Beaches, Dunes and Climate Change
Coastal Bulletin 16-1
Lake Huron Centre for Coastal Conservation

CLIMATE VS WEATHER

Weather is the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks. People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. We talk about changes in weather in terms of the near future: "How hot is it right now?" "What will it be like today?" and "Will we get a snowstorm this week?"

Climate is the weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location. We talk about climate change in terms of years, decades, and centuries. Scientists study climate to look for trends or cycles of variability, such as the changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña, and also to place cycles or other phenomena into the bigger picture of possible longer term or more permanent climate changes (National Snow and Ice Data Center, 2016).

Weather is a constant factor in daily life and we live with the variations it provides. Climate, on the other hand is a long term reflection of weather and our communities need to adapt to the changes that are now happening and are expected to occur in the future. As is the case with many ecosystems, those that are healthy and remain largely intact stand a better chance of surviving and adapting to these climatic changes. Beach and dune ecosystems are no different.

Beaches, Dunes and Climate Change

Introduction

Sandy beaches and dunes represent coastal features that are subject to change due to natural forces (wind and waves), and can be changed negatively as a result of human related impacts. Climate change will have the potential to dramatically alter these ecosystems. The capacity of these ecosystems to respond favourably to climate change conditions will depend on what degree these ecosystems have retained their natural functions. In most cases, beaches and dunes that have not been altered by human-related disturbances will have the resiliency to cope with the conditions presented by climate change.

Nearly all communities around the Great Lakes will need to adapt to changes in regional climate over the next century. These changes include warming air temperatures; shifts in the timing, frequency, and severity of precipitation events; dynamic lake levels; and higher water temperatures and reductions in lake ice cover.

Changes to regional climate pose increased risks to the water resources, built environment and infrastructure, ecosystems, and recreation and tourism sectors that already face other pressures, like invasive species, urbanized development, and economic competition (Cruce, et al, 2011). This document is intended to provide information to assist municipalities, beach communities and private landowners in understanding what to anticipate, specifically as it relates to beach and dune ecosystems, and how some basic conservation measures can help avoid issues related to erosion and beach degradation.

While all sandy beach and dune systems will be challenged in the face of changing conditions, relic beaches, like those along the Bruce County, Georgian Bay and Manitoulin Island shores, will be the most vulnerable to climate change, and will require particular attention, with respect to coastal conservation measures. Beaches in the Huron County area may experience diminished sand reserves and shrinking beaches, as we anticipate higher wave energy and longer ice-free conditions (Davidson-Arnott, 2016).

Climate Impacts and Threats to Lake Huron

Annual average temperatures are increasing in the Great Lakes region. We experienced a 1.3°C increase between 1968 and 2002. A 1-3°C increase is projected by 2050 (U.S. Global Change Research Program 2009). Increased air temperatures will affect water temperatures, ice cover, wind and wave conditions, and impact biodiversity.

The duration of Great Lakes ice cover is decreasing as air and water temperatures rise. Overall there has been a 71% reduction in the extent of Great Lakes ice cover between 1973 and 2010. Delay in the onset of protective shore ice could extend the period that beaches and dunes are vulnerable to erosion. The increased frequency of storms generating large waves, and storm surge, coupled with a delayed onset of protective ice cover, will increase the likelihood of erosion.

Changes to Wind Intensity

Warmer water temperatures will affect the wind regime on the Great Lakes. A wide temperature differential between water and air makes for a more stable atmosphere with calmer winds over the relatively cold water. However, as warming water closes the gap, as in the case of the Great Lakes, the atmosphere gets more turbulent.
Warmer lake temperatures will lead to higher wind speeds off the lake, due to the reduced differential between air and water temperatures. Higher wind speeds will lead to more sand erosion (both wind and wave) and sand drifting, unless appropriate dune conservation measures are in place to help minimize sand loss.

One of the factors influencing higher water temperatures has been less winter ice cover. Reflective ice lessens the amount of solar radiation on the lake. Once the final ice-melt has occurred, however, the large lakes turn into dark surfaces that absorb solar radiation to the maximum of any natural surface. This absorbed solar radiation is the primary agent that warms the lake. The relative timing of final ice-melt to the summer solstice — the season when the sun provides the most radiation — is therefore a key determinant of the degree of warming of lake waters (Rouse, 2009).

A result of longer periods of higher surface water temperatures is a weakening of the water–air temperature gradient. This has the effect of destabilizing the atmosphere above the lake, enabling faster wind speeds across the lake surface (Cruce, et al, 2011).
There are some interesting implications for higher wind speeds off the lake, including movement of airborne pollutants to the shore, increased lake-effect streamers in winter, potentially stronger alongshore currents, stronger wave energy impacting the shore, and wind movement of sand on beaches and dunes.

Increased sand movement and dune drifting could present problems to communities who do not have well managed dune systems in place. This is particularly important for many of Lake Huron and Georgian Bay's relic dune systems because they are made up of finite sand deposits where no new source of sand is present should the existing sands get eroded away by wind and/or waves. Erosion of beaches and dunes can be caused, or made worse, by high impact recreational activities, development pressure and poorly designed beach access.

Winds, Waves and Alongshore Currents

The greater frequency of storms, generating larger waves, and the resulting storm surge, will result in greater alongshore sand transport particularly along the Huron County shoreline (Davidson-Arnott, 2016). That shoreline's north-south configuration, and its open exposure to winds and waves from the northwest, could generate greater movement of sand, reducing the amount of beach material available. Winds from the northwest create the strongest waves, since the wind has a greater surface area of the lake to transfer energy to the water surface. The net movement of sand along this part of the Lake Huron shore, therefore, is from north to south, with sand deposition occurring in the Pinery-Ipperwash area. Less beach material along the Huron County shores will provide less protection to the bluffs, and so bluff erosion may increase as a result.

Precipitation

Precipitation events are becoming more intense. Between 1958 and 2007, the heaviest 1% of rain events increased by 31% in the Great Lakes region resulting in more flooding, runoff, and sediment and nutrient loading impacts (U.S. Global Change Research Program 2009).

Extreme precipitation events have been linked to beach postings by public health authorities due to elevations in pathogens getting into the lake. This places a higher risk to elderly, children, and people with compromised immune systems (Bush, et al, 2014). Sheltered beaches are generally more sensitive to pollution than exposed beaches.

Lake Levels

To protect coastal assets, experts suggest that the full historic extent of high and low water levels should be considered as possible when defining the potential range of variation that coastal communities could experience in the future (International Upper Great Lakes Study 2012). This includes designing coastal infrastructure to specifications that consider the extreme ends of the water levels spectrum. In other words, we need to prepare for both high and low water levels in waterfront design. In addition, more frequent and intense precipitation and storm waves could lead to beach erosion and dune cliffing.

A photograph taken along Lake Huron's shoreline in 1986 showing erosion during a period of high water levels

A photograph taken at the same beach in 2005, showing the development and expansion of dunes during low water levels

Coastal assets not only include the built environment (e.g. development, buildings and structures), but natural assets that sustain the healthy functioning of the coastline (e.g. wetlands, dunes, bluffs and beaches).

Beaches and dunes are dynamic features, and will experience changes relative to water level fluctuations. Our experience with extreme lake levels over the last 25 years has demonstrated what to expect. Under extreme high lake conditions, beaches and dunes will experience erosion, as a natural response to storm activity. Sand reserves in the dunes will be taken offshore to build the lakebed (usually in the form of sand bars) to help protect the beach from storm wave energy. Both beaches and dunes will narrow under high lake conditions.

Under low lake conditions, as experienced between 1999 and 2013, beaches expand, exposing more sand to wind erosion. Winds gradually bring sand back into the dunes, and dune re-development begins. Dune vegetation responds to sand burial with stimulated growth patterns, and depending on the duration of low lake levels, vegetation will expand lakeward. This expansion of dune vegetation allows the dunes to build laterally (lakeward). If, through human interference, the dunes are not permitted to expand lakeward, they will build vertically, and this could pose difficulties for beach users, like blocked vistas or reduced beach access.

As discussed earlier, overall increases in wind speeds will cause greater wind-blown sand erosion, causing problematic drifting and sand loss, unless conservation measures have been planned and employed.

The changing climate will compel beach users and shore managers to understand that the coast is a dynamic place. Adapting to these changes will require strategies that include high lake level and low lake level scenarios, increased wind and wave regimes, and responding to storm water management issues.

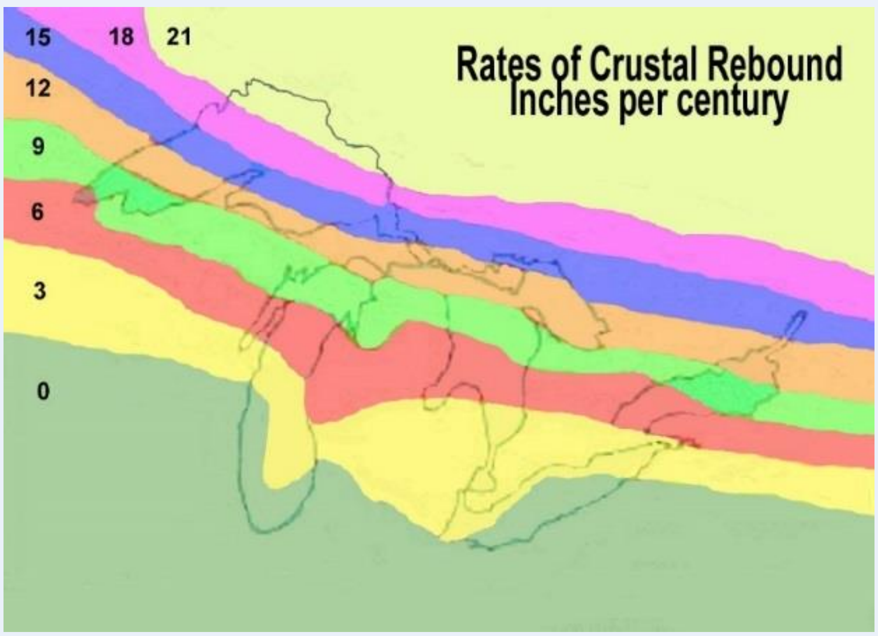
Changing Lake Levels

- Great Lakes water levels have been highly variable with no clear trend towards lower water levels from 1860 to 2000.
- The Great Lakes experienced three decades of high water levels until the 1990s (Environment and Climate Change Canada, 2016).
- Since 1997 water levels on Lakes Michigan and Huron fell approximately 1 metre.
- Between 1997 and 2000, the Great Lakes experienced a severe decline in lake levels. This episode is the most severe three-year drop on record for Lake Erie and the second most severe for Lakes Michigan, Huron, and Superior. Since the record low in January 2013 on Lake Huron, levels dramatically rebounded, and were above average in 2015 and 2016.

Beach areas that have natural or naturalized dune systems in place will be best positioned to be able to respond to changes and accommodate wind and wave impacts. Areas where dunes have been compromised from human-related impacts are likely to have poor outcomes with respect to erosion and overall beach quality. With an expected increase in frequency of extreme precipitation events, natural or naturalized shorelines will have a greater capacity to filter nutrients and pathogens that run off the landscape.

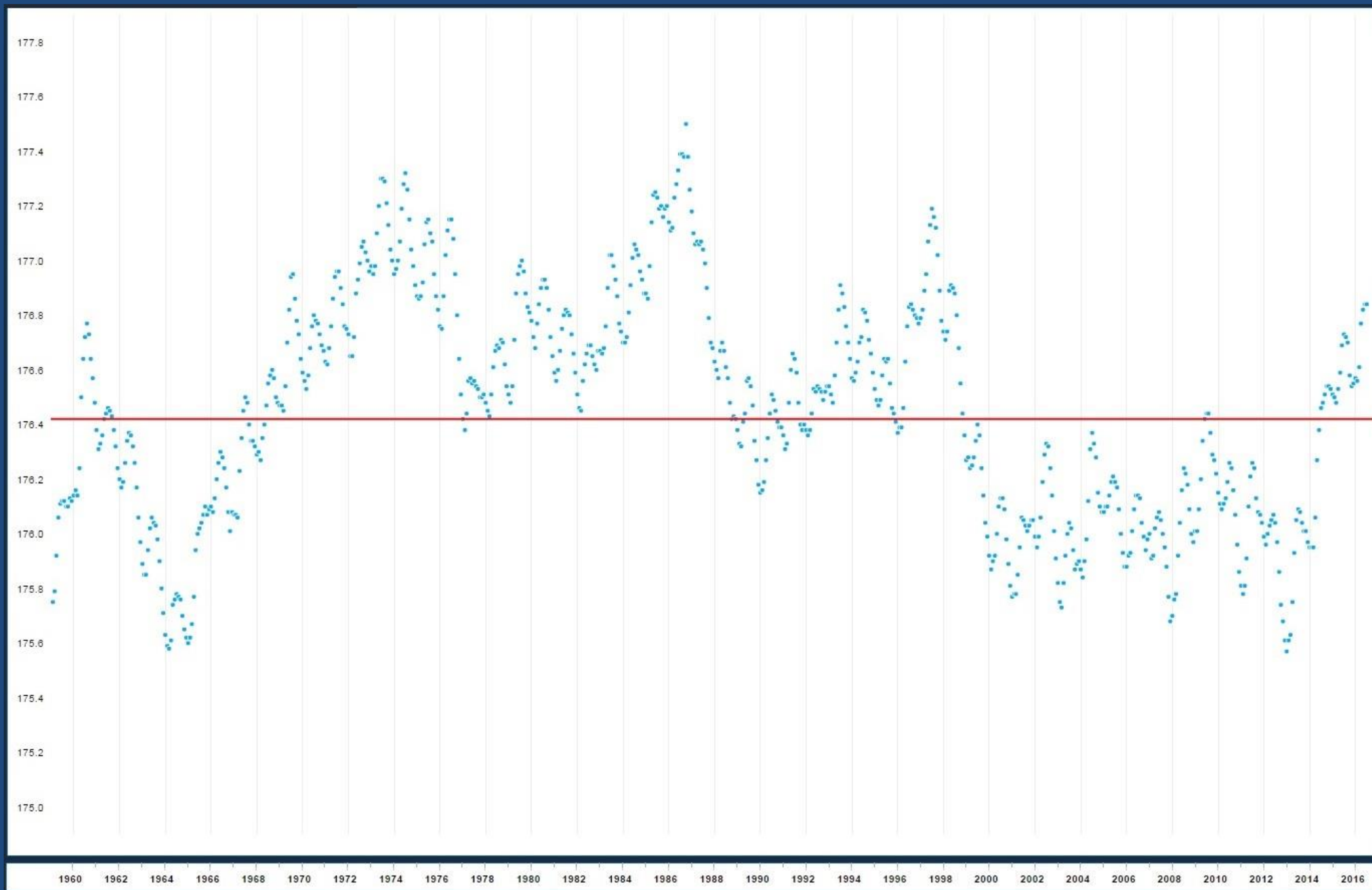
Isostatic Adjustments

Post-glacial isostatic rebound (also called “Glacial Isostatic Adjustment”) is slowly tilting the Great Lakes basin, causing water to be gradually displaced from the northeast to the southwest. The effects of this are more acute on the northern portions of the lake and on Georgian Bay. Water levels in Milwaukee, Wisconsin, for example, appear to be rising. At the same time, water levels in the northeastern portion of the basin (e.g., Georgian Bay) appear to be dropping. This rebound accounts for about 30 cm of water level change (rising or dropping) in a person’s lifetime (International Upper Great Lakes Study, 2012).



Isostatic adjustments across the Great Lakes

This effect will be most pronounced on the Bruce Peninsula and Georgian Bay, and this could lead to dune stranding, whereby the increasing land elevation gradually separates the dune from the active shore zone. Relic beaches, which are already sand deprived, will be additionally challenged by this land adjustment. Dune conservation efforts will help to mitigate negative effects.



Water levels graph for Lake Huron from 1960 to 2016. During this time period, the lake experienced extreme low levels in 1964 and 2013, and extreme highs in 1985-86. Scientists anticipate future water levels to remain within this range, with greater frequencies toward extreme ends of the range

Invasive Plant Species

Invasive plant species have been a problem for some lakeshore municipalities. During the most recent low lake period, many beaches along Lake Huron/Georgian Bay became infested with the invasive grass European Common Reed (*Phragmites australis*). This grass formed dense colonies which created beach access issues, reduction in ecological health (e.g. loss of habitat/species), and interference with dune processes. Municipalities were forced, at great expense, to undertake control programs to manage the problem. The fundamental lesson learned from this experience was that such infestations by aggressive invasive plants, like *Phragmites*, requires early detection and rapid response in order to deal with the issue in the most cost effective manner possible.

It is projected that under climate change, with warmer temperatures, lake level extremes and precipitation changes, invasive plant species may become a more prevalent issue along the coast.

Moving Forward

Coastal communities with intact dune systems will be the most resilient in being able to cope with the various challenges that climate change will pose. Where dunes have been compromised, conservation measures to restore the dunes need to be well planned and executed if they are to succeed. Since dunes are vulnerable to wind erosion caused by trampling or removal of dune vegetation as people access the shoreline, well planned beach access that aims to minimize impacts should be implemented. In high use areas, constructed access pathways may be necessary. This might include boardwalks (permanent or mobile), or railed/guided pathways that direct people to the beach in an efficient and least impactful manner.

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