



## Changes Affecting Coastal Processes



## Impacts and Vulnerabilities



## Adaptation Strategies



Photo: Dave Miess



## CHAPTER SIX

# COASTAL RESOURCES

Wisconsin is one of 30 coastal states in the country and one of only eight states with a Great Lakes coastline. The southern shore of Lake Superior runs more than 150 miles along northern Wisconsin; an additional 175 miles of coast is created by Lake Superior's Apostle Islands. Along the state's eastern side, Lake Michigan – including Green Bay – provides more than 400 miles of coastline. Wisconsin boasts a wealth of coastal resources, including 38 cities and villages with frontage on the Great Lakes (figure 1).

Wisconsin's coastline includes natural resources such as bluffs, estuaries, wetlands, dunes and beaches as well as economic activities like shipping and tourism. Four of the state's largest cities, Milwaukee, Green Bay, Kenosha and Racine, are located on the coast, which exerts a powerful influence on the infrastructure, economy and culture of these urban centers.

Wisconsin's Great Lakes coastal regions will face the same changes in climate faced by land areas plus a few that are more prevalent over large lakes than on land. These include projected increases in air temperature; precipitation during fall, winter and spring; heavy precipitation events and evaporation resulting from warmer temperatures and reduced ice cover. In addition, wind strengths have increased over the lakes and are expected to increase more in the future. These climatic changes are expected, in different measures, to influence lake levels, coastal erosion, spring flooding and shoreline stability. Along with long-term changes in lake levels, we expect the natural variability that occurs over the course of decades to continue. All of these climate changes affect both the natural and built environments. Certain habitats and structures are more vulnerable than others.

In this chapter, we discuss the effects of climate change on the natural and built environments of Wisconsin's coastlines, examine potential impacts and vulnerabilities, and recommend strategies for adaptation. Our information is in the early stages of development. Many uncertainties remain as climate projections improve and our understanding of the coastal zone advances.



Figure 1. Wisconsin's Coastal Counties.

Source: David Hart, University of Wisconsin Sea Grant Institute.



# Changes Affecting Coastal Processes

As discussed in previous chapters, climate change will affect natural and built habitats across the state, and the impacts of those changes will differ from region to region. The coastal regions of Wisconsin present unique vulnerabilities, and we focus here on three climate change effects that will impact the natural and built environments of the coast if temperatures continue to rise, precipitation increases, and intense rainfall events become more frequent:

*Reduced ice cover:* Historical analyses reveal that water temperatures in the Great Lakes have been increasing over the last 50 years and ice cover has decreased. In a study of Bayfield harbor in northern Wisconsin, records show that ice covers the lake 45 fewer days annually than it did 150 years ago. We expect these changes to continue.

*Changing lake levels:* Water levels are expected to decline slightly, on average, but also to continue to exhibit large variation over decades, as they have in the past 100 years or so (figure 2). The scientific consensus is that average water levels of Lake Michi-

gan and Lake Superior will fall 0.8 to 1.4 feet by the end of the century, with Lake Superior falling less than Lake Michigan. The combination of warmer temperatures and reduced ice cover will contribute to greater evaporation, which will eventually exceed the increases in

precipitation that have been occurring. Water levels will vary widely around their averages; hence, adapting to the variability in water levels and the long-term effects of climate change will require that we continue to address both high- and low-water decades. The general expectation is that by the end of this century, the

The combination of warmer temperatures and reduced ice cover will contribute to greater evaporation, which will eventually exceed the increases in precipitation that have been occurring.



Photo: Dave Mickelson

*High water and large waves combine to contribute to severe erosion at the base of bluffs. This bluff is on the Lake Superior shoreline.*



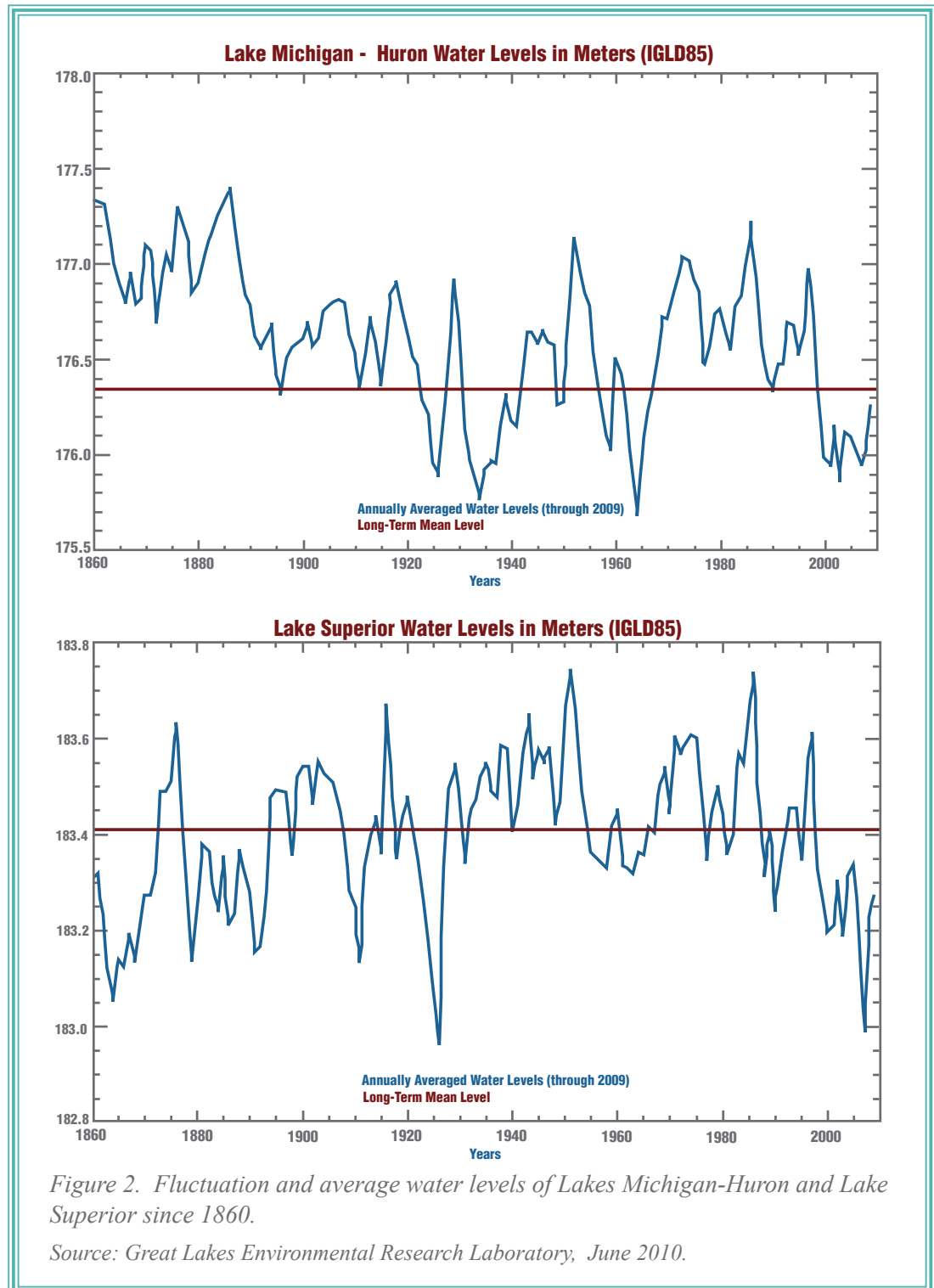
Photo: Gene Clark

*Dredging may be required to deepen channels in marinas during periods of low water.*



highest and lowest water levels will be slightly lower than they have been over the past 100 years.

**Increasing wind strength:** Scientists make the case for increasing wind strength over Lake Superior based on observations and physical dynamic simulations. Increased wind strength will lead to greater offshore wave development in the Great Lakes. With larger waves forming offshore, we can expect higher waves along the coast. These bigger waves will impact the shoreline, including bluffs, lakebeds and built structures.



# Impacts and Vulnerabilities

These effects of climate change on coastal resources will impact natural habitats such as beaches and wetlands as well as the facilities and infrastructure of the built environments along the coast. Below we discuss these impacts on a range of coastal habitats.

## Natural Environment

*Shore erosion and recession:* Erosion is the process of wind, water or gravity transporting sediment, dirt and rocks from one area to another. As wind strength increases over the lakes, stronger waves could influence shoreline and lakebed erosion rates on Great Lakes coastlines. Additionally, with the lakes remaining ice-free for longer stretches of time, shorelines are exposed to waves for longer periods, causing more erosion. Large precipitation events are expected to be more common in fall, winter and spring, and the shorelines with less ice cover will be more vulnerable to these increased events. Bluffs could also become less stable if soils are saturated with moisture more of the time.

When lake levels drop and remain low for a long period of time, erosion or down-cutting of the lakebed will result (figure 3). This lakebed erosion will then allow more storm waves to reach farther inland when the water level eventually rises again and can lead to more severe shoreline damage.

A key factor in the stability of bluff soils is the amount of water in the soil. The friction between soil particles holds them in place, and when water fills those spaces, the soil becomes more fluid and less stable. This means that if climate change brings increased precipitation or heavy storms, an increase in the number of freeze-thaw cycles or higher lake levels, shoreline bluffs will become less stable and more susceptible to slumping – a process in which bluffsides collapse and slide downhill. Additionally, as Wisconsin sees the early onset of spring, early snow-melt – especially when accompanied by large rainfall events – can

trigger bluff slumping as soils become saturated with meltwater.

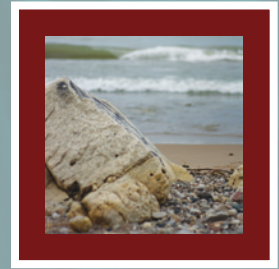
On the other hand, drought or prolonged dry periods can also affect the stability of coastal bluffs. As bluff soils dry out, cracks a few inches deep can form, weakening the surface soils. If long-term drought occurs, deep fractures can form, allowing rapid access for surface water to penetrate deep into the bluff soils. If heavy rainfall events occur following a drought, they may cause rapid saturation of these dry, cracked bluff soils and cause major slope failure.

Shore recession – a consequence of erosion – is the apparent landward movement of a landscape feature such as a bluff or dune crest and refers to the change in distance from the feature’s original position and its new, altered location after it has been eaten away by erosion. Recession is usually the most visible aspect of coastal erosion (figure 3); however, using it as an indicator of erosion can be misleading because a lag time occurs. Days, weeks, months or even years can pass after an erosion event before signs of recession become apparent on bluff shorelines. In fact, recession can occur during periods of little or no storm activity.

*Flooding and runoff:* Many factors – including wind, waves and water levels – contribute to coastal flooding. Climate change will influence these factors, either alleviating or increasing the threat of floods. And while the general consensus among scientists is that water levels in the Great Lakes will decline, they do naturally fluctuate and coastal flooding should continue in the high-water decades.

The combination of warmer, wetter winters and increases in intense storm events suggests also that Wisconsin will be dealing with increases in spring runoff in the future. More runoff will lead to longer periods of flooding in streams and associated wetlands, which will impact plant, animal and human communities in coastal areas.





**Coastal wetland and near-shore impacts:** Wetlands near the coasts of both Lake Michigan and Lake Superior provide rich habitat for plants and animals, and they greatly influence the larger processes of the Great Lakes ecosystem. Coastal wetlands comprise transitional zones, with vegetation changing from the submerged plants of the near-shore regions to the woody shrubs and swampy forests of the upland areas. They include marshes, bogs and swamps, and as transition zones between land and water, they are often rich in biological diversity and provide critical habitat for migratory and nesting birds, spawning fish and rare species. Their rooted aquatic plants anchor the sand and muck, keeping bottom sediments in place, providing habitat for fish and other aquatic species.

As Great Lakes water levels fall with climate change, stream channels will erode, delivering more sediment downstream to coastal wetlands and potentially burying natural aquatic communities. If water levels rise dramatically, coastal wetlands could be drowned out or severely eroded.

Additionally, coastal wetlands help prevent floods, protect shorelines and recharge groundwater supplies, but climate change will affect these habitats in many ways. Continued increases in temperature, changing lake levels and increased upland runoff and flooding will impact the food web, the make-up of plant communities and the overall quality of the wetland habitats.

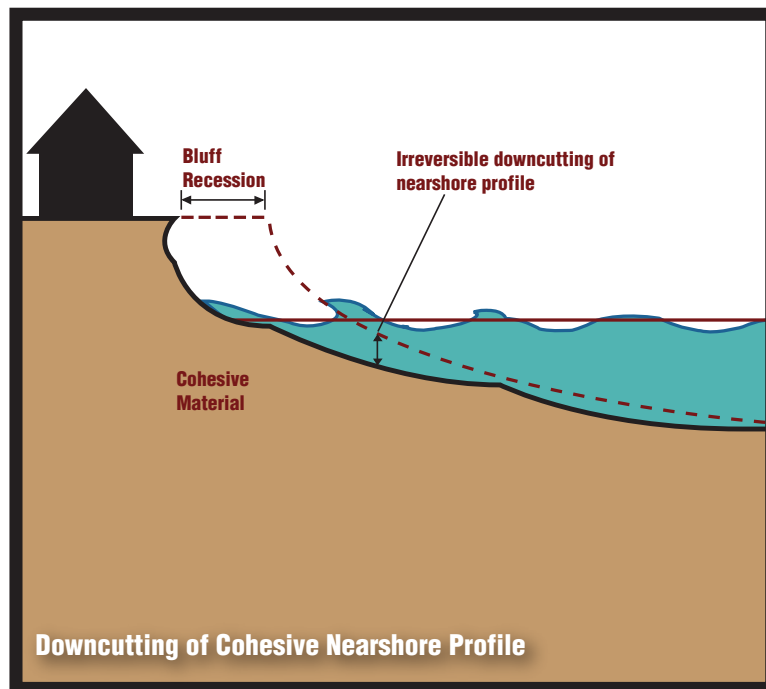


Figure 3. Lake bed downcutting is the gradual erosion of cohesive soil (clay or glacial till) in the nearshore area due to wave interaction. When most of the sand is stripped and the cohesive layer is exposed, cohesive material is lost to the water column. Unlike sand, cohesive material cannot be replenished by natural events such as bluff erosion. This erosion can result in recession of the shoreline.

Source: U.S. Army Corps of Engineers.

For example, plant diversity will decrease, and we could lose boreal wetland species altogether. Studies have shown that increasing temperatures allow seeds of weedy plant species to emerge and develop at higher rates than native species in boreal wetlands, giving weeds a competitive advantage if warming continues.

Changes in coastal wetlands increase opportunities for invasive species to take hold. Stormwater runoff can carry seeds of invasive species, distributing them throughout the landscape. Both flooding and drought put stress on aquatic plants, and invasive species can become established while native species are in a weakened state. For example, Lake Michigan wetlands are vulnerable to increasing introductions of the hybrid *Typha x glauca*, a cross between a native and invasive cattail, which can drive out native cattails and reduce biodiversity in sedge meadows on the Great Lakes coast. The hybrids are much hardier and more aggressive and can withstand a broader range of water levels than the native variety. In addition, when an area is frequently flooded, the phosphorus levels increase and the hybrid grows even bigger. Once an area is taken over by hybrid cattails, it may be difficult to restore to native sedges and cattails.

Changing lake levels will alter the ecology of the beach and near-shore habitat, with changes in fish spawning habitat resulting from wetland loss or siltation due to increasing erosion rates. As average lake levels drop, there will be a shoreward loss and a lakeward expansion of wetlands, resulting in a host of impacts, including those that affect fish living in streams and lakes by disconnecting some wetlands from the Great Lakes. If fish spawning and nursery habitat is impaired, we will see fewer young fish of certain species, and this will affect the overall health of fisheries, which are important to Wisconsin's culture and tourism.

Research on fishes also suggests that as warming occurs, warm water species will move from streams and lakes and invade the warming nearshore habitat, altering the nearshore fish community through predation on and competition with cool water species.

**Beach health:** As a coastal state, Wisconsin boasts an abundance of beaches along both Lake Michigan and Lake Superior. Our beaches are a major draw for tourism, and many Wisconsin residents spend their summers recreating on the shore. As temperatures rise, ice cover declines, followed by lower lake levels and altered beach ecosystems. These impacts will affect the integrity and aesthetic qualities of our state's beaches.

Across the state, elevated levels of bacteria are causing beach closings. Stormwater runoff and sewer overflow can be a major component of contamination, and as heavy rainfall events increase, scientists expect beach contamination to be more frequent and widespread, with runoff depositing sediments and pathogens on the beach. Increased water temperatures and longer ice-free periods will also create an environment that supports pathogens. At the same time, we can expect that Great Lakes beaches will become more popular as refuges from summer heat waves, leading to greater risk of illness among beachgoers.

## Built Environment

Although beaches and wetlands compose much of Wisconsin's shoreline, coastal resources include a built environment as well. Ports, harbors and marinas dot the coastline, supporting industry, fishing and tourism. Homes and cottages sit atop bluffs and sandy beaches, and four of the state's largest cities – Milwaukee, Green Bay, Kenosha and Racine – are located on the coast. Our coastal landscapes include built features such as shoreline protection structures, drinking water intakes and water treatment plants. Climate change poses challenges for every component of the built coastal environment.

**Ports, harbors and marinas:** Wisconsin's ports, harbors and marinas are also vulnerable to the impacts of climate change. These structures include large-scale commercial operations and smaller recreational facilities with fixed or floating docks. The lifespan of maritime infrastructure is typically 40 to 50 years for marinas and slightly longer for ports and harbors. This longer planning horizon means that developers of these installations will need to account for climate

## ORDINARY HIGH-WATER MARK

The ordinary high-water mark is the elevation on land at which the most permanent and prevalent water marks occur. Erosion, the destruction of terrestrial vegetation and other characteristics create the distinct signs of the ordinary high-water mark, which legally establishes the boundary between the publicly owned lakebed and privately owned land. This mark is the point from which Wisconsin's shoreland zoning setback is measured, so if lake levels are low for a long enough period of time that plant types shift from aquatic to land species, debate ensues regarding re-delineation of wetlands in this legal and policy context. If climate change lowers lake levels and the ordinary high-water mark moves lakeward, development and construction could follow, running the risk of future flooding if the lakes eventually return to higher levels. Given the large variation in Great Lakes water levels over decades, high-water mark definition and structural development should not closely track water levels; rather, they should be based on the water levels observed during high-water periods.



Photo: Dave Mickelson

*Aerial photo (2007) of part of the Door County shoreline showing structures below the ordinary high-water mark of Lake Michigan. Dashed line in photo represents ordinary high-water mark.*



events that will occur in the future because water level changes outside of normal lake fluctuations can greatly impact these facilities and their infrastructure.

#### ***Lower Water Levels***

The scientific consensus suggests that, on average, Great Lakes water levels will be slightly lower by the end of the century; however, the large variations that occur over decades will continue to occur, resulting in high-water decades and low-water decades.

The slow trend toward lower water levels will result in a variety of impacts on coastal resources. For instance, lower water levels create situations in ports and harbors where ships cannot be fully loaded or may need to carry less cargo per trip. Vessels may hit the channel or slip bottoms, requiring additional dredging. For marinas, boat bottoms may be damaged by shallow depths, and the vertical distance between the docks and water level may increase, posing a hazard to people.

#### ***Higher Water Levels***

High-water decades also have implications for ports, harbors and marinas. When Great Lakes water levels increase during high-water decades, the higher water weakens and destabilizes infrastructure and creates the

potential for flooding of critical land areas and operational structures. The interaction of higher water levels and intense storm events increases the risk of damage from large waves and surges. Navigation and mooring, as well as access to docks and other structures, will also be affected.

***Dredging and re-suspension of contaminated sediments:*** Some of Wisconsin's harbors and marinas contain contaminated sediments. If water levels are lower on average and navigation channels require additional dredging, buried toxic sediments may be exposed and re-suspended in the water. Lower water levels, more intense rainfall events or a combination of these conditions could also increase stream scouring and erosion, leading to more sedimentation downstream in Great Lakes bays and rivers, potentially exposing these areas to re-suspended pollutants.

#### ***Water Intakes***

As water temperatures increase and ice cover decreases, blue-green algae may get a jump start on producing their toxic blooms. Changes in lake currents may alter areas where pollutants concentrate, and increased storm intensity will impact stormwater volumes, increasing polluted runoff and even sewer



## COUNTY LS IN NORTHERN SHEBOYGAN COUNTY

**In 2003, sections of Sheboygan County Highway LS were within 10 feet of the edge of a 70-foot-high bluff overlooking Lake Michigan. During a site visit by federal, state and local officials and property owners, the group conversation suddenly stopped as everyone's eyes fixed on a school bus as it drove by the area of concern. The next day Wisconsin Sea Grant coastal engineers sent a certified letter warning the county of the potential consequences of the bluff collapsing. While the road was never closed, school buses were rerouted. The county got the U.S. Army Corps of Engineers to design and partially fund an emergency shoreline protection project to protect this segment of the road. Unfortunately, an additional mile of road to the north remains within an unstable erosion hazard area along the bluff.**

overflows. Such changes could result in additional pollutants entering water intakes.

Changing lake levels will also affect water intakes. Lower lake levels may reduce the concentration of oxygen in the lakes; lower oxygen levels would further contribute to blue-green algal blooms. If water levels became low enough, drinking water intakes could end up at depths that are subject to greater algal abundance, mussel growth or suspended sediments. The lake ice that remains may interfere with water intakes, and the dredging of harbors and marinas may affect water quality.

***Shoreline infrastructure:*** Infrastructure, homes and businesses, water and sewer operations, and recreational facilities located along the shoreline are vulnerable to changing lake levels, increased storms impacts and coastal erosion.

Millions of people living around the Great Lakes depend on vulnerable lakeside facilities. In areas with high bluffs, roads along a coastline can become vulnerable as the bluff recedes due to erosion and becomes unstable, posing challenges to engineers and residents.

**Source material for this chapter was drawn from the Coastal Communities, Green Bay and Water Resources Working Group reports, available online at [www.wicci.wisc.edu](http://www.wicci.wisc.edu).**



Photo: Elizabeth Katt-Reinders



# Adaptation Strategies

Because many factors can contribute to climate impacts on coastal resources, there is a wide range of possible strategies for adaptation. In keeping with the organizational framework presented in Chapter 2: *Understanding Adaptation*, we present here sev-

eral adaptation strategies that pertain to the natural and built environments of Wisconsin's coastal areas. (Please see the working group reports at [www.wicci.wisc.edu](http://www.wicci.wisc.edu) for a more detailed discussion of adaptation strategies.)

## ADAPTATION

### TAKING ACTION

#### Coastal Bluff Recession

Move buildings and roads back from the bluff edge and/or stabilize bluffs. Counties and municipalities should re-examine their setback ordinances to be sure that they account for likely increases in the bluff recession rate.

#### Coastal Site Design For Stormwater Runoff

An increasing frequency of large magnitude rainfall events requires control of surface water runoff along the shoreline and on bluffs. Possible actions:

- Develop erosion control and stormwater management plans.
- Do not construct stormwater infiltration systems (for example, rain gardens) unless they are specifically adapted to avoid destabilizing the bluff.
- Locate septic system drain fields away from bluffs and gullies.
- Preserve existing grass and trees and re-vegetate disturbed areas as soon as possible.

#### Ports, Harbors and Marinas

Anticipate and plan for greater dredging and the potential need for additional bottom scour protection at the base of harbor dock walls during periods of lower water levels. Anticipate potential dock top elevation modifications or modified loading/unloading procedures for periods of higher water levels.

Ports and harbors can increase the working dock heights, modify loading/unloading operations or relocate

important facility features to higher land to protect against flooding. Marinas can adapt to changing water level extremes by converting fixed dockage to floating dockage.

Ports and harbors can adapt to increased wave action, seiches and storm surges by rehabilitating, modifying or replacing weaker portions of their infrastructure to withstand greater wave forces. Marinas can adapt by using stronger dock designs.

Adaptation strategies for hardening existing shoreline structures against potential climate change must be considered and implemented if needed, and new structures must be designed with potential climate change impacts in mind.

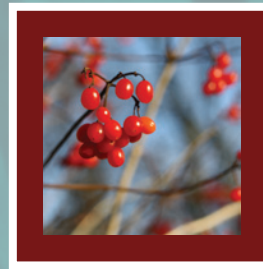
Proactively address contaminated sediment sites not within Great Lakes Areas of Concern and develop improved funding options for remediation.

#### Implement Comprehensive Community Planning

Growth and development management (zoning, redevelopment restrictions, conservation easements and compact community design).

Property protection (acquisition, relocation, setbacks, building codes, retrofitting, infrastructure protection and shore protection structures).

Shoreline management (regulation and removal of shore protection structures, rolling easements, living shore-



## Conclusion

Climate change poses a variety of challenges to Wisconsin's coastal resources, both natural and built. Some of our state's most fragile ecosystems lie in coastal zones along Lake Superior and Lake Michigan. Four of our largest cities reside on the shore of

Lake Michigan, and billions of dollars of economic activity are generated in Great Lakes coastal zones. Adaptation to the likely and potential impacts of climate change poses significant challenges for natural resource managers, urban planners, infrastructure designers and others whose decisions affect – and are affected by – these vital components of Wisconsin's landscape, economy and culture.

## STRATEGIES

lines, beach nourishment, dune management and sediment management).

### Water Intakes

Implement water conservation measures to offset any increased need for exploiting Great Lakes water to offset decreasing groundwater supplies.

### Beach Health

Use best stormwater management practices to reduce runoff and prevent polluted runoff from urban and agricultural areas, along with beach grooming to reduce pathogens and consequent beach closures (for example, reducing impervious surfaces and increasing buffers near beaches will help control stormwater runoff).

Monitor water quality at beaches and communicate results that may lead to beach closures but likely will prevent illness.

### Coastal Ecosystems

Implement coastal and aquatic ecosystem management (ecological buffer zones; open space preservation and conservation; ecosystem protection and maintenance; ecosystem restoration, creation, and enhancement; and aquatic invasive species management).

### BUILDING CAPACITY

#### Shoreline Structures

Develop adaptation strategies for conditions where lake levels may drop below historic levels, making shore

protection structures in coastal reaches unnecessary for the purpose of protecting coastal slopes from wave action.

### COMMUNICATING

#### Water Intakes

Infrastructure planning should consider the relocation of water intakes and increased water treatment needs from changing lake levels.

Anticipate increases in runoff volume to avoid sanitary sewer overflows, increased erosion and polluted runoff that can contaminate water supplies.

#### Tourism

Locate hotels and recreational facilities to avoid future access and erosion problems.

#### Lakeshore Communities

Target community lakeshore planning to provide for multiple-landowner boat access under variable water levels and low-impact marina siting.

### FILLING GAPS

#### Contaminated Sediments

Use bathymetric data to identify port, harbor and marina facilities that are at risk from re-suspended sediments. Work with the owners to develop strategies to adapt to changing lake levels and identify alternatives to dredging.