# Natural Factors

***The difference between the amount of water coming into a lake and the amount going out is the determining factor in whether the water level will rise, fall or remain stable. When several months of above-average precipitation occur with cooler, cloudy conditions that cause less evaporation, the levels gradually rise. Likewise, prolonged periods of lower-than-average precipitation and warmer temperatures typically result in lowering of water levels.***

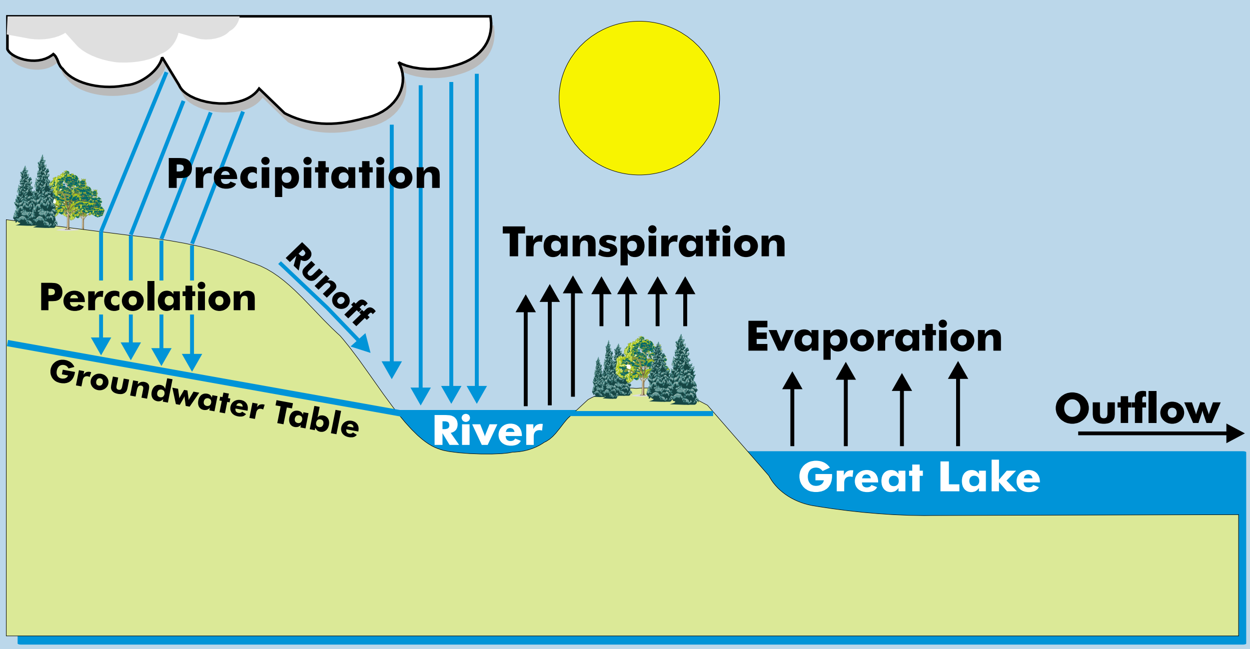
Grand Haven, Michigan, lighthouse on Lake Michigan during storm

## The hydrologic cycle

Water, a renewable resource, is continually recycled and returned to the ecosystem through the hydrologic cycle. Moisture is carried into the Great Lakes basin most commonly by continental air masses, originating in the northern Pacific Ocean, that traverse the North American continent. Tropical systems originating in the Gulf of Mexico or Arctic systems originating in the north polar region also carry moisture into the basin. As weather systems move through, they deposit moisture in the form of rain, snow, hail or sleet. Water enters the system as precipitation directly on the lake surface, runoff from the surrounding land including snowmelt, groundwater, and inflow from upstream lakes. Precipitation falling on the land infiltrates into the ground through percolation to replenish the groundwater.

Water leaves the system through evaporation from the land and water surface or through transpiration, a process where moisture is released from plants into the atmosphere. Water also leaves the system by groundwater outflow, consumptive uses, diversions and outflows to downstream lakes or rivers. Ultimately water flows out of each of the Great Lakes through their connecting channels and the St. Lawrence River to the Atlantic Ocean.

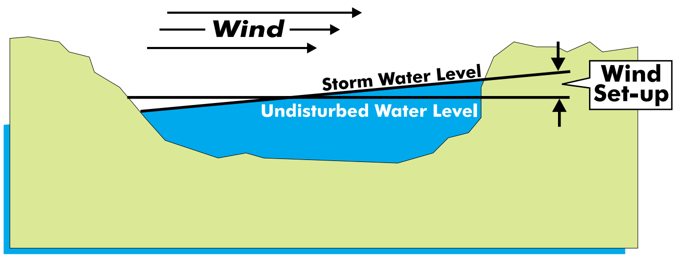
Evaporation from the lake surface is a major factor in the hydrologic cycle of the Great Lakes. Water evaporates from the lake surface when it comes in contact with dry air, forming water vapor. This vapor can remain as a gas, or it can condense and form water droplets, causing fog and clouds. Some of this moisture returns in the form of rain or snow, completing the hydrologic cycle. The best example of this is lake-effect snow squalls, which commonly occur on the leeward side of most lakes. Generally, much of the evaporated water is removed from the system by prevailing wind patterns.




Hydrologic Cycle

## Short-term fluctuations

Some water level fluctuations are not a function of changes in the amount of water in the lakes. These fluctuations, generally short in duration, are due to winds or changes in barometric pressure. Short-term fluctuations, lasting from a couple hours to several days, can be very dramatic. Fluctuations due to storms or ice jams are two examples.




**Lake profile showing wind set-up**

*There are three kinds of water level fluctuations: short-term, seasonal and long-term.*

### Wind set-up, storm surge and seiche

Sustained high winds from one direction can push the water level up at one end of the lake and make the level drop by a corresponding amount at the opposite end. This is called wind set-up or storm surge. Changes in barometric pressure can add to this effect. When the wind abruptly subsides or barometric pressure changes rapidly, the water level often will oscillate until it stabilizes again. This phenomenon is known as **seiche** (pronounced "sayshe"). The pendulum-like movements within seiches can continue for days after the forces that created them vanish. Lake Erie is most susceptible to storm surges and seiches due to its east-west orientation in an area of prevailing westerly winds and its generally shallow western end.

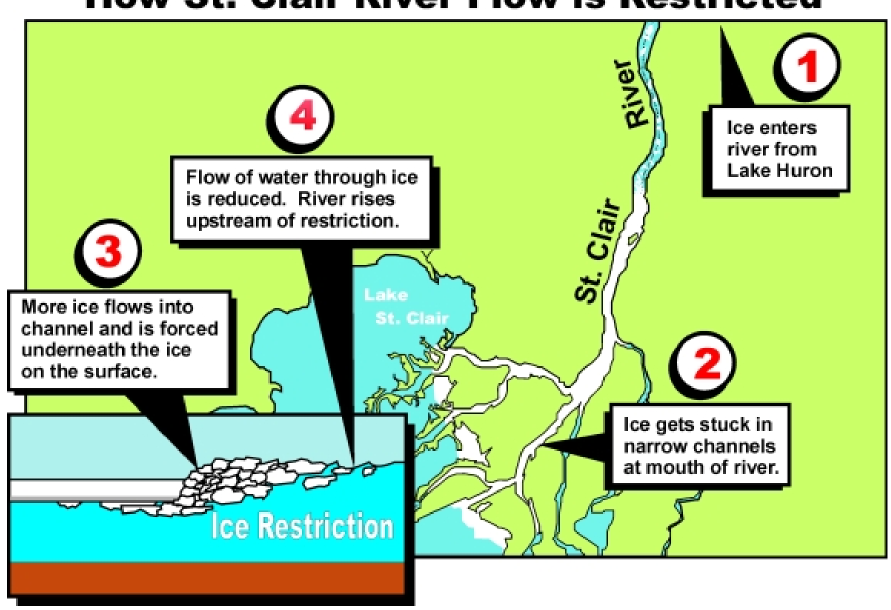
### Plant growth and ice development in the connecting channels

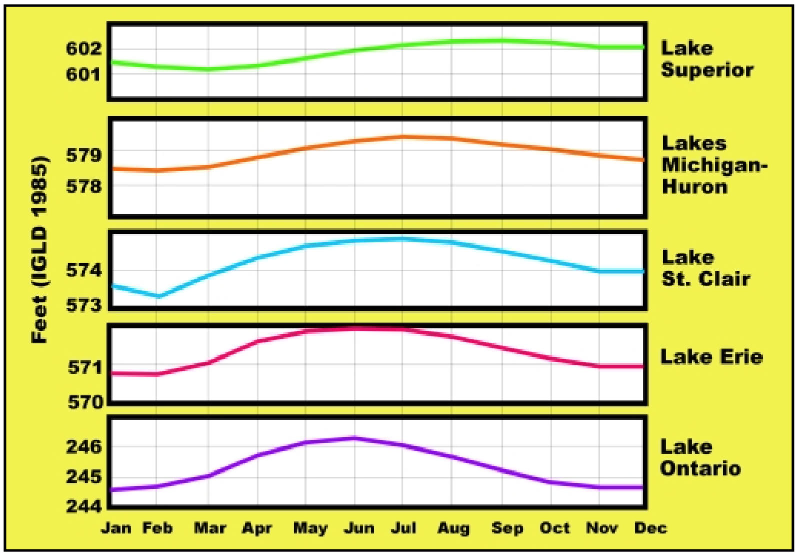
The natural growth of aquatic plants can affect the flow of water in the tributaries and connecting channels of the lakes. Plant growth decreases the flow of water by narrowing or partially obstructing the channel through which the water flows. Plant growth in part depends on the weather, and can vary from month to month and year to year. In the summer, aquatic plant growth in the Niagara River reduces its flow, on average, by about 2 percent.

An ice jam in an outlet river can drastically slow the flow of water out of one lake and into another. Water levels rise upstream of the jam and fall downstream. The effects are most noticeable on the water levels of the affected river, and of smaller lakes such as St. Clair and Erie.

On the St. Clair River, normal ice build-up can reduce the flow in the river by about 5 percent during the winter. A serious ice jam can reduce flows by as much as 65 percent for short periods of time. Ice jams can develop in a matter of hours, but it may take several days for the jam to be relieved and water levels and flows to return to normal.

**How St. Clair River Flow is Restricted**






## Seasonal fluctuations

The lakes are generally at their lowest levels in the winter months. In the fall and early winter, when the air above the lakes is cold and dry and the lakes are relatively warm, evaporation from the lakes is greatest. With more water leaving the lakes than entering, the water levels decline to their seasonal lows.

As the snow melts in the spring, runoff to the lakes increases. Evaporation from the lakes is least in the spring and early summer when the air above the lakes is warm and moist and the lakes are cold. At times, condensation on the lake surface replaces evaporation. With more water entering the lakes than leaving, the water levels rise. The levels peak in the summer. In the early fall, evaporation and outflows begin to exceed the amount of water entering the lakes.

*The range of seasonal water level fluctuations on the Great Lakes averages about 12 to 18 inches from winter lows to summer highs.*

The range of seasonal water level fluctuations on the Great Lakes averages about 12 to 18 inches from winter lows to summer highs. The timing of the annual peaks and lows varies geographically due to differences in climate across the basin. Seasonal rises begin earlier on the more southern lakes where it is warmer with peaks usually occurring in June or July. Lake Superior, the northernmost lake, is generally the last lake to peak, usually in August or September.

All water levels on the Great Lakes are measured relative to sea level and expressed relative to the International Great Lakes Datum (IGLD), last updated in 1985. *(For further information on the reference datum, see page 27.)*

### Weather in the Great Lakes basin

"Wait a day and the weather will change" is an apt description of weather in the Great Lakes region, especially in the spring and fall. That's because the region is affected by both warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic. In general, the north experiences cooler weather, while the south has warmer temperatures. The entire basin experiences four distinct seasons.

The Great Lakes also have a significant influence on the climate. Acting as a giant heat sink, the lakes moderate the temperatures of the surrounding land, cooling the summers and warming the winters. This results in a milder climate in portions of the basin compared to other locations of similar latitude. The lakes also act as a giant humidifier, increasing the moisture content of the air throughout the year. In the winter, this moisture condenses as snow when it reaches the land, creating heavy snowfall in some areas, known as "snow belts" on the downwind shores of the lakes. The shores of Lake Superior are particularly prone to this "lake-effect" snow. Some areas around the lake have recorded more than 350 inches of snow in a single year. During the winter, the temperature of the lakes continues to drop. Ice frequently covers Lake Erie but seldom fully covers the other lakes.

## Long-term fluctuations

Long-term fluctuations occur over periods of consecutive years and have varied dramatically since water levels have been recorded for the Great Lakes. Continuous wet and cold years will cause water levels to rise. Conversely, consecutive warm and dry years will cause water levels to decline. Water levels have been measured on the Great Lakes since the 1840s. Older records may not be as accurate as current observations, since measurements were only taken at a single gage per lake until 1918 and observations were not taken as frequently as they are today.

The Great Lakes system experienced extremely low levels in the late 1920s, mid-1930s and again in the mid-1960s. Extremely high water levels were experienced in the 1870s, early 1950s, early 1970s, mid-1980s and mid-1990s. Long-term fluctuations are shown on the hydrograph presented on the graph on the following page. A **hydrograph** is a plot of water levels versus time.

Global warming and a phenomenon known as the 'greenhouse effect' could cause significant changes in long-term lake levels. Although debatable, most predictions indicate that global warming would cause prolonged declines in average lake levels into the future. These declines could create large-scale economic concern for virtually every user group in the Great Lakes basin. Dramatic declines also could compromise the ecological health of the Great Lakes, particularly in the highly productive nearshore areas.

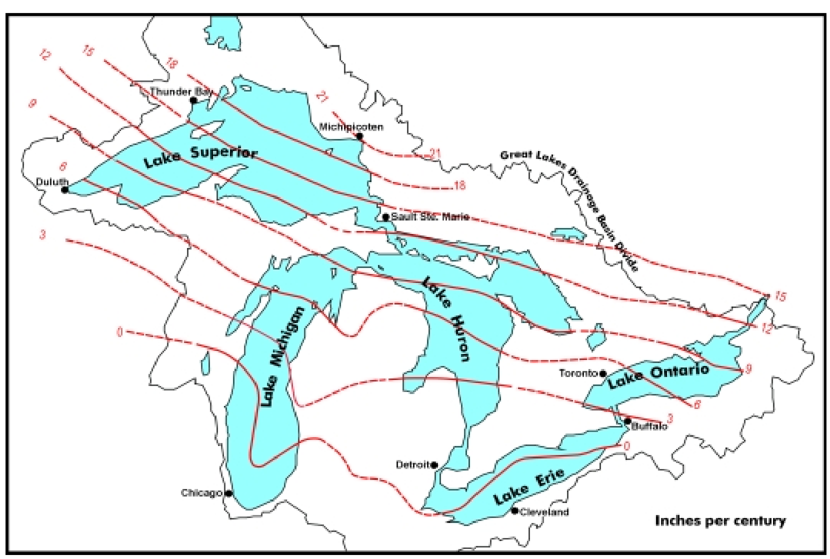
Besides natural climatic variability and potential man-made climate change, other factors can affect long-term fluctuations, including changes in consumptive use, channel dredging or encroachment and crustal movement.

*Over the last century, the range from extreme high to extreme low water levels has been nearly 4 feet for Lake Superior and between 6 and 7 feet for the other Great Lakes.*

## Crustal movement

Crustal movement, the rebounding of the earth's crust from the removed weight of the glaciers, does not affect the amount of water in a lake, but rather affects water levels at different points around the lake. Crustal rebound varies across the Great Lakes basin. The crust is rising the most, more than 21 inches per century, in the northern portion of the basin, where the glacial ice sheet was the thickest, heaviest and the last to retreat. There is little or no movement in the southern parts of the basin. As a result, the Great Lakes basin is gradually tipping, a phenomenon most pronounced around Lake Superior.

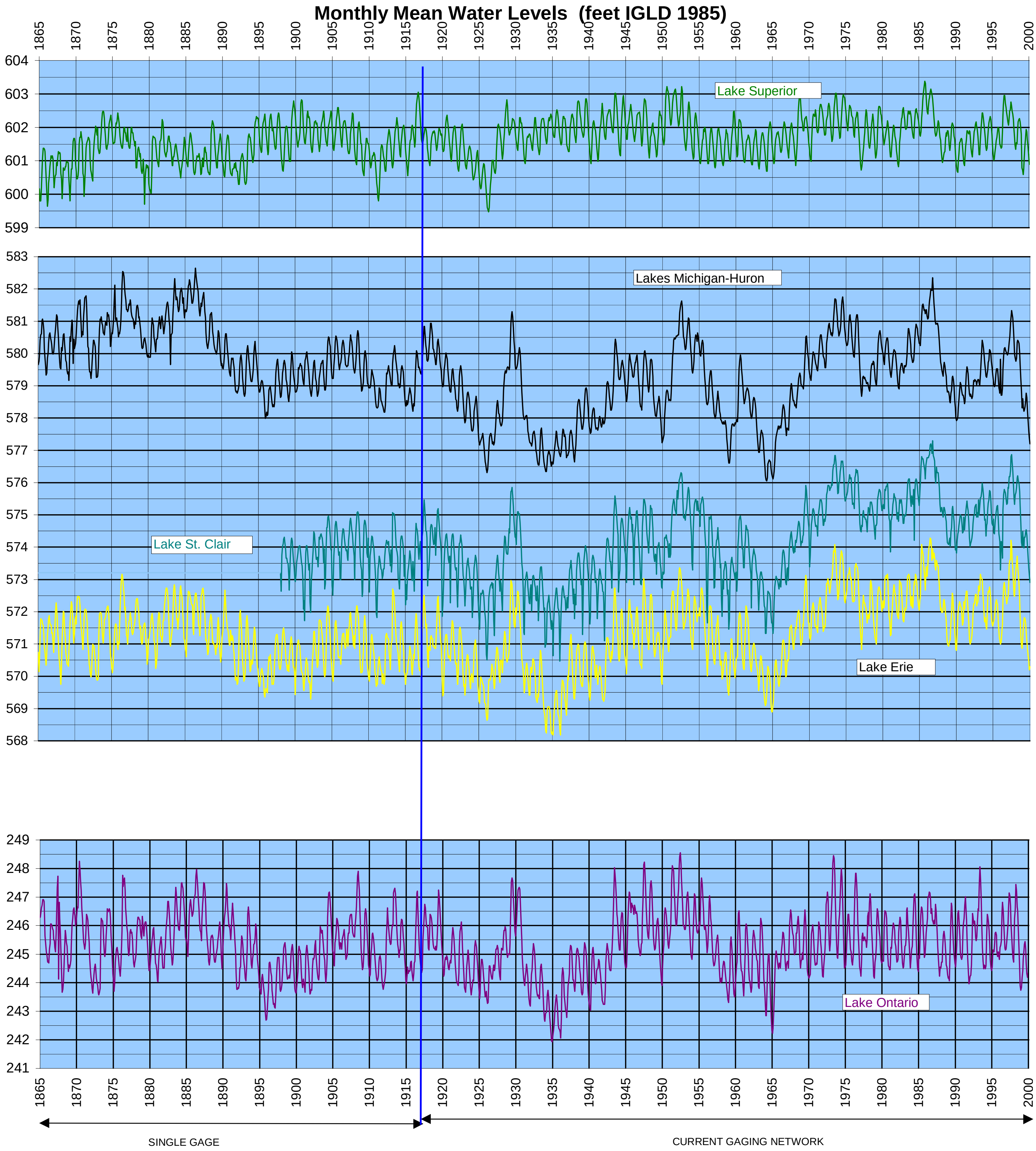
To see what this means for water levels, an analogy can be made using a cup of water. As the cup is tipped, the surface of the water comes closer to the edge of the cup on one side and is farther from the edge on the other side. This is why water levels are measurably higher today at Duluth, Minnesota, and lower at Michipicoten, Ontario, on the opposite side of Lake Superior, than they were several decades ago. This tipping phenomenon is particularly significant for Lake Superior, and somewhat lesser for lakes Michigan, Erie and Ontario as their outlet channels are rising faster than the western shores of these lakes. As such, there is a gradual decrease in outflow capacities for each of the lakes over time.




Rates of crustal rebound

# Great Lakes system historical levels

A hydrograph is a plot of lake levels versus time. These hydrographs show monthly average water levels for each of the Great Lakes and Lake St. Clair. Levels have been measured on most lakes since 1865, with the present network of water level gages operating since 1918. Lake levels change seasonally each year and can vary dramatically over longer periods. Short-term fluctuations are of a greater magnitude than the monthly averages.

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