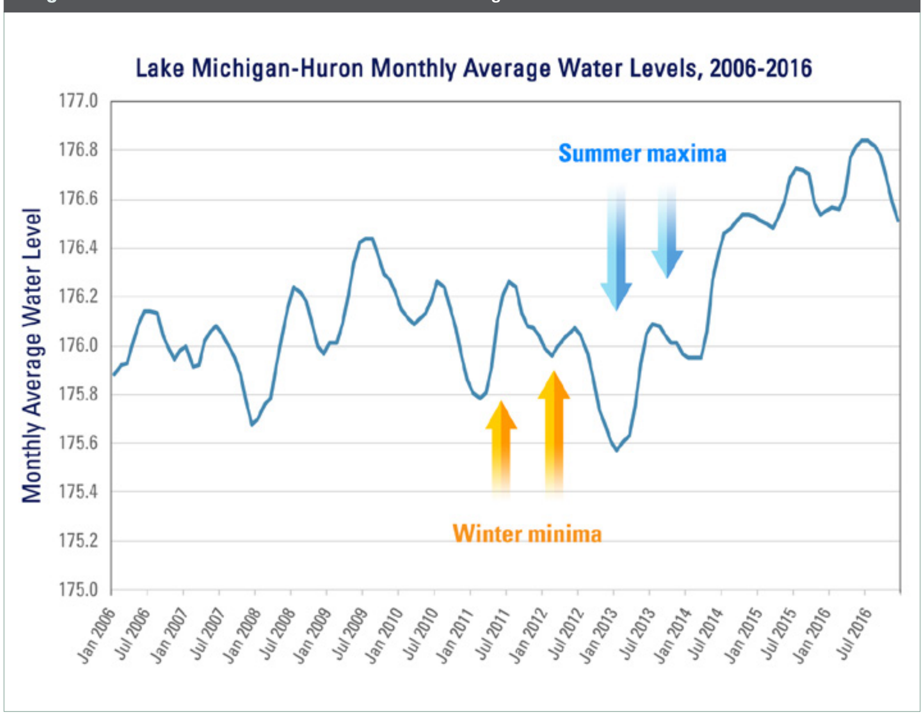
The magnitude of water level changes varies depending on the lake and the time scale considered. Over the course of a year water levels vary approximately 30-50 centimeters (cm) or 12-20 inches. Over longer time scales, monthly water levels range from about 60-90 cm (2-3 feet) above or below the long-term averages for the month.5 The historical range of recorded annual average water levels on Lakes Michigan and Huron, for instance, is close to 2 meters (6.5 feet).[25]

Fluctuations over short-periods—from hours to days—can be caused by differences in barometric pressure or winds that produce storm surge and wind set-up on the downwind side of the lake. These changes are often not a function of changes in the amount of water in the lakes.

Seasonal changes in water levels, in contrast, are caused by corresponding seasonal patterns in the various inputs to and outflows from the system. In general, the annual minimum water levels typically occur during the winter, following the period in which seasonally cool, dry air moves over the relatively warm waters of Lake Michigan, resulting in enhanced evaporation from the lake surface. The onset of ice cover results in the end of this enhanced period of evaporation. In contrast, the annual maximum water level typically occurs during the late spring and early summer following the end of winter snowmelt and spring rains.[26] Figure 2.2 illustrates the seasonal variation in Lake Michigan-Huron Water levels using the period of 2006-2016 as an example.

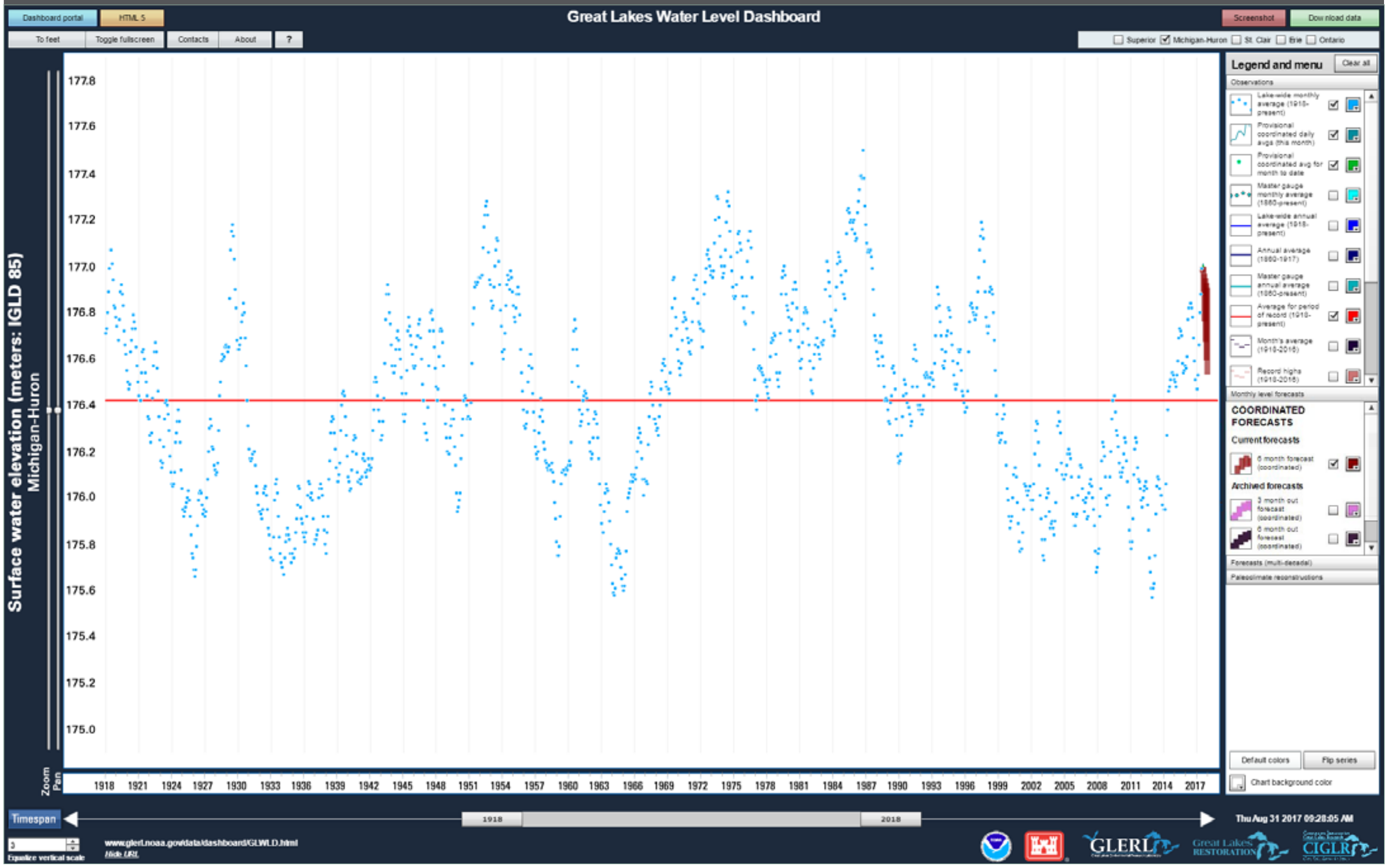
The drivers of high and low water levels also vary from lake to lake and from year to year. For instance, a 2016 study found that the rapid rise in water levels on Lake Michigan-Huron in 2013 was due to above-average spring runoff and persistent over-lake precipitation. In contrast, in 2014, the seasonal rise in water levels was due to a rare combination of below-average

Figure 2.2: Seasonal fluctuations in Lakes Michigan and Huron water levels[27]



Monthly average water level shown in meters. Figure derived from master gauge data provided by GLERL.

Figure 2.3: GLERL Great Lakes Water Level Dashboard – Lakes Michigan and Huron water levels, 1918-present [3]



Blue dots denote monthly lakewide average water levels from 1918-present. The solid red line shows the long-term average from 1918-2016. The USACE 6-month forecast is shown as dark red probability bands on the far right. Accessed August 3, 2017.

evaporation, above-average runoff and precipitation, and very high inflow rates from Lake Superior through the St. Marys River.[1]

Continuing high or low water supply conditions contribute to larger long-term fluctuations. Several-year periods of high or low levels are a normal feature of Great Lakes water levels dynamics, but they are very difficult to predict. Review of long-term water levels on Lakes Michigan and Huron from 1918 to the present (Figure 2.3) reveals periods of lows in the 1920s, mid-1930s, mid-1960s, and 2000s to 2013, with periods of highs in the early 1950s, early 1970s, mid-1980s, and mid-1990s. While they may be difficult to predict, extreme lake levels are not an unusual phenomenon.

As noted in the most recent State of the Great Lakes technical report, assessment of trends in water levels depends on the period of the historical record selected for consideration. For instance, the historical record shows decreasing water levels in Lakes Michigan and Huron over the last 30 years, but no significant trend over the last 100 years.[28]

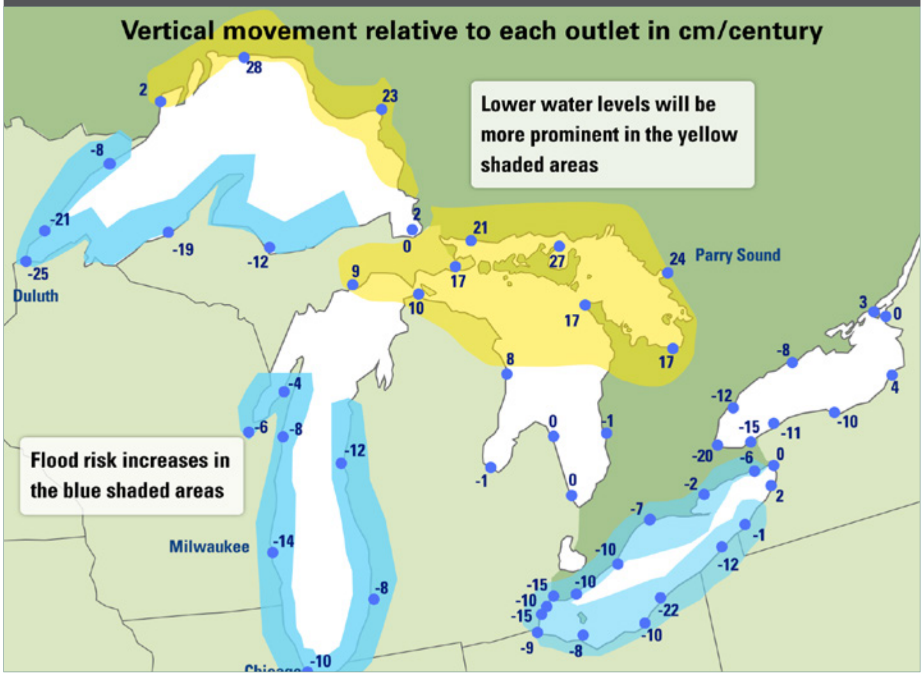
Glacial Isostatic Adjustment

Another factor affecting water levels over time is glacial isostatic adjustment (GIA), which is the ongoing movement of the earth's crust as it rebounds following the retreat of the glaciers at the end of the last ice age. The rate of vertical movement varies across the region, with northeastern portions of the basin rising and southwestern portions falling relative to the center of the earth—effectively tilting the basin southward over time. GIA affects long-term lake level by warping each lake's basin and changing the elevation of the lake's coastline in relation to its outlet. On a given lake, segments of coastline segments rebounding faster than the lake's outlet experience a net uplift, and long-term water levels appear to be falling. Coastlines where the isostatic adjustment rate is less than the outlet will experience a net drowning, and long-term water levels appear to be rising (see Figure 2.4). These effects of GIA are unrelated to—and experienced in addition to—changes in net basin supply. As a result, GIA affects how water levels changes are experienced across the region; falling water levels will be more prominent in northern areas, and rising water levels will be greater in southern areas.[19,29]

Climate Change

Climate change poses additional challenges to understanding and adapting to fluctuating Great Lakes water levels. As explained above, average lake levels and the range of fluctuations are primarily determined by the combination of precipitation and evaporation—factors that are affected by climate change. Climate models for the Great Lakes region project increases in air and lake surface temperatures and lake evaporation, which would reduce the net supply of water to the lakes.[31,32] However, precipitation is also expected to increase, having the opposite

Figure 2.4: Map of GIA impacts on the shorelines of the Upper Great Lakes[19,30]



Estimates of vertical crust velocity (in centimeters/century) at water level gauge station locations relative to their lake outlets represented by water level gauges at: Cape Vincent (for Lake Ontario); Buffalo (for Lake Erie); Lakeport (for Lake Michigan-Huron); and Point Iroquois (for Lake Superior). Source: IUGLS (2012) and Mainville and Craymer (2005).

effect.[33] Projections of drainage basin runoff, which is another key factor in the water budget, are mixed.[31-33] How these different factors play out will determine water levels in the future.[34]

Numerous studies over the last three decades have projected changes in the Great Lakes water budget under alternative climate scenarios. A number of them have used a similar underlying approach and projected drops in water levels, contributing to the notion that lower lake levels will accompany future climate change. However, studies using alternative methods for projecting water levels, either directly or indirectly, have predicted smaller decreases or even increases in water levels.[35-37]

As a result, there remains uncertainty regarding how exactly long-term changes in regional climate will affect future water levels in the Great Lakes. In its extensive analysis of climate impacts on future water levels, the International Upper Great Lakes Study (IUGLS) by the IJC concluded that "lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range. While lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered."[19]

Climate scientists also have noted that the frequency and intensity of severe storms has increased.[34,38] Moreover, climate modeling has shown a decrease in ice coverage on the lakes. Without ice to prevent large waves and storm surges, the result of a longer ice-free season is an increase in total annual wave energy reaching the shore, which can increase sediment transport, erosion of the nearshore lakebed and bluff toes, and potential impact to onshore development.[39]

Ultimately, predicting the effects of climate change will require constant and improved monitoring and modeling of lake levels, something that NOAA is currently addressing, alongside the USACE and Environment and Climate Change Canada.[34]

DIVERSE SHORELINES AND INTERESTS

These fluctuations in water levels affect the variety of land and habitat types along the shore and the myriad individual, institutional, and commercial interests within the Basin. The natural and human components of the system are described separately below, but the reality is that the two are interconnected parts of one Great Lakes system.

Natural System

In both Canada and the U.S., the lakes have a diversity of shore types including resistant bedrock, sand beaches and dunes, high bluffs, rocky beaches, and wetlands.[6] Lake waters affect each of these differently, with bluff areas most susceptible to erosion, and beaches and dunes constantly shifting in response to waves and wind. It is important to emphasize that erosion of both sandy and cohesive shoreline is generally controlled by coastal processes such as waves, wave set-up, longshore sediment transport and littoral cells, and is only modulated by water level variation.[40] (See Box 2.1 for more on sediment transport, erosion, and bluff stability.)

Changes in water levels can have markedly different effects on shorelines depending on the slope of the shore. Along gently-sloping shores, small fluctuations in water level elevations (vertical change) can have a much larger effect on the location of the shoreline (horizontal change). Human modifications further affect these shorelines.[41]

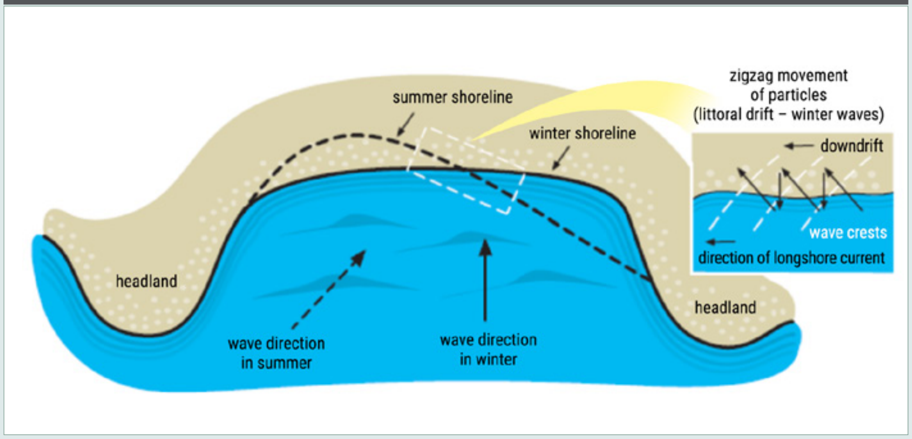
Natural water level fluctuations play an important role in maintaining the functioning and diversity of some shoreline habitats. For example, coastal wetlands depend on variable water levels to support diverse plant species adapted to a variety of water levels (see Figure 2.9 and Box 2.2).[49] These wetlands buffer floods, absorb and slow pollutants entering the lakes, and provide habitat for a wide array of animals. Despite the fact that wetlands comprise only 1% of the surface area of Lake Michigan, they provide spawning, nursery and foraging habitat for between 40-90% of Great Lakes fish species at some stage in the life cycles of these species.[26,50]

Human System

The Great Lakes are critical to the ecology, culture, and economy of the region. Coastal

BOX 2.1: SEDIMENT TRANSPORT, EROSION, AND BLUFF STABILITY

Figure 2.5: Littoral drift and a shoreline response to waves[42]



Littoral Drift

Littoral transport is the movement of sediment in the nearshore driven by waves and currents, and it is the method by which dynamic coastline features, such as beaches, dunes and offshore bars are built and maintained. This transport occurs both parallel (longshore) and perpendicular to the shoreline (cross shore).[42]

Shoreline and Lakebed Erosion

Erosion is a natural part of the littoral process, and it can happen slowly or suddenly. Coastal slopes erode as a result of storm waves, rising groundwater and instability in soils, surface water runoff, and other factors. On rocky shores where the toe has been gradually undercut by wave action, erosion typically involves rock falls.

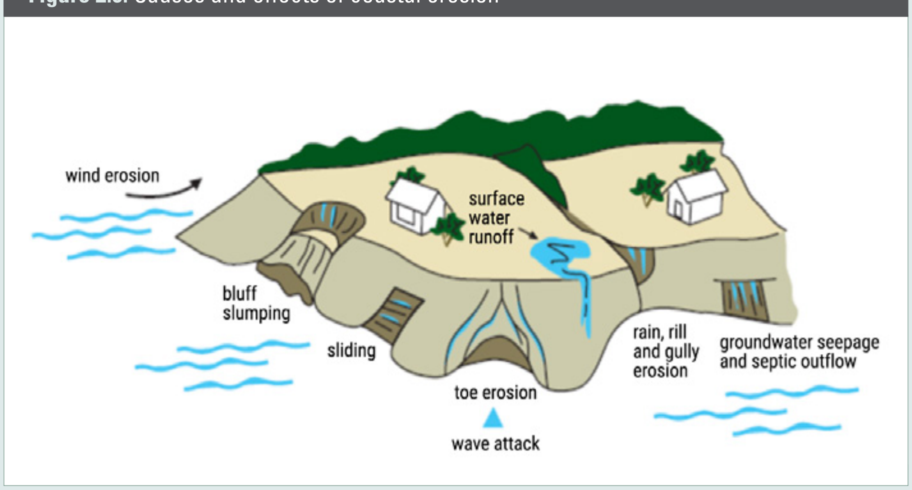
The lakebed itself is also subject to erosion. Unlike erosion of sandy shores that can be reversed by conditions that deposit materials, lakebed erosion is irreversible.[42] Where lakebed erosion is occurring, structures built to protect the toe of adjacent bluffs are subject to increasing wave energy and their foundations are undermined as the water depth in front of the structure increases.[43]

Changing Shorelines and Barriers to Sediment Transport

It is the ratio of incoming and outgoing material that causes changes in the shoreline. Where the rate of offshore sand transport exceeds the rate of supply from updrift sources (e.g., material eroded from bluffs or supplied by rivers), a beach erodes. During calmer periods when waves transport sand from offshore bars and deposit it at the beach, a beach accretes. With changes in water levels sandy beaches can advance and retreat. Low lake levels allow waves to build beaches and dunes from nearshore deposits, while high water levels and storms move shore materials offshore.[42]

Armoring can prevent longshore movement, reducing sediment supply downshore, resulting in narrower beaches and potentially exposing underlying till to irreversible erosion of the lakebed.[42]

Figure 2.6: Causes and effects of coastal erosion[42]



Bluff Instability

Bluff face and bluff top failures are caused when stable slopes become unstable. Many factors can cause unstable slopes including bluff toe erosion, the lessening of longshore transport (such as when adjacent properties install bluff protection structures which reduce the littoral drift contribution from their bluff), lakebed downcutting that allows greater wave energy to reach the bluff toe, and other factors such as layers of bluff material that allow for groundwater seeps to occur, intense rainfall or rapid snowmelt on top of the slope, increase in bluff top storm water runoff caused by impervious surface, excess weight added to the top of the slope (buildings, mound septic systems, pools), and the removal of bluff strengthening vegetation.[44]

This erosion can be unpredictable. A bluff may not have eroded significantly in decades, yet may lose five to 50 feet of bluff top in one failure event.[45]

Littoral Sediment Transport and Bluff Erosion

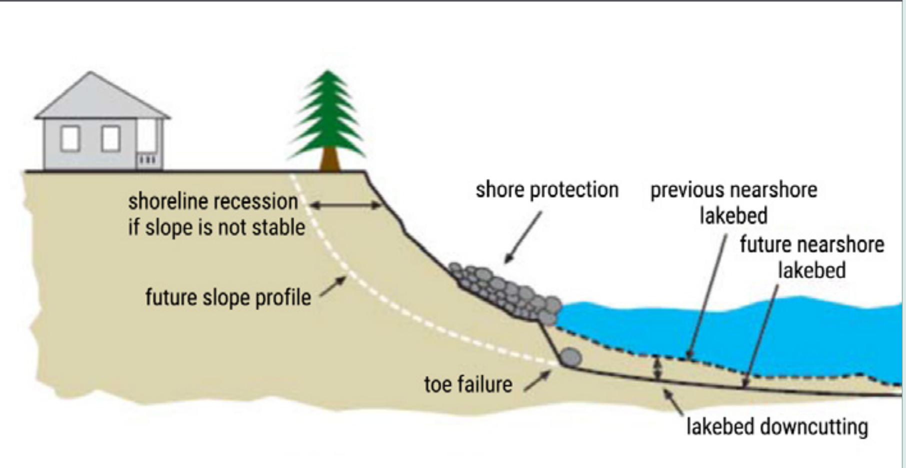
Littoral sediment transport is an important factor controlling ongoing erosion of cohesive and sandy bluffs. In instances where sediment is not transported away, the process of erosion can be shut down. This can occur naturally, as in the lee of barrier spits, or as a result of human intervention, as in the filet beaches updrift of major harbor breakwalls. In the case of the latter, the bluffs above those beaches face fewer concerns about erosion compared to bluffs updrift and downdrift of the filet beach where erosion is still occurring.[40]

Continued on the next page.

Erosion and Recession are Not the Same

Erosion is the wearing away of land or lake bottom, and is expressed as a volume or change in volume. In contrast, recession is the landward movement of a feature, such as a bluff or dune crest, and it is expressed as a distance or a change in distance. Recession can be thought of as a consequence of erosion[46] (more accurately, it is the result of numerous factors, including erosion). While beach erosion may occur and be followed by accretion, shoreline recession is a permanent change or impact.[47]

Figure 2.7: Lakebed erosion with slope recession and failure of shore protection structure[42]



Lake Level Fluctuations

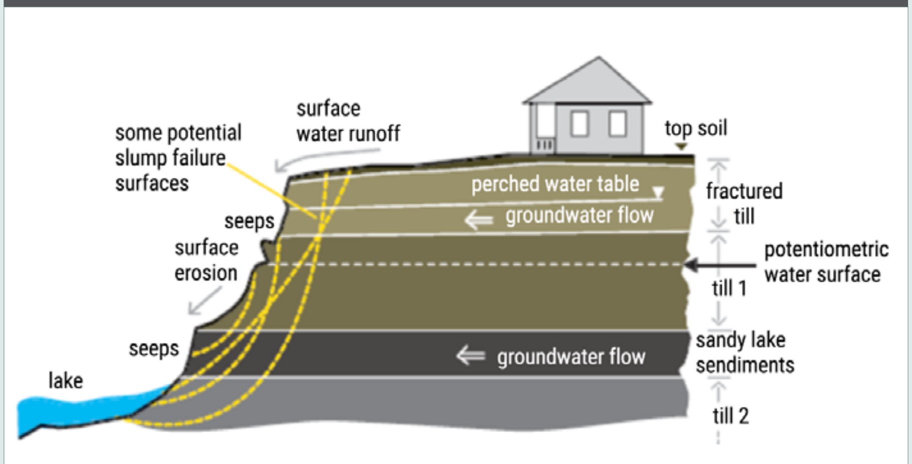
It is important to emphasize that water level variability is not a direct cause of erosion. Erosion of both sandy and cohesive shoreline is generally controlled by coastal processes such as waves, wave set-up, longshore sediment transport, and littoral cells. Water level variations modulate erosion—affecting the magnitude, timing, and location of erosion in the short-term—because water depth partially influences how and where waves will interact with the coastal area.

In the short-term the erosion of banks and bluffs increases during high lake levels and decreases during low lake levels. The opposite is true of nearshore lakebed erosion. When water levels decrease, the zone of wave breaking, where erosion is the strongest, moves further offshore. Then when water levels rebound, the water depth close to shore is deeper than it was during the last high water period, thereby increasing wave impacts on shore.[46] The consequence is ongoing recession of shoreline as the beach widens and narrows.

Despite these short-term effects of water levels on erosion, modeling has indicated that over the long-term recession rates are not dependent on water levels. Total long-term modeled recession varied little among water level scenarios, with no clear water level scenario that consistently caused relatively more or less shoreline recession.[48]

*Graphics from Living on the Coast: **Protecting Investments in Shore Property on the Great Lakes** (USACE and University of Wisconsin Sea Grant, 2003).*

Figure 2.8: Bluff instability and erosion[42]



areas in particular provide many benefits including access to water for recreation, consumption, power generation, and manufacturing, and a significant proportion of the region's population lives near the shore, including major cities like Chicago, Toronto, and Detroit. Great Lakes shorelines have been heavily developed in some areas for urban, industrial, and residential land use, and continued population growth, economic development, and recreation will continue to put more pressure on coastlines.

DIVERSE INTERESTS AND DIFFERENT IMPACTS

A large and diverse group of interests are affected by and connected to the lakes—through their business or livelihoods, recreation, infrastructure, and values—even if they don't live immediately along their shores. As noted in the 1993 IJC Levels Reference study, "Users of the water resource are as diverse as the system is vast, but they all have one thing in common: major changes in lake levels can have major impacts on them."[6]

The potential impacts of water level changes are similarly diverse. Periods of high water levels can lead to erosion, flooding, and property damage for some communities, cause hazardous currents in shipping channels, and reduce the size of beaches. While lower water levels may relieve some

BOX 2.2: WETLANDS NEED WATER LEVEL FLUCTUATIONS

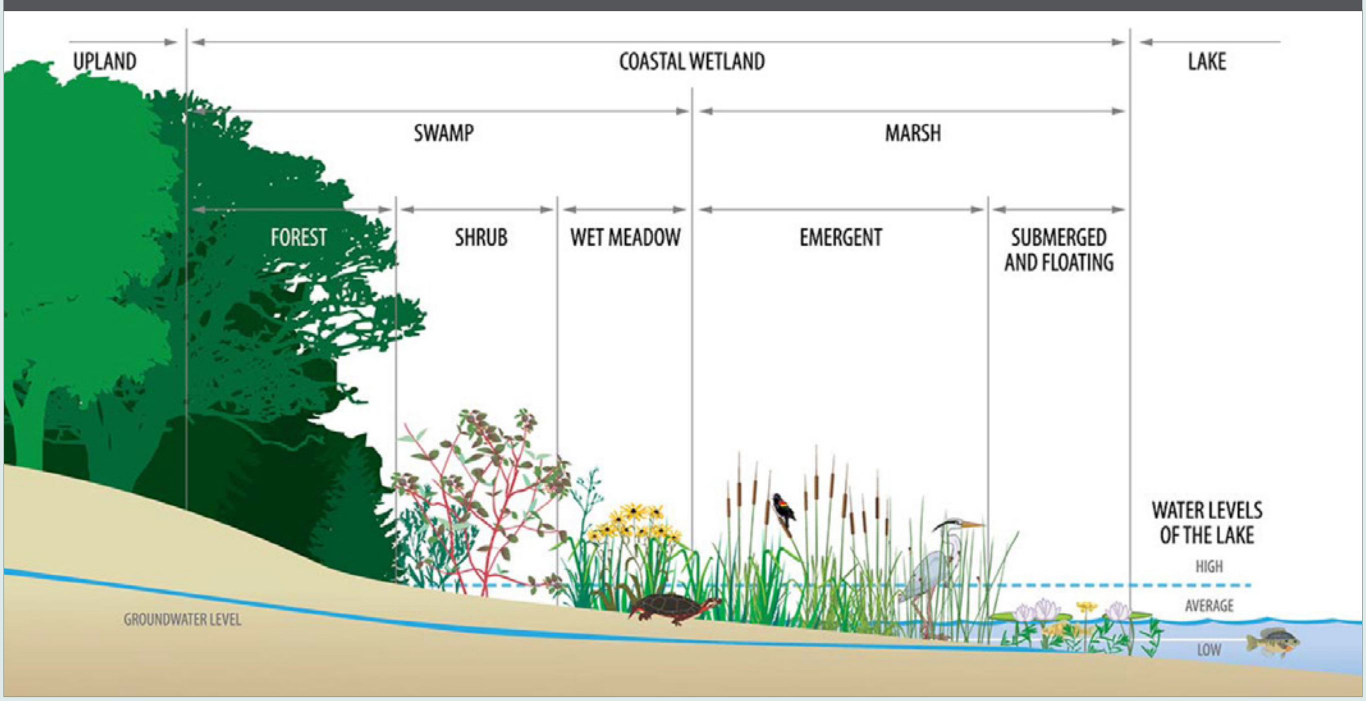
Open-shoreline wetland communities have diverse vegetation communities ranging from forest and shrubs in the drier portions of the ecosystem and meadows, emergent and floating vegetation as one moves toward the water.

Variable water levels provide the periodic flooding and then drying necessary to maintain wetlands at productive, intermediate stages of development. During low water level periods, the vegetation communities shift downward toward the land-water interface, while during high water level periods, the vegetation communities shift in the upland direction.

Stable water levels are not beneficial to coastal wetland ecosystems. During prolonged low water periods, perennial forest and shrub communities can take a foothold in locations formerly occupied by meadow and emergent communities.[52, 26] Invasive species, such as Phragmites, can also take hold in a wetland ecosystem during such dry conditions. When water levels rise, these areas may no longer provide suitable habitat for fish and wildlife. In the same way, if property owners remove native vegetation during times of low water (subject to regulatory approvals), when levels rise to, or near, their previous levels, the native vegetation may no longer be in place to serve as protective cover for young fish and other wildlife.[26] Additionally, development along the shoreline can restrict the natural migration of native communities as water levels rise. As a result, communities pinched out of existence during high water levels do not have recolonization sources when water levels drop.

While wetlands are affected by fluctuating water levels, they also can help to mitigate the impacts of water levels on human communities. Coastal wetlands can serve as buffers, reducing shoreline and property damage during storms by absorbing wave energy.

Figure 2.9: Illustration of a typical gradient for coastal wetlands associated with lakes[51]



of those challenges, they may simultaneously disrupt shipping and other commercial ventures that require deep-water ports, render docks inaccessible, expose navigation hazards, hinder municipal water intakes and power production or affect the aesthetics of the shoreline. At the same time, periodic highs and lows are necessary to sustain wetlands.

The IJC IUGLS provides a framework that is helpful for thinking about these various interests. It categorizes the individual, institutional, and commercial interests in the Upper Great Lakes into six broad groups and summarizes important values and perceptions of each, as well as the likely consequences they would experience from changing water levels (see Table 2.1).[19] This categorization is a simplification given that these groups are internally diverse, not mutually exclusive, and not comprehensive; yet it provides a useful overview of the interconnected social systems within the basin.

The IUGLS also uses the concept of “coping zones” to understand in more detail the impacts that these various interest groups experience under different water level conditions. Coping zones are divided into three levels of progressively more challenging conditions for a given interest group: Zone A conditions are within an interest’s expectations and tolerance; Zone B conditions have unfavorable but not irreversible impacts; and Zone C conditions entail significant long-lasting or permanent negative impacts (see Figure 2.10).[19,53]

While further details are beyond the scope of this report, it is worth emphasizing a few insights from the coping zone concept. First, a coping zone is not defined by only the absolute level of water, but also the rate, frequency, duration, and seasonality of water level change. For simplicity, this report mainly refers to high and low water levels, but it may be, for instance, that a particularly rapid increase or an unusually long duration of lows is more significant to a given interest group. Additionally, the coping zone concept recognizes that the effects of different water level conditions are not strictly negative or positive, as there are different degrees of impact. Lastly, coping zones differ among interests and across locations. That is, conditions that one group in a given location finds tolerable may have significant adverse effects on another interests.

COASTAL ZONE – SHORELINE PROPERTY OWNERS

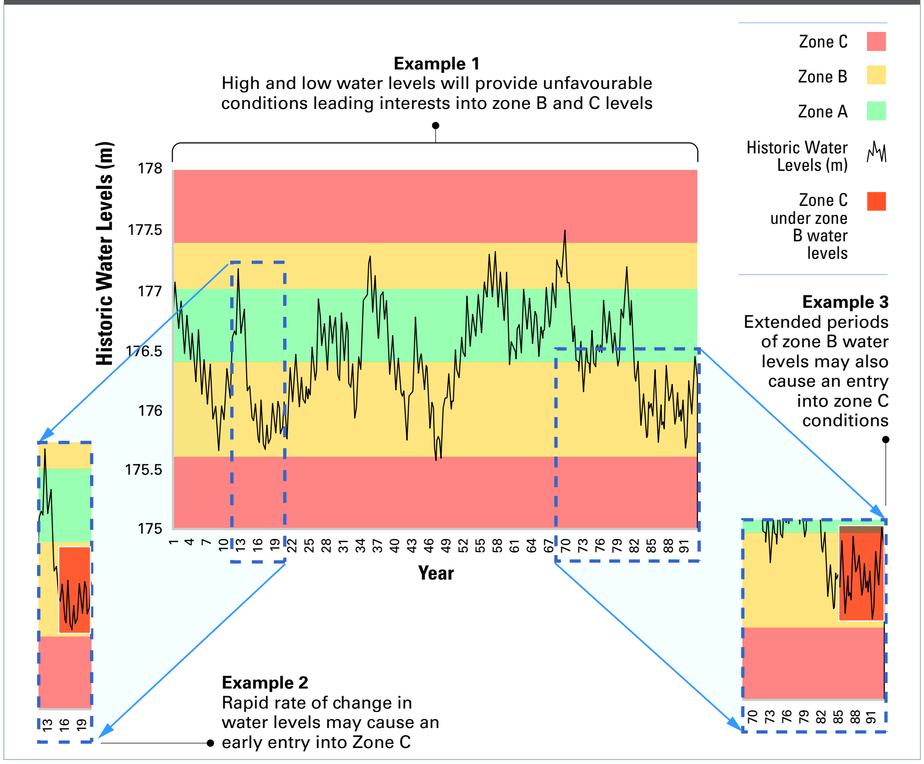
What the IUGLS report refers to as the Coastal Zone—individuals and organizations with a direct interest in property along the shorelines and connecting channels of lakes, particularly private property owners—most closely aligns this IA's focus on issues facing shoreline property owners and managers. As noted by the report, this group is significant and growing. As of 2012 it included an estimated 93,400 properties along the upper Great Lakes shorelines and connecting channels, and projections suggest that most of the Lake Michigan and Huron shorelines will be developed as residential in the next 50 years.[19]

Property owners often have preferences for water levels at their particular location. Depending on physical characteristics of a specific location, this group can experience negative impacts from both high and low water levels. Since the 1950s the most prevalent negative impacts during high water levels have been damages to land

Table 2.1: Interests in the Upper Great Lakes: Summary of vulnerabilities to water level fluctuations[19]

WATER USING INTEREST	VULNERABILITIES
Domestic, Municipal and Industrial Water Uses	Impacts at extreme water levels can include unusable or compromised water intakes, sedimentation problems, increased operations and maintenance requirements, and reductions in water quality.
Commercial Navigation	Adverse impacts are generally associated with low water levels; e.g., vessels forced to operate with reduced loads.
Hydroelectric Generation	Can be adversely affected by high water conditions; e.g., temporary local flooding, erosion concerns in power canals. Persistent low water conditions can have greater impact, forcing stations to operate below capacity and reducing revenues.
Ecosystems	Natural fluctuations in water levels (over both the short- and long-term) are essential to maintaining habitat diversity and critical ecological functions in the Great Lakes. Coastal, protected and riverine wetlands, beaches and dune systems, tributary connections and their estuaries, islands, and other coastal margin environments are particularly sensitive to fluctuations in levels.
Coastal Zone	Highly sensitive to water level changes and can suffer the greatest individual losses during extreme water level events. Historically, the most serious impacts to riparian interests have occurred when water levels were extremely high, such as flood and erosion damage during storm activity. Low water levels also can negatively affect use of or access to property; e.g., low lying, gently sloping shorelines/bays/river mouths can become exposed.
Recreational Boating and Tourism	Can be adversely affected by both high and low water conditions; e.g., persistent low water levels can affect the quality of beaches in an area, as well as limit the use of some marinas and limit access to the lakes; high water levels can flood some boat launches.
First Nations in Canada and Native Americans represent an important perspective in the upper Great Lakes. Their concerns cut across the Domestic Water Users, Coastal Zone and, in particular, the Ecosystems interests.	

Figure 2.10: Depiction of how water level regimes may cause interests to go into different coping zones[53]



Water level regimes—including water levels, rate of change, and duration—may cause interests to shift into different coping zones. Water levels and coping zones in this example are not representative of any interest and are for illustrative purposes only. Image modified from Ferreira (2011).

and structures from storm-related flood and erosion damage, as well as bluff and beach erosion; loss of beach access as beaches are narrowed or eliminated; and the related socio-economic impacts. In areas where boats are the primary means of access to the water (such as rocky coastal environments in Georgian Bay, sheltered embayments, and drowned rivermouth areas like Saugatuck, Michigan), low water levels may result in more difficult and costly use of or access to property. In other areas, low water levels may provide a wider more attractive beach for recreation.[19]

The report further notes that there had not been an extended period of low water levels for nearly four decades preceding the recent lows; given that much of the current shoreline development occurred after the low water levels of the mid-1960s, many shoreline residents have not had previous experience with such conditions.[19]

Glacial isostatic rebound, discussed earlier, is also an important factor underlying variations in public perception of the impacts of high and low water levels across the basin. Given that northern areas will experience low water levels more prominently, property owners in those areas will generally view low water levels as problematic but not be as concerned about higher water levels. Conversely, property owners in southwestern areas where the shoreline is effectively sinking will experience enhanced flooding during high lake level phases.

Although the previous paragraphs focus on negative impacts, it is worth noting that water level changes in the opposite direction bring corresponding positive benefits. Moreover, coastal zone interests may also experience, directly or indirectly, the effects on other interests—whether related to water quality, the economy, infrastructure, ecosystems or recreation.

GREAT LAKES GOVERNANCE

The Great Lakes are shared among a multitude of public and non-governmental entities that comprise the region's complex governance system. These include binational institutions, U.S. and Canadian federal and state/provincial agencies, thousands of regional, county, and local entities which have some resource management responsibility, as well as myriad non-governmental organizations that contribute to management decisions.[55]

These governing bodies are themselves important users of the lakes. Some are directly charged with protecting and managing coastal resources. Their decisions affect land use development and practices, many own or manage land and infrastructure along the shore, and they are key players in implementing measures responding to lake level fluctuations. One of their key roles is provision of information about the lakes and human activities in the basin.[56]

While these entities direct action in the region, their efforts are often not coordinated, and can result in a patchwork of decision-making. It also means that actions in a given location often require consideration of variety of jurisdictions and authorities.

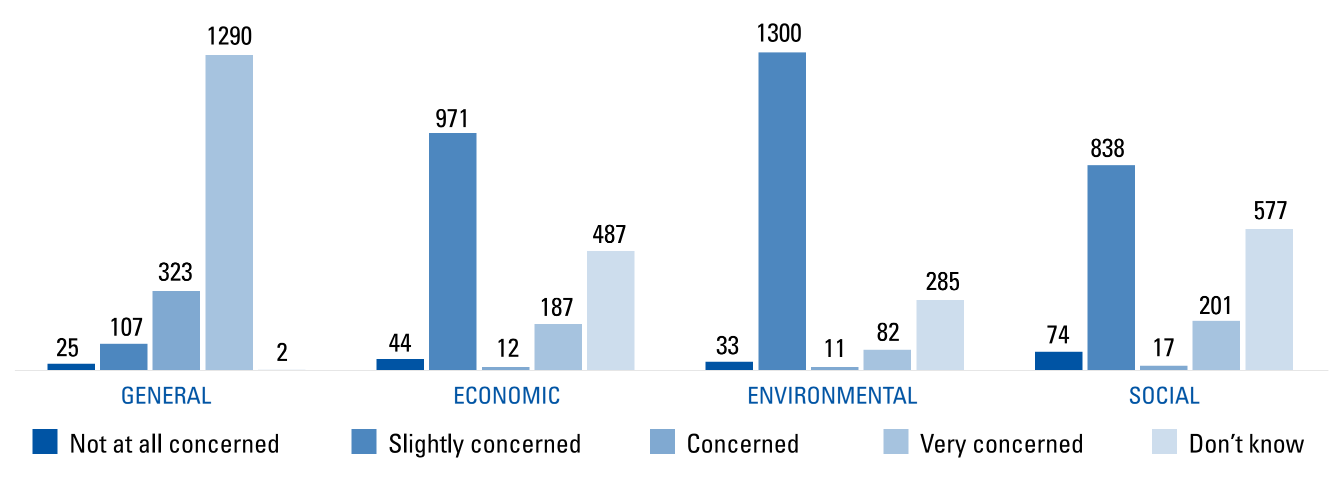
LIVING WITH HIGHS AND LOWS

Following this chapter's brief discussion of lake level variability and the basin's natural and human systems, it is worth emphasizing some key points that contributed to the development and implementation of this IA.

First and foremost, the Great Lakes are a complex and dynamic system, and a number of factors—environmental, geological, climatic, and human—contribute to water levels. Uncertainties regarding the exact contribution of various drivers of water level change make it challenging to predict future water levels, but lake levels will continue to fluctuate in the future, and both lower and higher levels must be considered.

BOX 2.3: SURVEY OF SHORELINE PROPERTY OWNER CONCERNS[54]

Figure 2.11: Property owner concern by type of concern related to water level



In 2014 the Graham Sustainability Institute conducted a non-representative survey of 1,815 Great Lakes property owners, managers, and other interested stakeholders primarily from the shores of Lakes Michigan and Huron. The following highlights some of the findings.

General Concerns

The results of the survey indicate that property owners and managers surveyed are highly concerned about water levels in the Great Lakes. Respondents indicated lower levels of concern for particular categories of problems associated with water levels, perhaps because they are concerned with different issues or perhaps because they do not conceptualize their concern based on particular categories; however, it is clear they are concerned, at least generally, about water levels.

Impacts Experienced

The survey also asked about the types of negative impacts experienced from water levels. 1307 respondents reported experiencing negative impacts related to low water levels, 662 respondents reported experiencing negative impacts due to high water levels, and 442 respondents reported experiencing negative impacts due to both high and low water levels.

Some key impacts that respondents have experienced include a decrease in recreational opportunities due to low water levels, an increase in operating expenses due to low water levels, a decrease in water quality due to low water levels, and property damage due to erosion. Although less often reported, respondents also indicated impacts to recreation and operating expenses from high water levels.

Qualitative responses to the survey also revealed that many respondents are concerned about environmental impacts, in particular those to fish habitat that can contribute to a decrease in recreational fishing opportunities.

Figure 2.12: Number of respondents who reported experiencing negative **high** water level impacts, by impact type

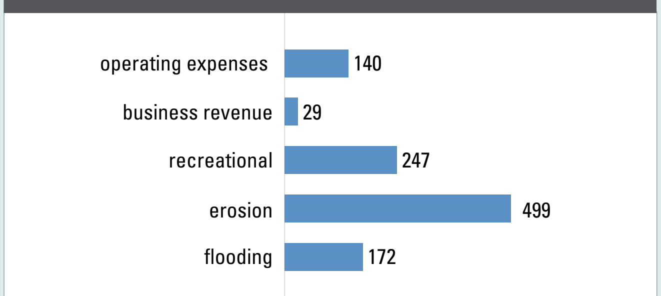
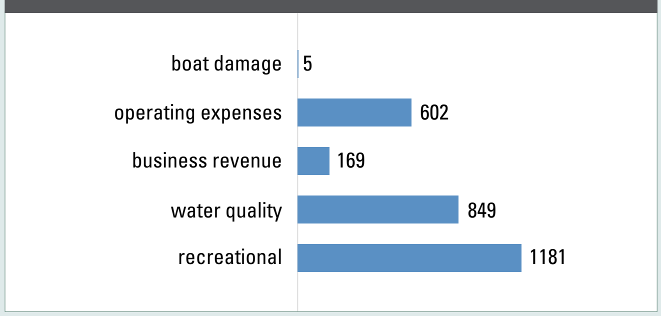


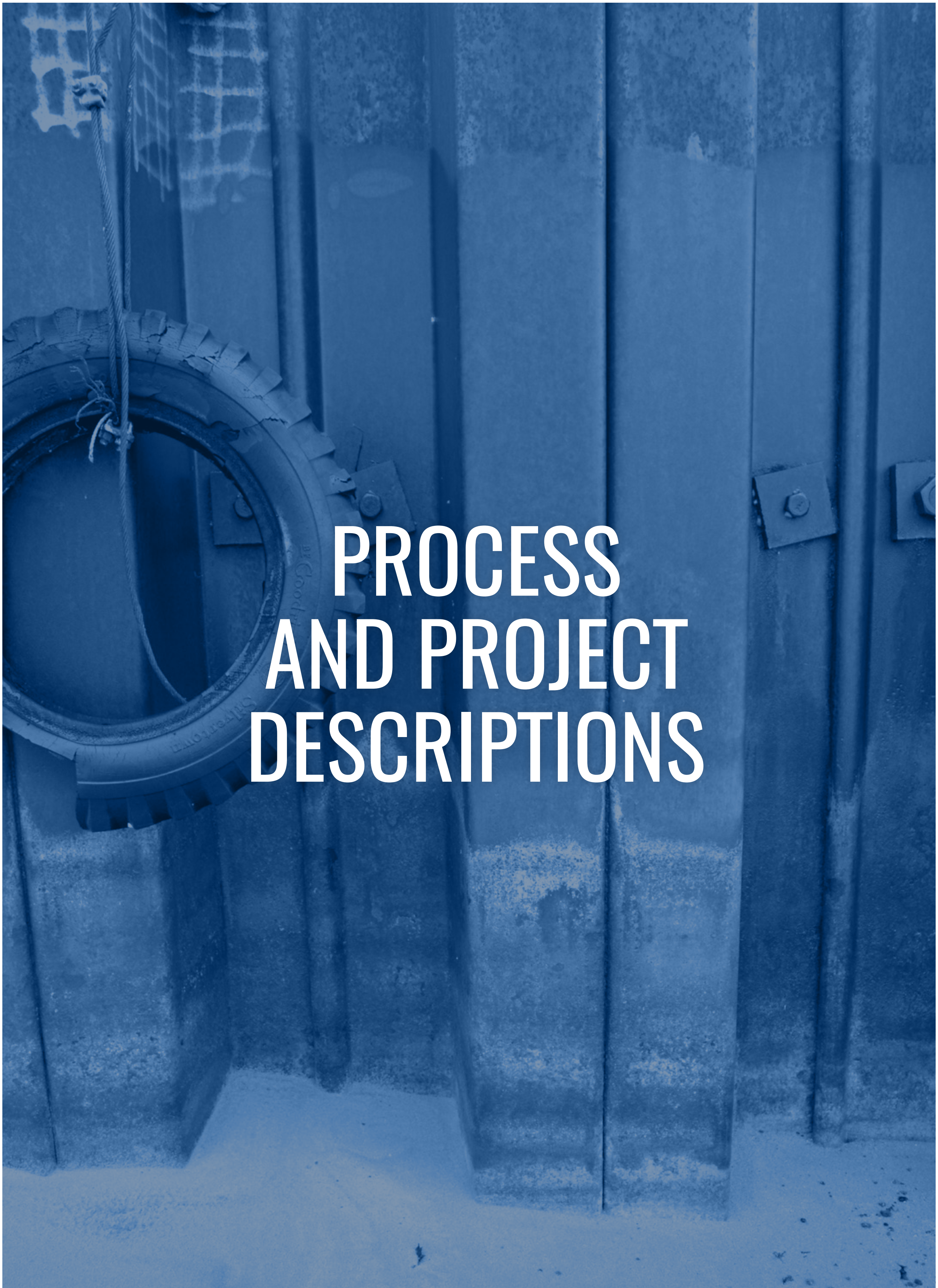
Figure 2.13: Number of respondents who reported experiencing negative **low** water level impacts, by impact type



High and low water levels, and changes in water levels, deliver both benefits and costs to different interests in the basin. While many interests in the region have demonstrated an ability to cope with water level fluctuations within a certain historical range,[19] there is a need to strengthen and expand those efforts, particularly given uncertainty regarding long-term changes associated with climate change. In doing so, shoreline communities will need to consider the challenges and opportunities posed by both high and low water levels.

Additionally, it is necessary to recognize the competing interests involved in lake level variability. At any given water level, there are some interests that may benefit and others that may suffer. Moreover, just as changes in water levels have different and sometimes opposite effects, so too do the potential measures for responding to those changes. Single strategies for responding to lake level changes are unlikely to address all of the issues or succeed in achieving all the objectives in a given location. Rather, adapting to current and future water level variability requires integrated solutions that recognize tradeoffs and conflicts—or potential synergies—and employ a combination of approaches.

Lastly, each shoreline locality has a unique combination of geology, shore types, land uses, interests, and jurisdictional considerations. As a result, the effects of changing water levels and the options available for adapting to them will vary. The next chapter introduces approaches for communities to use when identifying adaptive responses, including those used by the four place-based IA teams.



PROCESS AND PROJECT DESCRIPTIONS

CHAPTER 3

This chapter presents a brief overview of adaptation planning as a frame for understanding the work completed through the IA and thinking about potential efforts in other locations. The chapter also provides project descriptions for the four place-based IA teams in order to highlight the unique focus and approach each team utilized. This information also provides context for the discussion in Chapter 4 of options for responding to issues around variable water levels.

IA AND ADAPTATION PLANNING

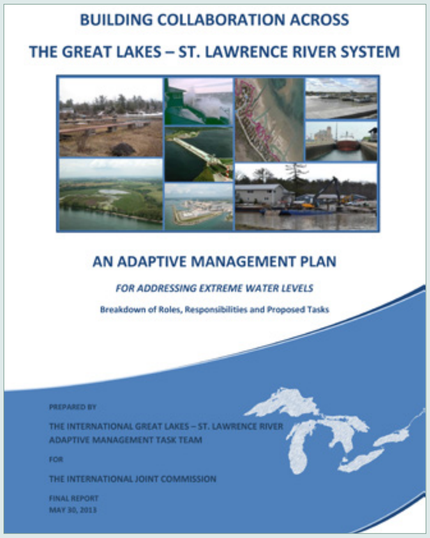
As communities and other groups around the region consider how to adapt to water level variability, both IA and adaptation planning provide possible frameworks. Adaptation planning is a multi-stakeholder process to ensure appropriate preparation for an uncertain future. Given that climate change is a major driver of uncertainty, many adaptation planning programs have been created to address climate change. These include the U.S. Global Change Research Program's Climate Resilience Toolkit,[57] U.S. EPA's Climate Change Adaptation plan,[58] and many other government and research publications.[59-63] Adaptation planning often blends process, impact, and response assessments to understand the needs of a community, and meet them in a collaborative way.[61]

The IA approach offers a collaborative process for identifying key information and

Table 3.1 Similarities in the IA and adaptation planning processes

GENERAL STEPS	IA	ADAPTATION PLANNING	
Source	Jensen Grace et al. 2016[60]	U.S. Climate Resilience Toolkit Steps to Resilience[57]	NOAA Adaptation Guide for State Coastal Managers[59]
Process and Issue Definition	Define the Issue and Identify Challenges	N/A	Establish the Planning Process
Issue, Risk and Vulnerability Assessment	Clarify the Issue (History, Causes and Consequences)	Explore Hazards Assess Vulnerability and Risks	Assess Vulnerability
Options Analysis	Identify and Evaluate Potential Solutions	Investigate Options	Create an Adaptation Strategy
Tool, Plan and Strategy Development	Develop Tools and Information to Guide Decisions	Prioritize and Plan	Execute Implementation and Maintenance Process
	Analysis of Strategies and Policy Options		
Implementation	N/A	Take Action	

BOX 3.1: ADAPTIVE MANAGEMENT



Adaptive management is not the same as adaptation.

Adaptive management is the iterative process for "learning while doing" and adjusting actions as necessary to address changing conditions.

Adaptation is the broader context of responses taken and actions implemented to address risk.

> - The International Great Lakes – St. Lawrence River Adaptive Management Task Team (2013)[41]

In its review of the water level regulation for the upper Great Lakes, the International Upper Great Lakes Study (IUGLS) Board recommended an adaptive management approach to water level issues.[19] Building on that recommendation, in 2013 a task team outlined a plan for adaptive management for Great Lakes variable water levels.[41]

The 2013 adaptive management plan "provides a new approach to addressing water level issues, one that is based on collaboratively working with partners across the Great Lakes-St. Lawrence system to gather and share critical information over time, assess the information with state-of-the art tools, develop adaptation strategies, measure success in managing the impacts of extreme water levels and adapt accordingly."[41] For communities considering adaptation, adaptive management offers a complementary framework for implementing and continually refining adaptation.

The plan recommends a series of regional or localized projects specifically designed to test the process, tools, and methods of adaptive management implementation. These so-called Adaptive Management Pilots would address pressing stakeholder-defined issues related to water level management and hydroclimate change, where past approaches have been less effective, and where a series of small successes can serve as examples for people outside the test regions to learn from and apply on larger scales.[41]

While not a formal part of the IA plan, this pilot approach and recommendation was suggested by several advisory committee members and other key stakeholders and has provided an important frame for the overall IA.

options. While an IA can have several goals, typically they are undertaken to:

1. build a multidisciplinary assessment of best available information,
2. inform policy, and
3. improve decision making. Its participatory process leads to relevant, balanced, and credible results and can effectively address the complexity of sustainability problems such as water level variability.[11]

There is no definitive guide for these processes. Guides may describe the same process slightly differently, and the processes themselves are flexible and can take on a variety of forms or approaches. However, both IA and adaptation planning share similar general steps as shown in Table 3.1. Before getting into the specifics of the four IA teams' approaches, the rest of this section describes the general steps in the context of water level variability.

With respect to water level variability, after the process, team, and focus are established, an important initial step in any planning or assessment effort is to catalog the relevant physical, ecological, and social characteristics of a locality, and then consider how each may be impacted—positively or negatively—by variable water levels. For example, this can include assessing the types of shoreline present, the extent and types of development, other possible resources (cultural, historical, economic), as well as the range of affected interests (see Chapter 2). There are different approaches to assessing potential impacts, but in general, it involves identifying what assets are exposed to harm, and assessing their vulnerability or risk under different scenarios. This process helps to identify where to focus subsequent efforts.

Participants then outline and evaluate various response options. Methods for evaluating and prioritizing options will vary depending on the specific issues and decision-makers' needs, but it is often necessary to evaluate options based on multiple criteria. Previous IJC efforts, for example, have evaluated measures based on their ability to meet stated objectives, as well as their economic impact, environmental impact, feasibility, and distribution of impacts.[6]

Based on the options analysis, next steps include developing tools to assist in decision making or a plan to move forward. As compared to other planning and assessment approaches, IA is distinct in that it provides information to support decision-making, but stops short of implementation. After an IA, or as the next steps of other planning and assessment approaches, states, localities, entities and individual citizens would then work to make these options a reality. Under an adaptive management approach (see Box 3.1), the process continues as the actions are monitored, assessed, and adjusted in an ongoing cycle.

PROJECT DESCRIPTIONS[ii]

The rest of this chapter provides a brief overview of each team's work with the dual goals of illustrating how the IA process was flexible to the needs of partners and specific conditions in a given area, and providing context for the more detailed discussion of options for responding to water level variability in the next chapter. Each of the four project summaries describes the participants, location, objectives, methodology, and key findings. More detailed descriptions of each of the four projects are available in the teams' Phase I and Phase II reports available on the project website (http://graham.umich.edu/emopps/water-levels).

Wisconsin Team

IA on Water Level Variability and Coastal Bluff Erosion in Northern Milwaukee County and Southern Ozaukee County, Wisconsin

PROJECT PARTICIPANTS

Principal Investigator

- David Hart, University of Wisconsin Sea Grant Institute

Other Investigators & Project Staff

- Adam Bechle, University of Wisconsin Sea Grant Institute
- Gene Clark, University of Wisconsin Sea Grant Institute
- John Janssen, University of Wisconsin-Milwaukee
- Jenny Kehl, University of Wisconsin-Milwaukee
- Ben Kranner, University of Wisconsin-Madison
- Jim LaGro, University of Wisconsin-Madison
- Andrew Mangham, University of Wisconsin-Madison
- Adam Mednick, Wisconsin Sea Grant Institute (now with Wisconsin Department of Natural Resources)
- David Mickelson, University of Wisconsin-Madison
- Julia Noordyk, University of Wisconsin Sea Grant Institute
- Brian Ohm, University of Wisconsin-Madison
- Deidre Peroff, University of Wisconsin Sea Grant Institute

Figure 3.1: Map of the Wisconsin project area[44]

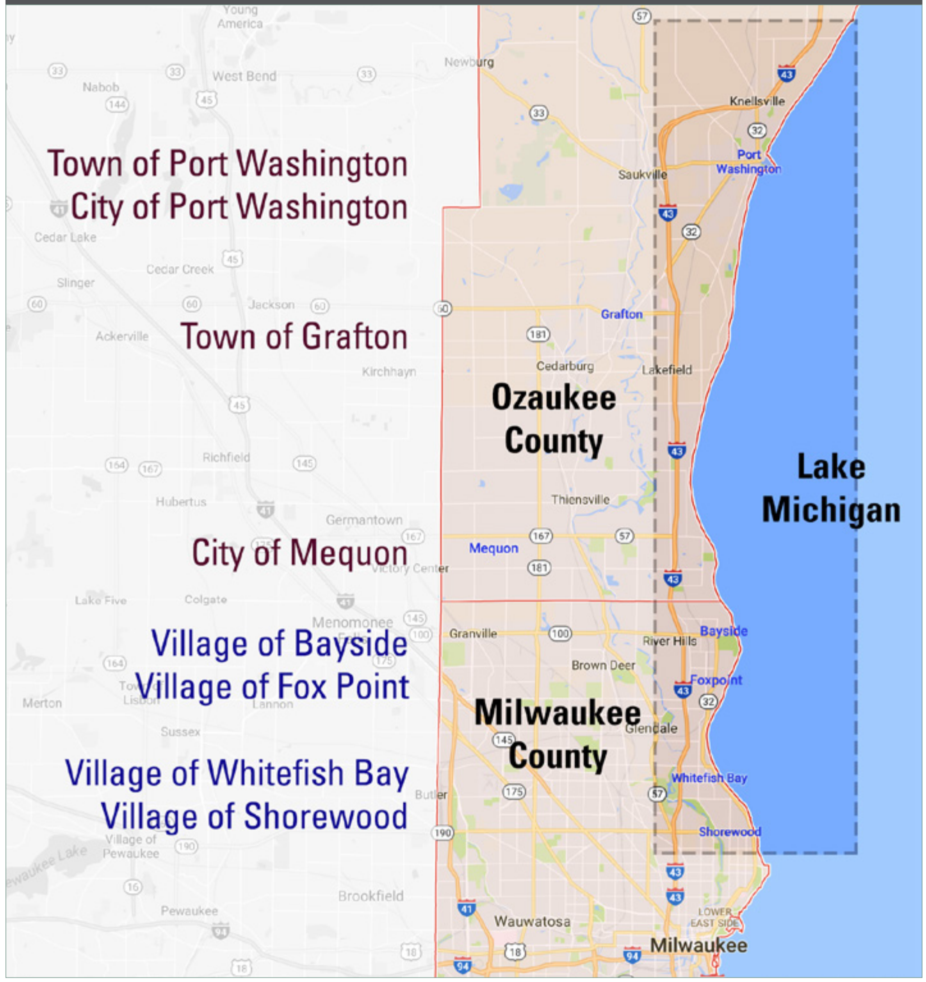


Figure 3.2: Photograph illustrating coastal bluffs within the Wisconsin project area[64]

The image shows both unarmored and armored shoreline.

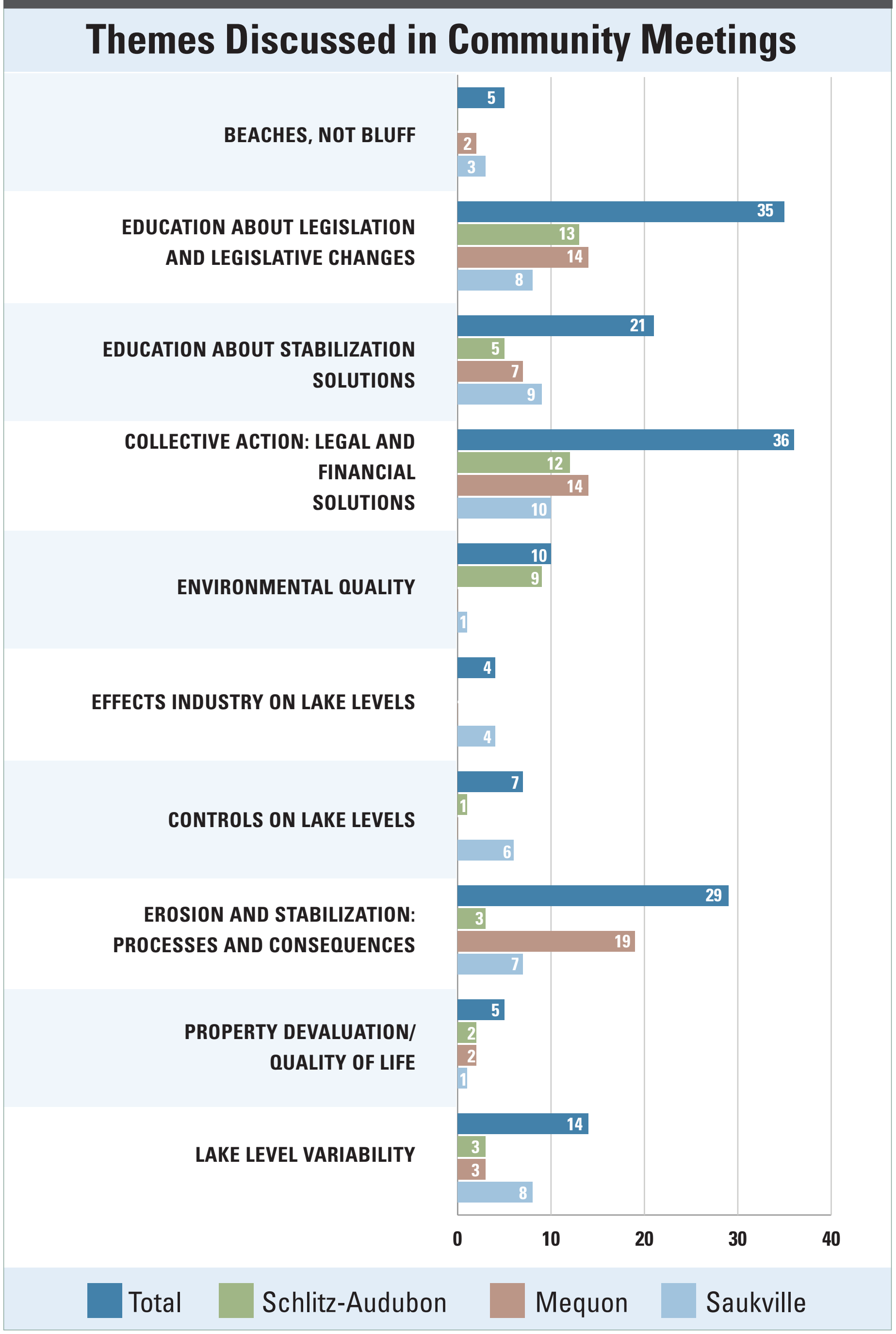
ii Based primarily on work completed during Phase II of the IA. Some individuals or organizations may have also contributed to earlier phases of work. For more information, see the IA project page and research team materials available at http://graham.umich.edu/emopps/water-levels.

- Bert and Linda Stitt, Stitt and Associates
- Chin Wu, University of Wisconsin-Madison

Primary Partners and Stakeholders

- City of Mequon
- City of Port Washington
- National Sea Grant Law Center
- Ozaukee County, Land and Water Management Department
- Ozaukee County, Planning & Parks Department
- Schlitz Audubon Nature Center
- Southeastern Wisconsin Regional Planning Commission
- Town of Grafton
- University of Wisconsin Sea Grant Institute
- Village of Bayside
- Village of Fox Point
- Village of Shorewood
- Village of Whitefish Bay
- Wisconsin Coastal Management Program, Coastal Hazards Work Group
- Wisconsin Department of Natural Resources
- Wisconsin Emergency Management

Figure 3.3: Themes that emerged from the Wisconsin community meetings by location[64]



Numbers refer to the number of times an issue came up in questions or comments at each meeting. The total category represents the sum of occurrences across meetings.

LOCATION AND CONTEXT

The project led by David Hart focused on eight communities north of Milwaukee, Wisconsin, in Milwaukee and Ozaukee Counties (see Figure 3.1). These communities have shorelines with bluffs ranging from 21 to 43 meters (70 to 140 feet) in height and prone to episodic erosion (see Figure 3.2). From 1976 to 2012, there was a trend towards more stable coastal bluffs in the study area, but new bluff failures continue to occur, and property owners and officials throughout the region were concerned about how the rapid rise in water levels beginning in 2013 would affect their beaches and bluffs.

Research by David Mickelson on the project team noted a substantial increase in armoring of shorelines across the region since the mid-1970s. While bluffs immediately behind single-property stabilization structures had higher factors of safety, single-property structures are typically designed and constructed with little planning for regional impacts, and the overall increase in armoring is leading to reduced regional sediment supply and increased likelihood of erosion and bluff collapse.[44]

Combined with these physical changes in the lake and shoreline, there have been legislative changes in Wisconsin that favor an increase in private property rights and affect planning and zoning, which are primary management tools for addressing development along the shoreline.[44]

OBJECTIVE

The project aimed to engage local stakeholders and broader partners to explore policy options and decision tools for increasing resilience to coastal bluff erosion in the face of possible increases in the variability of water levels. The desired outcome of this work is to support the adoption of a select set of policy alternatives by local governments and adaptive actions by coastal property owners leading to a measurable increase in the resilience of bluffs in the study area to coastal erosion.[65]

APPROACH

In scoping and conducting its work, the group took a highly engaged approach that included many opportunities for input from community members, and local, state, and regional officials. The team kept interested community members and partners updated through its project website, email updates, and social media.

During the initial work synthesizing existing data, the team gathered additional information from and shared resources with stakeholders, partners, and researchers through workshops, which helped to identify and prioritize the most relevant data and resources to support the project. Part of this work focused on the physical characteristics of the study area, including investigating the extent and impacts of shoreline armoring, as well as changes to the lake bed and relative stability of various bluffs.

They also conducted three community conversations to understand residents' hopes, wishes, concerns, and issues for a healthy and vital future for coastal bluffs and shores. Based on the themes that emerged from those meetings (see Figure 3.3), and additional interviews with partners, the team developed a list of potential response options. Community members had an opportunity to prioritize the options (see Figure 3.4), and that information was then shared with local and state officials. It is important to note that the work did not include a comparison of the measures' effectiveness; but rather, the process was designed to generate a full range of possible ideas and to gauge interest.

KEY TAKEAWAYS

The most important areas of concern that emerged from the community meetings were focused on ways to take collective action, and understanding of legislation, erosion processes, and the consequences of various stabilization efforts. The potential responses fell into three main categories: structural options that could be taken by the

Figure 3.5: Map of the Ontario project area[66]

Figure 3.4: Wisconsin IA participant review of options[64]

property owners; policies to be considered by local governments in the project area; and outreach and education activities that could be performed by the research and outreach organizations involved in the project.[65]

In general, there was very strong support for education, outreach and decision support tools. Policy options receiving strong support included collaboration among neighbors, updated bluff-top construction ordinances, easing approval for offshore structures and establishing a trigger mechanism for policy review when water levels or erosion rates exceed a threshold. Review of structural options showed that, "greening" of conventional gray infrastructure shore protection approaches was viewed most favorably.[65]

Ontario Team

Huron County IA of Extreme Water Levels

PROJECT PARTICIPANTS

Principal Investigator

- Lynne Peterson, Local Government and Integrated Policy Consultant

Other Investigators and Project Members

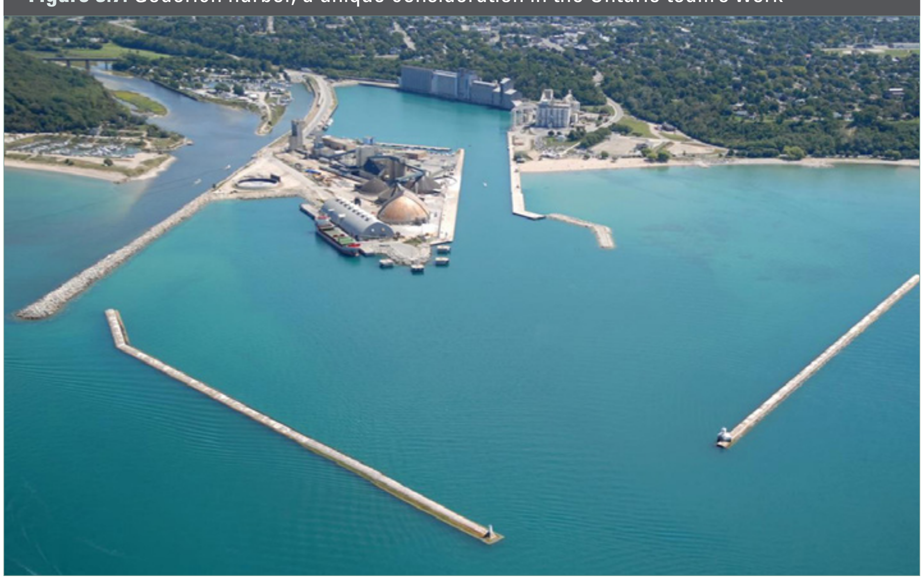
- George Ahronditsis, University of Toronto
- Meghan Allerton, University of Toronto
- Helen McRae, University of Toronto
- Kate Proctor, Land-use planning consultant and Huron County farmer
- Agnes Richards, Environment and Climate Change Canada
- Tanya Wanio, Municipal finance and land-use planning consultant

Primary Partners and Stakeholders

- Ashfield-Colborne Lakefront Association
- Ausable Bayfield Conservation Authority (ABCA)
- Bluewater Shoreline Residents' Association
- Huron County Planning and Development Department
- Huron County Water Protection Steering Committee (HCWPSC)
- Lake Huron Centre for Coastal Conservation (LHCCC)
- Maitland Valley Conservation Authority (MVCA)

Figure 3.6: Photograph from the Ontario project area[66]

Figure 3.7: Goderich harbor, a unique consideration in the Ontario team's work[66]



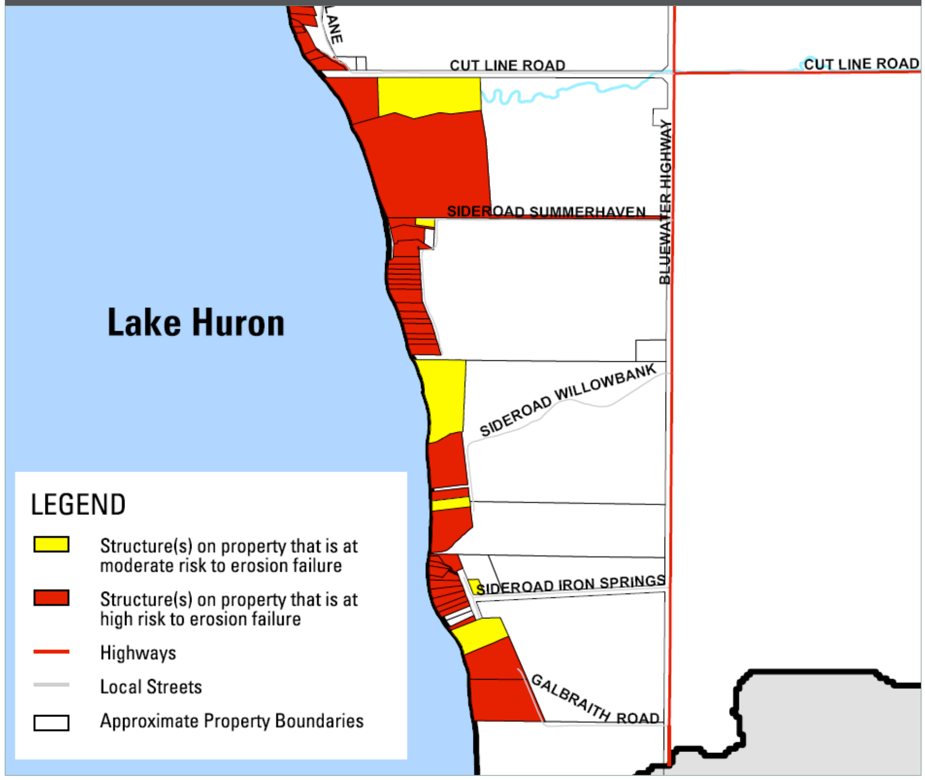
LOCATION & CONTEXT

The Ontario team, led by Lynne Peterson, focused on the Huron County, Ontario, Canada shoreline of Lake Huron, including the Town of Goderich and Village of Bayfield (see Figures 3.5 and 3.6). The county is primarily an agricultural area, but the shoreline includes dunes, beaches, bluffs, and harbors that make it important for tourism and commerce.

Whether at historical lows or more recent highs, water levels have significant, but mixed impacts on the area. The period of low water levels had benefitted tourism in the area, by increasing the size of various beaches. Yet low levels had also harmed shipping in the area, especially as Goderich is home to the world's largest salt mine and the only deep-water port on the eastern shore of Lake Huron (see Figure 3.7). Low lake levels increase the need for costly dredging and infrastructure adjustments by marina and harbor operators, and they reduce the profitability of Great Lakes shipping due to the need to reduce cargo weight per ship.

As water levels rebounded, marina operations, fishing, and Great Lakes shipping benefitted, but beaches have shrunk and bluff erosion is threatening cottage and other waterfront structures. Lining Huron County's 50 kilometers (30 miles) of steep bluffs are more than 750 residences in a natural hazard area subject to sudden slumps (see Figure 3.8).[67, 68]

Figure 3.8: Map illustrating the high proportion of properties facing erosion failure risks in a stretch of shoreline within the Ontario project area[66]



OBJECTIVES

The overall project objective was to develop a site-specific description of issues arising from both high and low water extremes, together with potential actions, policy options and adaptive strategies to prepare governments, environmental and conservation organizations, businesses, and residential stakeholders for living with variability.[67] Based on stakeholder input, the team worked to identify policy and management options for the following key topics:

- Enhancing public awareness and discussion of lake level issues.
- Complementing the activities of the local conservation authorities on shoreline management planning and natural hazard mapping updates.
- Complementing the activities of municipalities on emergency planning for hazard lands.
- Supporting the conservation and stewardship activities of the LHCCC
- Identifying local economic development opportunities and municipal infrastructure issues and challenges.
- Identifying potential federal and provincial legislation, funding programs and tools that could be useful to Huron County, its municipalities and conservation authorities for actions to adapt to high and low lake level impacts.[68]

APPROACH

The team began by meeting with existing conservation organizations in the area to assess their current understanding of, and approach to, variable water levels. In particular, the HCWPSC was a valuable partner throughout the process. It served as an advisory committee for the project, worked with the project team to connect them with a variety of regional stakeholders on water issues, and a special subcommittee reviewed the draft reports. A November 2015 presentation and a January 2016 workshop with the HCWPSC provided opportunities for the team to share background research and to learn what government-sponsored organizations and citizen groups were most concerned about and interested in regarding water levels.[34] The background research and findings were also shared through public presentations at lakefront and residents associations meetings, and conservation authority (CA) meetings. Together these workshops, presentations, and additional discussions with key stakeholders guided the team as they developed a series of policy and adaptive management proposals for understanding and dealing with the effects of high and low extreme water levels.

KEY TAKEAWAYS

The project team ultimately recommended 20 policy and adaptive management actions that could be taken by governments, non-profit conservation organizations, residents' associations, businesses and property owners. These options fell into six categories including:

- Address the combined effects of climate change and high and low lake levels by pursuing federal and provincial opportunities and funding related to climate change, and Great Lakes protection
- Build on Ontario's strong policy framework including CA hazard mapping and regulations, and planning tools under the Planning Act
- Enhance emergency preparedness
- Engage/inform shoreline property owners of natural hazard designations
- Capitalize on local economic development opportunities
- Promote increased conservation and stewardship capacity by prioritizing and coordinating efforts[68]

Throughout the process, the Ontario project benefitted from its connection with existing decision-making groups and timing that coincided with other initiatives. For instance, the HCWPSC includes diverse stakeholder representatives, thereby facilitating the team's efforts to address a broad array of interests and ensuring the options were actionable. Additionally, other initiatives—such as the ABCA's updates to its shoreline management plan, MVCA's development of a public education strategy, and Goderich's development of a Waterfront Master Plan—provided additional opportunities and traction for the team's efforts.

Figure 3.9: Map of the Southern Michigan project area[69]

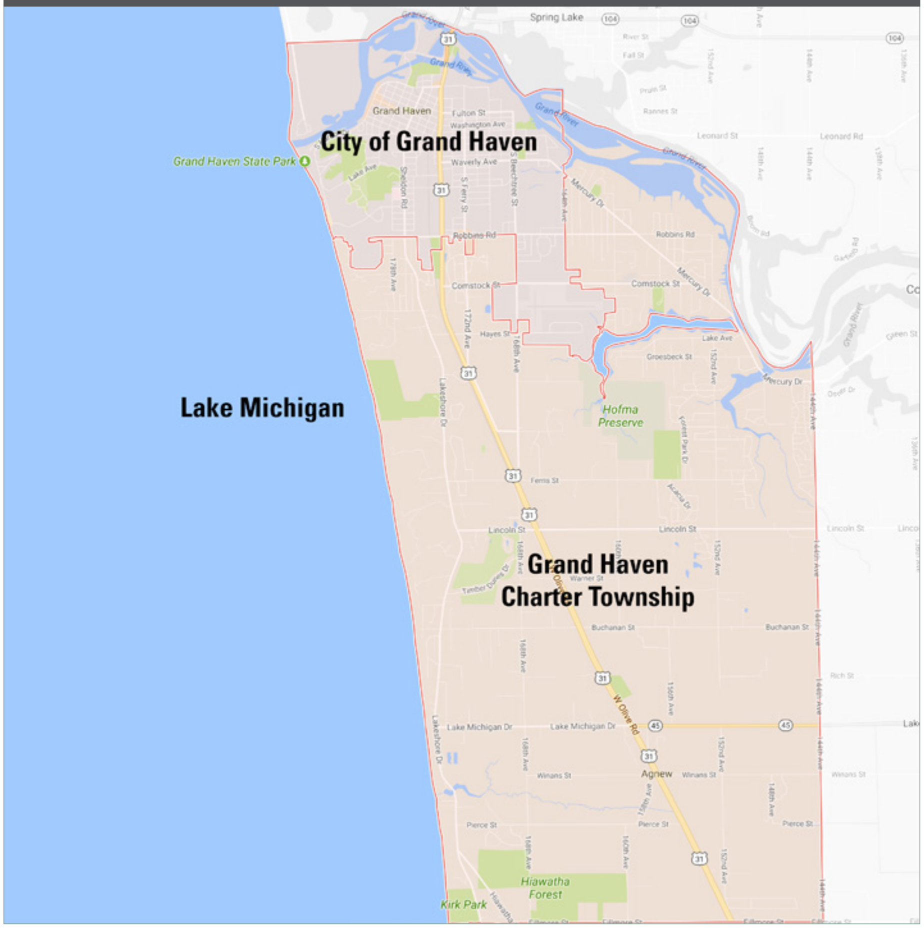


Figure 3.10: Photograph of residential development along the shoreline in the City of Grand Haven, Michigan[70]

Southern Michigan Team

Implementing Adaptation - Developing Land Use Regulations and Infrastructure Policies to Implement Great Lakes Shoreland Area Management Plans

PROJECT PARTICIPANTS

Principal Investigator

- Richard Norton, University of Michigan

Other Investigators

- Harry Burkholder, LIAA
- Guy Meadows, Michigan Technical University
- Zachary Rable, University of Michigan
- Katie Sieb, LIAA

Primary Partners and Stakeholders

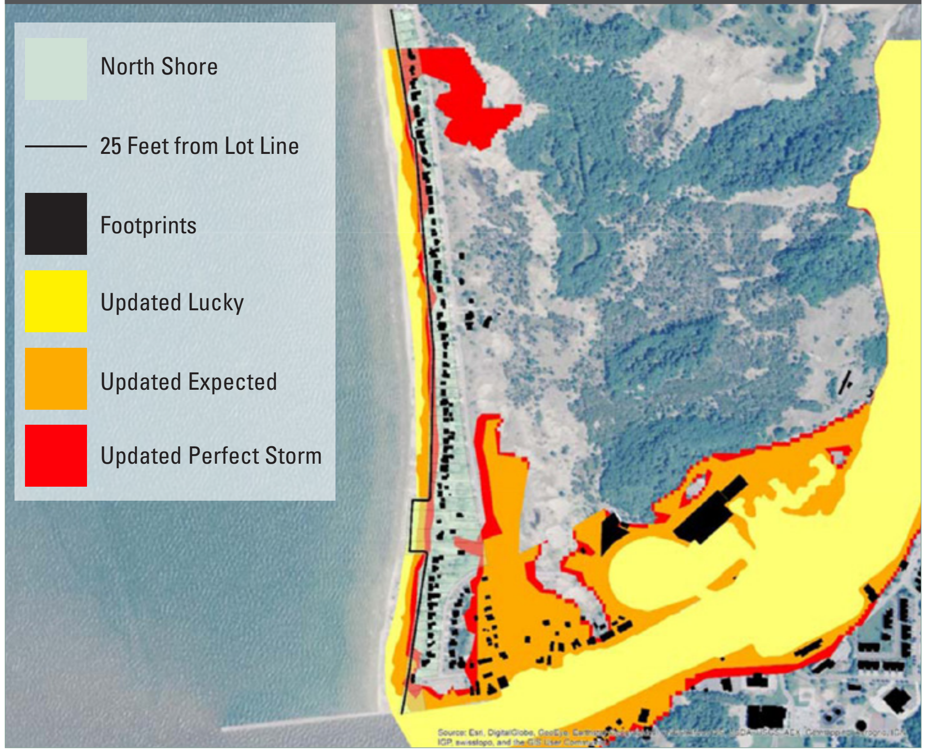
- City of Grand Haven
- Grand Haven Charter Township
- Michigan Planning Association

LOCATION AND CONTEXT

Dick Norton, from the University of Michigan, led a project working with the City of Grand Haven and Grand Haven Charter Township, which are located in the southern portion of Michigan along the shores of Lake Michigan (see Figures 3.9 and 3.10). The issues the communities face are common throughout the Great Lakes—environmental issues related to beach erosion, dunes, and wetlands, and social and economic impacts related to damage and loss of residential and commercial development and public infrastructure.[69]

While the City of Grand Haven and Grand Haven Charter Township share many of the same benefits and potential burdens of the natural resources that accompany their location, they look and operate differently from a management perspective. The City of Grand Haven is much smaller and more urban than the Township, and as a result is almost fully developed, while Grand Haven Township is rapidly growing and still retains large areas that are not yet developed. As a consequence of these and other differences (political climate, hierarchy of goals), the concerns of and options available to each community vary despite their sharing very similar ecological environments.[71]

Figure 3.11: Existing development in the City of Grand Haven is potentially subject to coastal hazards predicted under different climate futures[71]



Note: The yellow, orange, and red shading show the potential extent of coastal hazards (flooding and high-energy wave run-up) for three different climate futures referred to as "Lucky," "Expected," and "Perfect Storm."

OBJECTIVES

Building on previous work with the communities that incorporated coastal concerns into their master plans, this project aimed to take the next step and develop methods for implementing local master plans or shoreland area management plans through regulation and infrastructure policy.[71]

APPROACH

Prior to the IA, in 2013 – 2015, the team worked with these and other communities to incorporate information regarding Great Lakes shoreline dynamics into their local master plans and shoreland area management plans in a project funded by the University of Michigan Water Center and the Michigan Department of Environmental Quality Coastal Zone Management Program.[69] That work began with the creation of various "climate futures"—that is, different combinations of Lake Michigan standing water levels and storminess—and used GIS mapping to identify areas potentially subject to coastal hazards under each. Climate futures were then combined with different options for managing future development within those high-hazard shoreland areas, yielding decision-centered planning scenarios (i.e., combinations of climate futures and management options) for local officials and residents to consider.[69] See Figure 3.11 for an example of this analysis for the City of Grand Haven.

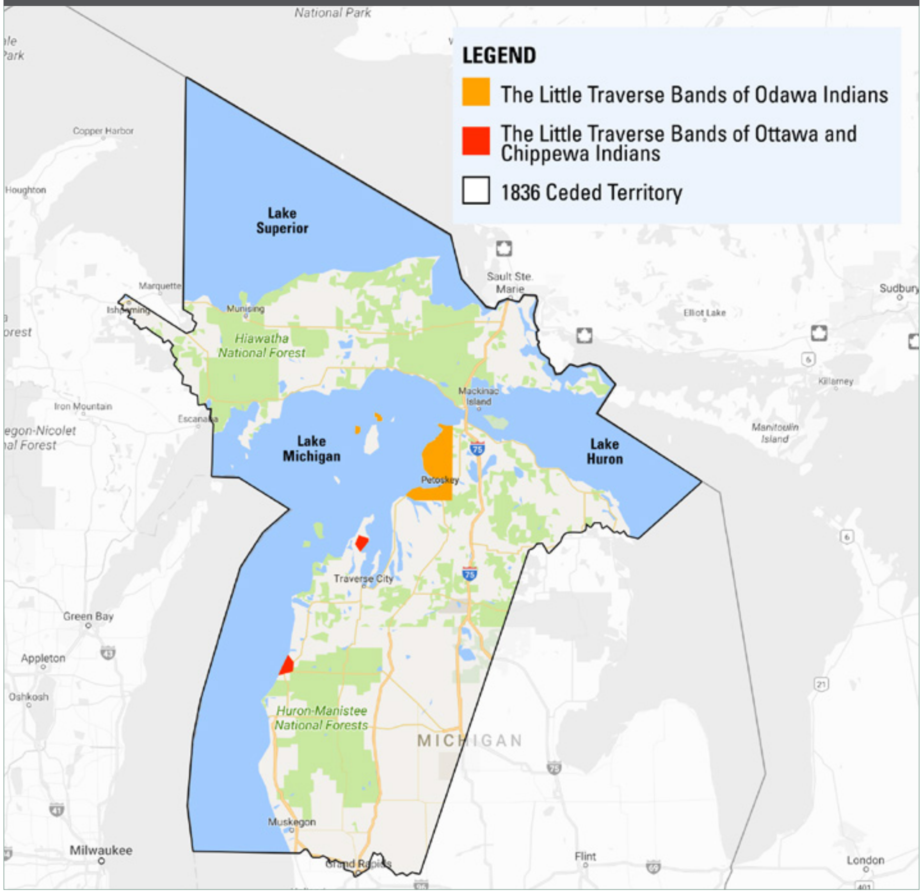
While this previous work helped the communities include coastal issues in their land use planning, this IA sought to assist them in identifying options for actually implementing those plans. To do so, the team held meetings with planning staff, planning commissions, and other stakeholders from both communities to identify coastal assets and challenges, understand each community's unique concerns, and identify potential adaptive opportunities. Options identified by the community stakeholders and the team were then evaluated for political viability, potential benefits, potential disadvantages, and potential governmental cost, and then further refined through feedback from the planning commissions. Final ranges of policy options of increasing intensity were developed for each municipality to consider.[72, 73]

KEY TAKEAWAYS

Based on feedback provided by the communities, the team focused on developing policies for both the city and township to address more protective land management in high risk flood areas, improved stormwater management, and more protective management of development within shoreline coastal hazard zones, as well as modified land management options for the sake of addressing fire hazards within state-designated Critical Dune Areas in the township.[71] For each of these policy areas, the team identified and evaluated a range of options that each community might adopt, including most notably the adoption of low impact development regulations, policies, and programs for stormwater management; the establishment of setbacks and corresponding development regulations and policies within high risk coastal zones; and the development of land management and service delivery policies and regulations within Critical Dune Areas to better address wildfire and structural fire hazards within dune settings that are especially inaccessible and/or at high risk.

An important aspect of the team's approach was the way it considered issues that are not clearly or strictly related to coastal area management, but that would affect the shoreline and that local citizens and officials believe should be addressed concurrently as part of a larger regulatory reform effort. On the community site, local political interest and capacity were also essential to ensure that the work was desired by, and helpful to, each community.[71]

Figure 3.12: Map of the Northern Michigan project area[74]



Treaty of 1836
Indigenous Nations ceded lands from which the State of Michigan was established, while retaining hunting, fishing and gathering rights

Treaty of 1855
U.S. acquired much of the remainder of what is now the State of Michigan. Indigenous Nations were provided with reserved land.

Northern Michigan Team

Inclusion of Climate-Change Effects on Lake Levels in Management Plans of Tribal Fisheries

PROJECT PARTICIPANTS

Principal Investigator

- Frank Marsik, University of Michigan

Other Investigators

- Barbara Doyle, University of Michigan
- Ellie Masters, Oberlin College
- Richard Rood, University of Michigan
- Kyle Whyte, Michigan State University

Primary Partners and Stakeholders

- Grand Traverse Band of Ottawa and Chippewa Indians (GTB)
- Little Traverse Bay Bands of Odawa Indians (LTBB)

LOCATION AND CONTEXT

The team focused on the priorities and preferences of their partners, the LTBB and GTB, regarding shoreline management, fisheries, and cultural resources. Both tribes have reservation lands in the northwestern portion of Michigan's Lower Peninsula (Figure 3.12). Although each tribe actually owns limited territory along Lake Michigan (called Trust Lands), nearby lands and waters have cultural and fishing significance to the tribes, including protected hunting, fishing, and gathering rights, and they have the potential to be affected significantly by changes in climate and lake levels.

For instance, Tribal fishing activities are regulated under the 2000 Federal Consent Decree, which details how fishing in the 1836 Treaty waters will be allocated, managed and regulated through 2020 (Figure 3.13). The next agreement will dictate how fishing in the 1836 waters will be regulated for the following 20 years, a period which is expected to experience potentially significant climatic changes that can impact lake levels and coastal wetland ecosystems and thus the number, species diversity and distribution of fish species. Other key topics of concern include potential impact of climate change and lake levels on the economic and cultural assets of each community, as well as the sovereignty and jurisdiction of Tribal governments.[26]

OBJECTIVES

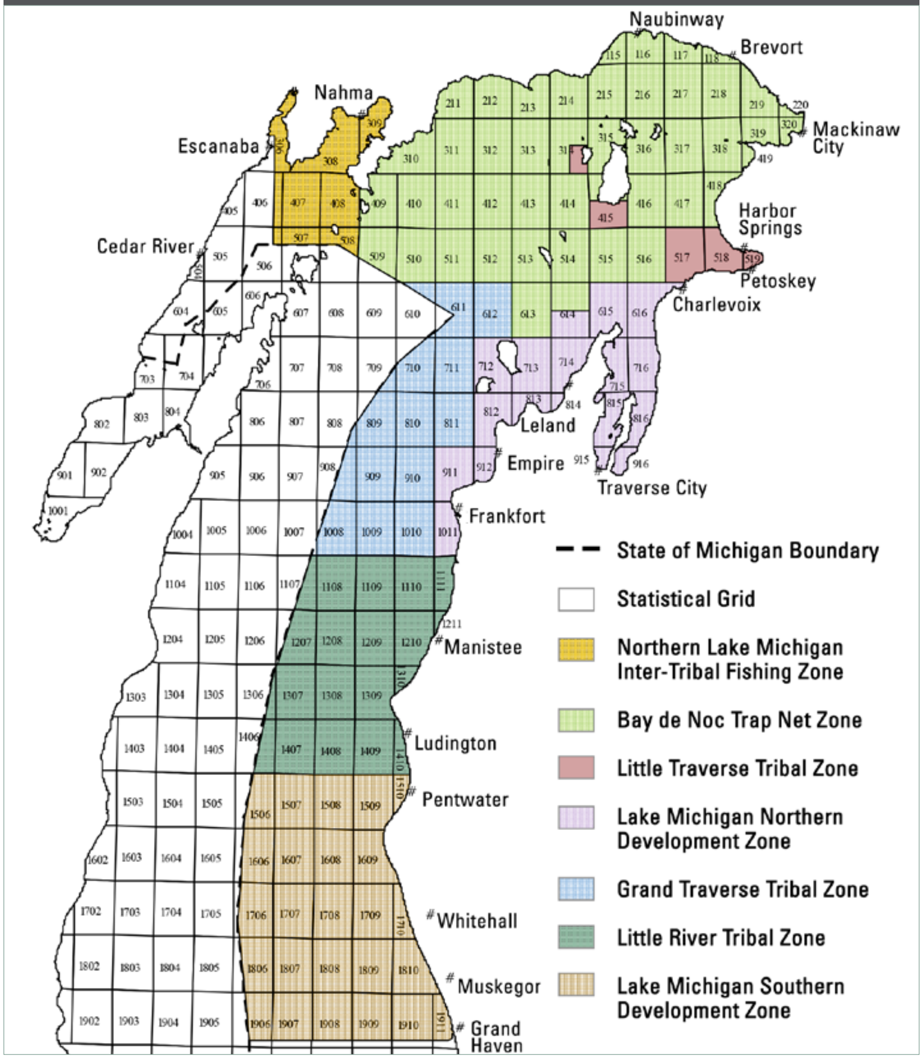
The project sought to identify climate-driven lake level futures for the Lake Michigan-Huron system and then assess the potential impact of these plausible futures on the vulnerabilities of Tribal communities, their fisheries and their Tribal governance.[74]

APPROACH

The team began by meeting with LTBB and GTB tribes and developing a collaborative work plan outlining a process for sharing of information, collaborative analysis and decision making, and community education.[77] As part of that, the team also developed working relationships with an individual in each tribe, with whom they could share initial findings, and from whom they could receive initial ideas and feedback.

The team's initial work consisted of exploring methods for developing plausible climate futures and likely lake levels, and understanding the impacts of lake level variability that tribes have experienced. Through this process, the team discovered some specific issues that concerned the tribe: how low water levels affected their ability to use traditional fishing sites and exposed cultural artifacts; how low water levels and reduced winter ice cover could negatively affect fish habitat and populations; and how changing water levels could impact the role of women, who the LTBB consider to be

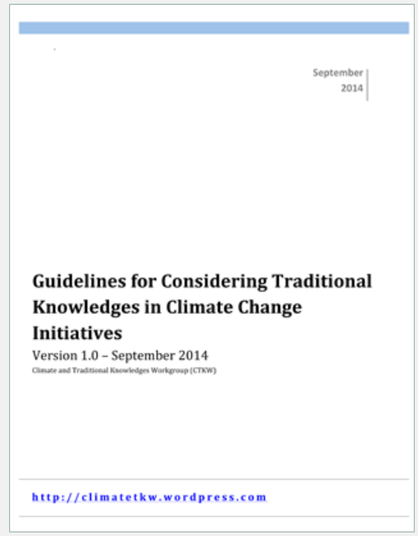
Figure 3.13: 2000 Consent Decree Tribal commercial fishing zones[75]



2000 Consent Decree

Federal court order that represents a negotiated agreement between the U.S., the State of Michigan, and five Native American Tribes, which details how fishing in the 1836 Treaty waters will be allocated, managed, and regulated through 2020.

KEY RESOURCE


September 2014

Guidelines for Considering Traditional Knowledges in Climate Change Initiatives

Version 1.0 – September 2014

Climate and Traditional Knowledges Workgroup (CTKW)

http://climatetkw.wordpress.com

Guidelines for Considering Traditional Knowledges in Climate Change Initiatives Climate and Traditional Knowledges Workgroup (2014)[76]

https://climatetkw.wordpress.com

This is an informational resource for tribes, agencies, and organizations across the U.S. interested in understanding Traditional Knowledge in the context of climate change. This document guided the work plans developed between the Northern Michigan team and its Tribal partners.

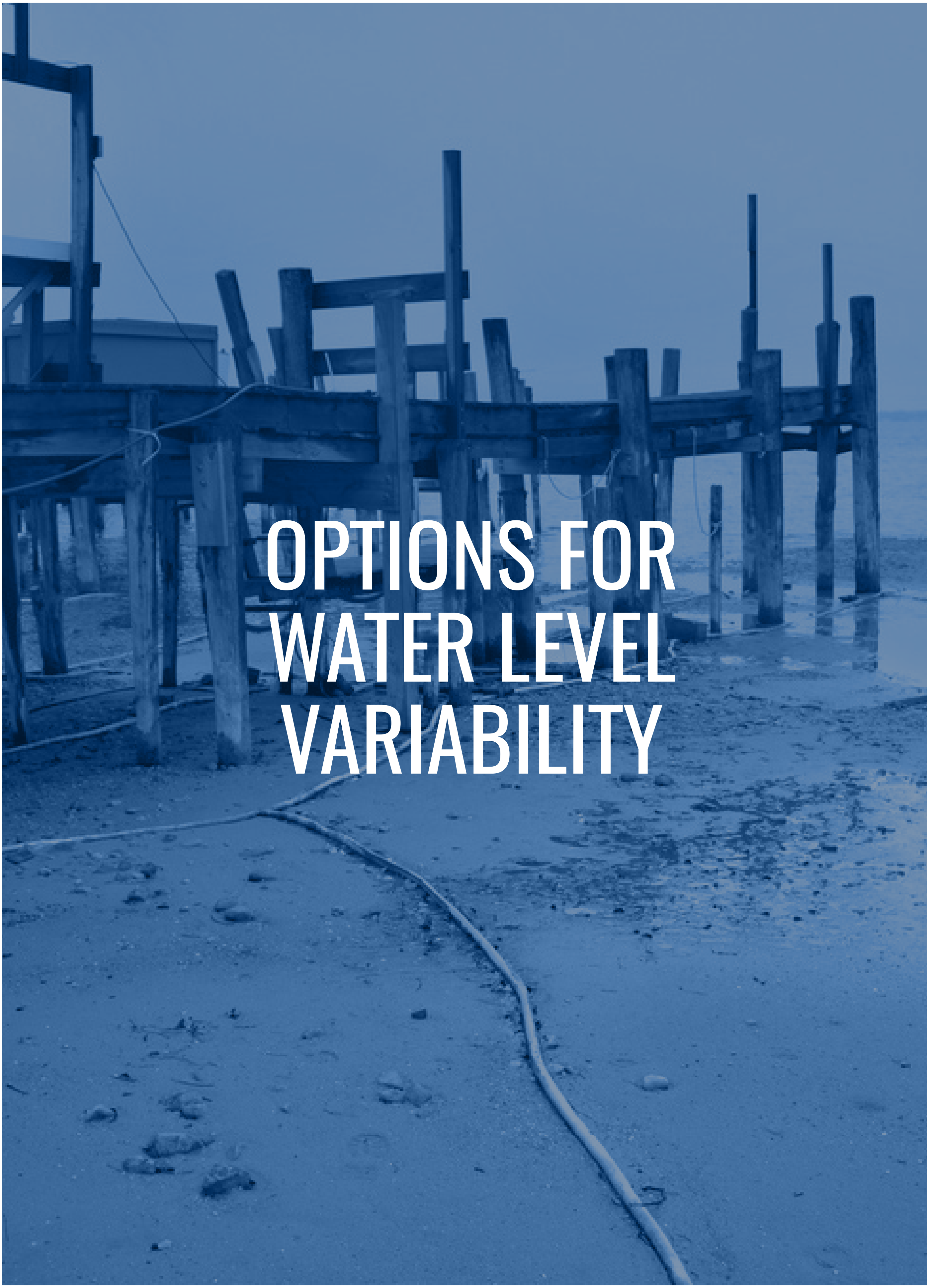
caretakers of water. For plausible futures, the team considered scenarios with both prolonged high water and low water, the latter of which was supported by the team's work investigating the relationship between the areal extent of the polar cold pool and Great Lakes water levels.[74]

The team then shared their findings with more members of each tribe, and sought their feedback on how best to turn these findings into useful recommendations based on the tribes' individual needs. The tribes expressed a desire for self-sufficient and sustainable solutions to variable water levels. Therefore, the team's "climate change adaptation strategies [and] community education and engagement activities" emphasized how the communities might protect important resources now and prepare for future variability.[74]

KEY TAKEAWAYS

An exciting element of this collaborative effort was that it provided a unique opportunity to address this topic with a blend of "western science" and "Indigenous science" approaches. Traditional Indigenous approaches to understanding natural science involve the observation of nature and the relations of elements of the natural system with other elements within the system, as opposed to the more linear measurement and theoretical approaches often applied as part of "western science."

Options that the team has discussed with Tribal partners include approaches to mitigate impacts on fisheries through direct stocking; to protect fish habitat and cultural resources through public input on wetland impact permits, outreach and education, and conservation easements; and to plan infrastructure using various decision-support tools. The team continues to work with their partners on an analysis of options and determination of preferred options.[74]



OPTIONS FOR WATER LEVEL VARIABILITY

CHAPTER 4

There exists a wide array of options that communities and shoreline property owners can implement in order to adapt to current and future variability in Great Lakes water levels. Many of these options are not new. Going back decades the IJC and others have completed extensive studies identifying and assessing options around Great Lakes water level fluctuations. One key challenge, as those studies noted, is identifying and tailoring the suite of options according to unique local conditions and interests.

As described briefly in the last chapter, during Phase II of the IA, the four place-based research teams proposed and assessed a variety of options and strategies for their partner communities to consider. To support other communities and interest groups in thinking through ways to approach variable water levels, this chapter organizes and explores the options the teams considered during their Phase II work.

The options are grouped into four broad categories that include the most common options among the teams:

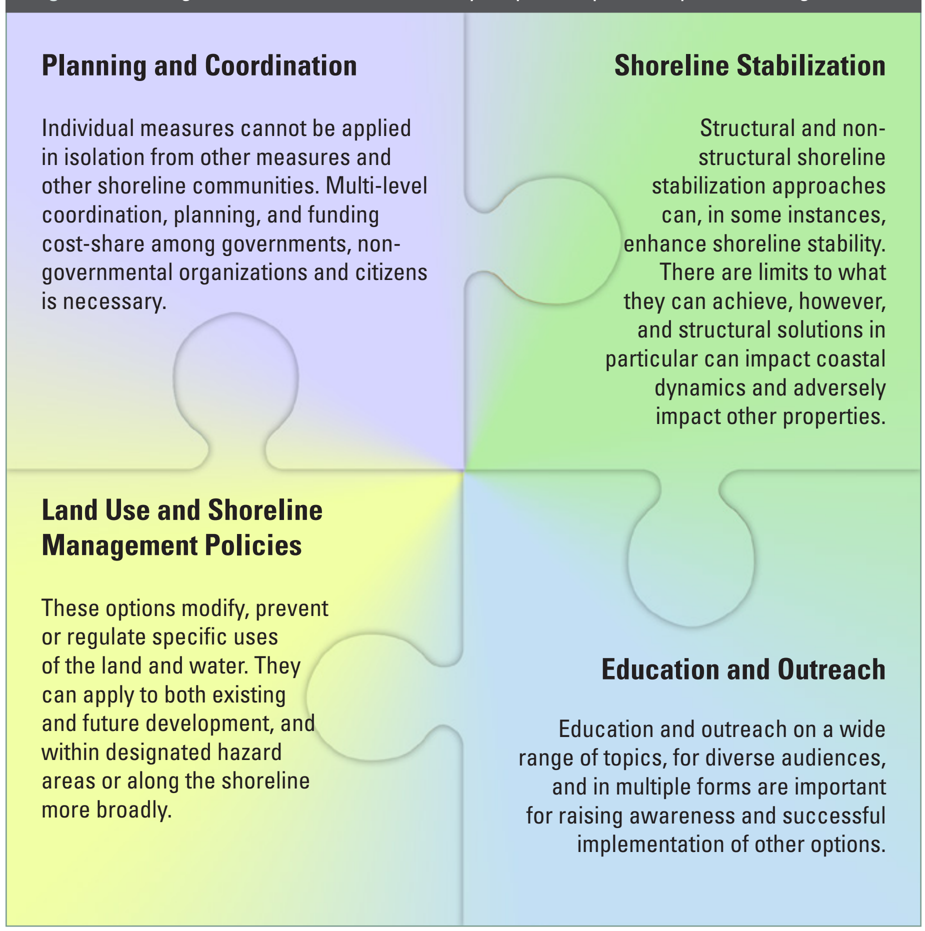
- **Planning and Coordination**
- **Shoreline Stabilization**
- **Land Use and Shoreline Management Policies**
- **Education and Outreach**

For each general option (**shown in slightly bolded text**), descriptions and considerations are provided along with select detailed examples of these options as analyzed by the research groups. Some options considered by the teams do not fall within these categories, and select examples are included in boxes throughout the chapter.

This chapter does not seek to duplicate previous reports that comprehensively enumerate potential options; admittedly, the options explored here are a reflection of the issues and approaches considered by the place-based teams. The chapter also does not provide detailed technical guidance or effectiveness analyses of the options. Rather, it aims to organize examples from the Phase II place-based work to illustrate what select options might look like and highlight some of the associated challenges or opportunities to be considered. For a full list of the options generated during Phase II refer to Appendix A.

Lastly, this IA recognizes that no single measure will be sufficient. Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political

Figure 4.1: Categories of water level variability response options explored through the IA



Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political and legal factors. The categories of response options here are often interrelated, and they do not represent a comprehensive list of options. Rather, they represent the most common options identified by the place-based teams during Phase II of the IA.

and legal factors. In addition, even these suites of options cannot completely eliminate potential negative impacts of water level fluctuations. They do, however, have the potential to address specific issues and to assist communities and interests in adapting to and living with variability.

PLANNING AND COORDINATION

Planning and coordination are critical to any land use and shoreline management approaches. In the 1993 Levels Reference Study the IJC emphasized that "individual measures cannot be applied in isolation from other measures and other shoreline communities; nor can they be applied without consideration for local situations." They called for multi-level government coordination, planning, and funding cost-share, while at the same time acknowledging that the complex governance system poses challenges to "concerted and coherent collaboration."[6]

The Adaptive Management Plan for the IJC reiterated that "no one agency manages the issues associated with water level impacts and therefore a more intensive level of collaboration is needed than has been seen to date on the issue."[41] Not surprisingly, coordination emerged as an important theme for all four IA teams. Given the place-based nature of the projects, many of the options for coordination that the teams explored are focused more locally, addressing opportunities among and within jurisdictions, and among different organizations and individuals.

Coordinating Among Jurisdictions

Multiple IA teams identified opportunities to align and coordinate policies among adjacent jurisdictions. In Canada conservation authorities provide hazard land mapping to provincial policy standards, and they monitor and forecast potential riverine and lake effect flood events. They ensure that proposed development or site alteration does not affect flood control, erosion, pollution, or conservation of land. CA jurisdiction for Huron County's Lake Huron shoreline is split between the ABCA and the MVCA.[68] The ABCA is currently in the process of updating its Shoreline Management Plan, which aims to develop and support solutions to current and future issues and problems along the shoreline including hazards for flooding, erosion, and dynamic beaches and their impact on shoreline development.[78] The Ontario team noted that the ABCA's draft report includes updated mapping of hazard land areas as well as recession rates along the ABCA jurisdiction shoreline that will greatly improve local shoreline property owners' ability to assess their individual property erosion risks. However, the team further noted that as the ABCA updates its natural hazard mapping and policies, discrepancies between it and the MVCA will become greater. This means that similar bluff property situations under the jurisdiction of one CA will be treated differently, and have more or fewer up-to-date information resources, than the same situation across the CA jurisdiction line. The Ontario team recommended that the ABCA and MVCA work to **harmonize their mapping and policies** to ensure consistent information for property owners along the 50 kilometer (31 mile) stretch of bluff.[68]

At the local level, the Wisconsin team explored an option for **coordination of consistent ordinances among Lake Michigan shoreline municipalities** within the project area. Benefits would include more consistent rules and an opportunity to review and revise existing ordinances; however, the team also noted that impacts to the power of individual municipalities, changes to the stringency of regulations in any specific municipality, and concerns that a one-size-fits-all approach may ignore local needs pose challenges to coordination.[65]

In contrast to formal coordination between entities, the teams also explored a number of opportunities to **use model ordinances to inform local actions.** For instance, to address bluff stability, the Ontario team recommended that municipalities in the Huron County project area consider passing a Shoreline Tree Protection Bylaw, as done by the nearby Township of Ashfield-Colborne-Wawanosh to prohibit or regulate the destruction or injuring of living trees along and near the Lake Huron shoreline.[68] In the Wisconsin community workshops, residents expressed an interest in model bluff and ravine ordinances with consistent terminology and definitions across jurisdictions.[65] The southwest Michigan team drew heavily on model ordinances, using them and other best management practices as guides to produce ranges of potential adaptive zoning options for their community partners to consider.[71]

The teams also addressed the need for **coordination across multiple levels of government**. The Ontario team, for instance, explicitly identified which options would require coordination among local, provincial, and federal agencies and which could be implemented entirely by one authority.

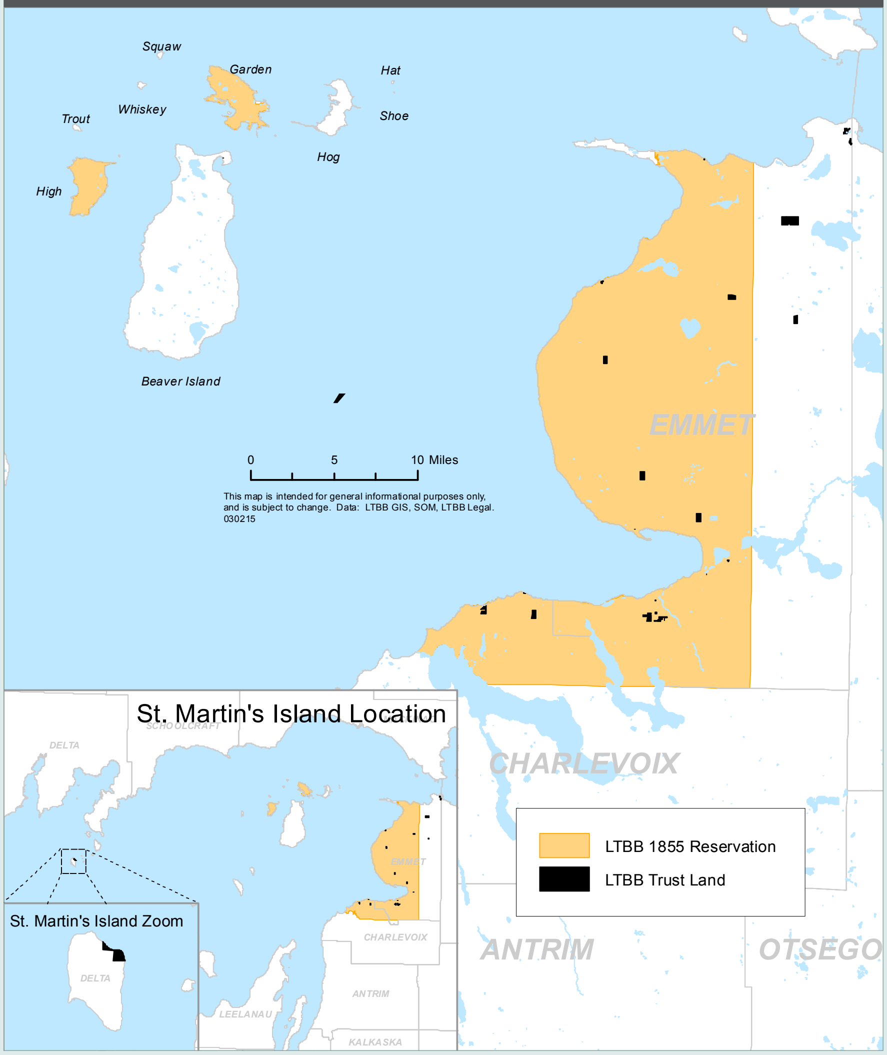
The Northern Michigan team's work with the LTBB and GTB provides an important additional perspective. Policy considerations for indigenous peoples involve more than the coordination of federal, state, and local governments, but also **consideration of the autonomy of indigenous tribes as sovereign nations and the manner in which these indigenous tribes interact with federal, state and local governments**.[77] Though the Treaty of 1855 established reservation lands for each of the three collaborating Tribes, in reality, the Tribes actually own very little of the land that falls within the reservation boundaries. The lands owned by the Tribes, called Trust Lands, are the only land areas for which the Tribes can establish legally binding regulatory policies (see Box 4.1). The reservation lands that are not Trust Lands fall under the jurisdiction of the State of Michigan. In the past, the Indigenous Tribes have not always been included in the deliberations regarding possible natural resources and/or other regulatory actions imposed by the State and Federal governments. Moreover, many of the Tribes' natural and cultural resources exist beyond their reservation boundaries. These include spawning and nursery habitat for fisheries the Tribes rely on, as well as ancient Tribal burial grounds and artifacts.[74]

BOX 4.1: TRUST LANDS

Trust Lands are land for which the Federal government holds the legal title, but for which the beneficial interest remains with the Tribe. Trust lands are the only lands over which the Tribes can impose policy.

The LTBB Trust Lands comprise a small subset of the 1855 Reservation Lands.

Figure 4.2: Map of LTBB reservation and trust lands[7]



Working with Other Partners

Non-governmental organizations can provide a useful role in this coordination. One organization that has been particularly effective in bringing together Tribal representatives and other local governments in northern Lower Michigan is the Tip of the Mitt Watershed Council (www.watershedcouncil.org), which the Northern Michigan IA team noted could be a key partner in Tribal efforts to carry out future adaptation plans. The non-profit organization has facilitated the development of regional watershed management plans, and their regional meetings could provide an appropriate and effective venue for the LTBB to present their concerns to other communities and to seek their assistance in disseminating educational and other information about vulnerable Tribal resources and cultural sites to these respective communities.[74] Non-governmental organizations can also make important connections between agencies and communities.

Planning Across Departments

The IA work completed in southwest Michigan provides a reminder that coordination is also needed within jurisdictions during both planning phases and implementation. Although the team coordinated closely with planning staffs and planning commissions, they noted that coastal concerns can often involve many different municipal departments. For instance, they note that many of the options they proposed to the communities would likely require assistance from public works and building standards departments. As such, **interdepartmental coordination and communication** is crucial to successful planning and implementation of adaptive policies.[69]

Coordinating Funding

Many measures for responding to water level variability are capital-intensive or may be long-term and require long-term commitment. Identifying funding is a significant additional challenge for communities and shoreline property owners interested in pursuing different adaptive actions. The Ontario and Wisconsin teams each explored specific options for funding including identification of existing funding sources, coordination of opportunities, and potential voluntary collaboration.

It is important for communities to consider **opportunities for state/provincial, federal and non-profit funding**, even if they're limited. The Ontario team identified specific opportunities for Huron County that may also be available to other Canadian shoreline communities. These include federal climate change "disaster-readiness" infrastructure funding for stormwater management and drainage improvements; provincial Climate Change Action Plan funding opportunities; and, support for beneficial land use practices. Beyond applying for funding, the team stressed the importance of engagement with federal and provincial governments and municipality associations in developing indicators, action plans, and identification of high-risk areas to ensure relevant projects are an eligible priority (see Table 4.1).

The Ontario team acknowledged that funding is often piecemeal at best—a challenge common to both U.S. and Canadian communities. To address this, they encouraged Huron County and its partners to **find ways to strategically "stack" ad-hoc and fragmented stewardship funding programs** in order to target activities and investment where they will have the greatest beneficial impact. The strategy of increasing conservation and stewardship capacity through prioritization and coordination of existing programs is one that applies broadly.[68]

Table 4.1: Funding opportunities and strategies identified by the Ontario Team[68]

OPTION	DESCRIPTION
Pursue funding	Pursue funding applications under federal and provincial infrastructure grant programs (such as the National Disaster Mitigation Program) for stormwater management, municipal drain, access road, and bridge infrastructure improvements to adapt to extreme lake levels and weather events resulting from climate change.
	Take advantage of Great Lakes Agricultural Stewardship Initiative (GLASI) financial support and advice provided by the non-profit Ontario Soil and Crop Improvement Association for major soil-related best management practices (BMPs) for farms in the Lake Huron watershed.
Advocate for inclusion in plans and eligibility for funding	Communicate to federal and provincial authorities Huron County's bluff and gully erosion risk status, and the urgent need to prepare for potential disaster situations from bluff erosion, to ensure this scenario is included in the federal funding program indicators and to identify the Huron Bluffs as a high-risk area for funding.
	Engage with the federal and provincial governments, the Association of Municipalities of Ontario, and the Federation of Canadian Municipalities on development of indicators and action plans for federal infrastructure funding for climate change disaster readiness.

Table 4.2: Options for collective funding identified by the Wisconsin team[65]

OPTION	DESCRIPTION
Collaborate voluntarily with neighbors	Work together to share the costs of a larger project that benefits multiple properties
Create aid fund for bluff and shore properties	Formation of a fund for use in erosion control, bluff stabilization or managed retreats by properties along bluffs and shores.
Establish a Neighborhood Improvement District (NID)	Using Wisconsin ACT 186 (2005), neighborhoods of residential or mixed residential and business properties can form an NID Board to develop and contribute to improvement projects.

Collaborating with Neighbors

At all three community meetings in Wisconsin, there was a clear call for collective action around shoreline and bluff stability. A significant motivation behind this was financial. Many people simply do not have the resources to have stabilization structures built on their properties. The other motivation for collaboration was the recognition that individual actions affect other properties. The team noted that these two motivators clearly reinforce each other. If an engineered design is proposed that is large enough to protect several miles of bluff, then it will absolutely have to be paid for by a group. By contrast, if each person acts independently, the effectiveness of structures could be compromised by the piecemeal nature of implementation.[65]

In response to these concerns, the team identified **potential forms of collective funding ranging from informal to formal cost-sharing mechanisms** (see Table 4.2). When the team solicited feedback on the options, informal collaboration was favored over the formal legal structure of neighborhood improvement districts. Specific comments by participants indicated caution at developing a formal framework for cooperation due to potential fees and taxes that could be imposed.[65]

SHORELINE STABILIZATION AND PROTECTION

Another category of response options the teams addressed is direct modification of the shoreline to reduce erosion and improve stability. Note that while water level variability is not itself a direct cause of erosion, it does affect the timing and location of erosion in the short term and certainly affects public perception of the issue.[40]

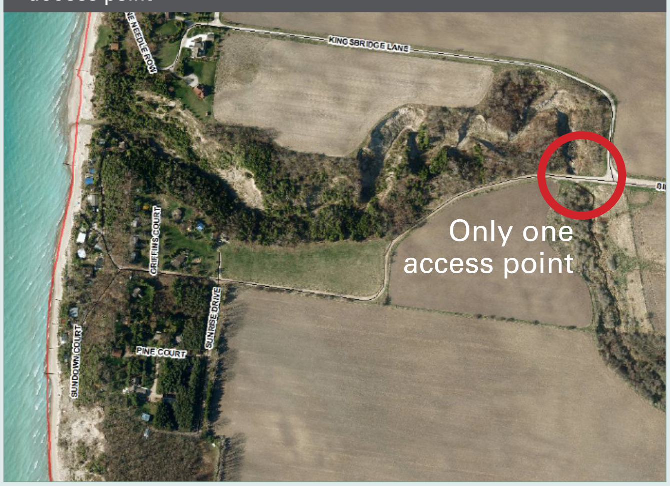
Shoreline stabilization and protection include non-structural and structural approaches, as well as combination approaches. This section provides an overview of stabilization approaches, including some benefits and concerns, and provides an example of how these options figured into the place-based IA work.

BOX 4.2: EMERGENCY PLANNING AND ACCESS

Figure 4.3: Properties in Huron County, Ontario located beyond stable slope limits[66]

Thick yellow line represents stable slope. Areas to the west (shaded) are at risk to fail.

Figure 4.4: Properties in Huron County, Ontario with only one access point[66]



Potential land-based measures for responding to emergencies caused by high or low water levels include: emergency plans, storm and water level forecasting and warning, emergency shore protection, and temporary use restrictions. To respond to emergencies effectively, it is important that these mechanisms and processes be in place before a crisis.[6]

Some 1000 structures along the Lake Huron shoreline within the jurisdiction of the MVCA and ABCA are classified either as being at "imminent risk" of erosion or within 15 meters of the top of the bank. Bluff erosion is particularly difficult to predict, as it is not necessarily triggered by storms. Should a cottage be occupied at the time of a slump, the risk of human tragedy is high, with very little that first responders could do to provide aid because of the danger to their safety on the shifting soils and debris. This is particularly an issue with rural fire departments which don't have the equipment and experience for this type of search and rescue.

To address concerns about bluff collapse, the Ontario team identified opportunities for municipalities to enhance existing emergency management planning. These include: notifying shoreline land owners of the hazards and risks associated with building and activities that may be subject to natural shoreline hazards; participating in erosion emergency exercises; including bluff erosion scenarios in the plans; and promoting awareness among residents of what to look out for and what they should do in the event of a bluff slump.

The team also noted that there are situations where the only municipal road into a shoreline neighborhood runs adjacent to a gully subject to erosion and flooding, which could cut off or wash out the road, eliminating ingress and egress for residents or emergency vehicles. The team recommended that municipalities review municipal road access to shoreline residential areas to ensure more than one secure access, and that they remind shoreline private road owners of their responsibility for maintaining roads.[68]

Structural Approaches

Both the Wisconsin and Ontario teams discussed **structural methods,** which involve construction of hardened structures along the shoreline or lakebed to create a barrier to erosion or flooding. Structural approaches—sometimes referred to as shoreline armoring— can be taken at the community level or at the individual property level. Where the shoreline has already been developed intensively, structural shore protection may be considered the only available option. It is important, however, to recognize the limits of this approach.

Even well-designed stabilization structures may still adversely affect adjacent property as well as shoreline areas a considerable distance away. That is because "hard" coastal structures can cause additional erosion and interrupt longshore sediment movements, leading to the collection of sediments in some areas and sand starvation in others.[80] The increased erosion on shores flanking the structure often leads to an ongoing cycle of more armoring, more erosion, and more armoring—with impacts increasing with the shore hardening. In addition to the sediment and erosion impacts, structural approaches may also negatively affect habitat and ecosystem function.[81] Moreover, erosion and ice damage reduce the lifespan of traditional structural shore protection structures, necessitating constant monitoring and eventual repair or replacement.[39]

Based on their analysis of the topic, the Ontario team noted that "until recently many believed that, with careful planning, hard shoreline protection structures could be constructed without significant adverse impact to other properties. With an enhanced appreciation of coastal dynamics and dune/ erosion cycles in recent years, and increasing recognition of the complexity of Great

KEY RESOURCE

Living on the Coast: Protecting investments in shore property on the Great Lakes

USACE and the University of Wisconsin Sea Grant Institute (2003)[42]

This report developed by the USACE and University of Wisconsin Sea Grant Institute provides U.S. and Canadian property owners more detailed information on coastal processes and options for protecting shoreline property investments.

Lakes cycles and the danger of unintended consequences from well-meant actions, in general, engineered structures are now rarely considered an appropriate response to erosion."[34]

There are also broader concerns that protective structures can provide a false sense of security and inadvertently increase risks. At best, and depending on their design and maintenance, structures can only lessen the effects of natural hazards; a protective structure always has the potential to fail."[82]

Non-structural Approaches

Non-structural approaches aim to stabilize the shoreline using natural materials or to reduce erosion by modifying surface and groundwater management. Examples include restoration of natural shoreline, beach nourishment, revegetation to stabilize bluffs, and the creation and maintenance of sand dune. Other avoidance approaches, such as relocation or managed retreat (see Box 4.6), are also considered non-structural approaches.

Bioengineering and soft stabilization are terms that refer to using live plants and plant parts—rather than hard construction materials—to perform a structural function to stabilize bluffs or banks. The plants serve to reinforce the soil, improve water drainage, prevent erosion and dewater wet soils.[34] Guidelines and manuals for coastal property owners on planting vegetation and vegetation management can help advise property owners on local regulations, the types of plants that grow best on bluffs, slopes, and banks, and how to care for the vegetation. Native plants are suggested to prevent propagation of invasive species.[68,83]

There are limits to the extent to which planting, vegetation maintenance, and other measures designed to reduce the impact of water on slopes can enhance bluff stability. Where there is little to no ongoing erosion of the toe (lowest part of a slope), these approaches can enhance long-term stability and reduce bluff crest recession. However, where there is ongoing toe erosion, these measures can only enhance stability in the short-term, and over the medium to long-term they have no effect on changing the recession rate.[40]

Gray-Green Infrastructure

It is important to note that stabilization methods do not necessarily fall into only one of the two preceding categories. **Green-gray stabilization approaches**, which are sometimes referred to as living shorelines or biotechnical engineering, combine the elements of the traditional structural and non-structural approaches. While traditional hardening design uses materials such as stone, wood, and concrete, and is built using techniques familiar to local contractors and property owners, gray-green approaches incorporate plants, plant-based materials, and geotextile fabrics with hard structural elements to prevent erosion or stabilize bluffs.

Community Voice and Concerns

Not surprisingly, shoreline and bluff stabilization emerged as an important topic for the IA teams working in Wisconsin and Ontario, where high bluff stability is an issue, and in Grand Haven, Michigan where erosion threatens beach homes. This interest was clearly articulated by the community itself during the listening meetings conducted by the Wisconsin team.

> "[Shoreline stabilization] was one of the most frequently occurring topics and it came up at every meeting. People want to know what they can do. Some people wanted a range of options to choose from and some wanted clear guidance from the government on what to do. In the Schlitz-Audubon meeting, there were more questions about best management practices and greener approaches to stabilization, while the first two meetings [in Saukville and Mequon] mostly focused on engineered solutions. This is perhaps not surprising given the extent of shoreline armoring that has already occurred in the coastal villages north of Milwaukee where most attendants to the third meeting [in Schlitz-Audobon] live. Whether or not people wanted a range of options or clear guidance, engineered or green solutions, the most common desire was that any options they chose carried no risk of violating some regulation or requirement resulting in the property owner having to pay fines and pay for more work to be done"[65]

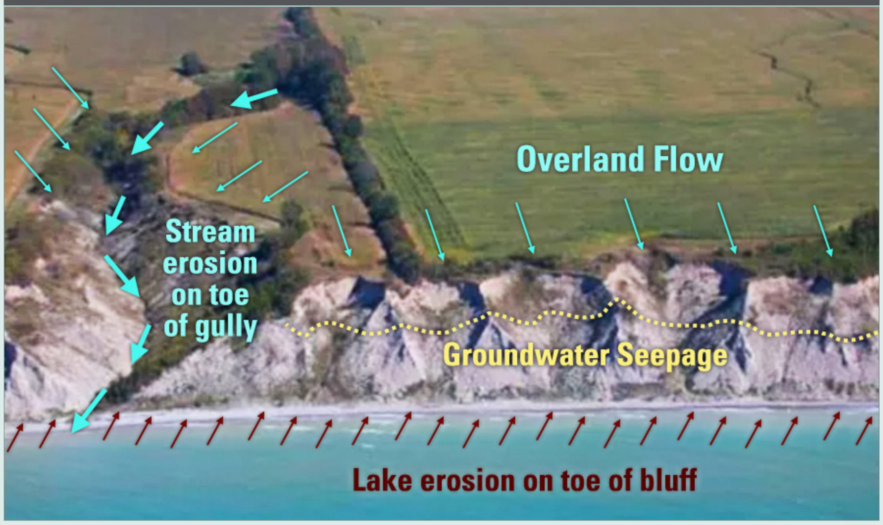
Table 4.3: Examples of shoreline stabilization and protection approaches

STRUCTURAL	NON-STRUCTURAL	GRAY-GREEN
Revetment	Vegetation maintenance and enhancement	Breakwater with living shoreline
Groin	Sand dune construction	Living breakwater or artificial reef
Sea wall	Wetland restoration	Living revetment/ sea wall
Breakwater	Beach nourishment	
	Managed retreat	

BOX 4.3: FOCUSING UPLAND TO STABILIZE SLOPES

Approaches to shoreline stabilization are not limited to the shore zone. In fact, surface water and groundwater management are the first defenses for protecting slope stability.[42] Policy options related to stormwater management are presented later in this chapter.

Figure 4.5: Surface water and groundwater affect slope stability[66]



The options the Wisconsin team identified and presented during subsequent meetings with the public and local officials included a range of stabilization approaches, including structural, non-structural, and gray-green approaches. The team provided an overview of each option (see Figure 4.6) and then solicited feedback. In general, public meeting attendees viewed the "greening" of conventional gray infrastructure favorably, and they exhibited skepticism about the effectiveness of strictly green approaches in the high energy environment of that particular stretch of Wisconsin shoreline. Moreover, while stabilization structures were viewed favorably, residents also expressed strong desires to be good neighbors, as evidenced by the support for collaboration and development of projects that would not aggravate erosion on adjacent properties.[65] Given the effects of structures on littoral drift (see Box 2.1 in Chapter 2), these competing desires may reflect an inescapable tradeoff.

Figure 4.6: Example of an option summary the Wisconsin team shared with public meeting attendees[65]

REVETMENT

Definition:
A protective structure of stone/concrete/sandbags parallel to the shore with sloping face designed to protect against wave erosion.

Benefit:

- Resists erosion of shoreline/buff toe by waves
- Strong and durable

Disadvantages:

- Can result in increased erosion of adjacent natural shoreline of lakebed along the bottom edge.
- Loss of beaches and natural habitat, prevents sediment flow in lakes
- Can limit water access due to large size and unsteady footing

PURPOSE	WHEN IS THIS NECESSARY?	SCALE	COMPLICATION	COST
Erosion	Strong waves hitting shore and base of bluff	Individual or Group Action	Site Access (can use barge)	Medium

LAND USE AND SHORELINE MANAGEMENT POLICIES

This section describes options to modify, prevent or regulate specific uses of the land and water. These options can affect both existing and future development, and they can apply within designated hazards areas along the shoreline or more broadly.

The section is divided into two parts. The first discusses land use planning and development requirements, while the second looks at options related to permitting processes more generally. What unites these are a primary reliance on regulations or other mandatory requirements, rather than voluntary approaches, although exceptions are noted.

Land Use Planning and Development Requirements

SETBACKS

The idea of a setback or buffer is to prevent new development in a hazard or sensitive area. It can also be used to address removal

Table 4.4: Options for where to establish a setback line from the Lake Michigan shoreline identified by the Southern Michigan team[71, 73]

OPTION	DESCRIPTION
Current setback	In the City of Grand Haven this is 25 feet from the parcel lot line
Fix development at its current location	In the City of Grand Haven this would mean retaining the 25 foot setback but disallowing any additional shifting of current structures lakeward if the shoreline shifted
Set a line based on estimated erosion rates	For the City of Grand Haven this would entail adopting a setback premised on setting structures landward of the anticipated distance of shoreline erosion for two generations of a house (i.e., where one generation equals 30 years, the life of a typical mortgage, and two generations equals 60 years); this is consistent with the State of Michigan's High Risk Erosion program
Set a line based on a high-risk hazard line	This option for the City of Grand Haven would set a line that represents the predicted landward extent along the shoreline of inundation and/or wash-over by high-energy waves during an extreme coastal storm event that occurs while Lake Michigan is at or near an all-time high water level. *Note: this type of option would not be available to the Charter Township of Grand Haven, whose shoreline consists of steep bluffs, as it is not possible to predict when or how much coastal bluff might collapse into the lake during a storm event.*

Table 4.5: Options for policies to associate with a setback line from Lake Michigan identified by the Southern Michigan team[71, 73]

OPTION	DESCRIPTION
Prohibit new structures	Prohibiting the placement of any new structure lakeward of the setback line
Moveable structures	Allowing only readily moveable structures lakeward of the setback line
Nonconforming structures	Establishing that existing structures currently lakeward of the setback line (or structures that become lakeward of that line as the shoreline erodes over time) are nonconforming structures, such that they must be removed if substantially damaged by a coastal storm event
Surety bond	Requiring that owners of structures currently lakeward of the setback line (or that become lakeward) post a surety bond sufficient to clean up and restore the shoreline should the structure need to be removed following a coastal storm event

or clean-up of structures within those areas should they be damaged. The Southern Michigan team, which explored this option in depth and whose work informs this discussion, notes that setbacks are actually a multidimensional approach, with multiple **options for how and where to set a setback line, as well as the policies to associate with it**.

The Southern Michigan team considered a number of options for how to establish a setback line from the Lake Michigan shoreline. The options available to the City of Grand Haven and the Charter Township were similar, but varied based on the type of shoreline present (i.e., sandy beach in the city, bluffs in the township), and current zoning in each community. Table 4.4 outlines these options for the city. The specifics may not be applicable more broadly, but the options illustrate the types of approaches that could be considered.

It is also necessary to determine what policies would be associated with a setback line. The options the Southern Michigan team identified (see Table 4.5) are not mutually exclusive, and they each speak to various aspects of risk and fairness (i.e., fairness to both individual property owners and the larger community) in terms of allowing development while not putting people and structures in harm's way and ensuring the adequate cleanup of structures once damaged.[71]

It is important to note that these setbacks and associated polices would be in addition to other state-designated setbacks and hazard delineations. In Michigan, localities may adopt setback and other provisions through their zoning codes in addition to the state program, and that in such instances a property owner must comply with both state and local regulations.[72] The extent to which municipalities can control land use and the options available to them will vary across jurisdictions in the basin (see Box 4.4).

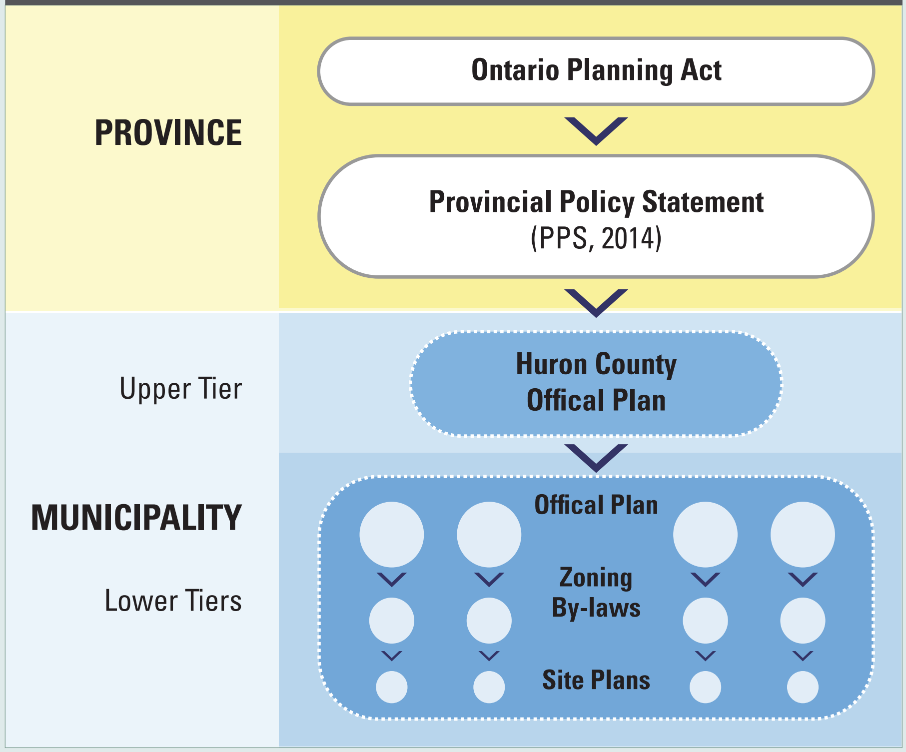
Stormwater Management

The lake shorelines are affected by not only the water in the lakes, but also the water that moves over the land. For that reason, teams considered **options for stormwater**

BOX 4.4: LAND USE PLANNING IN CANADA AND THE U.S.

Land use is primarily under the jurisdiction of provinces in Canada and states in the U.S.; however, in both countries much of the regulation has been delegated to the local level. As a result of this, there is variation in land use policy-making and management both between and within each country.[56] Moreover, a single location may be subject to requirements at multiple jurisdictional levels (e.g., local building codes, federal permitting requirements). While an in-depth comparison of land use policy across the Great Lakes basin is beyond the scope of this IA, a brief discussion of Michigan and Ontario follows.

Figure 4.7: Ontario's planning framework[34]



Ontario

The Ontario team explains:

For land use planning and development, the province of Ontario provides policy direction through the Provincial Policy Statement (PPS). Sections 3.0, 3.1.1, and 3.1.2 direct development away from areas of natural hazards with an estimated planning horizon of 100 years. Development includes new lot creation, any change in land use, and construction of buildings and structures that require Planning Act approval.

As illustrated in Figure 4.7, Ontario has a "policy-led" land-use planning framework with the province setting the policy regime through the Planning Act and PPS and municipalities implementing those policies through development of their Official Plans and zoning by-laws. Designated agencies such as CAs play a key role in regulating and permitting processes for development in areas that may be subject to flooding, erosion or dynamic beach hazards.[34]

Michigan

The Southern Michigan team notes:

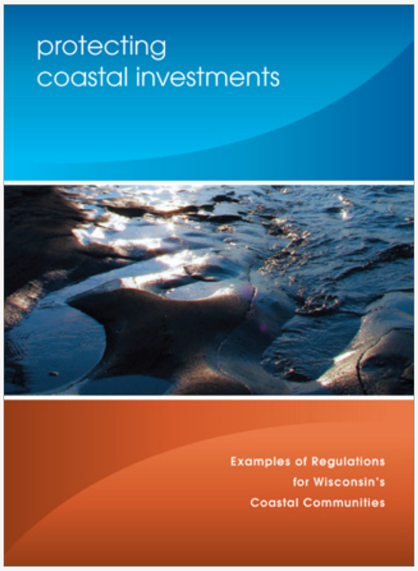
In the U.S. in particular, there is no coherent or unified national land use planning policy, such that most planning policies are established at the state and local levels. In the State of Michigan, as with most states, both local land use planning and regulatory authorities are broadly enabled and permissive; they are neither mandated nor very constrained or prescriptive (see the Michigan Planning Enabling Act, 2008 Public Act 33, and the Michigan Zoning Enabling Act, 2006 Public Act 110, as amended).

As a result, although land use and community planning in Michigan and elsewhere unfolds within a hodgepodge framework of federal and state infrastructure policies, social laws and policies (e.g., housing assistance programs), and environmental protection laws, it remains largely a local endeavor. Similarly, most public infrastructure related to land development (e.g., water, wastewater, and roads) is provided at the local level, funded substantially by local ad valorem property taxes and fees (see, e.g., Citizens Research Council (1999)[84] for a discussion of local government services and tax authorities in Michigan).[69]

management and related soil erosion control. The Southern Michigan team identified a range of low-impact development (LID) approaches to address stormwater concerns in the City of Grand Haven and the Grand Haven Charter Township. LID is a design approach to managing stormwater by using natural features. It emphasizes conservation and use of on-site natural resources to control stormwater and improve water quality. Table 4.6 presents a combined list of select options developed for the two communities.

Stormwater management highlights an important aspect of the Southern Michigan team's approach. In their work, they purposefully took special note of the kinds of issues that are not clearly or strictly related to coastal area management, but that local citizens and officials believe should be addressed concurrently with coastal management concerns as part of a larger regulatory/policy reform effort. They point

KEY RESOURCE



Protecting Coastal Investments: Example of Regulations for Wisconsin's Coastal Communities

University of Wisconsin Sea Grant (Ohm, 2008)[85]

http://nsgl.gso.uri.edu/wiscu/wiscuh08001.pdf

This report aims to develop best practices for addressing coastal hazards like bluff erosion in Wisconsin. These include approaches discussed in this chapter such as setbacks, stormwater management, disclosure, and more information on coastal processes and options for protecting shoreline property investments.

Table 4.6: Options for stormwater management identified by the Southern Michigan Team[6]

OPTION	EXAMPLES OF HOW TO IMPLEMENT
Update stormwater ordinance to meet new county standards	Require non-structural best management practices in sensitive areas; amend ordinance to address pretreatment, hot spots, cold water streams
Incentive participation in LID	Offer development incentives only to those that employ best management practices that go beyond treating runoff (e.g., restoring/enhancing native vegetation and buffers; minimizing soil compaction)
Coordinate between the planning commission and public works department to advocate for and enable LID	Establish standing meetings between planning and public works staff; incentivize participation in LID (e.g., reduced review fees, accelerating plan review); enable LID in zoning regulations

Table 4.7: Options for updating shoreline structure permitting requirements identified by Wisconsin team[65]

OPTION	EXAMPLES OF HOW TO IMPLEMENT
Consider additional factors	Require site plans to include study of sediment flow in site and potential impacts on sediment flow from new structure.
Fund desired activities	Add fee to permit to create funds for monitoring of new structures for a set period of time.
Incentives	Allow reduction of permit cost if site includes green practices (e.g. vegetation).

out that issues that originate due to policy or land use farther inland may hold greater implications for shorelands than in other settings.[69]

There are a variety of mechanisms outside of LID for addressing stormwater management and associated erosion concerns. Moreover, in some instances it may not be possible to mandate the use of certain practices. The Ontario team identified a number of voluntary approaches for encouraging sediment and erosion control measures. For instance, they recommended that Huron County and agricultural organizations aggressively promote erosion control measures by farmers to reduce gully erosion and Lake Huron pollution and take advantage of related funding opportunities (Table 4.1). Examples of these measures include windbreaks, buffer strips, grassed waterways, and sediment control basins. They also recommend that the HWCPSC review its grant program with an eye to promoting and enhancing storm water management initiatives.[68]

Municipal Ordinance Review and Updates

Teams recognized the need to **update ordinances based on changing conditions**. In its discussion of options for setbacks, the Southern Michigan team noted that communities may want to adjust setbacks periodically, such as every 10 or 15 years, to account for changes in the shoreline.[72] A more general approach that emerged from the community conversations in Wisconsin is the idea of establishing a mechanism to "trigger" a review of existing policies. The specific option the team considered consisted of establishing a policy for a particular condition (e.g., water level change of a certain amount in one year) that would result in immediate review or revision of local ordinances of policies.[65]

PERMITTING

Implementation of the shoreline stabilization approaches described in the previous section and other coastal activities are subject to regulatory requirements in both the U.S.

BOX 4.5: CONSTRUCTION STANDARDS

Figure 4.8 Residential development along bluffs in Ozaukee County, Wisconsin[86]

Great Lakes Oblique Imagery (2012)

Although not a focus of the four place-based teams, construction or building requirements are a common land development approach for responding to natural hazard concerns.

Flood Elevation and Floodproofing

Both Canada and the U.S. have regulations requiring that new structures be constructed above a certain elevation (the 100-year flood level, or one percent exceedance probability flood elevation). Older structures developed before the regulations and structures built in areas where no formal flood mapping or regulations exist may still be at risk of storm-related or high water level-related flooding. Additionally, it is not clear that current mapping reflects the full extent of risk with future climate change. Property owners with structures threatened by flooding or wave damage can voluntarily choose to elevate their structures or to bring in material to raise their lots, but the IUGLS noted there is little evidence around the upper lakes shoreline that this is occurring.[19]

Updated Bluff-top Construction Standards

The Wisconsin team generated an option related to building code standards that reflected the hazards along their project shoreline. Specifically, the option suggested including stability and erosion consideration in construction ordinances for bluff-top properties.[65]

and Canada. Although none of the place-based teams explored options for technical requirements associated with various types of shoreline permitting, they did identify options for utilizing existing permitting processes.

The Wisconsin team, for instance, identified a number of ways to **use existing permitting processes as a mechanism to achieve additional aims** (see Table 4.7). These options included amending permit requirements to include consideration of additional factors (e.g., a study of effects on sediment transport), collecting additional fees to support desired activities (e.g., monitoring), or adjusting fees to incentivize certain approaches (e.g., living shorelines).

Permitting processes also provide an important opportunity for consultation and public input. The Northern Michigan team noted that while the LTBB have their own environmental protection statutes that include permitting requirements for wetland modification, those statutes apply only to lands subject to LTBB jurisdiction. Regulated activities elsewhere in Michigan are subject to state and federal permitting requirements. Given that Tribal concerns about wetlands and fisheries habitat extend beyond their Trust Lands, the **public notice and comment periods and consultation process associated with state and federal permitting provide an important opportunity for Tribes to provide input** on activities that could impact Tribal resources. Tribes have the opportunity to provide public comment when a public notice is issued for a proposed project or, in the case of USACE permits, when potential Tribal resources are identified that may be affected by proposed work even if a public notice is not required.[74]

EDUCATION AND OUTREACH

All of the place-based IA teams explored options related to outreach and education, but the topics addressed, audiences targeted, and forms of the outreach resources or tools varied based on the needs of the given community. This section describes selected options from each of the teams to illustrate a range of opportunities.

BOX 4.6: ACQUISITION, CONSERVATION AND RELOCATION

Figure 4.9: Conservation easement sign

NRCS photo by Beverley Moseley

Other commonly discussed land use and management approaches that aim to prevent coastal damages include land acquisition, conservation strategies, and relocation.

Acquisition

Government or non-governmental organizations may purchase developed or undeveloped property within hazard areas in order to reduce or prevent future damages. These properties could be left or restored to natural habitat, or developed as open recreational area that would be less prone to damage. Programs to buy developed properties can help break a cycle in which homeowners are incentivized to live in hazard areas by the availability of federally subsidized flood insurance, which effectively shifts financial risks to the public, but they are costly and can be politically and socially controversial.

Conservation and Cultural Easement

Rather than purchasing the land outright, conservation easements allow governments or land trusts to acquire easements on land of environmental value as a means to protect the property containing natural resources. This is often accomplished by purchasing development rights from a landowner, which will then attach a deed restriction prohibiting any further development that would alter the environment.[87]

The Northern Michigan team noted that the LTBB has previously used this approach to protect property within their reservation boundaries that contained both ecological and cultural resources, and the same approach could be used to protect additional sites along the lakeshore.[74]

Relocation or Managed Retreat

Relocating a structure away from a shoreline is another way to avoid potential impacts. Although costly, relocation may be the only way to save a structure. Given the number of residences at risk in Huron County, the Ontario team explored possible ways to help homeowners interested in considering moving their house or cottage to a new location farther from the eroding edge of a bluff. The team noted there had been previous discussion during the high water levels of the 1990s about the need to plan for "runaway" or "move-back" lots—vacant lots delineated behind at-risk lots so that there would be a place to relocate a cottage when erosion becomes an imminent threat—but no steps were taken.

To assist interested homeowners, the team recommended that Huron County and the local municipalities consider reviewing the current availability of land for development during land use planning and zoning by-law updates; providing information (e.g., explanation of the severance process, contact information for construction firms); and financial incentives (e.g., planning fee forgiveness) for potentially interested property owners.[68]

Keeping Property Owners Informed

Significant efforts are already in place regarding information for property owners in Huron County, Ontario on the causes of bluff erosion and why they should adhere to regulations. Governments and conservation organizations have already issued guidelines, manuals, and websites, and held public meetings to provide useful information. In addition, shoreline residents' associations post links to information and work to keep their memberships informed. Despite those efforts, however, the Huron County IA team concluded that **property owner outreach needs to be continuous** because of population turnover, and many Huron County shoreline residents seem largely unaware of bluff erosion issues despite the efforts of their homeowners associations.[68] Options the team identified are described in Table 4.8.

Engaging Youth

Property owners are not the only relevant audience. The Northern Michigan IA team explored **youth education and outreach options** with their tribal partners. These were conceived as ways to address concerns around the protection of native vegetation and cultural sites during low lake water periods that would also serve to build capacity within the tribes. Through their Education Department's Summer Youth Camp, the LTBB have already been providing education about the impact of a changing climate on the environment, which includes lake levels. The program has been able to provide the Tribal youth with important lessons regarding climate change and adaptation, and at the same time, the information has been presented in a way that is consistent with their traditional/cultural relationship with the natural environment. Through the IA the GTB learned about the LTBB's efforts and expressed interest in a similar program. The research team has continued to discuss ways to move forward in that direction.[74] The Wisconsin team also recognized the importance of youth education and suggested K-12 curriculum activities.[65]

Providing Resources and Engagement Opportunities

As described previously, the Wisconsin community conversations revealed that property owners want more information about stabilization. This included information on erosion processes and consequences, as well as examples of past coastal projects to see how others have addressed erosion successfully and unsuccessfully. Many also expressed the need for information about relevant legislation and policies, including clearer guidelines pertaining to getting permits for action taken at the individual property level.

In response to these desires and other feedback, the team identified a diverse **range of educational resources, tools, and activities** to meet the communities' desire for more information. These approaches, particularly the educational resources and decision-support tools, emerged as highly favored options for responding to water levels when the team polled public meeting attendees about their preferences (see Table 4.9).[65]

Mapping and Visualization

Among the teams, maps and other visual products emerged as a key type of educational resource. By depicting the location and extent of issues associated with variable water levels and potential response options, these approaches can ease and increase the effectiveness of planning processes, and they can enhance understanding of important coastal processes. Some existing resources are included in Box 4.7.

The Wisconsin team identified a variety of **informative and visual resources** that could assist in communicating conditions, changes over time, and examples of different projects. These include oblique aerial photography, maps of bluff erosion rates and stability factors, and maps of beach profiles at different possible water levels.[65] Property owners in the Wisconsin project area also expressed a desire for an online tool that would allow them to track erosion at their property through aerial photograph analysis. Work has commenced on a prototype tool that would leverage different dates of historical aerial photography and bluff feature mapping, and include a slider bar to visually contrast photos from two different dates to show change. The team also proposed a three-dimensional visualization of coastal erosion processes.[65]

Table 4.8: Options for outreach to shoreline property owners identified by the Ontario team[68]

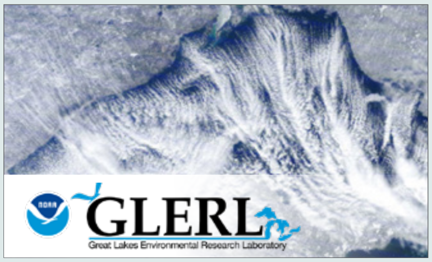
OPTION	DESCRIPTION
Annual mailer	Sending an annual mailer to the home address of the owners of properties within the 100-year bluff recession line, including a "Do You Know" fact sheet advising of their property's bluff erosion and hazard land status along with links to additional online resources.
Other outreach materials	Engage and inform current and prospective shoreline property owners of land with natural hazard designations through CA and local government webpages; shoreline residents' association webpages and communications; direct mail-outs of fact sheets; and aggressive marketing and promotion of safe and responsible shoreline property management.
Workshops for expert assistance	Hold workshops for shoreline property owners to review, with the assistance of CA staff and other experts, their individual property situations; relevant land-use planning and regulatory/permitting requirements; climate change, lake level and bluff erosion trends; do's and don'ts for landscaping to improve bluff stability; local landscaping experts for bluff stability planting; local geo-technical consultants.

Table 4.9: Select tool and outreach options identified by the Wisconsin team[65]

OPTION	DESCRIPTION
Educational resources	Publications such as a bluff vegetation guide; video series such as an explanation of coastal processes through a virtual tour of the coast; enhanced website to share comprehensive information on coastal processes and engineering.
Decision-support tools	Erosion and bluff stability self-assessment guide; spectrum of erosion control methods.
Outreach activities	Educational boat tours of the coast; annual workshop series on coastal erosion.

For outreach around wetland habitat concerns, the Northern Michigan team proposed utilizing the ESRI Story Map Tool, which is an innovative resource that combines educational text, graphics, and geographic information system (GIS) mapping capabilities. The spatial component of the tool would allow lessons to be tailored to specific wetlands of concern in the region. Depending on the intended audience, the story maps could omit geographic information about culturally-important sites in order to protect them from vandalism. However, appropriate information could be presented to heighten public awareness of the potential importance of various resource types which may become more vulnerable under a changing climate and subsequent plausible lake water level futures.[74]

BOX 4.7: MAPPING AND VISUALIZATION RESOURCES AND TOOLS



GLERL Dashboard Project

Gateway to long-term, basin-scale hydrological and climatological data for the Great Lakes

http://www.glerl.noaa.gov/data/dashboard/portal.html

NOAA Lake Level Viewer

An interactive visualization and mapping tool that uses high-resolution elevation data to enable users to display and visualize water levels associated with different lake level scenarios with a high degree of accuracy

https://coast.noaa.gov/llv

Wisconsin Coastal Atlas

Gateway to interactive maps, geospatial data, and tools to support decision-making about the Great Lakes

http://wicoastalatlas.net/

Great Lakes Coastal Resilience Planning Guide

Resource showing how coastal communities are addressing coastal hazards such as lake-level fluctuations, shore erosion, and flooding. Features case studies, maps, data, tools, and other information

http://greatlakesresilience.org/

Great Lakes Coastal Analysis & Mapping

Federal Emergency Management Agency coastal analysis and mapping study to produce updated Digital Flood Insurance Rate Maps for U.S. coastal counties around the Great Lakes

http://www.greatlakescoast.org/great-lakes-coastal-analysis-and-mapping/

ABCA Mapping Portal

GIS mapping tool with information on properties owned by and hazard areas regulated by the ABCA

http://www.abca.on.ca/page.php?page=mapping-portal

Michigan High Risk Erosion Areas

http://www.michigan.gov/deq/0,4561,7-135-3311_4114-344443--,00.html

BOX 4.8: REAL ESTATE DISCLOSURE

ORDINANCE LANGUAGE

The following is some possible ordinance language to require a disclosure statement:

Prior to the issuance of any permit for the use of real property or the construction or alteration of any structure located within the Coastal Hazard Zone, the owner of the property shall sign a Coastal Hazards Disclosure Statement. The statement shall be on a form provided by the [zoning administrator/planning department/clerk] and shall be filed with the Register of Deeds of _____________ County.

Sample disclosure ordinance language from *Protecting Coastal Investments: Examples of Regulations for Wisconsin's Coastal Communities*[85]

Despite existing outreach and education efforts, some remain unaware of the hazards associated with shoreline property they own or are considering to purchase. Recognizing the importance of information in making decisions about property ownership, the Ontario team noted:

> "Real estate agents may have a role to play since they are the first point of contact with buyers. Some, but not all, do advise prospective purchasers that a shoreline residence may have hazard land designation. Bluff erosion is a "known defect," so it is up to a home inspector to raise it, provided that a professional home inspection is done. However, disclosure of features affecting the property may be a safety issue as well as a matter of ethics. If a dangerous situation is not disclosed, the agent could be liable. This issue was noted as early as the 1993 IJC report, which recommended 'real estate disclosure requirements where the seller should be required to disclose to prospective buyers that the property is within a mapped or known flood or erosion hazard area. The buyer should sign an acknowledgement that he or she has been informed of the risk.'"[68]

A report by the University of Wisconsin Sea Grant notes that disclosure statements can help ensure that current property owners are aware of the risks inherent in building on or making changes to coastal lands, and they can help ensure that future purchasers of coastal properties are aware of the risks involved. The report offers sample ordinance language requiring disclosure prior to the issuance of a construction permit (illustrated here) and disclosure upon sale of a property.

The actual process of mapping was an important aspect of some of the teams' approaches to the IA. The Southern Michigan team, for instance, employed GIS mapping and a scenario-based planning framework to present to local officials and citizens arrays of potential outcomes from combinations of reasonable climate—and associated water levels—futures and development management responses, such as the setback permutations described earlier.

The team first crafted an array of reasonably anticipated "climate futures" each reflecting a combination of Great Lakes standing water elevation and level of storminess based on historical levels and anticipated trends. Applying each climate future to the study communities' topography through GIS analysis, the team then identified areas potentially subject to coastal hazards, including inundation (shoreline to upstream riverine flooding potentially influenced by lake water levels) and high-energy wave action along lake shorelines. To understand how different community land use planning options would affect areas at risk, the team then combined the three climate futures with projected development under different zoning requirements (e.g., different setback lines). These mapping and analysis techniques helped the communities see and understand their vulnerabilities and differences among various response options.[69]

TAKEAWAYS

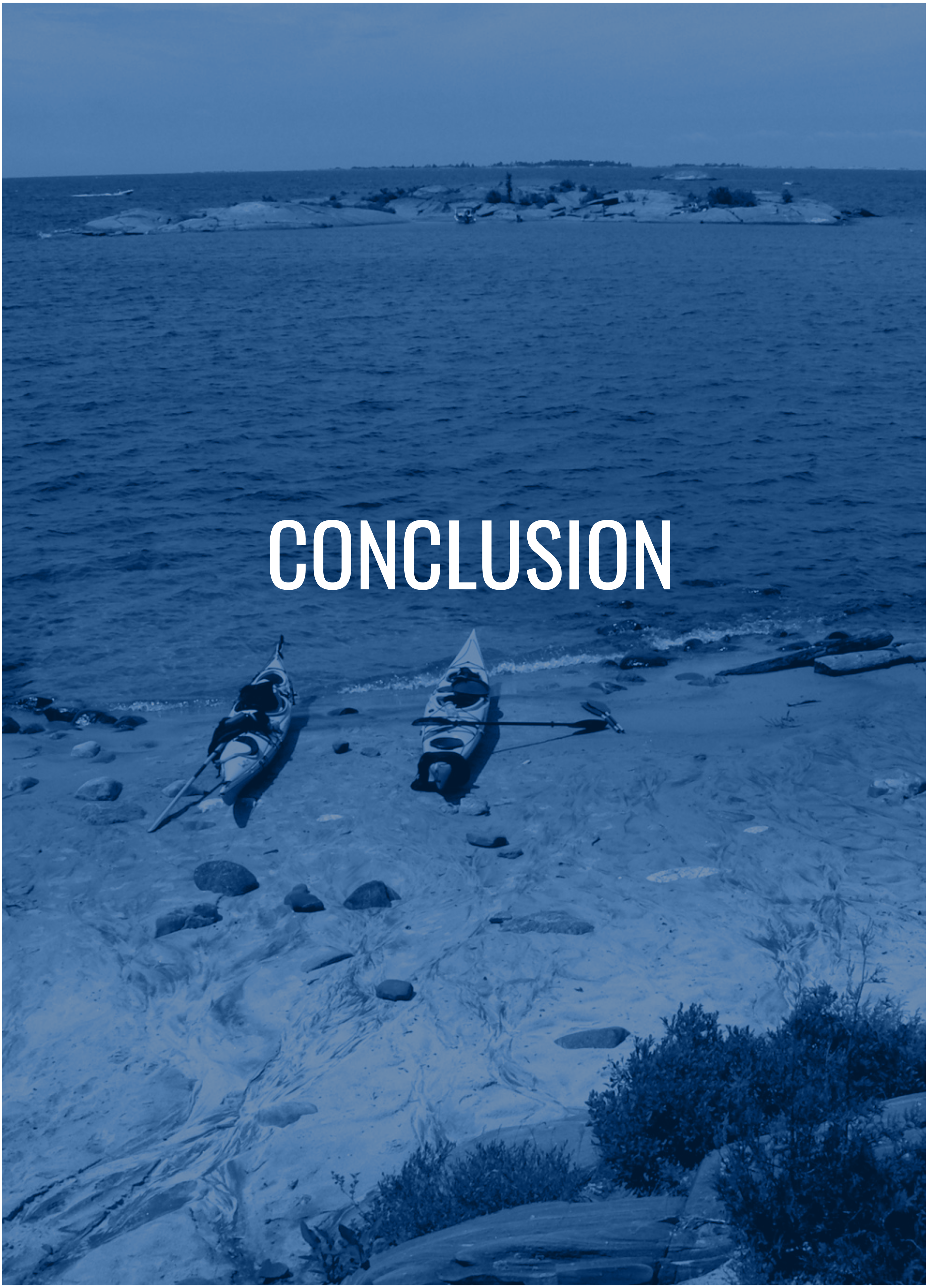
This chapter has categorized and described the most common options for responding to variable lake levels identified by the place-based teams during Phase II of the IA. These were grouped into four categories:

- **Planning and Coordination**
- **Shoreline Stabilization**
- **Land Use and Shoreline Management Policies**
- **Education and Outreach**

Although described separately, these categories of response measures and the specific options described within them are often interrelated. For instance, planning and coordination are important for most of the options discussed in the other categories, from considering structural or non-structural approaches to aligning and funding outreach efforts. Education and outreach approaches are important for building support for and implementing potential regulations or incentives, while land use and permitting requirements may affect the need and ability to pursue different stabilization approaches. The complex, multi-level governance system in the basin ensures that jurisdictional considerations are unavoidable for many options.

As mentioned at the start of this chapter, no single measure will be sufficient. The place-based IA teams identified ranges of opportunities for their partner communities to consider, and there are additional options beyond those discussed here. Admittedly, the options here are a reflection of the place-based teams' work and do not address the full range of issues such as, but not limited to, recreation and fishing, shipping, dock accessibility, and others.

In general terms, however, living with Great Lakes water level variability will require a combination of approaches that seek to prevent negative impacts, mitigate the effects of unavoidable negative impacts, respond to emergency impacts, and on the positive side, capitalize on the benefits associated with inevitable changes.



CONCLUSION

CHAPTER 5

The primary objective of the Great Lakes Water Levels IA has been to identify strategies for mitigating the harm and maximizing the benefits of water level variation in the Great Lakes. As was noted in Chapter 3 and Chapter 4, a wide array of resources and options regarding lake levels already exist. Going back decades, the IJC and others have completed extensive studies identifying and assessing options around Great Lakes water level fluctuations.[6,17,19,41,61,88] One key challenge, as several of those studies have noted, is identifying and tailoring a suite of options according to unique local conditions and interests. In addition to variability and uncertainty in water levels, determining an appropriate integrated mix of options that take into consideration local conditions, multiple objectives, and jurisdictional constraints is not a simple task.

Overcoming these obstacles required a different approach that emphasized creative solutions and engagement with decision-makers, and that coupled place-based work with a broader regional perspective. The goal of this assessment was to build upon existing efforts, bring in best-available science, and recognize the dynamic nature of the Great Lakes system. The options identified through the assessment will hopefully assist the partner communities in adapting and contribute to advancing adaptive strategies that protect the ecological integrity, economic stability, and cultural values of the broader region. These strategies are also intended to support the notion of living with variability and address the uncertainties of an evolving future associated with climate change and the potential for high and low water levels and associated impacts.

Through several phases, the teams involved with the assessment worked to understand key local issues and related perspectives. The teams also met regularly to share resources, provide progress updates, and discuss the regional applications of their work. This Phase III report has attempted to integrate key findings of all the teams, noting the unique challenges and opportunities faced by each community to identify opportunities for the region. The hope is that this report can inform communities facing similar situations and provide approaches for ways to adapt to issues associated with water level variability.

OVERARCHING THEMES

While the primary focus of the IA was to identify place-based adaptive strategies and options for issues associated with water level variability in the Great Lakes, several common themes can be identified when examining the work of the research teams. These themes are reminders of conditions that may be critical for the success of any suite of strategies, or overall approach to identifying strategies, that a community takes.

Capacity

At the local level, capacity is variable, and efforts should be cognizant of capacity needs and develop strategies to meet them. As noted previously, while a significant amount of data and information are available on a range of water level issues, it can require a substantial amount of work and expertise to convert those resources into actionable items at the local level. A good understanding of capacity can also provide insights on where partnerships can be particularly useful, as well as the merits of working with existing decision-making groups or forming new coalitions and groups to address the topic.

Context

When implementing policy options, context matters. Significant effort is needed to move general policy recommendations to locally-specific adaptive management strategies. The Southern Michigan team noted in their Phase I report that "there are a number of common regulatory and non-regulatory options that address managing Great Lakes coastal shorelands, but applying an abstract policy prescribed in a general plan to a particular place, and ensuring that it can yield the desired outcome, is difficult—especially considering potential political and legal implications."[69] They further explain that this is in part because existing tools and guidelines may lack important local details or instructions, and also because there are specific socioeconomic considerations or values which may be more important in one context than another. These different and sometimes competing considerations can also impact a community's ability to take action on an issue, particularly in light of other pressing issues or a lack of immediate concerns about lake levels.

Jurisdiction

It is critical to understand the relevant authorities for decision making, particularly when multiple authorities (local, state, provincial, etc.) are involved, as is often the case with the Great Lakes resource issues. All of the teams dealt with this to a degree, but both the Ontario team and the Northern Michigan Team addressed this issue in detail through the alignment of provincial efforts or the sovereignty and jurisdiction of Tribal governments, respectively.[68,74]

Key Institutions

Efforts should be made to identify and engage critical partners and key institutions. Depending on the context, a key institution may be a property owners' association, a local community organization, or a planning commission. Devoting time to understanding the relevance of the other themes discussed here can be very helpful for identifying key institutions for advancing or implementing a particular strategy or option. Determining how to best apply limited resources and time can hinge on engaging key institutions.

Public Input

To find acceptable solutions, it is critical to solicit input from stakeholders, and competing perspectives should be sought out in a thoughtful manner. The work of all four of the research teams provides important insights on the value of and approaches to this engagement. The Wisconsin team in particular made broad public engagement a central component of its process. Because of the diversity of interests that depend on the lakes and the varied effects of both high and low water levels, future water level changes and adaptive responses to that variability will impact members of the community differently. As a result, it is vital to consider multiple and potentially competing perspectives–particularly if considering new approaches that deviate from past practice. How stakeholder input is conducted can be as influential to an outcome as the methods of data collection and analysis.[69]

Uncertainty

Although uncertainty may be unavoidable to a certain extent, it need not preclude action. Tools such as scenario planning or approaches like adaptive management can help to develop and refine adaptive approaches in light of incomplete information.

PUBLIC PERCEPTION, INFORMATION, AND ENGAGEMENT

This overall study, as well as the four-placed based teams' work, recognizes that public perception of the issue of water levels, and of the validity of the approaches to address water levels, is critical for adaptation to current and future Great Lakes water level variability. As described throughout the report, there are diverse interests in the region who are affected differently by water levels. This diversity of views can contribute to lack of agreement as to what the problem even is, let alone approaches for addressing it.

Access to information can help build understanding and acceptance, and all four teams included educational strategies in their analyses. Yet, while better information is important, it is not necessarily sufficient. Even with additional information, disagreement can persist, for instance, around causes of water level fluctuations, the level of risk associated with developing in certain areas, or the acceptability of different adaptation strategies.

While a full discussion of factors affecting such things as risk perception, resistance to changing strongly held beliefs, and trustworthiness of information is beyond the scope of this report, it is worth making a couple key points. First, while development along the shoreline offers benefits, it also entails risks, and often technical experts and the lay public view these risks differently. Research into risk perception emphasizes that neither groups' assessment of risk is right or wrong, but instead they evaluate risks using different criteria. These can include factors beyond the potential for direct harm such as characteristics of the risk itself, social factors, and implicit bias, for example.[89,90] Further complicating matters, as noted by Scyphers et al. (2014),[91] research demonstrates that coastal homeowners' decisions are also affected by values, beliefs, personal and property attributes, social norms, legacy effects of previous decisions, and more. These situations where parties disagree about an issue or misunderstand each other's perspective call for more engaged forms of public participation so that parties feel that their concerns are heard. Additionally, efforts to understand different stakeholder attitudes around an issue can help to identify priority issues and misunderstandings causing unnecessary tension.[89,92]

LIMITATIONS

Prior to the start of the IA, much discussion around water levels focused on control measures to address concerns about low water levels in Lakes Michigan and Huron.[93] Now with higher overall levels, the discussion in some areas has focused to increasing the outflow of water, particularly with respect to Lake Ontario.[94,95] To not address these lake and basin wide concerns about structural controls may seem a significant gap in a report focused on Great Lakes water levels; however, while important discussions, they are outside the focus of a place-based analysis of adaptive strategies. Moreover, the relatively quick change in the public discourse around water levels—from a focus on lows to highs—during just the course of this project underscores the dynamic nature of the Great Lakes system and the rationale for this IA's focus on variable water levels. Great Lakes water levels change over the short- and long-term, and will continue to do so, and proposals focused on a short-term condition may not be the solution that they appear to be.

The scope of the IA was further bounded both geographically and topically, with a focus on Lakes Michigan and Huron and issues facing primarily shoreline property owners and managers. The work of the four research teams involved a limited number of areas along Lakes Michigan and Huron, and the main issues and approaches explored through the assessment reflect the concerns focused on in those communities. As a result, there are certainly topics of concern that are not addressed by the work of the teams and this report. However, it is the hope of this project that many of the topics that are addressed in the report, as well as the approaches taken by the teams, will have relevance to other Lake Michigan and Huron communities and communities along Lakes Superior, Erie, and Ontario.

Lastly, the assessment does not provide detailed technical guidance or effectiveness analyses, nor did it involve implementation funding for the place-based teams. Certainly both technical and financial resources are critical to successful adaptation, and, in the case of the latter, some of the options addressed in the report aim to meet those needs.

NEXT STEPS

Although this project concludes, efforts around adaptation to water levels continue. It is our hope that the place-based work will inform local decision-making and that this Phase III report will assist other communities' thinking around options to consider. One benefit of an IA approach is that the work can help contribute to follow-on studies. Indeed, several members of the Wisconsin team now have a role in a project led by the Wisconsin Coastal Management Program that received a $840,000 Coastal Resilience Grant to help communities and property owners in Southeastern Wisconsin reduce damages from coastal hazards and sustain the operation of their coastal economic assets.[96]

More generally, a goal of this IA is that its engagement efforts would help to sustain work around the issue after the project ends. In the past, interest has peaked around periods of particularly high or low levels, but diminished when trends reversed. The framing of the issue around variability, rather than just highs or lows, reflects the dynamics of the lakes, uncertainty around the effects of climate change, and a desire to improve resilience over the long term.

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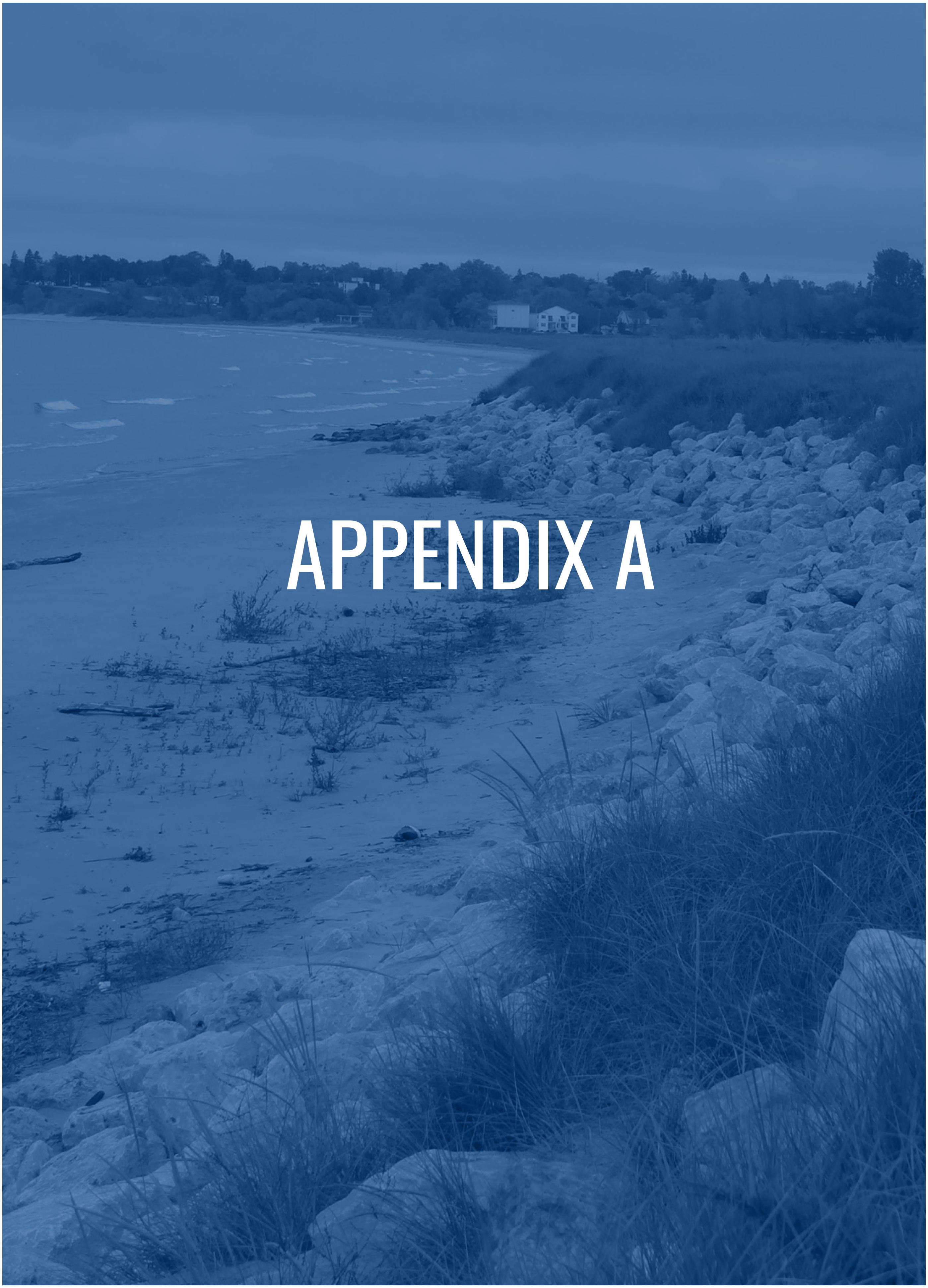
APPENDIX A



LIST OF OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS

These options were explored by the placed-based teams. They generally correspond to the options summarized in this report; however, some of the listed options are not discussed in this report. Refer to the Phase I and Phase II reports for additional details.

PLANNING & COORDINATION OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Among Jurisdictions		
Coordinate ordinances between municipalities	Municipalities along Lake Michigan shoreline in project area collaborate to create and maintain consistent ordinances	Wisconsin
Use model ordinances	Adopt Shoreline Tree Protection Bylaw, as done by the nearby Township, to prohibit or regulate impacts to trees along Lake Huron shoreline	Ontario
	Use model bluff and ravine ordinances with consistent terminology and definitions across jurisdictions	Wisconsin
Harmonize shoreline mapping and policies	ABCA and MVCA update and harmonize shoreline mapping and policies	Ontario
Form a Great Lakes Regional authority	Should an inter-state or international authority be formed to coordinate, regulate, and fund a big-picture, regional approach to lake management?	Wisconsin
Tribal Sovereignty		
Formal recognition of the LTBB by the State of Michigan	Offers a framework for future government to government agreements with the Tribe and State and Local Governments	Northern Michigan
With Non-Governmental/Non-Profit Partners		
Coordinate with non-governmental organizations	Non-profit Tip of the Mitt Watershed organization can assist LTBB and GTB collaboration with surrounding non-tribal communities	Northern Michigan
Shoreline residents' associations communicate between residents and local authorities	Bluewater Shoreline Residents' Association and Ashfield-Colborne Lakefront Association representatives continue to monitor, lobby, and communicate between residents and local authorities	Ontario
Funding Opportunities		
Pursue federal/provincial climate change funding	Pursue Canadian federal and provincial climate change grant programs (e.g., National Disaster Mitigation Program) for infrastructure investment	Ontario
Advocate for inclusion in plans and eligibility for climate change funding	Communicate bluff risk to provincial and federal governments to ensure it is a high risk issue for climate change disaster relief and infrastructure/stormwater management funding	Ontario

PLANNING & COORDINATION OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Funding Opportunities		
Consider a "Geographically Focused Initiative" under the Canadian Great Lakes Protection Act 2015		Ontario
Identify opportunities to "stack" fragmented stewardship funding & plans	Take advantage of available conservation grant programs to achieve prioritized, strategic goals	Ontario
Collective Funding Mechanisms for Shoreline Stabilization		
Voluntary collaboration with neighbors	Work together to share the costs of a larger shoreline stabilization project that benefits multiple properties	Wisconsin
Neighborhood Improvement District	Using Wisconsin ACT 186 (2005) neighborhoods can form an NID Board to develop and contribute to improvement projects.	Wisconsin
Create aid fund for bluff and shore properties	Formation of a fund for use in erosion control, bluff stabilization or managed retreats by properties along bluffs and shores	Wisconsin
Enhance Emergency Planning		
Notify property owners	Notify shoreline property owners of hazard land status as part of Emergency Management Planning (e.g., annual mailer with municipal tax bill)	Ontario
Participate in erosion emergency exercises	Exercises give local first responders an opportunity to test and refine their emergency plans	Ontario
Review emergency access	Municipalities review municipal road access to shoreline residential areas to ensure more than one secure access in the event of storms, flooding, or erosion	Ontario
Lobby for mandatory disclosure of natural hazard designation in real estate transactions	County, municipalities, and CAs lobby their local M.P.P, the Provincial Minister of Government and Consumer Services, Emergency Management Ontario, and the Ontario Real Estate Association	Ontario
Also see Education & Outreach > Outreach activities		

SHORELINE STABILIZATION & PROTECTION OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Structural Approaches (Gray Infrastructure)		
Revetment	A protective structure of stone/concrete/sandbags parallel to the shore with a sloping face designed to protect against wave erosion	Wisconsin
Sea wall	A vertical or sloping wall running parallel to the shoreline typically at base of bluff made of stone, concrete, steel/vinyl sheets	Wisconsin
Breakwater	Offshore structure made of stone/concrete blocks. Can be floating or built on lake bed; submerged; continuous wall or series of segments	Wisconsin
Groin	Perpendicular structures jutting into the lake from shoreline; made of stone or concrete rubble or steel sheet pile; often used on beaches	Wisconsin
Bluff regrading	Cutting into face of bluff to create shallower, more stable slope	Wisconsin
Groundwater drainage	Groundwater drainage systems can be added to drain groundwater and stabilize bluffs	Wisconsin
Non-structural Approaches (Green Infrastructure)		
Managed retreat	Moving structure back from edge of bluff; can be a last resort or can be performed pre-emptively with bluff regrading for long-term solution *Also see Land Use & Shoreline Management Policies > Managed Retreat*	Wisconsin
Artificial beaches	Adding sand/sediment to shoreline to restore beaches washed away by erosion	Wisconsin
Living shoreline	Using native plants and stones to resist shoreline erosion	Wisconsin
Greening of Gray Infrastructure		
Breakwater with living shoreline	Offshore "gray" breakwater built to reduce wave energy, allowing use of green approaches on shoreline for additional protection	Wisconsin
Living breakwater or artificial reef	Offshore structure built with porous material, often includes vegetation and sand on exposed portions	Wisconsin
Living revetment/sea wall	Use of native vegetation to improve stability of shoreline/bluff face behind an existing revetment or seawall	Wisconsin

LAND USE & SHORELINE MANAGEMENT POLICIES OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Setbacks for High-Risk Development		
Setback location	Retain 25 foot setback from lake	Southern Michigan
	Retain 25 foot setback from lake but disallow shifting current structures lakeward	Southern Michigan
	Adopt setback based on estimated 60-year shoreline erosion rate (consistent with Michigan's High Risk Erosion program)	Southern Michigan
	Adopt setback based on high-risk hazard line (landward extent of inundation and/or wash-over during extreme storm during historical high water levels)	Southern Michigan
Setback policy	Prohibit placing any new structure lakeward of the setback line	Southern Michigan
	Allow only readily moveable structures lakeward of the setback line	Southern Michigan
	Structures currently lakeward are nonconforming structures and must be removed if damaged by storm	Southern Michigan
	Owners of lakeward structures post surety bond for future damages	Southern Michigan
Stormwater Management & Soil Erosion Control		
Grant program updates	The Huron County Water Protection Steering Committee review its grant program with an eye to promoting/enhancing storm water management initiatives to reduce gully and bluff erosion	Ontario
Low Impact Development (LID)	Require non-structural best management practices in sensitive areas	Southern Michigan
	Incentivize participation in LID - offering development incentives only to those that employ best management practices that go beyond treating runoff	Southern Michigan
	Coordinate effort between the planning commission and public works department to advocate for and enable LID	Southern Michigan
	Enable LID in zoning regulations	Southern Michigan
	Adopt a stormwater utility program to provide incentives to participating in LID	Southern Michigan
Promote soil erosion control measures by farmers	Great Lakes Agricultural Stewardship Initiative (GLASI) offers advice and financial support for adopting all the major soil-related best management practices (BMPs) for farms in the Lake Huron watershed	Ontario
Adopt Shoreline Tree Protection By-laws to reduce rate of erosion		Ontario

LAND USE & SHORELINE MANAGEMENT POLICIES OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Policy Updates		
Establishing an ordinance/policy review mechanism	Establish a condition that results in an immediate review/revision of ordinances and policies (e.g. water level change of 6 feet, or 1.8 meters, in one year)	Wisconsin
Permitting		
As a mechanism for other aims	Require sediment impact study in site plans for new structure	Wisconsin
	Add fee to permit to create funds for monitoring of new structure	Wisconsin
	Include incentives for living shorelines (e.g., reduced permit fee)	Wisconsin
Consultation / Public notice and comment	Tribal governments utilize consultation and public notice and comment periods to provide input on state and federal wetland impact permits that may affect cultural or natural resources	Northern Michigan
Easing approval for offshore structures	Approving permits for offshore structures is complicated by impacts to navigation and effectiveness in variable lake levels. Promote new guidelines easing approval by allowing impacts to navigation to be offset by reduction in shoreline erosion and/or implementation of Living Shoreline practices.	Wisconsin
Construction Standards		
Updated bluff-top construction ordinances	Include stability and erosion considerations in construction ordinances	Wisconsin
Easements		
Pursue conservation & cultural conservation easements to protect resources in perpetuity		Northern Michigan
Managed Retreat/Relocation		
Provide information to property owners interested in relocating a structure away from a hazard area	Includes information on: available residential land and existing lots behind shoreline cottages within hazard land designated areas; process for severance or subdivision; construction firms capable of relocating structures; case studies	Ontario
Establish financial incentives for managed retreat	Waive fees for severance or other land-use planning processes	Ontario
Shoreline Access		
Consider future lake level fluctuations for future boat launch and multi-use marinas		Northern Michigan

LAND USE & SHORELINE MANAGEMENT POLICIES OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Coastal Dune Access & Fire Risk		
Existing efforts to plan for and practice emergency response		Southern Michigan
Widen roads and remove vegetation	Requires seeking permission within state-designed critical dunes in Michigan	Southern Michigan
Adopt wild fire hazard overlay district	Notify property owners within district that emergency services are not available; require fire suppression devices	Southern Michigan

OUTREACH & EDUCATION OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Outreach Activities		
Educational boat tours of the coast		Wisconsin
Annual workshop series on coastal erosion		Wisconsin
Annual mailer for property owners	"Do You Know" fact sheet advising of bluff erosion and hazard land status, with links to resources from CAs and conservation non-profit organizations	Ontario
Workshops for expert assistance	CA expertise is available to property owners for individual property risk assessments, information on land-use planning and regulatory/ permitting requirements, landscaping for slope stability, and contacts for geotechnical engineering.	Ontario
Encourage residents to review and comment on ABCA shoreline management plan updates	Updated mapping provides residents with a better idea of erosion rates (low, medium, substantial) for their properties	Ontario
Outreach to Tribal and non-tribal communities	Regarding protecting native vegetation during low lake water periods & the need to protect cultural sites	Northern Michigan
Resources		
Bluff vegetation guide		Wisconsin
Video series such as an explanation of coastal processes through a virtual tour of the coast		Wisconsin
Enhanced website to share comprehensive information on coastal processes and engineering		Wisconsin
Youth Education		
K-12 curriculum activities		Wisconsin
Tribal youth education	Programs integrate traditional environmental knowledge and western science around climate change, adaptation, and lake levels	Northern Michigan

OUTREACH & EDUCATION OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Maps & Visualizations		
Maps of bluff erosion rates & stability factors		Wisconsin
Maps of beach profiles at different possible water levels		Wisconsin
3D visualization of coastal erosion		Wisconsin
GIS story maps		Northern Michigan
Tools		
Erosion & bluff stability self-assessment guides		Wisconsin
Spectrum of erosion control methods		Wisconsin

OTHER APPROACHES OPTIONS GENERATED BY THE PLACE-BASED IA TEAMS		IA TEAM
Fisheries		
Utilize fish hatcheries to address potential impacts to spawning habitat from lake level fluctuations		Northern Michigan
Financial Incentives		
Include assessments of bluff stability or erosion rates in insurance rates		Wisconsin
Economic Development		
Coordinate tourism initiatives and Port Authority plans	Longer shipping seasons and a longer tourism season may present opportunities. In Goderich, Ontario both port and tourism planning will need to consider adaptation.	Ontario
Consider lake levels in growth plans and lakefront marketing	Bayfield is a tourism destination but infrastructure is vulnerable to lake level impacts (e.g., marinas, harbor depth, municipal infrastructure such as roads and bridges)	Ontario
Data & Analysis to Aid Decision-Making		
Assess impact of erosion on property values and property tax base		Wisconsin
Update recession rate and stability analyses		Wisconsin
Analyze and map bluffs which contribute the most sand to coastal beaches (feeder bluffs)		Wisconsin

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