LOW LAKE WATER LEVELS In September 2007, Lake Superior broke an 81-year-old record low for the month when it dropped more than two feet below its historic average September water level. In December 2007, Lake Michigan nearly broke its December record low set in 1964 when its water level dropped 27 inches below the monthly average. All along both Wisconsin coasts, the drop in water levels left lakefront property far from the water's edge. Ships were forced to carry less cargo to avoid grounding in shallow channels, docks were rendered useless, boats left high and dry, and shallow bays dried up entirely. The Bad River Band of Lake Superior Chippewa canceled its wild rice harvest for the first time in history because low water levels had dramatically reduced the rice crop in their coastal wetlands.

Some suspect that climate change is the culprit behind the recent low water levels in the upper Great Lakes and that this may be the harbinger of a long-term continuing decline. In fact, models of regional climate change that

UNKNOWNS ON OUR COAST

Based on a presentation by J. Philip Keillor, Coastal Engineering Advisory Services Specialist (Retired), University of Wisconsin Sea Grant Institute assume less rainfall and greater evaporation from much warmer temperatures predict a drop in average lake levels of one foot to more than four feet in less than 50 years, while models assuming greater rainfall with a lesser increase in temperatures indicate average lake water levels could rise instead by as much as a foot by the end of the century.

The immediate cause of the recent low water levels is a two-year drought affecting the basins of both lakes that may or may not be related to climate change. Another contributing factor may be the erosion of the Lake Michigan-Huron outlet at the St. Clair River northeast of Detroit that has expanded and/or deepened sections of the river by six to nearly 22 feet, greatly increasing the rate of outflow and causing an estimated one-foot long-term drop in the average level of both lakes since the early 1960s.

DOWN AND UP AGAIN The water level of Lake Superior has fluctuated by as much as four feet during the last century, while Lake Michigan's has varied by as much as six feet. And the rate of rise and decline in lake water levels can be relatively rapid.

For example, Lake Michigan's water level declined nearly five feet in three and half years on two occasions during the 20th century, and once it went down as much as four feet in just over two years. Twice during the last century the lake's water level dropped as much as three feet in just one year. Conversely, Lake Michigan's water level rose more than three feet in 18 months or less on three occasions during the 20th century, and it went up more than five feet in just over eight years during the 1965-73 period.

During the last century, the water levels of both Lakes Michigan and Superior have been at times much lower than any recorded in recent years. In the distant past, Great Lakes water levels have been both much higher and much lower than anything seen since Europeans came to this continent 400 years ago.

The 140-year-long record of historic Great Lakes water levels is simply too short to make a confident prediction of future lake-level fluctuations in a changed climate, particularly if global warming induces more extreme fluctuations in temperature and precipitation than projected or experienced to date. Coupled with projected changes in the long-term average water levels of the lakes, those extremes could also cause greater extremes in the seasonal high and low water levels on the Great Lakes.

Because Great Lakes coastal cities were built for the relatively narrow range of lake levels seen over the last two centuries, this creates a multi-billion-dollar dilemma for private and public owners of coastal facilities, including water utilities, power plants, ports, marinas, and business and residential property.

The questions surrounding future Great Lakes water levels resemble those for the projected rise in sea level in one respect: Our coastal communities and infrastructure were developed for a range of water levels that no longer seems valid, and coastal property managers need to evaluate the sensitivity of such places to water levels beyond the ranges for which they were designed.

CLIMATE CHANGE PROJECTIONS Climate model projections do not predict the future but provide plausible scenarios of what our climate may look like in the future. These scenarios can then be used to understand the range of risks this presents that can be used to identify our options for dealing with them effectively.

Climate model projections for Wisconsin indicate that by 2030 average summer temperatures will rise five to eight degrees Fahrenheit in summer and two to three degrees in winter. Precipitation may remain about the same as today, or it may be as much as 10 percent less in summer and 25 percent more in winter.

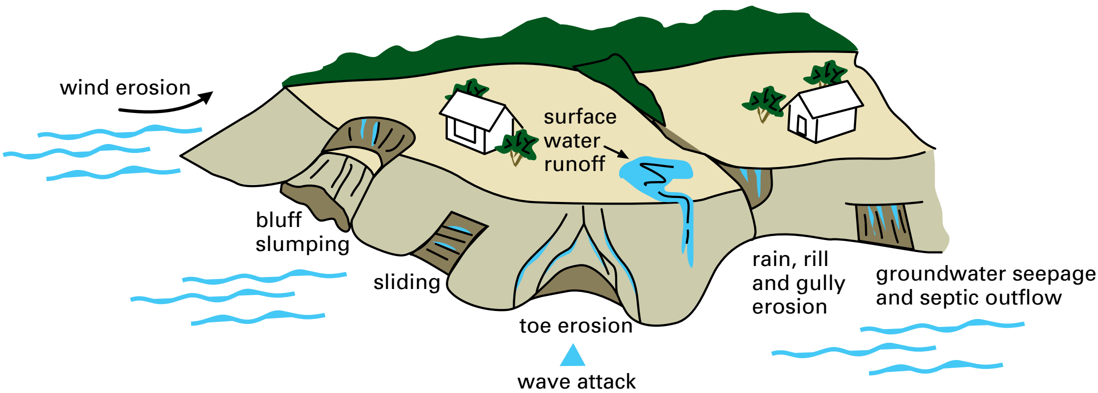
Severe or extreme storms are likely to become more frequent, increasing 50 to100 percent by 2095. As a result of global warming, the atmosphere can hold more moisture, increasing the amount available for precipitation. Together, these changes are expected to result in greater and more frequent extreme precipitation events.

Wisconsin has already seen an increase in such events. Since 1970, the proportion of *heavy* (top five percentile) and *very heavy* (top one percentile) precipitation events has increased in the western Great Lakes and Upper Midwest. In southeastern Wisconsin, three of the four rainfall events that matched or exceeded the hypothetical "once-in-500-years" standard during the 20th century have occurred since 1970—in August 1986, June 1996 and June 1997. (The fourth was in August 1924.)

Wisconsin may also be in for some climate surprises from shifts in storm tracks due to the changes in atmospheric circulation occurring in most seasons in both hemispheres. This is similar to the way an El Niño event in the Pacific Ocean affects storm tracks crossing North America and the Great Lakes. Such changes in storm tracks can cause abrupt changes in climate. One possibility is a persistent shift in storm tracks either into or outside the Great Lakes Basin.

For the Great Lakes, warming air temperatures are also expected to result in warmer water temperatures that could eventually lead to the disappearance of lake ice in winter. On Lake Superior, the coldest Great Lake, surface water temperatures are rising at a faster rate than air temperatures over the

Causes and Effects of Coastal Erosion



lake. This is the result of a "positive feedback" mechanism similar to that occurring in the Arctic Ocean, in which warmer air temperatures reduce the amount of ice cover, leaving more open water to absorb heat from the sun, which melts more ice cover and creates more open water that absorbs yet more heat. At the current rate of ice cover loss, Lake Superior could be ice-free in a typical winter within 40 years.

EFFECTS ON THE COAST Some potential effects of these projected changes in climate on our coastal areas include more erosion of coastal slopes, added stress on coastal structures from extreme events, and disruption of human activities due to swings in Great Lakes water levels beyond their historic range of high and low water levels.

Warmer, wetter winters with shallow frost and more frequent, longer freeze-thaw periods will increase surface erosion, causing shallow slides and more failures of slopes subject to deep slips, along with the possibility of massive failures during complete thaws. This would cause even more erosion in coastal areas where soil creep exists, such as along the Lake Superior shore.

More extreme precipitation events in winters without frozen soil will cause similar problems and contribute to massive slope failures due to higher groundwater levels.

A lack of ice cover on the Great Lakes would mean no protective ice ridges or ice shelves along the shore and expose erodible slopes to a greater amount of wave attack at their base, which can cause shallow as well as massive slope failures.

Dryer soils in summer and fall, combined with more frequent extreme precipitation events, would also result in greater surface erosion and shallow slides and increase erosion in areas where soil creep is a problem.

Extreme precipitation events are also likely to cause catastrophic failures of coastal slopes, washouts of coastal roads and storm sewers, record-setting stormwater discharges, flooding and other damage to harbor infrastructure, and failures of old bulkheads, dock walls and seawalls.

Lakebed erosion can be a significant and continuing problem wherever and whenever waves, currents, and abrasive sand and gravel move across soft clay sediments. In other Great Lakes states, lakebed erosion at rates of one to six inches per year has deepened lakebeds by one to five feet within a decade.

RESPONDING TO THE RISKS

Four strategies for coping with coastal erosion are to:

- Moderate erosion.
- Adapt to natural coastal processes.
- Restore natural shorelines.
- Armor the shore (shore protection).

The risks to coastal property posed by erosion can be moderated by controlling surface runoff, intercepting groundwater beneath the property, and monitoring development in the area that may route more groundwater and surface water through the property. Other ways to moderate erosion are to slow wind erosion by planting vegetation and to improve existing slope toe protection structures.

Adaptation to natural coastal processes can be accomplished by relocating houses threatened by coastal erosion or flooding, adopting greater setback distances for new coastal construction and building houses that are easily relocated.

Natural shorelines can be restored by creating and preserving coastal environmental corridors, and by improving or restoring natural shore protection features, such as beaches, dunes, wetlands, nearshore shoals and islands.

Armoring the shore is the strategy of last resort. One reason is that shore protection structures may have adverse effects on the property they are designed to protect and on neighboring property as well. Another is that lakebed erosion can undermine and destroy virtually every type of shore protection structure known.

For more detailed information about coastal processes and managing the risks, Keillor recommended *Living on the Coast: Protecting Investments in*

Shore Property on the Great Lakes, a 2003 publication of the University of Wisconsin Sea Grant Institute and the U.S. Army Corps of Engineers-Detroit District.

Another potentially useful reference is *Coastal Processes Manual: How to Estimate the Conditions of Risk to Coastal Property from Extreme Lake Levels, Storms and Erosion in the Great Lakes Basin,* a UW Sea Grant coastal engineering guide published in 1998.

Copies of both may be downloaded free of charge from the "Water Levels/Erosion" section of the UW-Madison Aquatic Sciences Center's "Publications Store" Web site at *http://aqua.wisc.edu/publications*.

MINIMIZING THE RISKS Ultimately, the level of risk to Great Lakes coastal property and infrastructure posed by changes in Great Lakes water levels and extreme precipitation events caused by climate change can best be minimized and managed by minimizing the rate and extent of global climate change in the decades ahead. Failure to reduce global greenhouse gas emissions, particularly carbon dioxide, could have unforeseen and potentially catastrophic effects on the Great Lakes as well as the rest of the world.

How fast and how much our climate and Great Lakes water levels change will largely determine our ability to adapt—and how costly it will be.