Appendix C

COASTAL RESILIENCY PLAN

Financial assistance for this project was provided by the Michigan Coastal Management Program, Water Resources Division, EGLE, with funding through the National Coastal Zone Management Program.

EXECUTIVE SUMMARY: Coastal Dynamics and Mitigation Strategies for Grand Marais Bay

Burt Township is a natural paradise framed by the Pictured Rocks National Lakeshore (PRNL) and beaches, dotted with waterways, and blanketed in forests. Although the township covers 234.4 square miles, most residents live within the unincorporated community of Grand Marais on what is today the Lake Superior shore. Situated on one of the most beautiful bays in Michigan, Grand Marais hosts most of the commercial businesses within the township and is dotted with fishing shacks, a public marina, private rentals, residences, and a township park. The northwest corner of the bay is designated as a harbor of refuge and is dredged by the U.S. Army Corps of Engineers.

As picturesque as the setting may be, Burt Township's shoreline on Lake Superior is in constant flux. Township residents are concerned with the deposition of sand within the bay and the impacts of wind, waves and sediment movements on their current and future community. The Army Corps of Engineers is charged with maintaining a harbor of refuge in the bay, which has influenced and will continue to influence the complex natural dynamics that are inherent to Lake Superior. Climate change is making all of these dynamics less predictable and more extreme.

As called for in the township's 2023 Master Plan, this report aims to summarize the complex coastal dynamics influencing the bay in Grand Marais, with consideration of both natural forces and manmade interventions, to help inform Burt Township's community planning, zoning and development along its ever-changing shoreline. No community anywhere on the Great Lakes enjoys full local control over these challenges, but local communities can take measures on their own to become more resilient and adaptive to the ebbs and flows that will inevitably occur.

Some main takeaways for Burt Township include:

- Great Lakes shorelines are naturally in a constant state of change.
- Climate change is impacting the natural processes of the Great Lakes, making past observations and experiences less reliable as future predictors.
- The bay at Grand Marais is manmade, and human intervention is needed to maintain it.
- The township should develop a relationship and open lines of communication with the Army Corps of Engineers to understand maintenance approaches and schedules for the Harbor of Refuge and to seek "win-win" opportunities that benefit both the Harbor of Refuge and the community at large.

- Any development on or near the Lake Superior shoreline should be carefully considered in the context of the ever-changing conditions that are inherent to the Burt Township shoreline. To the greatest extent possible, local policies and actions should embody the need for resilience and adaptability along the shoreline, balancing use and enjoyment of the shoreline with the natural forces that are constantly working to modify it.

PURPOSE OF THE RESEARCH

The purpose of this research is to better understand the coastal dynamics that influence the bay in Grand Marais. There are some explanations of options, but it should be noted that these are not intended to be the only possible solutions. Due to the significant presence and influence from the activities undertaken and maintained by the Army Corps of Engineers, some things discussed in this research may not be applicable or may change over time.

Providing a harbor of refuge is the primary goal of the Army Corps of Engineers. For this reason, a dredging depth between 15-17 feet (with a maximum dredging depth of between 18-20 feet) is maintained through the channel to enter the bay in Grand Marais. This depth accommodates the ships that may seek refuge in the harbor during severe storms on Lake Superior.

To assist with maintaining these depths, seawalls have been installed on either side of the channel. These seawalls influence the movement of sand along the coast, which results in both the erosion (on the north) and deposit (on the south) of the sands throughout the bay. Due to the shape of the bay and lake dynamics happening on a larger scale, the bay itself becomes a natural depository for sands and sediment that move along the Lake Superior shoreline. Without maintenance or human intervention, the bay would likely continue to fill in along the south side and erode along the north side. It is important to note that this is an assumption based on the review of relevant information that is currently available. There are currently no scientific models that can illustrate the severity of these dynamics nor predict a timeline. Further research and study would have to be conducted that goes beyond the scope of this report.

CONDITIONS

Financial assistance for this project was provided, in part, by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Department (WRD), Michigan Coastal Management Program through funding provided by the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations in this report are those of the authors and do not necessarily reflect the views of EGLE or NOAA.

PROCESS

To better understand the process, the following tasks were undertaken:

- A literature review of existing information and past reports on the Grand Marais region was undertaken to delineate the history and prior findings with reference to the coastal dynamics in the area.
- Review of relevant maps (flooding, wave energy, etc.) and aerial photography dating back to the 1930s.

- Review of relevant reports and studies from Michigan Technological University (such as the 2001 Grand Marais Harbor Rehabilitation Design Alternatives), the US Army Corps of Engineers (Great Lakes Navigation System and harbor dredging charts), and the local community (2022 Alger County Hazard Mitigation Plan and Burt Township 2023 Master Plan).
- Interview with Guy Meadows, Director of the Marine Engineering Laboratory and Professor of Sustainable Marine Engineering at Michigan Technological University.

Before discussing some of the specific influences on the bay, it is important to understand that there are many outside factors that have an impact on the overall dynamics of the bay. These factors are more lake-wide, so it is important to understand the broader scope and its impact on more localized coastal dynamics, wave energy, and planning in Burt Township.

THE IMPORTANCE OF PLANNING IN COASTAL COMMUNITIES

The Great Lakes are one of the most unique and important environmental systems in the world. In fact, "the Great Lakes basin contains more than 20% of the world's surface freshwater supplies and supports a population of more than 30 million people."[1] The lake's ecosystem plays a key role in the environmental, social and economic makeup of the region. Michigan is home to nearly 3,300 miles of Great Lakes shoreline, along with 36,000 miles of rivers and streams, and 11,000 inland lakes.[2] Communities across the Great Lakes shoreline have an important role to play in ensuring the long-term sustainability of their shorelines. Riparian land (land adjacent to a water body) throughout Michigan is not adequately protected from development pressures.[3] This has been especially clear during high water periods, which communities across the state, including Burt Township, have experienced in recent years. In 2001, the Michigan Department of Environmental Quality (DEQ; now EGLE) acknowledged "fragmentation of coastal habitats, loss of agricultural and forest lands, increased impervious surfaces and resulting stormwater runoff, and the increased development in coastal hazard areas, wetlands, and Great Lakes Islands, could be improved through better coastal land-use planning."[4]

OVERVIEW OF COASTAL DYNAMICS AND THE GREAT LAKES

The Great Lakes function differently than other inland water bodies and tidal oceans. Understanding these dynamics can help Burt Township plan for naturally occurring changes along the shoreline.

> How are Great Lakes Water Levels Measured?
>
> Great Lakes water levels are measured via the International Great Lakes Datum (IGLD), a reference system of benchmarks at various locations on the lakes that approximate sea level. Great Lakes water levels are expressed as measurements above this reference elevation.

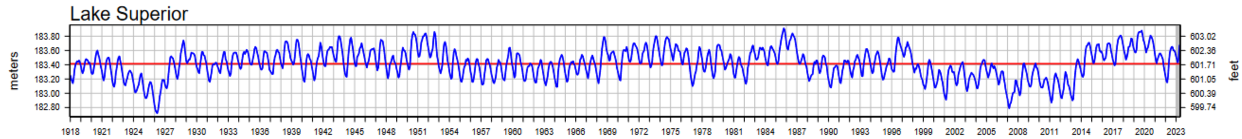
Footnotes

1. Mackey, S.D. 2012: Great Lakes Nearshore and Coastal Systems. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators
2. Ardizone, Katherine A. and Mark A. Wyckoff, FAICP. Filling the Gaps: Environmental Protection

Options for Local Governments, 2nd Edition. 2010.

3. As cited by Norton 2007 – Michigan Department of Environmental Quality. 2001. 309 Enhancement Grants Assessment/Strategy. Lansing, MI: DEQ Coastal Management Program.
4. Ibid

Figure 1. Lake Superior Water Level Changes, 1918 – 2023



Source: http://lre-wm.usace.army.mil/ForecastData/GLBasinConditions/LTA-GLWL-Graph.pdf

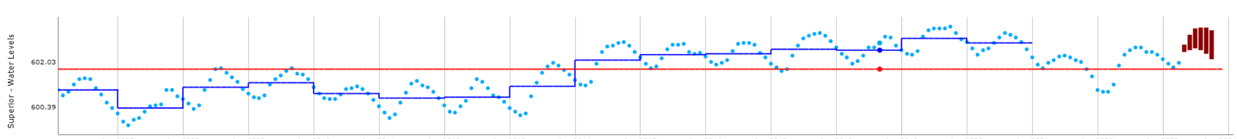
CHANGING WATER LEVELS OF THE GREAT LAKES

Great Lakes water level changes result not from the moon's gravitational pull, but from cyclical changes in rainfall, evaporation, and river and groundwater inflows.[5] These factors work together to raise and lower the water levels of the Great Lakes in small increments daily, and larger increments seasonally and over the course of years and decades. Long-term water levels fluctuate by multiple feet. Figure 1 illustrates the water levels of Lake Superior from 1918 to 2023. However, under certain climate conditions, water levels can dramatically fluctuate over short periods of time. For example, following the extreme winters of 2013 and 2014, water levels in Lake Superior rose between two to three feet from a low of 599 feet in 2011 and 600 feet in 2012.

The Great Lakes recently experienced a period of rising lake levels. Since the early 2000s, water levels had remained low, but historical patterns over the last century indicated that higher water levels were sure to return.[6] After a period of lows in 2013, Lake Superior's water level peaked in October of 2019 when it averaged 603.28 feet, which was 2.59 inches above its long-term average level for the month. According to a recent U.S. Army Corps of Engineers summary, based on current conditions, Lake Superior is seeing lake levels decline after seeing record highs throughout 2019-2020. It is important to note that the lake-wide annual average water level in Lake Superior has steadily increased and decrease in more rapid succession since average annual water levels were tracked starting in 1918.

It is important to note that changes in water levels are not solely responsible for the movement of the shoreline landward and lakeward over time. The velocity and height of waves, erosion of shorelines, and the pace of fluctuating water levels also contribute to coastal dynamics on the Great Lakes.

Figure 2. Lake Superior Water Levels Jan 2006 – Apr 2023; predictions through Oct 2023



Source: glerl.noaa.gov/data

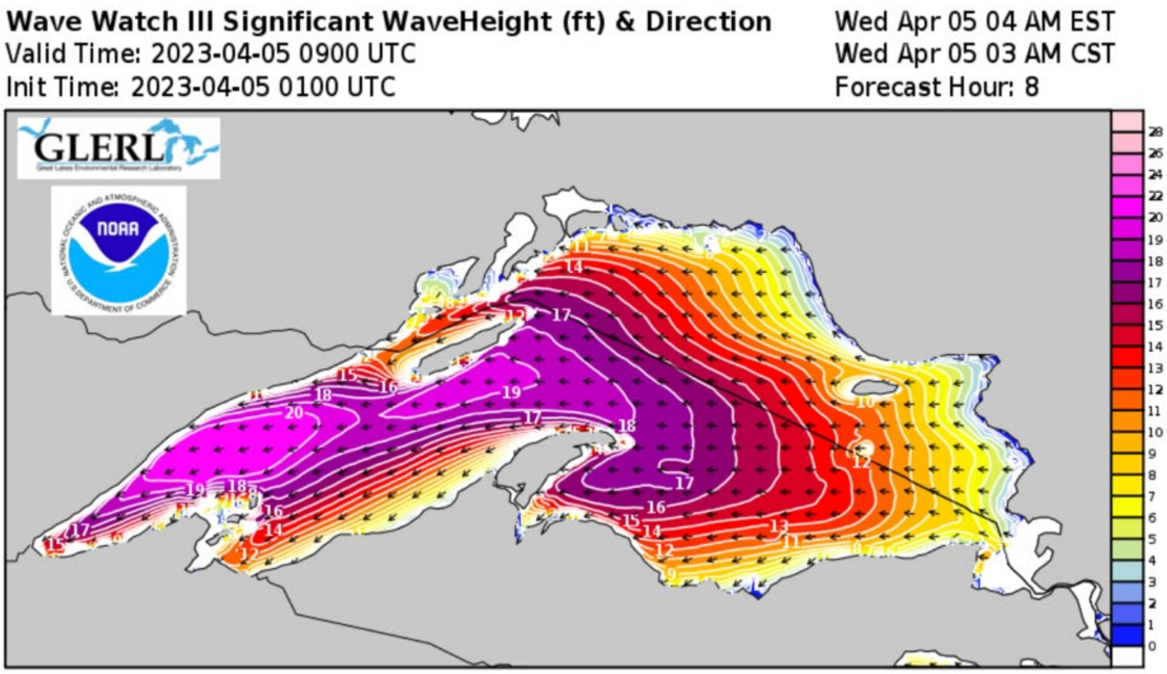
WAVE ENERGY AND HEIGHT

The Great Lakes experience high-energy waves and wave setup along the coastline. High-energy waves are high in speed and strong in intensity and are primarily created as fast winds move across the surface of the water for extended distances.[7] "Wave setup" is the height of the water as waves reach the shore. High wave setup results as regional storms create high winds on the Great Lakes.[8] Powerful and tall waves can quicken the rate of erosion and damage structures near the shoreline.[9]

On April 4th and 5th of 2023, the Marine Engineering Laboratory at Michigan Technological University collected wave gauge station data during a high-wave energy storm on Lake Superior. The data collected aided in modeling the potential for wave energy along the southern shoreline of Lake Superior (or the northern shoreline of Michigan's Upper Peninsula). Surface winds reached approximately 40 mph with wave heights reaching as high as 23 feet in parts of the lake.

The data collected is one of many instances that illustrates the potential for the power of the waves along the Lake Superior shoreline, waves that play a role in the movement of sand and sediment that impacts coastal communities.

Figure 3. Lake Superior Wave Height and Direction



EROSION

Some portions of the shorelines of Lake Superior are made of gravel and sands that easily erode during times of high-energy waves.[10] Coastal erosion can cause flooding and damage infrastructure along bluffs and beaches. Erosion is caused mainly by storms and winds and is exacerbated when lake levels are high.[11]

Footnotes

5. Norton, Richard K., Meadows, Lorelle A. and Meadows, Guy A. (2011) “Drawing Lines in Books and on Sandy Beaches; Marking Ordinary High Water on Michigan’s Great Lakes Shorelines under the Public Trust Doctrine.” Coastal Management, 39: 2, 133 – 157, First published on 19 February 2001 (iFirst).
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7. National Oceanic and Atmospheric Administration. “Coastal Currents” Ocean Services Education, NOAA, 25 March 2008. Web. Accessed July 2015.
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9. Ibid.
10. Ibid.
11. Meadows, Guy A., and Meadows, Lorelle, A., Wood, W.L., Hubertz, J.M., Perlin, M. “The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage.” Bulletin of the American Meteorological Society Series 78:4. (1997): 675-683. Print.

QUICKLY CHANGING CONDITIONS

The Great Lakes are contained in gradually shifting and tilting basins. This tilting results as the Earth slowly decompresses and rebounds from the immense weight of the glaciers that created the Great Lakes.[12] This shifting causes water levels to change more quickly in some places than others, because the shape of the water basin varies along the coast.[13] This attribute of the Great Lakes makes it difficult to predict the pace of shoreline movement. Therefore, it is safest to plan for great variability and rapid change in water levels.[14]

CLIMATE CHANGE AND THE GREAT LAKES

Each of the factors described in the previous section have implications for the Burt Township shoreline. In addition, these processes are expected to become more dramatic in scale and effect going forward. It is therefore important to understand how communities can meet these new challenges. This section will discuss climatologist predictions of increased precipitation and storminess in the Great Lakes region, variable lake water levels, and rising water temperatures. First, it is important to understand the global context of climate disruption.

GLOBAL CHANGES IN CLIMATE

Climate and weather are directly related, but not the same thing. Weather refers to the day-to-day conditions in a particular place, like sunny or rainy, hot or cold. Climate refers to the long-term patterns of weather over large areas. When scientists speak of global climate change, they are referring to changes in the generalized, regional patterns of weather over months, years and decades. Climate change is the ongoing change in a region’s general weather characteristics or averages. In the long-term, a changing climate will have more substantial effects on the Great Lakes than individual weather events.

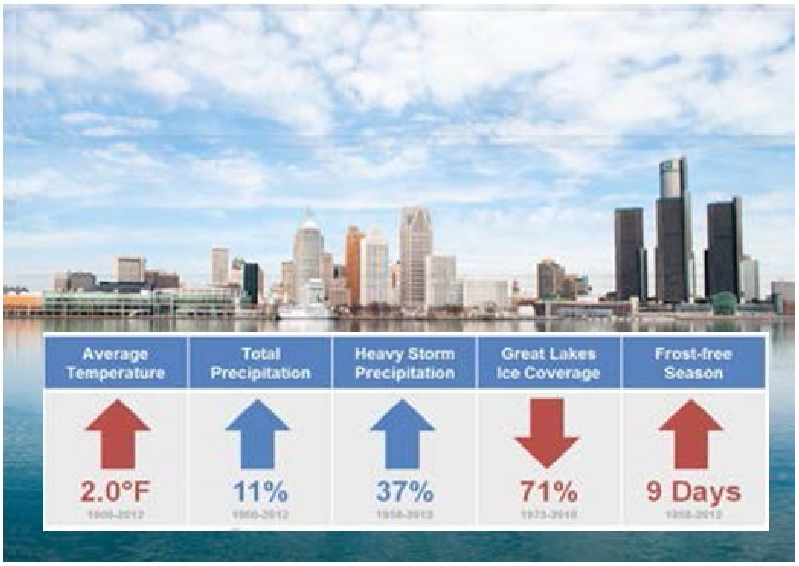
Evidence collected over the last century shows a trend toward warmer global temperatures, higher sea levels, and less snow cover in the Northern Hemisphere. Scientists from many fields have observed and documented significant changes in the Earth’s climate.[15] Warming of the climate system is unequivocal and is now expressed in higher air and ocean temperatures, rising sea levels, and melting ice.[16]

To help predict what the climate will be in the future, scientists use computer models of the Earth to predict large-scale changes in climate. These General Circulation Models (GCMs) have been improved and verified in recent years, resulting in relatively reliable predictions for climate changes over large regions.[17] Scientists downscale these techniques to predict climate change for smaller regions.

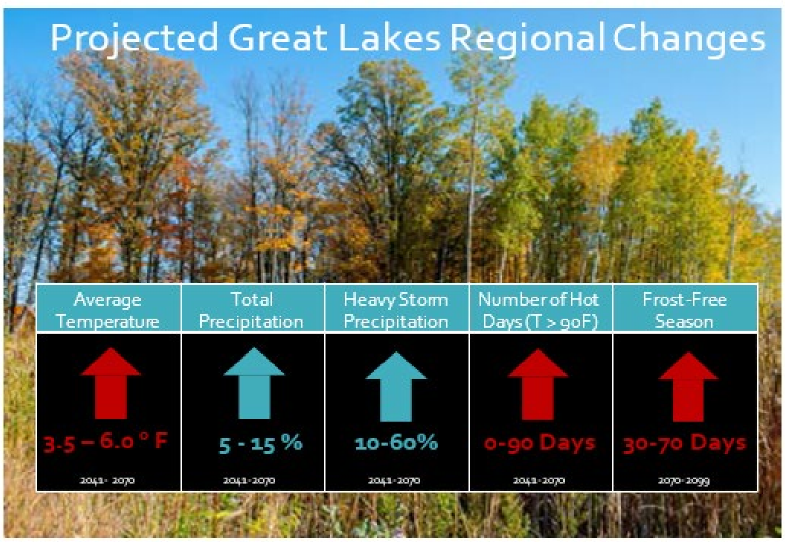
CLIMATE CHANGE ON THE GREAT LAKES

The Great Lakes Integrated Sciences and Assessments Program (GLISA) is a consortium of scientists and educators from the University of Michigan and Michigan State University that provides climate models for the Great Lakes region in support of community planning efforts like this Master Plan. Figure 4 illustrates the historical and predicted climate changes from GLISA for the Great Lakes region. According to GLISA, the Great Lakes region experienced a 2.3° Fahrenheit increase in average air temperatures from 1951 to 2017.[18] An additional increase of 3° to 6° F in average air temperatures is projected by 2050. Although these numbers appear relatively small, they are driving very dramatic changes in Michigan’s climate and greatly impact the Great Lakes.

Figure 4.

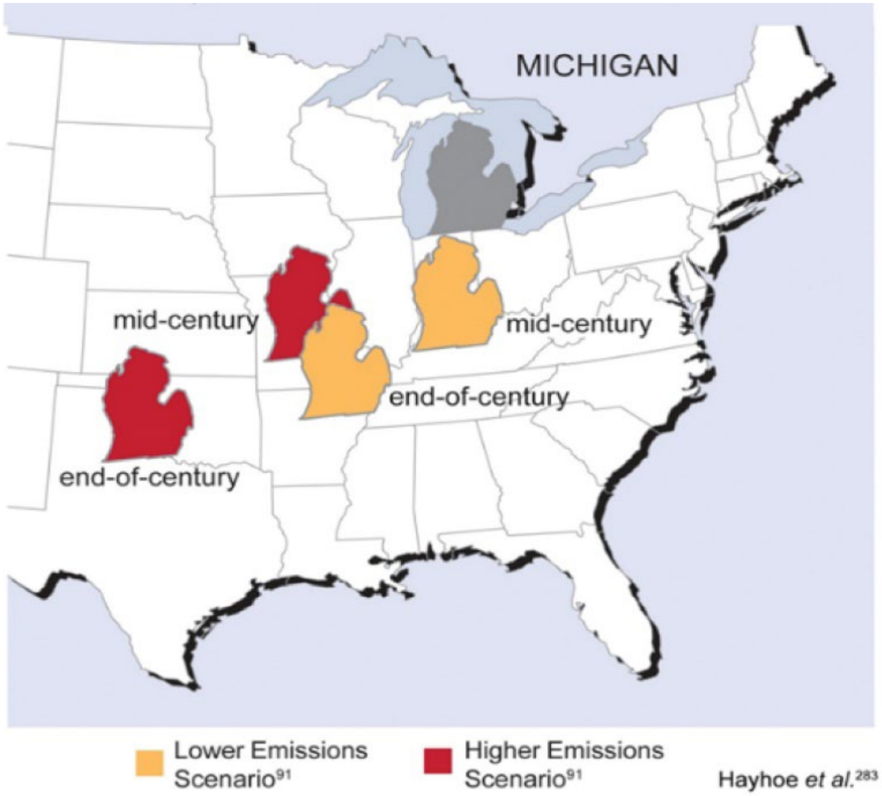


Average Temperature
2.0°F
Total Precipitation
11%
Heavy Storm Precipitation
37%
Great Lakes Ice Coverage
71%
Frost-free Season
9 Days



Projected Great Lakes Regional Changes
Average Temperature
3.5 – 6.0 ° F
2041- 2070
Total Precipitation
5 - 15 %
2041-2070
Heavy Storm Precipitation
10-60%
2041-2070
Number of Hot Days (T > 90F)
0-90 Days
2041-2070
Frost-Free Season
30-70 Days
2070-2099

Figure 5.



Model projections of summer average temperature and precipitation changes in Illinois and Michigan for mid-century (2040-2059), and end-of-century (2080-2099), indicate that summers in these states are expected to feel progressively more like summers currently experienced in states south and west. Both states are projected to get considerably warmer and have less summer precipitation.

The National Climate Assessment for 2009 included a number of illustrations to help us understand the extent and character of anticipated climate change impacts.[19] One of these illustrations, Figure 5, shows Michigan under several emissions scenarios, each leading to changes in Michigan's climate. Just by maintaining current emission levels, Michigan's climate will feel more like present-day Arkansas or Oklahoma by the end of the century.[20]

Footnotes

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13. Wilcox, D. A, Thompson, T.A., Booth, R.K., and Nicholas, J. R., 2007, Lake-level variability and water availability in the Great Lakes: U.S. Geological Survey Circular 1311, 25 p
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15. Intergovernmental Panel on Climate Change. (2007). Observed changes in the climate and their effects. Eb. Accessed July 2015.

16. Ibid.
17. Intergovernmental Panel on Climate Change (2013). What is a GCM? Web. Access July 2015
18. Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.
19. U.S. Global Change Research Program. Global Climate Change in the United States, 2009. Cambridge University Press, Cambridge, MA.
20. Ibid.

INCREASED PRECIPITATION AND STORMINESS

There is consensus among climate experts that storms greater in number and intensity will occur in the Great Lakes region as a result of climate change.[21] This is already happening as "the amount of precipitation falling in the heaviest 1% of storms increased by 35% in the Midwest from 1951 to 2017."[22] As storms drop more precipitation and generate stronger sustained winds, the Great Lakes will see stronger and higher waves. In addition to direct damage caused by storms, sustained increases in the number of storms and their intensity can both directly and indirectly pollute waters by overloading sewage and stormwater capabilities.[23] Increases in the intensity of storms also quickens the pace of erosion on Great Lakes shorelines. In fact, the Federal Emergency Management Agency (FEMA) projects approximately 28% of structures within 500 feet of a Great Lake shoreline are susceptible to erosion by 2060.[24]

VARIABILITY OF LAKE WATER LEVELS

The natural ups and downs in the water levels of Lake Superior will continue regardless of the impacts of climate change.[25] However, climate change is likely to augment this natural process, resulting in more variable water levels as warmer air temperatures result in fewer days of ice cover and faster evaporation.[26] In other words, lake levels will rise and fall faster and with even less predictability than in the past. Fortunately, much of Michigan's coastal infrastructure was built in previous decades during times of high water levels.[27] However, as we recently experienced, fast-rising waters can erode shorelines, damage infrastructure, and cause extensive flooding in inland rivers.[28] When lake levels fall, access to infrastructure like docks may be restricted and navigation hazards in shallow waters may be exposed. Low lake levels pose a threat to coastal vegetation and can reduce the pumping efficiency of drinking water intake pipes.[29] Additional ramifications of changing lake levels include a drop in water supply,[30] restricted fish habitats,[31] more invasive species,[32] faster erosion, and an overall decline in beach health.[33] Climate change is likely to augment the natural highs and lows of lake levels, causing more variability and a faster rate of change, making each of these potential ramifications both more likely and less predictable.

Footnotes

21. Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed December 2019.
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25. Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.
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27. Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web.

Accessed July 2015.
28. Ibid.
29. Ibid.
30. Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.
31. Ibid.
32. Ibid.
33. Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

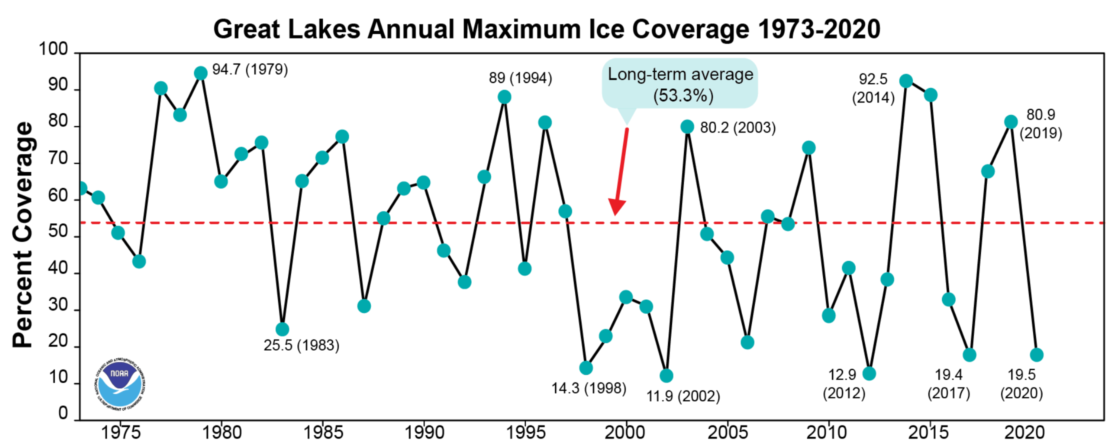
WATER TEMPERATURE

Climatologists predict there will be fewer days below freezing in Michigan and other Great Lakes states. As temperatures remain warm for a greater part of the year, the winter season will shorten and the lake ice cover that accompanies winter weather will decline. In general, annual average ice cover on the Great Lakes underwent a shift from higher amounts prior to the 1990s to lower amounts in recent decades. However, there remains strong year-to-year variability, and high ice years are still possible.[34] Figure 6 illustrates the variability in ice coverage in the Great Lakes between 1973 and 2020.

Lake ice cover allows heat radiation from the sun to be reflected, so when ice declines, the surface water temperature will increase as more heat is absorbed by the water. In the Great Lakes, average summer lake surface temperatures have been increasing faster than the surrounding air temperatures, with Lake Superior surface temperatures increasing by 4.5°F between 1979 and 2006.[35]

The associated impacts of rising water temperatures include changes to where fish and other aquatic animals can live, increased vulnerability to invasive species, and increased risk of algae blooms.[36] Rising water temperatures also enable winds to travel faster across the surface of the lake, increasing the vulnerability of coastal communities to damaging waves as storms and winds increase.[37] Lastly, ice cover protects the shoreline during winter storms. With less ice cover, the shoreline is more susceptible to erosion and habitat disruption.

Figure 6.



Footnotes

34. Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.
35. Ibid.
36. Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.
37. Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

DEFINING VULNERABILITY IN THE COMMUNITY

The effects of climate change have been felt by everyone. With planning and preparation, communities can weather the storms and recover, becoming even better places to live and thrive. Through community-wide planning, resilient communities actively cultivate their abilities to recover from adverse situations and events, working to strengthen and diversify their local economies and communication networks, increase social capital and civic engagement, enhance ecosystem services, improve human health and social systems, and build local adaptive capacity.

BUILDING COMMUNITY RESILIENCE

As defined by the Urban Sustainability Directors Network, community resilience is the ability of a community to anticipate, accommodate and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality and conservation of resources for present and future generations.

The Rockefeller Foundation emphasizes equity as an important component of resilience, stating that community resilience is the capacity of people — particularly the poor and vulnerable — to survive and thrive no matter what stresses or shocks they encounter. Communities that are resilient are able to learn from adversity and adapt quickly to change. In general, the most important qualities of resilient communities are: (1) Reflective, (2) Flexible, (3) Integrated, (4) Robust, (5) Resourceful, (6) Redundant and (7) Inclusive.

The Rockefeller Foundation has identified 12 indicators within these qualities that make for a resilient community (see inset). However, it is important to acknowledge that Burt Township is unique, and not all of these indicators or characteristics may be necessary for the community to be “resilient.” The key for Burt Township and for all Great Lakes communities is to understand that, while there are forces impacting local communities that are well beyond local control, there are measures that can be taken locally to prepare and strengthen the community to absorb a hit and come back stronger than ever.

According to the Rockefeller Foundation, a Resilient Community has…

1. Minimal human vulnerability
2. Diverse livelihoods and employment
3. Effective safeguards to human life and health
4. A collective identity and mutual support
5. Comprehensive security and rule of law
6. A sustainable economy
7. Reduced exposure and fragility
8. Effective provision of critical services
9. Reliable mobility and communication
10. Effective leadership and management
11. Empowered stakeholders
12. Integrated development planning

CLIMATE VARIABILITY

Based on the most recent models, the climate of Alger County will continue to warm, with greater increases in average temperatures during the winter months and at night. There are a variety of weather impacts expected with this change in average temperatures. Some of the potential impacts of climate change in the community are listed below:

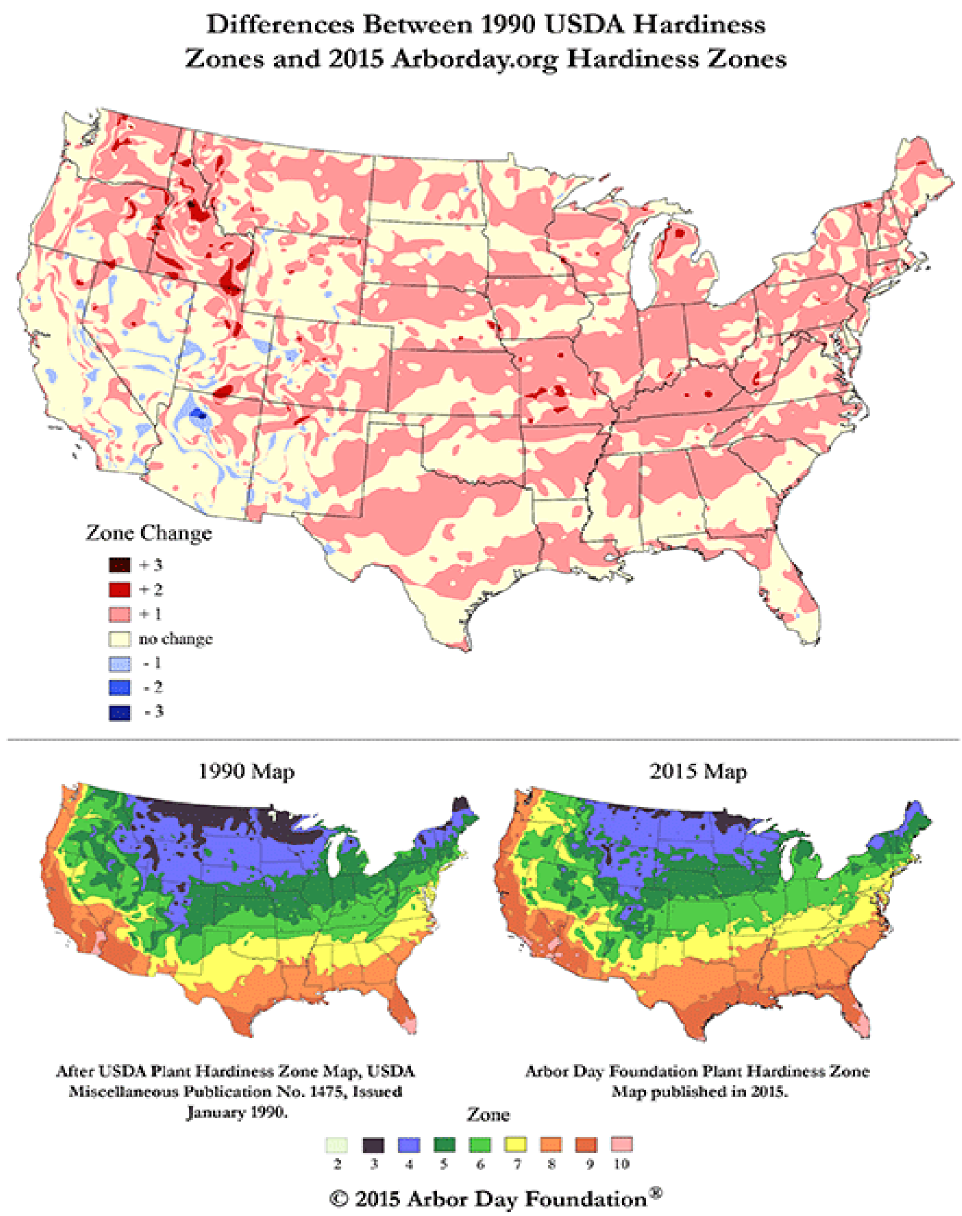
- Storms are expected to become more frequent and more severe
- Increases in winter and spring precipitation
- Less precipitation as snow and more as rain
- Less winter ice on lakes
- Extended growing season (earlier spring/later fall)
- More flooding events with risks of erosion
- Increases in frequency and length of severe heat events (heat waves)
- Increased risk of drought, particularly in summer

It is important to note that increased flooding and more intense drought are not mutually exclusive nor contradictory. In the Great Lakes region, scientists are predicting more intense rain events in the fall and winter along with more intense droughts in the summer months.

These changes in climate could have a number of both positive and negative effects in Burt Township.

For example, an extended growing season could help support new crops and increase crop yields for area farmers. On the other hand, the highly variable weather conditions — such as severe storms and flooding mixed with summer droughts — present big challenges to farming. Much of the U.S. has been warmer in recent years, and that affects which plants grow best in various regions. The Arbor Day Foundation completed an extensive update of U.S. Hardiness Zones based on data from 5,000 National Climatic Data Center cooperative stations across the continental United States. As illustrated in Figure 7, zones in Michigan are shifting northward. A few decades ago, the Upper Peninsula was predominantly in Zone 4; today, Zone 5 plants that once thrived far to the south are now increasing their range.

Figure 7.



HEAVY RAIN AND FLOODING

Climate scientists say that Alger County and all of the Upper Peninsula of Michigan can expect more frequent storms of increasing severity in the decades ahead. The total amount of rainfall per year is also likely to increase. However, climate models suggest the precipitation will be more concentrated in the winter, spring and fall seasons and there will be more localized, intense storms at almost any time of year. The potential for substantially larger rain events raises concerns over the potential for harm to human health and damage to land, buildings and infrastructure.

In assessing vulnerability, community planners must evaluate potential exposures as well as sensitivity. Buildings, roads, sewer lines and other infrastructure located near the shoreline are exposed to greater risks. When waters in Lake Superior rise, the movement and deposition of sand becomes more intense. This would contribute to the continued deposition of sand along the south side of the bay while eroding the north side of the bay. This topic will be discussed in further detail in the next section.

WHAT IS HAPPENING TO THE BAY IN GRAND MARAIS?

As discussed, there has always been sand movement along the shoreline. Dynamic and ever-changing water levels on Lake Superior as well as a changing climate are contributing causes to the increase in the sand migration near Grand Marais. Major factors include increased wind and wave energy because of more volatile and frequent storms on the lake.

The prevailing winds on Lake Superior typically move from the west to the east. As the wind moves the waves along the coastline, the waves pick up sand from the shore as they move out, which is called backwash. The waves then deposit the sand farther down the coastline, which is called swash (Figure 8). This is repeated over and over again through a process called *longshore drift,* moving the sand from the west to the east along the southern shoreline of Lake Superior (Figure 9).

Figure 8.

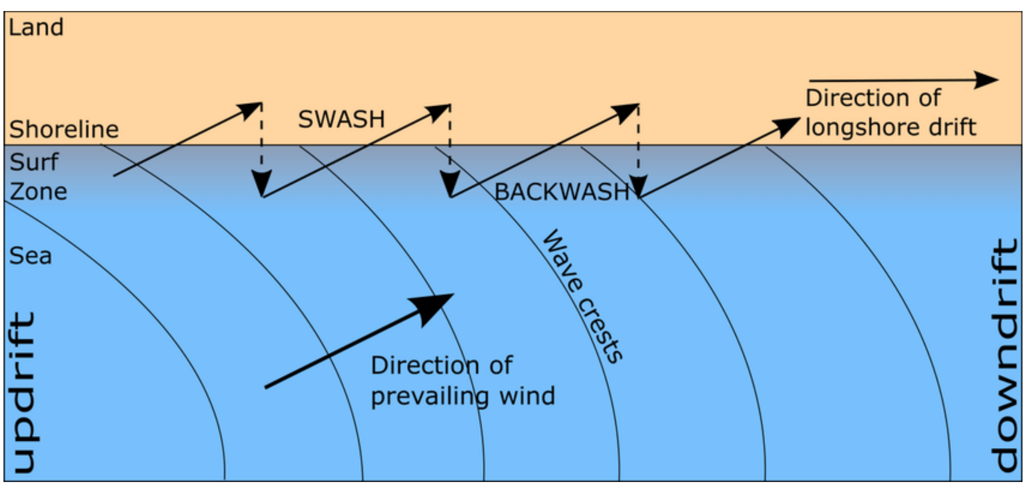


Figure 9.

According to an air photo from Michigan State University's Aerial Imagery Archives that was taken in 1939 (Figure 10), the bay in Grand Marais used to be an inland lake not dissimilar from Muskallonge Lake (Figure 11), which is located farther to the east. An inlet was dredged from Lake Superior into the lake.

Figure 10.

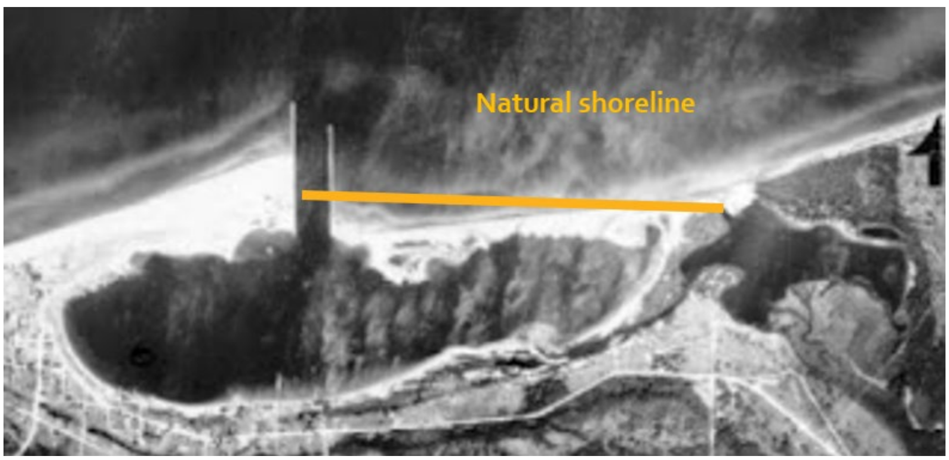
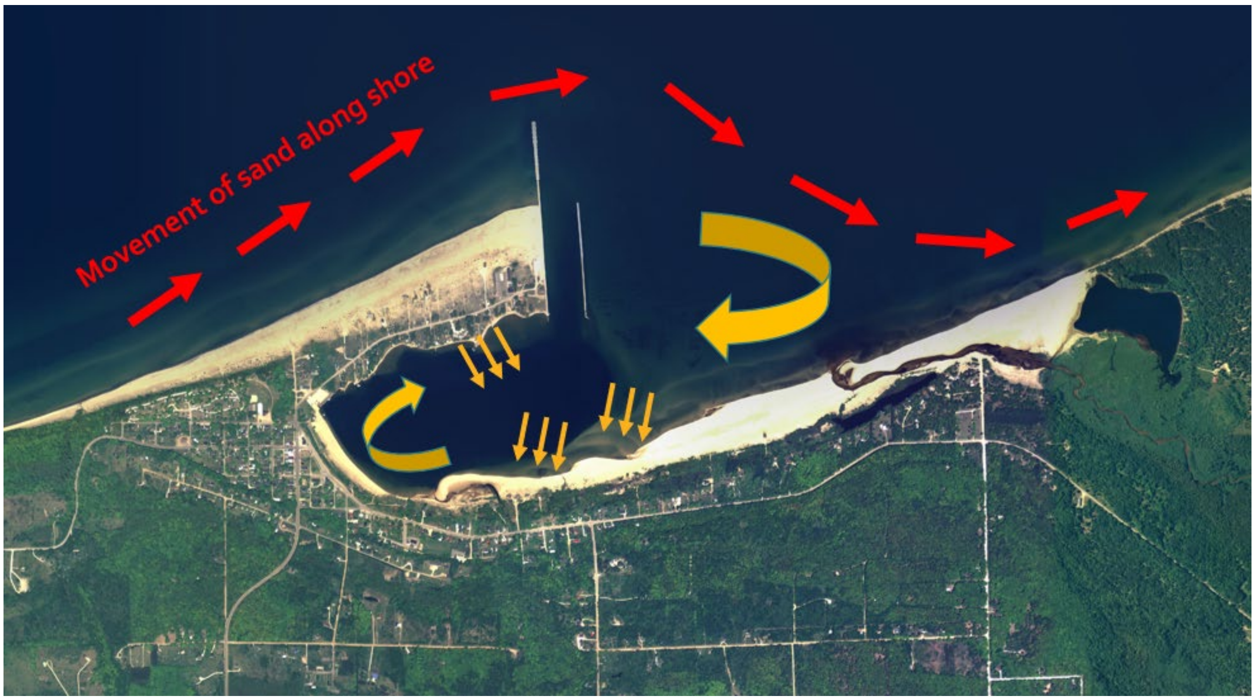


Figure 11.

After the installation of two piers, the natural movement of sand along the shoreline was obstructed. The sand began to deposit on the west side of the west pier and never made it around to be deposited on the other side. This resulted in the constant buildup of sand on the west side of the piers. Meanwhile, the beach on the east side of the pier was eroded by the wave energy. Eventually, the eastern beach was eroded away and the wave energy began to swirl around the newly formed bay. As it swirled around the bay, sand was deposited on the south shore of the bay. The wave energy then reversed direction as it entered the bay, and eroded the north side of the bay as it exited the bay (see Figure 12).

Figure 12.



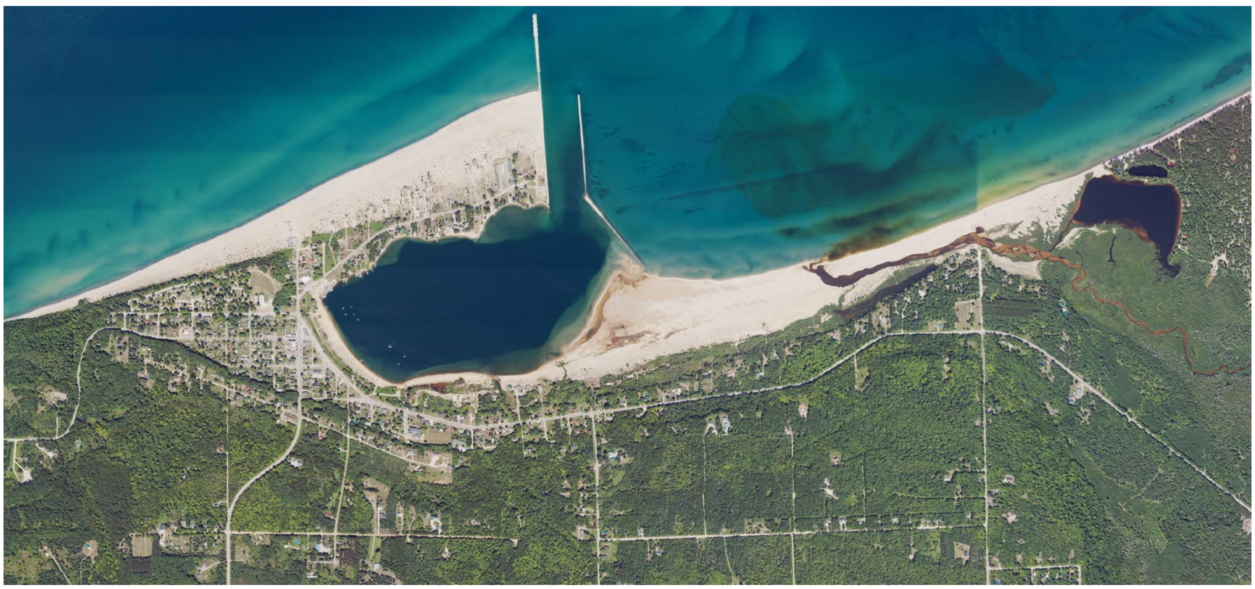
The Army Corps of Engineers is primarily responsible for the maintenance of the piers and bay, as it is maintained to allow for a Harbor of Refuge from storms. To help reduce the need for dredging due to sand movement around and within the bay, a new breakwall was installed in 2012 to catch the swirling motion of the waves, thus allowing sand to be deposited along both sides of the breakwall and preventing more sand from being deposited within the bay. Figure 13 shows the progression of the sand deposition before and after the installation of the breakwall. Figure 14 shows the circulation of wave energy today.

Figure 13.

Above: Photo from 2010

Above: Photo from 2014

Above: Photo from 2018



Above: Photo from 2022

Figure 14.

COMMUNITY MITIGATION OPTIONS

When the 2001 Grand Marais Harbor Rehabilitation Design Alternatives Study was conducted, the option to establish a sand bypassing program was chosen for implementation. This option could have been achieved in one of two ways: an annual maintenance dredging, or a continuous permanent bypass facility.

- Annual Maintenance Dredging: The first option consisted of periodic maintenance dredging of material trapped by the west jetty as well as dredging of the entrance channel. This material would then be placed either directly on the beach or in the nearshore zone as feeder material to a downdrift location. Proper placement of the feeder beach would limit the amount of sand available to travel back to the west into the bay.
- Continuous Permanent Bypass Facility: The other option was the construction of a pile dike breakwater, which was chosen and implemented in 2012. Continued dredging of the inlet is still needed with this option. The Army Corps of Engineers also used a Harbor Resonance Model to predict how much sand might bypass the bay and where it would be deposited. The study did indicate that sand would continue to pile up along the new breakwater as well as between the breakwater and coast, which is exactly what is happening today.

PROPERTY-LEVEL MITIGATION OPTIONS

Community members across the Great Lakes shorelines are beginning to recognize the importance of long-range planning when it comes to their coastal development. For example, times of low water often beckon property owners to build in beach and dune locations that appear suitable for a permanent structure, but these properties experience inundation when high waters return. Many communities continue to allow risky development patterns along their shoreline. This section briefly describes how planning processes can help the community make more informed and deliberate decisions going forward.

The first issue that comes with short-term coastal planning is that it is almost always reactionary. Rather than restricting high-risk development when waters are low, many coastal jurisdictions are being forced to respond to shoreline erosion and flooding with expensive engineered solutions that have demonstrated negative consequences for ecological sustainability and beach health. While this may save the property owner's infrastructure at that moment, it is also vital to recognize the potential degradation of nearshore habitat, the potential loss of the natural beach, the cost of cleaning up failed revetments, and the negative effects hardened shorelines can have on neighboring properties.

Thus, communities have difficult decisions to make regarding their shorelines. These consequences have prompted many communities to reevaluate the short-term mitigation options that are available to communities.

SHORT-TERM MITIGATION OPTIONS

In the short term, communities that face erosion and flood damage to structures are really left with three options: they can armor the shoreline, nourish (i.e., add sand to) the beach, or relocate structures. Each of these works to ease the problem in the short term, but comes with a series of pros, cons and interests as illustrated in Table 2. To summarize, armoring slows erosional processes but is only a temporary solution and one that can destroy the natural beach by interrupting the natural flows of sediment that would otherwise replenish lost sand. Beach nourishment can also slow erosional processes but is often costly, especially when considering that it can take just one storm to wash away the nourished beach sand and the public's investment. Relocation is perhaps the best short-term solution to save both the beach and the structure, but zoning setbacks, easements and cost can all hinder this as a viable option.

Table 2. Short-Term Mitigation Options, Pros and Cons

	Armor	Nourish	Relocate
Pros	Slows erosional processes	Slows erosional processes	Conserves natural Public Trust beach and shoreline
Cons	Loss of natural shoreline and Public Trust beach; damage to neighboring shoreline	Short-term solution (e.g., one storm may destroy the investment)	Cost of relocation, loss of land
Owner's Interest	Safeguarding infrastructure prioritized over the cost of armor, loss of Public Trust beach, and damage elsewhere	Safeguarding property and structures prioritized over cost and feasibility	Preservation of infrastructure and natural shoreline prioritized over cost of relocation
Public Interest	Owner's interest prioritized over loss of natural beach and potential future public cost of cleanup when armor fails	Safeguarding property and structures prioritized over cost and feasibility	Preservation of natural beach prioritized over cost of relocation and loss of land

Footnotes

1. Prosser, D.J., Jordan, T.E., Nagel, J.L., Seitz, R.D., Weller, D.E., Whigham, D.F. (2018). Impacts of Coastal Land Use and Shoreline Armoring on Estuarine Ecosystems: an Introduction to a Special Issue. Estuaries and Coasts 41 (S1).
2. Wensink, S.M. & Tiegs, S.D. (2016). Shoreline hardening alters freshwater shoreline ecosystems. Freshwater Science 35 (3).

LONG-TERM MITIGATION OPTIONS

Local policy options to address coastal erosion often involve a combination of regulatory measures, land-use planning, and community engagement. The township's 2023 Master Plan urges the community to "take the long view" in preserving, enhancing and protecting the very characteristics that make the township a desirable place to live and visit. Some policy options Burt Township can consider include:

- Zoning and Setback Regulations: The township's 2023 Master Plan repeatedly calls for the use of low-impact development strategies, and recommends that the township revisit assigned setbacks and buffers from water bodies to ensure they are adequate in the face of more frequent and intense storm events as well as greater fluctuations in water levels. Setback regulations can help prevent risky development close to the shoreline, reducing vulnerability to erosion and other coastal variables due to lake level rise, wave and wind energy, and sand deposition due to human activity, such as the installation of breakwalls. Codes should also consider allowing retreat from the shoreline (e.g., lot sizes that would allow for existing structures to be moved farther away from the shoreline as needed).

- Land Use Planning: Develop comprehensive coastal management plans that account for erosion risk and guide development away from high-risk areas. Consider land-use planning tools such as overlay districts to designate sensitive coastal zones and establish appropriate land uses. The 2023 Master Plan repeatedly emphasizes the protection of water quality in the harbor and suggests the creation of a formal harbor management plan.

- Building Codes and Standards: Enforce building codes that require structures to be designed and constructed to withstand coastal hazards. The township's 2023 Master Plan recommends that trailers/mobile homes be kept off waterfront lots, and recommends that building heights be limited along the waterfront to preserve views of the bay and Lake Superior.

- Coastline Nourishment Programs: Consider programs to periodically replenish eroded beaches with natural features that enhance the natural protective buffers. Coordinate with the appropriate state and federal agencies (particularly with the Army Corps and EGLE) to ensure the sourcing of sand aligns with ecological considerations.

- Vegetative Stabilization: Promote the use of native vegetation to stabilize coastal soils and reduce erosion. Implement landscaping regulations that encourage the planting of vegetation with strong root systems. Encouraging native vegetation also supports goals in the township's Master Plan related to protecting habitat corridors for wildlife and protecting the dunes, waterways and quiet natural spaces within the township.

- Revetments and Seawalls: Regulate or eliminate the construction of hard structures like seawalls and revetments, particularly to minimize adverse impacts on neighboring properties, ecosystems and beaches. If any are allowed, consider conditional permits for such structures, requiring periodic assessment of their effectiveness.

- Erosion Monitoring and Early Warning Systems: Invest in erosion monitoring programs to track coastal changes over time. Implement early warning systems to alert residents and authorities about imminent erosion threats, providing time for evacuation or protective measures. The Army Corps may already be conducting some monitoring as part of its care for the Harbor of Refuge.
- Community Education and Outreach: Conduct outreach programs to educate residents about the dynamics of the bay and the importance of sustainable coastal development.
- Managed Retreat Strategies: Develop policies that acknowledge the inevitability of some level of coastal retreat in the face of severe erosion. Establish managed retreat plans to guide the gradual relocation of at-risk structures away from eroding shorelines.
- Collaboration with State and Federal Agencies: Collaborate with state and federal agencies to access funding, technical expertise, and resources for projects and ongoing efforts. Align local policies with regional coastal management strategies.

Not all of these choices may be appropriate for Burt Township; local policymakers can tailor these options to the specific characteristics and needs of the township while considering potential tradeoffs and engaging stakeholders in the decision-making process.

CONCLUSION

The bay at Grand Marias is not a naturally occurring feature along the Lake Superior coastline. The Army Corps of Engineers identified a former inland lake along the coastline and cut an opening into it to be used as a safe harbor for ships. Through natural processes, the lake became a bay in Lake Superior and likely would fill in with sand if there were no human interventions to maintain the harbor. The ongoing natural process of longshore drift will continue and likely intensify over the coming years as the storms on Lake Superior intensify while wave and wind energy increases. These factors along with the regular rising and falling of water levels will continue to contribute to the shifting of the sands in the bay.

There is no one-size-fits-all solution to promote a resilient coastline and to maintain the bay, but with its new master plan and this study, Burt Township has begun to craft a long-term vision for its shoreline. In this way, the community will be better prepared to address the issues that arise from living on the shoreline, and to make decisions that balance the interests of property owners with the public interest in maintaining a healthy shoreline.