Vol. No. 140 August 4, 2000

US Army Corps
of Engineers
Detroit District

Great Lakes
Update

A Geologic Perspective on Lake Michigan Water Levels

By
Todd A. Thompson, Ph. D. and Steve J. Baedke, Ph. D.

With water levels in some Great Lakes decreasing by as much as three feet over the past three years, there is considerable interest in the timing and magnitude of water-level changes in the Great Lakes. Historical records from water-level gages provide the most accurate means to assess the magnitude and timing of water-level fluctuations. For most of the Great Lakes, these records extend back only to the mid-1800s.

With 150 years or more of recorded lake levels available for all the Great Lakes, it appears that we have captured most, if not all, possible lake-level extremes not associated with glacial times. However, advances in technology and developments in our knowledge of shoreline behavior and coastal systems are giving us a better understanding of past lake-level changes over thousands of years instead of just the hundreds of years observed in the historical record.

The Great Lakes are rimmed by ancient coastal features that are sometimes many feet above or several miles inland from the modern lakes. These relict coastal structures include ancient deltas, coastal and riverine-formed terraces, shorelines, and spits.

The lake levels, processes, and time needed to form the relict features have been studied by geologists for more than a century. Their physical features and locations can give scientists clues about lake-level changes that occurred before modern water-level gages were in place.

We have conducted research into geologic water levels of Lake Michigan over the past 10 years. Similar research is just beginning on Lake Superior. Other researchers have conducted geologic water level investigations on some of the other Great Lakes. Work on Lakes St. Clair, Erie, and Ontario offer many challenges and complexity to investigators, as geologic evidence is more likely to be obscured by urban development or drowned by long-term rising water levels. Continued research is needed on the remaining lakes. This article summarizes the results of the Lake Michigan investigations.

What Do We Need to Know?

To reconstruct past lake levels from relict coastal features, we need to determine the *elevation* of the lake at the time the feature formed and the *time* the lake was at that elevation (elevation and age).

The most common approach to determining the elevation of past lake levels is to first measure the elevation of some part of a coastal feature. Then, the elevation of that feature can be used to determine where the water surface was when the feature formed. For example, we can measure the elevation of a flat area at the base of a relict bluff and then calculate where the lake level probably was for the waves to cut the bluff. There is some error in this approach because the best place to measure is not always apparent. Using modern global-positioning satellite systems, however, such data can be collected rapidly.

Another approach is to dig into a relict coastal feature and determine the elevation of sediment layers. Certain sediment types have a well-known relationship to the position of the water surface when the feature formed. It is much more difficult to collect information using this second approach, but the elevation data can be more accurate.

The age of the coastal feature or deposit is the second piece of information needed to reconstruct past lake levels. In a general sense, the farther landward and higher in elevation a feature or deposit is located, the older it is. This "relative" age relationship, however, does not relate directly to calendar years on a graph.

Most scientists use radiocarbon dating of wood, peat, or some other organic material associated with the feature to approximate its age. For example, dating a piece of driftwood found in an ancient beach can provide an indication of the age of the beach. A newer approach is now available that determines the last time sunlight touched a grain of sand. With this technique, it is possible to determine the age of the sediment layers in the coastal features.

Collecting and Processing Data

In Lake Michigan, we have collected lake-level data by studying beach ridges that occur in embayments along the lake's coastline. Beach ridges are ridges of sand that arc from one side of an embayment to another (Figure 1).

Figure 1. Oblique aerial photograph of beach ridges near Manistique, Michigan. The oldest ridges are to the left and become younger toward the right near Lake Michigan.

We select embayments where there are several dozen or more beach ridges to study, like the ones shown in Figure 1. Beach ridges mark former shoreline positions at high lake elevations and preserve information that can be used to reconstruct past lake levels.

By digging into each beach ridge using a coring device, we can determine the elevation of the lake when a ridge formed. This is done by identifying sediment deposits that accumulate at or very near lake level. These sediment deposits are called *swash-zone* sediments. The gravelly base of the swash-zone sediment is known as the *plunge point* or *plunge step*. This is of particular interest because it is a close approximation of actual lake level at the time the ridge formed.

Beach ridges generally have wetlands in the swales between the ridges. These wetlands can be used to date the age of the ridges. By hand-augering to the base of a wetland and dating the organic sediment found at the base, we can approximate the age of the beach ridge that is lakeward of the wetland. Using data from many radiocarbon-dated wetlands and cored beach ridges, we can construct a historical lake level graph.

We have now conducted more than 10 years of field and laboratory work at five sites around Lake Michigan. In that time, we have collected hundreds of sediment cores, determined more than one hundred radiocarbon dates, and processed thousands of grain-size analyses. Processing the data includes conducting regression analyses to remove the effects of tilting of the earth, which continues to occur even today at a very slow rate as the earth's crust rebounds from the weight of the glaciers. As a result of all the data collection, testing, and analyses, we have constructed a graph that shows the upper limit of lake level for Lake Michigan over the past 4,700 years. (See the bold upper line on Figure 2.)

Because beach ridges only preserve a record of high stands, the graph of Lake Michigan levels over the past 4,700 years shows only high lake levels. We do not know to what elevation lake levels fell between the development of successive beach ridges. We can estimate the low levels, however, by shifting the high lake-level line 1.5 to 2 feet lower, which is the range of the approximate 33-year fluctuation observed in the historical record. The graph in Figure 2 indicates the estimated low lake levels by the lighter line, which mirrors the bold high lake level line. Lake levels over the past 4,700 years probably occurred within these two extremes. This assertion, however, is only an estimate. Other types of geologic data are needed to better define the lows.

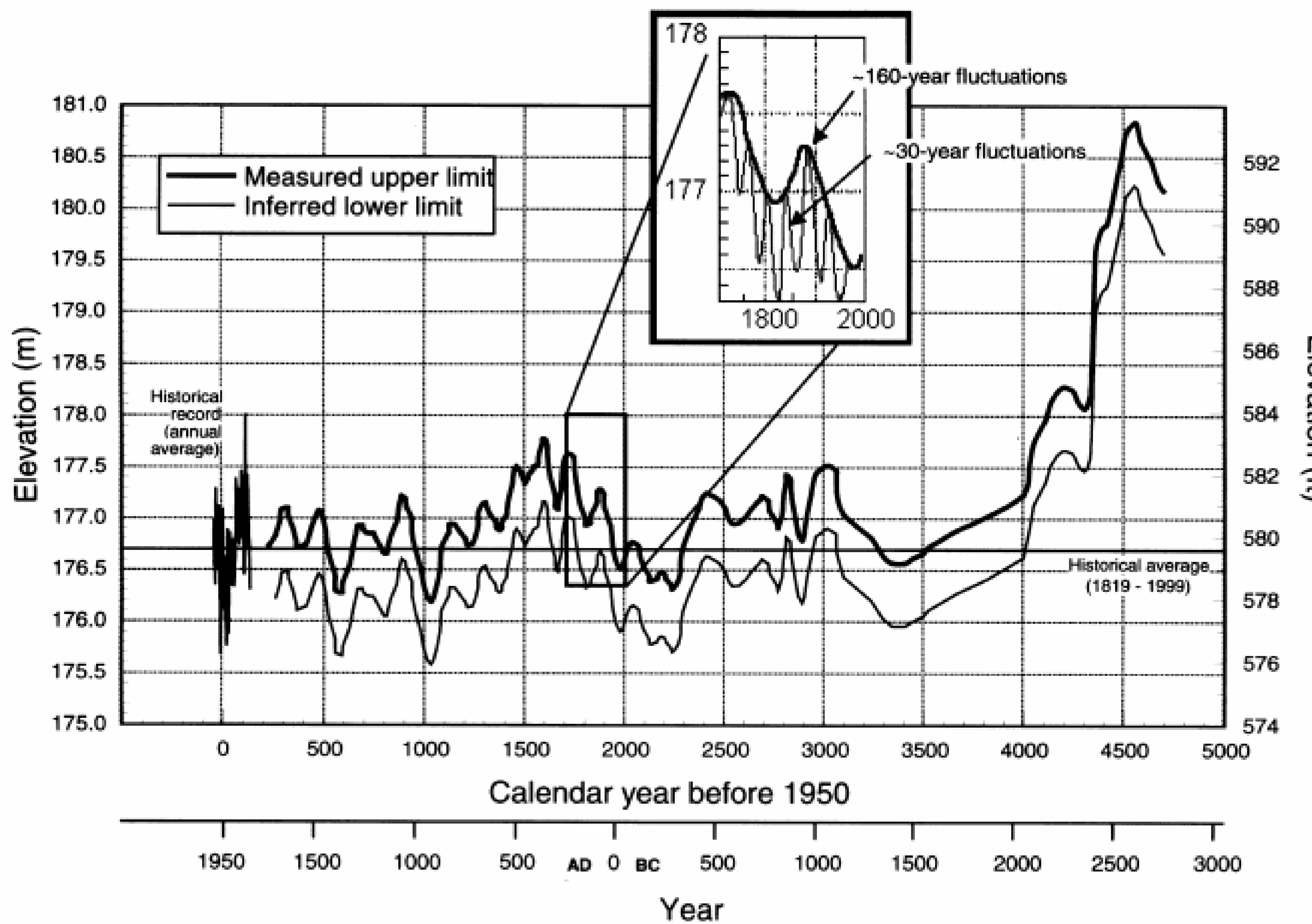
What Have We Learned?

In the construction of this graph, we have learned that Lake Michigan has two quasi-periodic lake-level fluctuations: a shorter-term fluctuation from 29 to 38 years (averaging about 33 years) and a longer-term fluctuation from 120 to 200 years (averaging about 160 years).

Individual beach ridges are created by the 33-year periodic lake-level fluctuation. Typically, 4 to 6 ridges are grouped together, which suggests that there is a longer-term fluctuation of about 160 years. Within the approximate 160 years, there may be 4 to 6 short-term periods of lake level rise and fall. This is illustrated in the inset on the graph on Figure 2, which shows several approximate 33-year water-level fluctuations within the longer-term 160-year fluctuation.

Although two periodic fluctuations occur in the Lake Michigan data, these fluctuations do not repeat in perfect cycles, and thus cannot be used to definitively predict future water levels.

Figure 2. Graph of historical and geologic lake level for Lake Michigan over the past 4,700 years



Note: Bold line is measured upper limit of lake level through time observed at the Port Huron outlet, and lower line is an inferred possible lower limit. All elevations are referenced to the International Great Lakes Datum (IGLD) of 1985. Historical data prior to 1865 is not USACE data. The data were obtained from a single gage. The validity of the data cannot be verified.

Each has a range of variation in period and amplitude. Both of these fluctuations are superimposed on even longer-term lake-level changes associated with changes in water volume and flows out of the basin.

Reviewing the graph as a whole gives us an indication of the lake levels over the past 5,000 years. Lake Michigan's water level was very high 4,500 years ago — more than 12 feet higher than the long-term historical average for the lake! At that time, Lake Michigan and its sister Lake Huron had two outlets — one at Port Huron, Michigan and the other at Chicago, Illinois.

Between 4,500 and 3,400 years ago, the lake level fell almost 15 feet, with most of the fall occurring in only 500 years. The lake appears to have stopped falling when the level in Lake Michigan dropped below the level of the Chicago outlet. At that time, the St. Clair River at Port Huron began to handle the entire discharge of the upper lakes. The modern phase of Lake Michigan was established at this time.

From 3,400 years ago to the present, the upper limit of the lake level reached an elevation of 1.5 to 3.5 feet above and about 1.5 feet below the historical average. Two prominent highs occurred from 2,300 to 3,100 and from 1,100 to 1,900 years ago. The older high lake level period corresponds with a lake level phase known as the Algoma phase of ancestral Lake Michigan. The younger high lake level period is currently unnamed.

The graph also shows us that the range in variation observed in the last 150 years of historical records encompasses almost all of the range observed in the geologic record over the past 3,400 years. Therefore, recent high and low water levels appear to be part of the natural hydrologic variability of the lake, driven by climate. Although the graph does not allow us to predict future lake levels with any certainty, it helps us understand the likelihood of extreme high and low lake levels in the future.

About the Authors

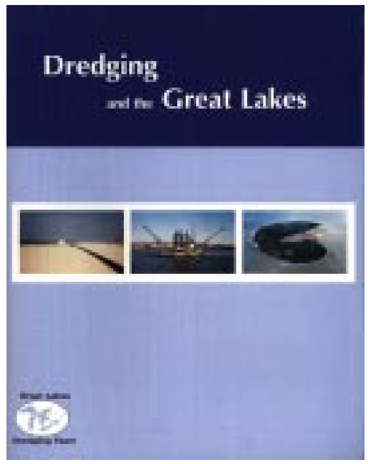
Todd Thompson (pictured on the left) is an Associate Scientist with the Indiana Geological Survey, an Institute of Indiana University. Steve Baedke (pictured on the right) is an Assistant Professor in the Department of Geology and Environmental Science at James Madison University. Both received their Ph.D.s from Indiana University in sedimentology and hydrology, respectively. They have been working on Great Lakes water levels with financial support from the U.S. Geological Survey and Fish and Wildlife Service for more than a decade. They are currently studying ancient shorelines along Lake Superior.

They can be contacted by email at:

tthomps@indiana.edu

baedkesj@jmu.edu

Want to learn more about dredging in the Great Lakes?



Order

Dredging and the Great Lakes!

A joint product of the U.S. Army Corps of Engineers and the Great Lakes Commission

- When and how is dredging conducted in the Great Lakes?
- What is environmental dredging?
- How can dredged material be used beneficially?
- What role does the public play in the dredging process?

ORDER FORM

Please send me a copy of ***Dredging and the Great Lakes***.

Name ____

Street Address ______________________________________

City________________________ State/Province _________ Zip/Postal code__________

Phone______________________________________

Mail to: U.S. Army Corps of Engineers – Detroit District, ATTN: CELRE-ET-HH-W,
P.O. Box 1027, Detroit, MI 48231

Dredging the Great Lakes

The current period of low lake levels is having an effect on Great Lakes navigation. Both commercial vessels and recreational boats are coping with navigation draft problems throughout the upper and middle Great Lakes. For example, a thousand-foot bulk carrier loses 270 tons of cargo for each inch reduction in draft. For some voyages this season, thousands of tons of potential revenue-generating cargo have been left on the dock.

Dredging permit requests for fiscal year 2000 are about double the long-term average. This demand has also translated into a 25-30 percent increase in costs for dredging.

A 13-page illustrated booklet that describes the dredging / navigation depth connection and overall dredging issues was published last year by the Great Lakes Dredging Team, a federal-state partnership. *Dredging and the Great Lakes* is available online at:

www.glc.org/projects/dredging

or in hardcopy by submitting the order form on the opposite page to the USACE, Detroit District.

Public Meetings

International Niagara Board of Control

The International Niagara Board of Control (INBC) will hold an open house on Tuesday, September 12, 2000 in Niagara Falls. The purpose of the open house is to inform the public of the Board's current activities and hear public comments and suggestions regarding the Board's work. Information on Great Lakes' water levels will also be presented. The public is invited to attend. The meeting will be held at 7:30 p.m. on Tuesday, September 12, 2000 at the Four Points/Sheraton Hotel, 114 Buffalo Avenue, Niagara Falls. For more information, contact John Kangas at (312) 353-4333 or check the Board's home page at:

http://huron.lre.usace.army.mil/ijc/niagara.html

Lake Superior Board of Control's Annual Meeting

The International Lake Superior Board of Control (ILSBC) held its annual public meeting on June 27 in Marquette, Michigan to discuss the regulation of Lake Superior outflows and water level conditions on all the Great Lakes, with a focus on Lakes Superior, Michigan, and Huron. Following a brief presentation on current conditions and the outlook for the summer, the ILSBC responded to comments from the floor. For additional information on ILSBC activities, check the home page at:

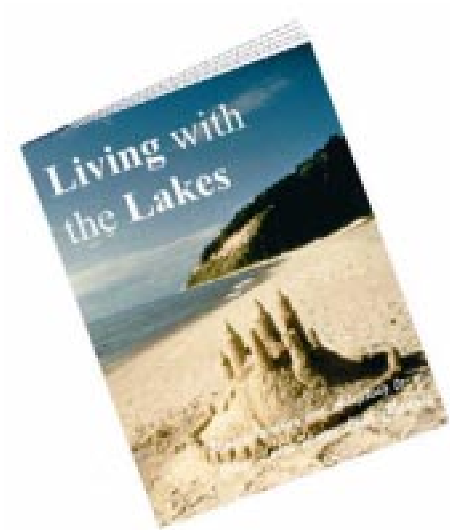
http://huron.lre.usace.army.mil/ijc/superior.html

Lake Michigan Potential Damages Study Workshops

The USACE held two meetings in late July to discuss the implications of extreme water levels on coastal processes, planning policy and management, effectiveness of shoreline structures, and coastal hazard management. An update of the Lake Michigan Potential Damages Study was presented at the workshops, which were held in Zeeland, Michigan and Milwaukee, Wisconsin. For more information on the study, visit our home page at:

http://huron.lre.usace.army.mil/coastal/LMPDS

Want to learn more about the ups and downs of the Great Lakes water levels?



Order

Living with the Lakes!

A joint product of the U.S. Army Corps of Engineers and the Great Lakes Commission

- Why do water levels fluctuate?
- How can residents protect their shoreline property?
- How do lake level changes affect the region's environment and economy?
- How are the water levels managed?

ORDER FORM

Please send me a copy of ***Living with the Lakes***.

Name ______________________________

Street Address ______________________________

City______________ State/Province ________ Zip/Postal code________

Phone______________________________

Mail to: U.S. Army Corps of Engineers – Detroit District, ATTN: CELRE-ET-HH-W, P.O. Box 1027, Detroit, MI 48231