Environment Canada / Environnement Canada

Canada

This brochure was designed for use by the general public who wish to know more about the water levels of the Great Lakes. Its main purpose is to explain the causes and effects of Great Lakes water level fluctuations.

To further general understanding, descriptions have been kept simple, and excessive use of technical words and details has been avoided. A list of references has been provided for readers who want additional information.

This brochure should lead to a greater understanding of the causes and effects of water level fluctuations. It is hoped that it will increase awareness of the importance of protecting and preserving, as well as living in harmony with the environment.

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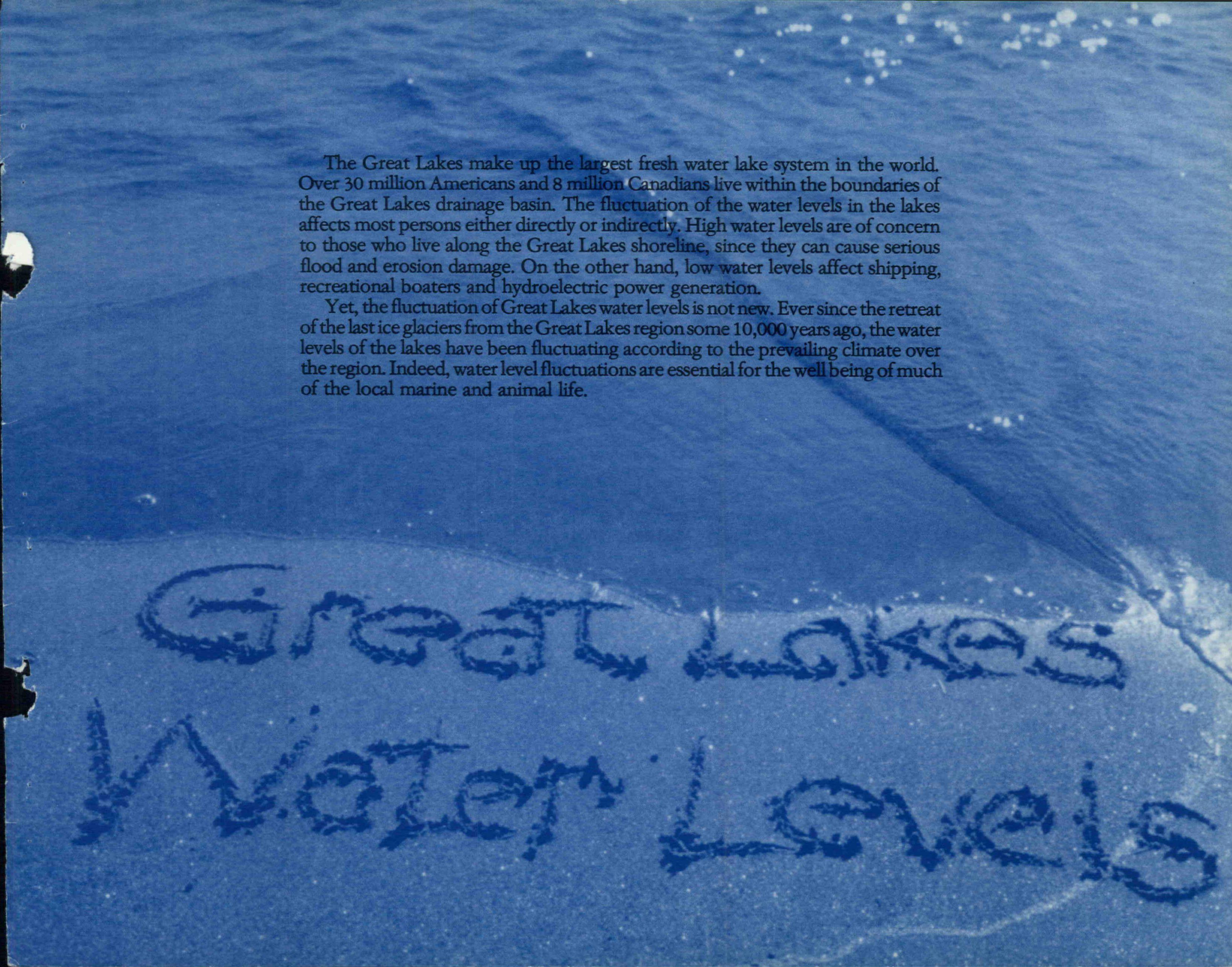
The Great Lakes make up the largest fresh water lake system in the world. Over 30 million Americans and 8 million Canadians live within the boundaries of the Great Lakes drainage basin. The fluctuation of the water levels in the lakes affects most persons either directly or indirectly. High water levels are of concern to those who live along the Great Lakes shoreline, since they can cause serious flood and erosion damage. On the other hand, low water levels affect shipping, recreational boaters and hydroelectric power generation.

Yet, the fluctuation of Great Lakes water levels is not new. Ever since the retreat of the last ice glaciers from the Great Lakes region some 10,000 years ago, the water levels of the lakes have been fluctuating according to the prevailing climate over the region. Indeed, water level fluctuations are essential for the well being of much of the local marine and animal life.



PHYSICAL FEATURES

The Great Lakes have a water surface area of about 246,000 square kilometres. The area of the surrounding land and other smaller lakes draining into the Great Lakes is about 528,000 square kilometres (see Table 1).

The Great Lakes consist of Lakes Superior, Michigan, Huron, Erie and Ontario. They form a chain of reservoirs with each one draining to the next. Lake Superior is the uppermost lake and, the largest. It drains to Lake Huron by way of the St. Mary's River. Lake Michigan, located entirely in the United States, also drains to Lake Huron. The water levels of both Lake Michigan and Lake Huron are essentially at the same elevation since both lakes are connected by the wide and deep Straits of Mackinac.

GENERAL MAP OF THE GREAT LAKES

TABLE 1.
PHYSICAL DIMENSIONS OF THE GREAT LAKES BASIN

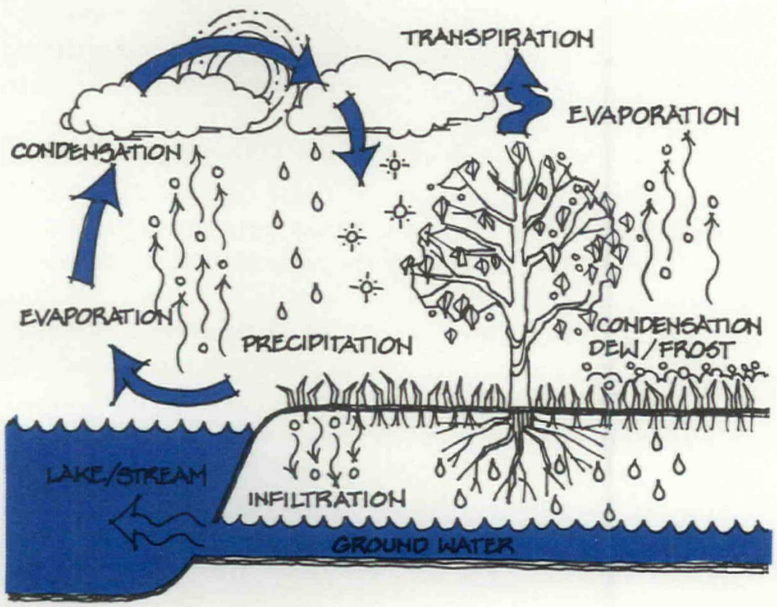
	Area (square kilometres) Land (2)	Area (square kilometres) Water	Shoreline Length (3) (kilometres)	Water Volume (cubic kilometres)
Lake Superior	127700	82100	4380	12100
St. Mary's River	2600	230	397	
Lake Michigan	118000	57800	2630	4920
Lake Huron	131300	59600	6160	3540
St. Clair River	3290	60	101	
Lake St. Clair	12430	1110	413	
Detroit River	2230	100	212	
Lake Erie	58800	25700	1400	484
Niagara River	3370	60	171	
Lake Ontario	60600	18960	1150	1640
St. Lawrence (1)	7190	610	1050	
Total	527510	246330	18064	22684

(1) Measured from the outlet of Lake Ontario to Cornwall, Ontario/ Massena, New York.
(2) Land area includes other small lakes and rivers in the basin.
(3) Including islands.

From Lake Huron, water flows to Lake Erie by way of the St. Clair River, Lake St. Clair and the Detroit River. Lake Erie is the shallowest of the five Great Lakes and second smallest in surface area. Its outflow is mainly through the Niagara River to Lake Ontario. Lake Ontario water in turn flows into the St. Lawrence River which carries the total outflow of the Great Lakes some 870 kilometres to the Gulf of St. Lawrence.

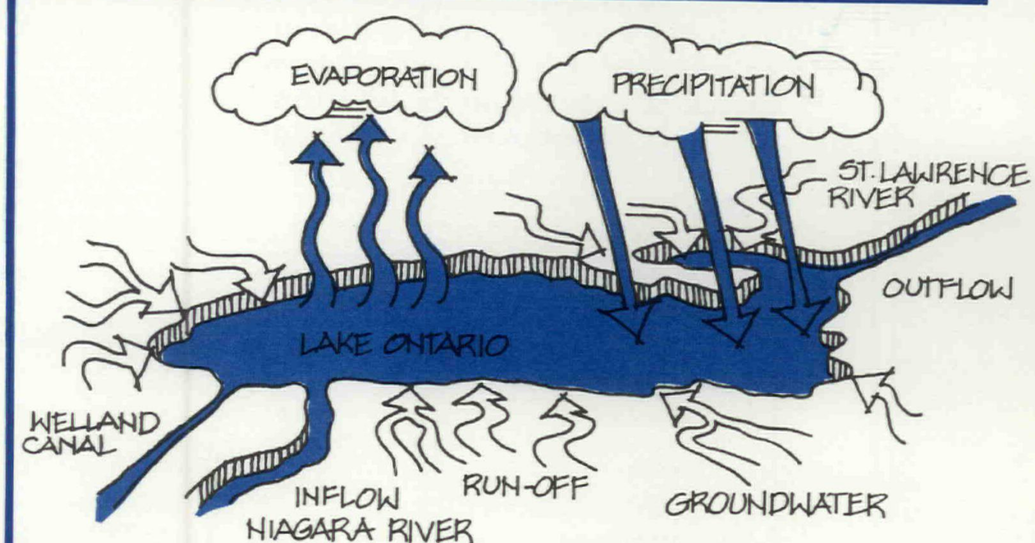
HYDROLOGY

The hydrologic cycle is a world-wide natural circulation system in which water evaporates from oceans, other large bodies of water (such as the Great Lakes) and land areas, condenses to form clouds, and is returned to the earth's surface as precipitation.

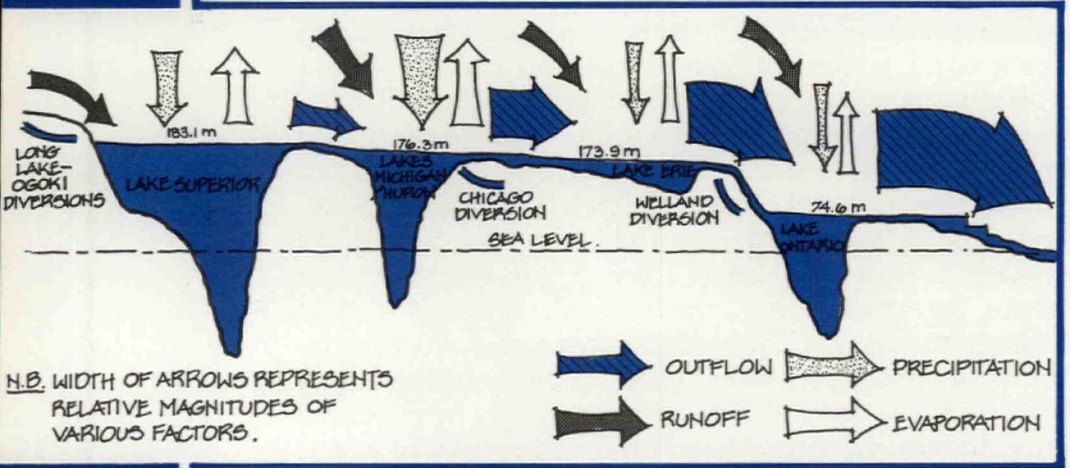


HYDROLOGIC CYCLE

Precipitation that falls over the Great Lakes provides a direct input to these water bodies. Precipitation in the form of rain or snow that falls over the basin may follow any number of courses. Snow that falls on the land during the winter remains on the ground until the following spring. Snowmelt in the spring forms a major part of the total water supply to the lakes. Some of the precipitation will evaporate before it reaches the ground, while another portion will drop on plants, buildings or pavement, and will evaporate directly. Of the large amount that reaches the ground, some will flow overland to streams while a portion will be stored in the soil near the surface and will eventually also evaporate. Part will be used by plants and then be returned to the atmosphere by transpiration. Another portion will become the ground water and eventually find its way to streams and lakes, re-appear at the surface in springs or travel through the ground to the ocean. Streamflow that enters the Great Lakes is often referred to as runoff. The various processes, such as precipitation and evaporation that make up the hydrologic cycle are never constant and can vary substantially from time to time. In fact, there have been extended periods of wet or dry years in the Great Lakes basin which were responsible for extremely high lake levels in the early 1970s and in 1986, or low water levels of the mid-1960s.



FACTORS AFFECTING LAKE ONTARIO LEVELS



HYDROLOGY OF THE GREAT LAKES SYSTEM

The water level in each of the Great Lakes rises or falls according to the amount of water entering a lake and the amount leaving it. The amount entering a lake includes precipitation falling on the lake, runoff including snowmelt from the surrounding area, and ground water inflow.

The water leaving a lake consists of evaporation from the lake's surface, ground water outflow and outflow at the lake outlet. Water levels will rise when the amount entering a lake exceeds the amount leaving it. This happens every spring. The converse is also true every fall and winter.

A lake's outflow depends on the elevation of the lake. The higher the lake level, the higher its outflow. Low lake levels will bring about low outflows. This self-regulating feature helps to keep levels on the lake within certain ranges.

Because of the large size of the Great Lakes and the limited discharge capacities of their outflow rivers, extremely high or low levels and flows sometimes persist for some considerable time after the factors which caused the extremes have changed.

Table 2 shows the magnitudes of the range of water level fluctuation and outflow that have been recorded. On the Great Lakes and along the St. Lawrence River, there are water level gauges which measure and record continuously the water surface elevations. Records in Canada are published annually by Environment Canada.

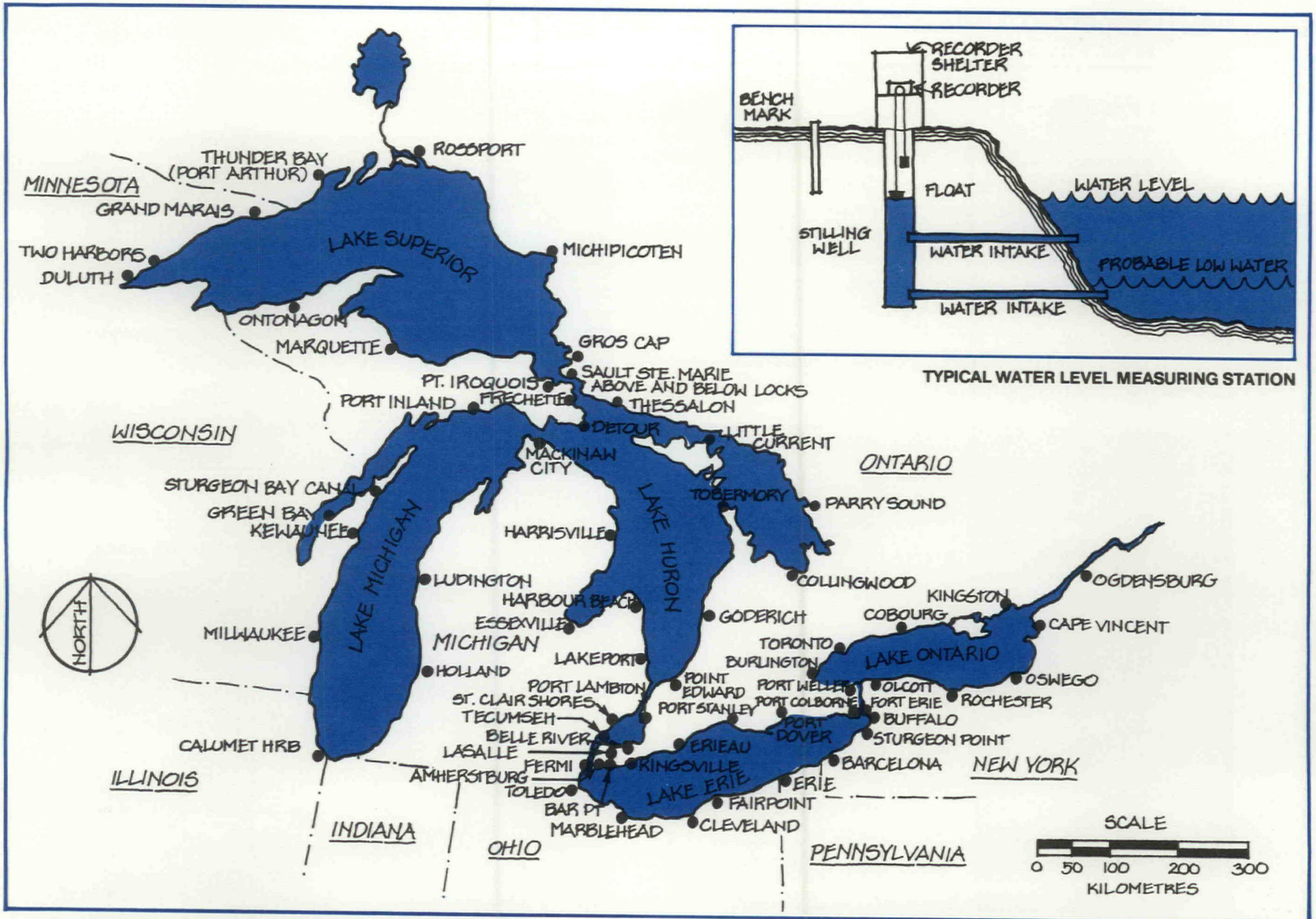
TABLE 2.
SUMMARY OF HISTORICAL WATER SURFACE ELEVATIONS AND OUTFLOWS OF THE GREAT LAKES

	Water Surface Elevation (metres)	Outflows (cubic metres per second)
Lake Superior		
Average	183.1	2120
Maximum	183.5	3600
Minimum	182.4	1160
Range	1.1	2440
Lakes Michigan/Huron		
Average	176.3	5150
Maximum	177.2	6570
Minimum	175.4	3000
Range	1.8	3570
Lake Erie		
Average	173.9	5800
Maximum	174.8	7760
Minimum	173.0	3340
Range	1.8	4420
Lake Ontario		
Average	74.6	6800
Maximum	75.6	9910
Minimum	73.6	4360
Range	2.0	5550

(1) All figures are based on monthly values for the period 1900-1983.

(2) Water surface elevations shown here for each lake are based on the average of a number of water level recording instruments located on the lakes, and do not represent extreme high or low water levels experienced at any specific site.

(3) Elevations are measured in metres above mean sea level.



TYPICAL WATER LEVEL MEASURING STATION

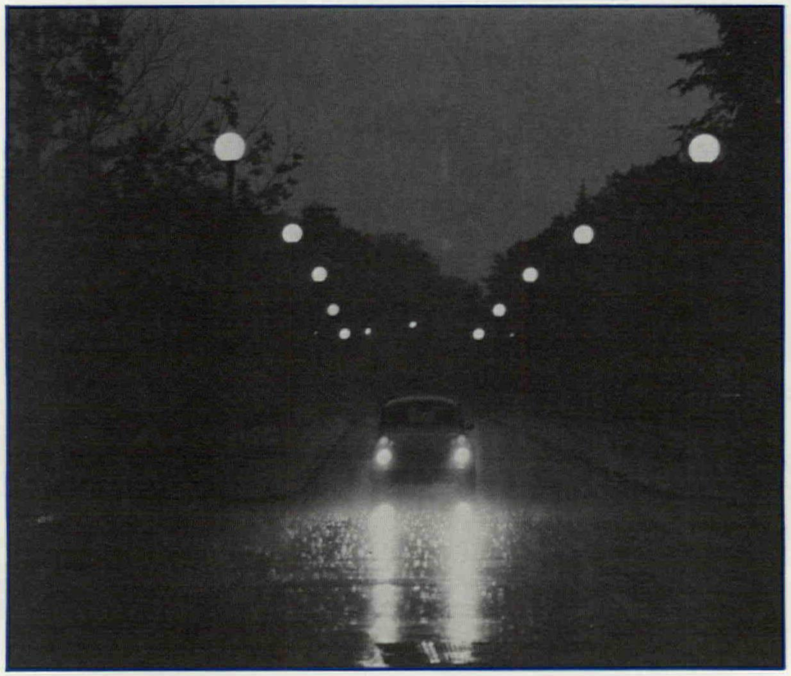
WATER LEVEL GAUGING STATIONS ON THE GREAT LAKES

FACTORS AFFECTING GREAT LAKES WATER LEVELS

Natural Factors

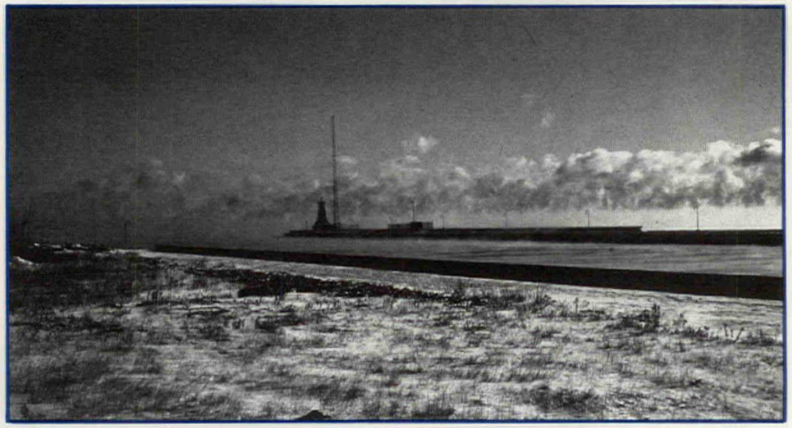
PRECIPITATION

Precipitation or lack of it is the main cause of long-term extreme fluctuations in lake levels. For example, in the early 1960's an extended period of below average precipitation brought about record low lake levels. In 1973 and 1985, high precipitation resulted in extreme high levels on the Great Lakes. A review of the past 100 years of water level records shows that no regular, predictable cycle between lows and highs exists. The intervals between high and low levels, and the durations of these highs and lows, can vary widely over a number of years.



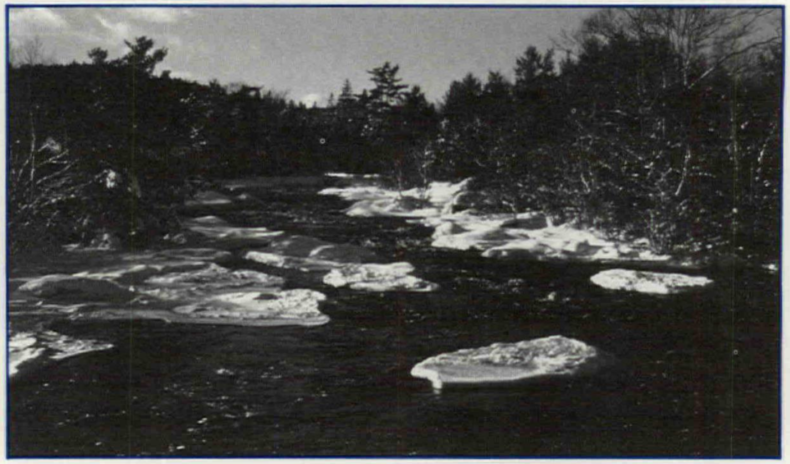
EVAPORATION

Evaporation is least in the spring with condensation occurring at times when the lakes are cold relative to the air, and is greatest in the fall and early winter when the lake water is warm relative to the air temperatures. In one month up to 200 mm can evaporate from Lake Erie.



RUNOFF

In the spring, the snow on the lake's drainage basin melts and greatly increases the runoff into the lake.



This high inflow results in higher lake levels during the spring and early summer. The normal range from winter lows to summer highs is about 0.3 metre on Lakes Superior, Michigan and Huron and 0.5 metre on Lakes Erie and Ontario.

ICE RETARDATION

As the ice cover forms on the connecting rivers of the Great Lakes the flow is reduced because of the added surface friction and the reduction in channel cross-section area. If the ice cover breaks, ice jams can form, causing serious flooding upstream, ice damages along the shoreline, and greatly reduced flows downstream.

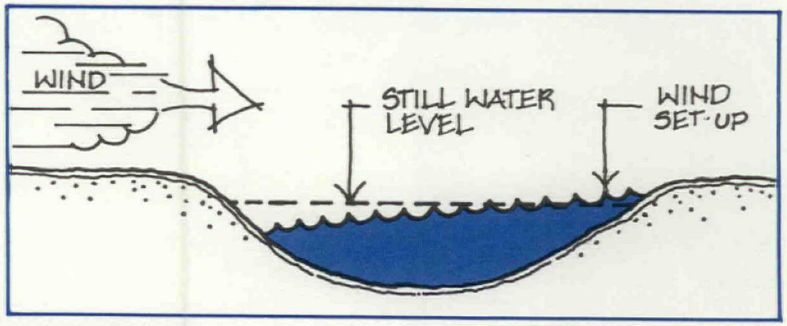
An ice jam in the St. Clair River occurred for some 26 days in April 1984, cutting the flow rate by up to 50%. During this period, the rise in level of Lakes Michigan and Huron was negligible due to their vast storage capacity. However, the level of the much smaller Lake St. Clair fell as much as 0.6 metre.

AQUATIC GROWTH

Weeds or aquatic growth in the connecting rivers during the summer can reduce flow by the friction they introduce. In the Niagara River weeds reduce the flow by 3% on average.

METEOROLOGICAL DISTURBANCES

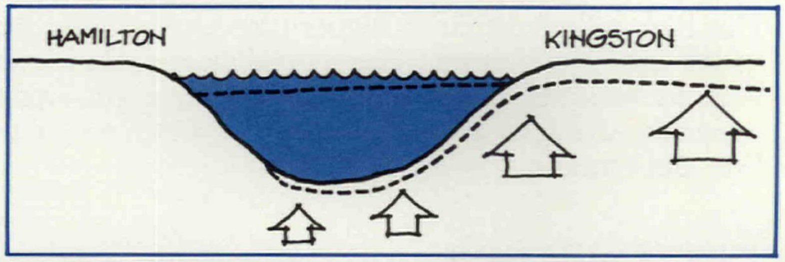
Another cause of lake level changes is wind. When strong winds continue to blow over a lake in one direction for a number of hours, they produce a surface tilt, referred to as 'wind set-up'. This wind set-up can cause the water level on eastern Lake Erie to rise over 2 metres on a temporary basis in less than a day.



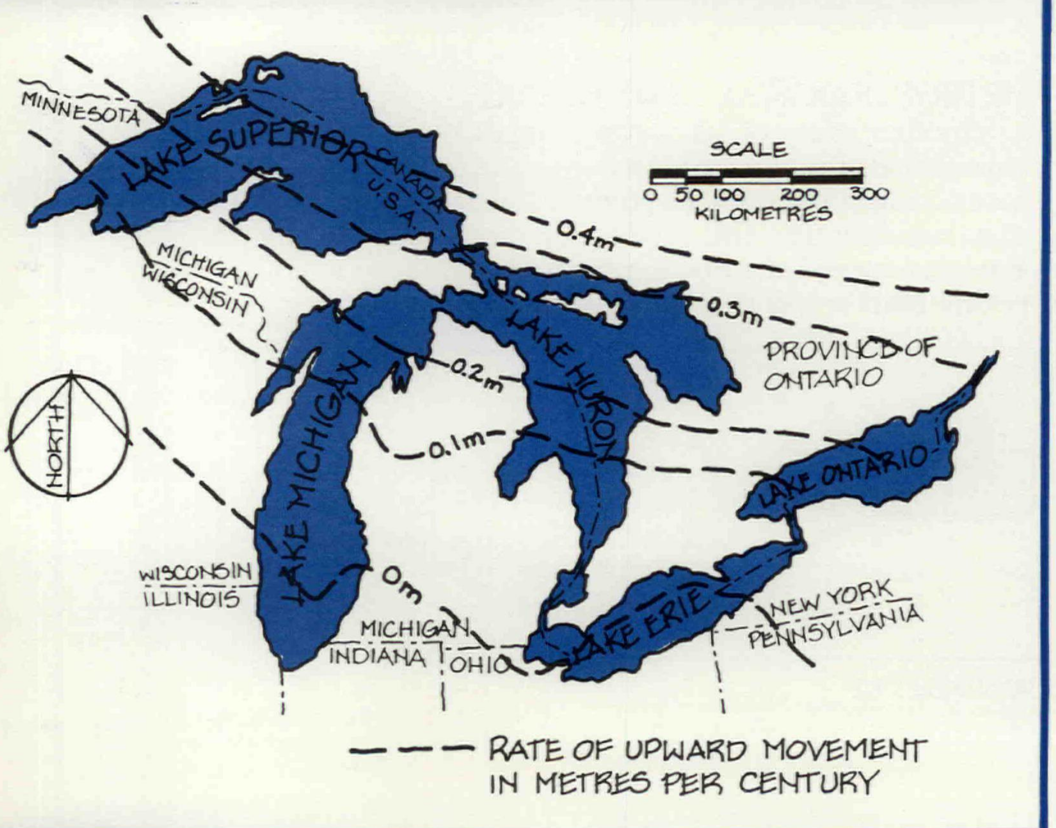
WIND SET-UP

CRUSTAL MOVEMENT

Crustal Movement, a vertical uplifting or rebounding of the earth's surface after the removal of the tremendous weight of glaciers, has occurred since glacial time. In the Great Lakes area the land to the north and east is rising faster than that to the south and west. For example, on Lake Ontario the eastern outlet end is rising with respect to the western inlet end at a rate of about 17 centimetres per century. The result is that the shore at the western end of the lake is experiencing a gradual increase in water level.



CRUSTAL MOVEMENT ON LAKE ONTARIO

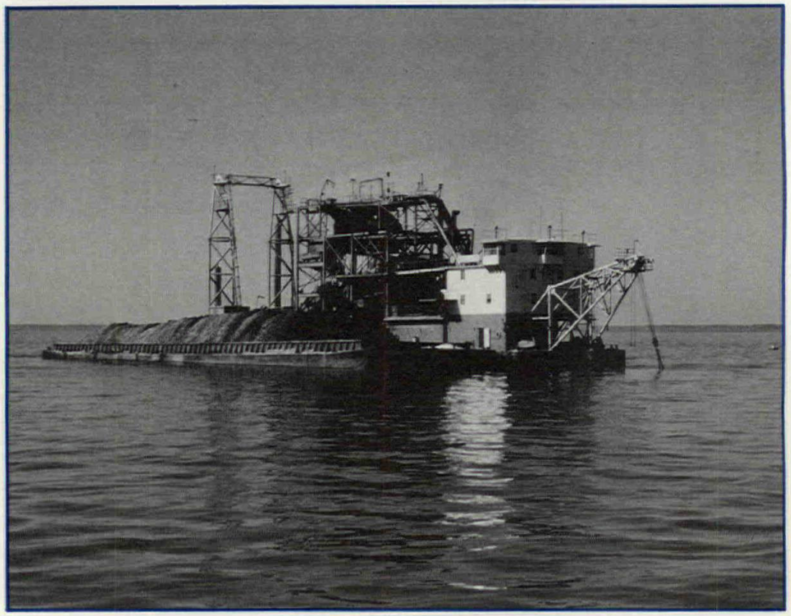


CRUSTAL MOVEMENT

Man-Made Factors

DREDGING

Dredging is done primarily to maintain adequate depths in shipping lanes for navigation. Dredging in the St. Clair-Detroit River system has over the years lowered Lakes Michigan and Huron by up to 30 cm in some estimates.



DIVERSIONS

There are four locations on the Great Lakes where major diversions of water occur. Two of these, the Ogoki River and Long Lac diversions, flow southward into Lake Superior carrying a total of about 160 cubic metres of water per second, which would naturally flow northward into James Bay. At Chicago, water is withdrawn from Lake Michigan at a rate of 90 cubic metres per second for domestic and sanitation purposes. This water is discharged into the Mississippi River system and is lost to the Great Lakes basin. The Welland Canal diverts up to 270 cubic metres per second, at present, from Lake Erie to provide for commercial navigation between Lake Ontario and Lake Erie and to operate the Decew Falls power plant. To operate the New York State Barge Canal, about 30 cubic metres per second of water are taken out of the Niagara River at Tonawanda, New York during the navigation season and returned to Lake Ontario at several points. The effects of the New York State Barge Canal diversion on the water levels of the Great Lakes are negligible, owing to the relatively small amount of water diverted and the location of the diversion. The major diversion flows and their estimated long-term effects on lake levels are shown in the following table.

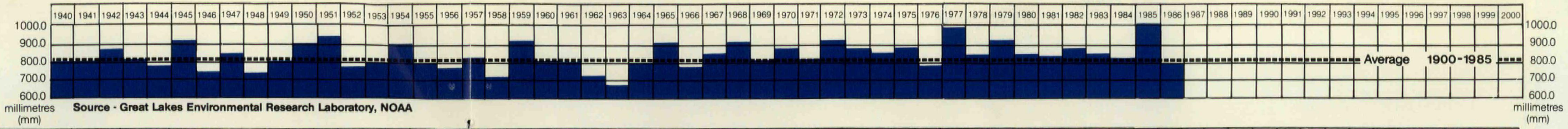
TABLE 3.
MAJOR DIVERSIONS AND THEIR EFFECTS (1) ON THE GREAT LAKES WATER LEVELS

	Long Lac and Ogoki	Chicago	Welland	Net Effect
Lake Superior	+0.06 metre	-0.02 metre	-0.02 metre	+0.02 metre
Lakes Michigan and Huron	+0.11 metre	-0.06 metre	-0.06 metre	-0.01
Lake Erie	+0.08 metre	-0.04 metre	-0.13 metre	-0.09 metre
Lake Ontario	+0.07 metre	-0.03 metre	negligible	+0.04 metre

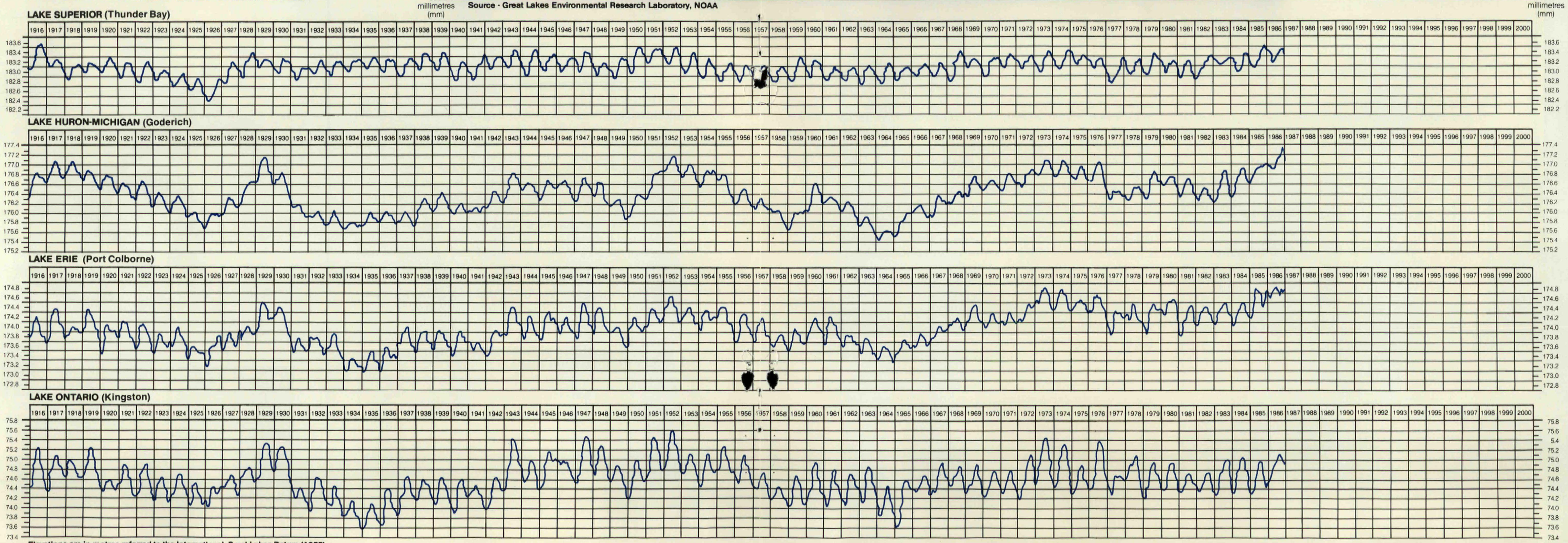
Note: (1) Positive value means raising of the water levels.
Negative value means lowering of the water levels.
These values are calculated assuming Lake Superior and Lake Ontario regulation to be in effect.

MAJOR DIVERSONS ON THE GREAT LAKES

GREAT LAKES BASIN PRECIPITATION



HYDROGRAPH OF GREAT LAKES WATER LEVELS

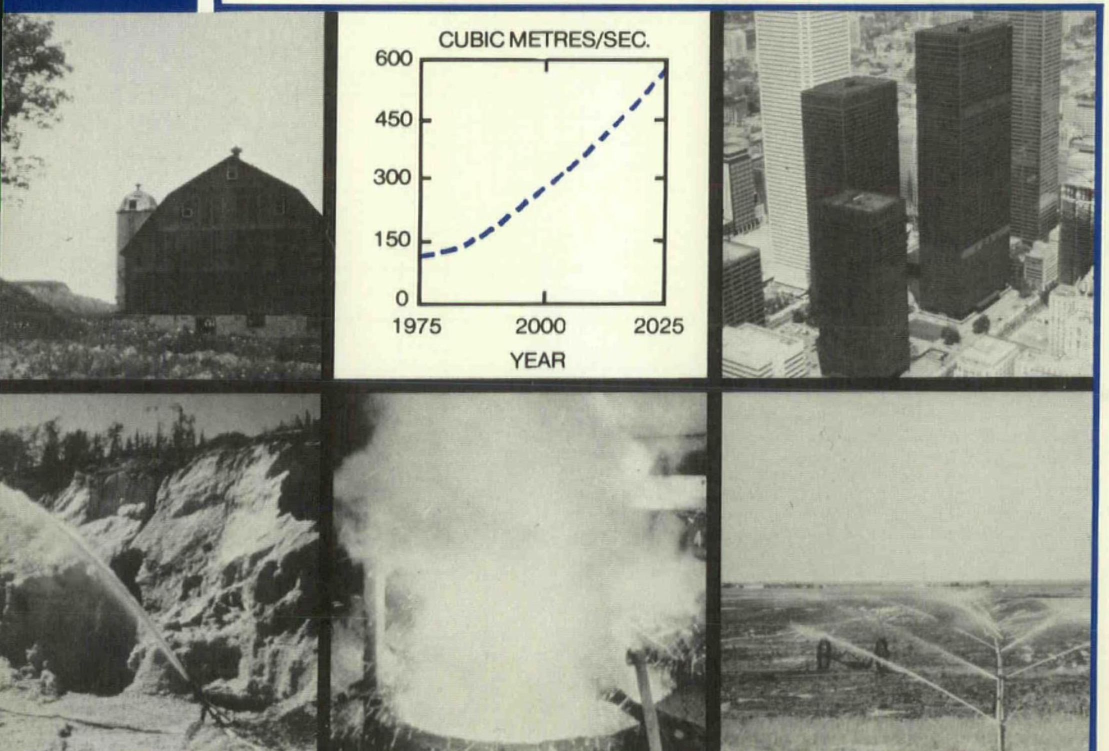


Elevations are in metres referred to the International Great Lakes Datum (1955)

CONSUMPTIVE USES

Consumptive use is water that is withdrawn and not returned to the Great Lakes. Present consumptive uses total over 140 cubic metres per second on all the Lakes and this will increase rapidly in the future. The amount of consumptive use increases progressively through the Great Lakes system. Thus, the effect on water levels is least on Lake Superior, and greatest on Lake Ontario.

Consumptive use of water lowers Great Lakes levels and reduces their outflows. This subject is of concern to both Canada and the United States because of adverse economic and environmental impacts associated with progressively lower lake levels.



CONSUMPTIVE USES

REGULATION

Of all the man-made factors affecting lake levels, artificial control or regulation of lake outflows is by far the most dominant. To regulate a lake means to adjust or modify its outflows according to certain rules in order to bring about more desirable lake levels or outflows. Yet, regulation too has its limitations and cannot always be relied upon for desirable water levels. Regulation takes place on Lake Superior and Lake Ontario.

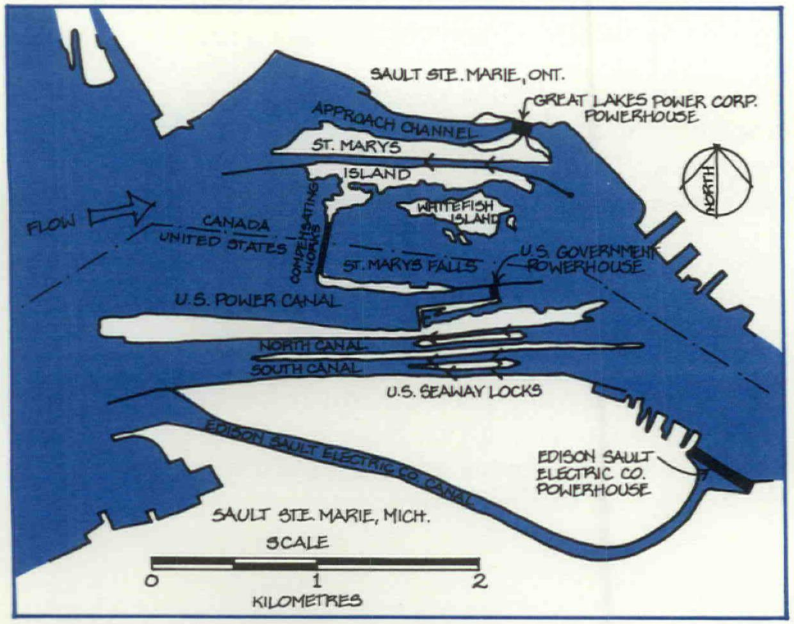
Two steps are taken before regulation can take place:

(1) enlargement of the outlet river so that at times more water can be released; and

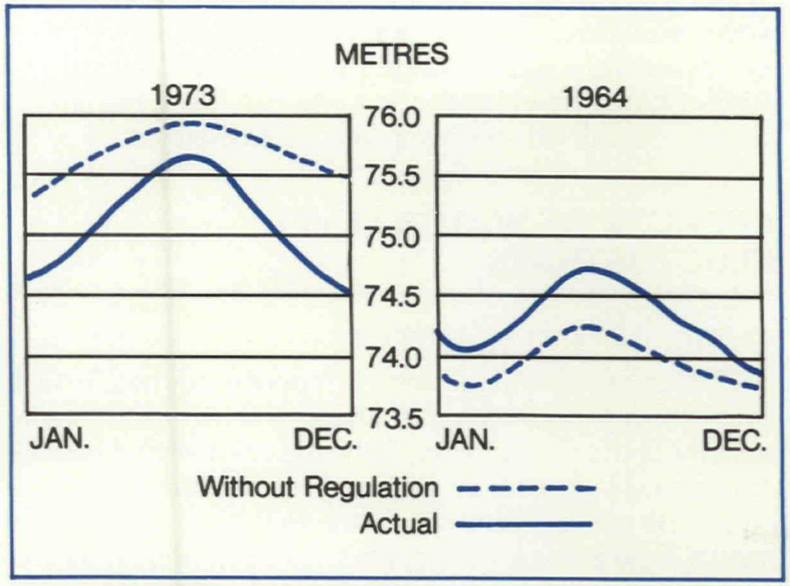
(2) installation of structures capable of reducing the outflows when required. The procedures in Great Lakes regulation are established by the International Joint Commission – a bilateral body set up by Canada and the United States to seek solutions to water problems along their International Boundary.

The outflow from Lake Superior to the St. Mary's River has been completely regulated or controlled since 1921 at Sault Ste. Marie, using various control structures, seaway navigation locks and hydro power installations.

Present regulation procedure calls for outflows that maintain a desirable water level on both upstream (Lake Superior) and downstream (Lakes Michigan and Huron).



FACILITIES AT SAULT STE. MARIE

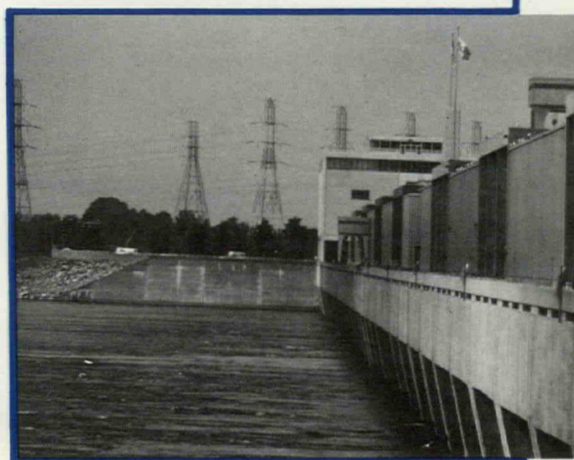


LAKE ONTARIO LEVELS WITH AND WITHOUT REGULATION

Since the completion of the St. Lawrence Seaway and Power Project in 1958, the outflow from Lake Ontario has been regulated. The regulation of Lake Ontario has a similar objective to that of Lake Superior, which is to keep the lake level near its long-term average. The enlargement of the St. Lawrence River by dredging during construction of the Power and Seaway Project has made it possible to increase Lake Ontario's outflows. The benefits of Lake Ontario regulation can best be illustrated by comparing the water levels during 1973-1974 with those that would have occurred if there had been no regulation.

Regulation has another benefit in that it can raise water levels when the basin experiences periods of low precipitation, and in the case of Lake Ontario, below average inflows from the upper lakes.

The construction of the Moses-Saunders Power Dam and other regulatory works in the St. Lawrence River allow Lake Ontario outflows to be reduced when Lake Ontario levels are low or when flood conditions are occurring downstream at Montreal. These works are also used to maintain adequate depth for safe navigation in the St. Lawrence River.



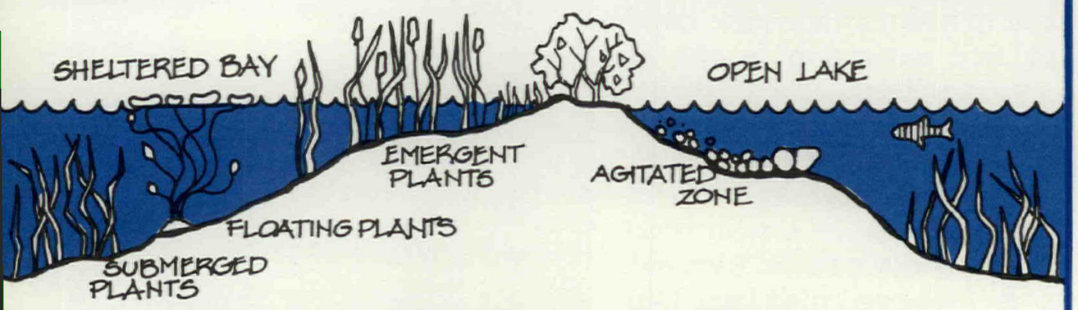
The highest recorded water supplies to Lake Ontario could raise the water level by 0.3 metre in one month, even with maximum flow down the St. Lawrence River. However, high Lake Ontario outflows are not always achievable nor allowable because high outflows, occurring simultaneously with high flows in the Ottawa River, can cause very serious flood problems in Montreal and further downstream on the St. Lawrence River. High flows during the fall can be hazardous to navigation.

EFFECTS OF WATER LEVEL FLUCTUATIONS

ENVIRONMENTAL EFFECTS

Water level fluctuations are not necessarily bad. In fact, they form a process which is natural to the fish and wildlife inhabiting the Great Lakes. Extreme or extended periods of high and low water levels, however, can compound the effects of natural lake processes and cause undesirable results. Low water levels or flows, for example, can aggravate pollution problems in the Great Lakes by reducing their dilution capacity.

Wetlands require fluctuating lake levels to enhance their productivity. Periodic flooding is necessary to maintain a variety of plant communities at different stages and thereby the wetland's ability to support a diversity of fish and wildlife species.



Long-term lake level fluctuations, on the other hand, generally produce plant community shifts:

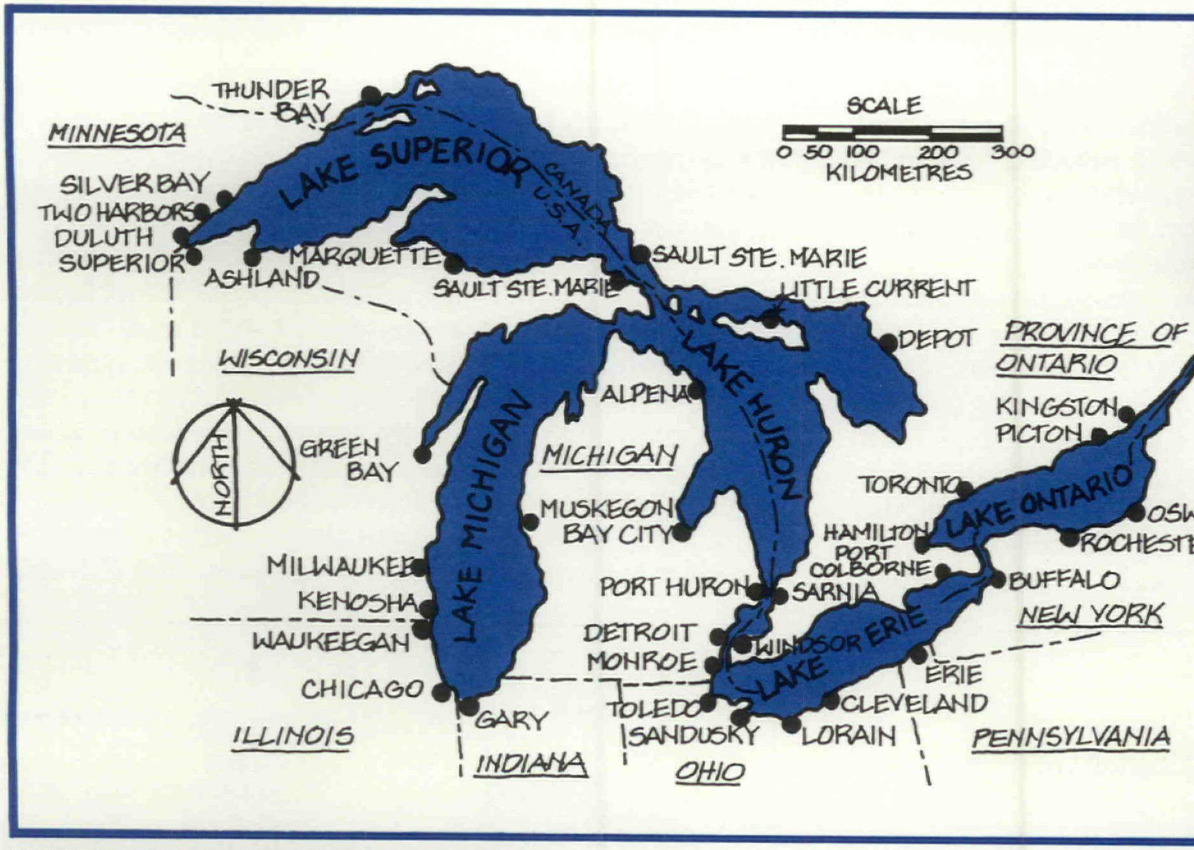
Low water conditions generate an invasion of sedge/meadow plants by shrubs, a displacement of emergent vegetation by sedge/meadow and result in less open water and associated aquatic communities.

High water conditions result in increased open water aquatics, as other communities decrease.

Shallow water environments provide important spawning, nursery and feeding grounds which are essential for the maintenance of fish stocks. High lake levels provide more favourable fish habitats whereas low levels could dry up spawning and feeding grounds.

NAVIGATION

Recreational boating facilities are sensitive to fluctuating levels. Docks can be inundated or left high and dry.



MAJOR PORTS ON THE GREAT LAKES

The Great Lakes - St. Lawrence River navigation system provides the means of transporting over 200 million tonnes of waterborne freight annually. About 85% of the cargo consists of iron ore, coal, limestone and grain. The remaining 15% includes petroleum products, newsprint, rock salt, iron and steel products, cement and chemicals and overseas general cargo trades.

Low lake levels can reduce the available vessel draft and thus the capacity to carry loads, thereby increasing the cost of transportation and necessitating costly dredging.

HYDRO - ELECTRIC POWER

Major hydro-electric power generating facilities are located on the Niagara, St. Lawrence and the St. Mary's Rivers. These facilities use water from the rivers to generate electric power.

High lake levels bring about high river flows which increase power generation, while low flows cause reductions in power generation. Electric utilities use coal, oil or nuclear thermal power plants to supplement the power produced by the hydro plants.

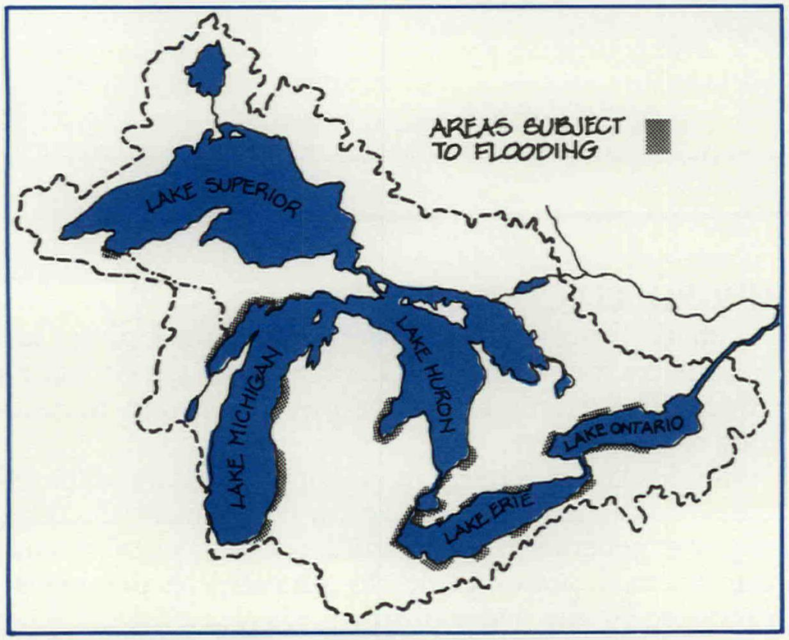
SHORE EROSION AND FLOODING

Shore erosion is caused principally by storm induced waves and associated currents along the shoreline. The problem can be compounded by high lake levels.

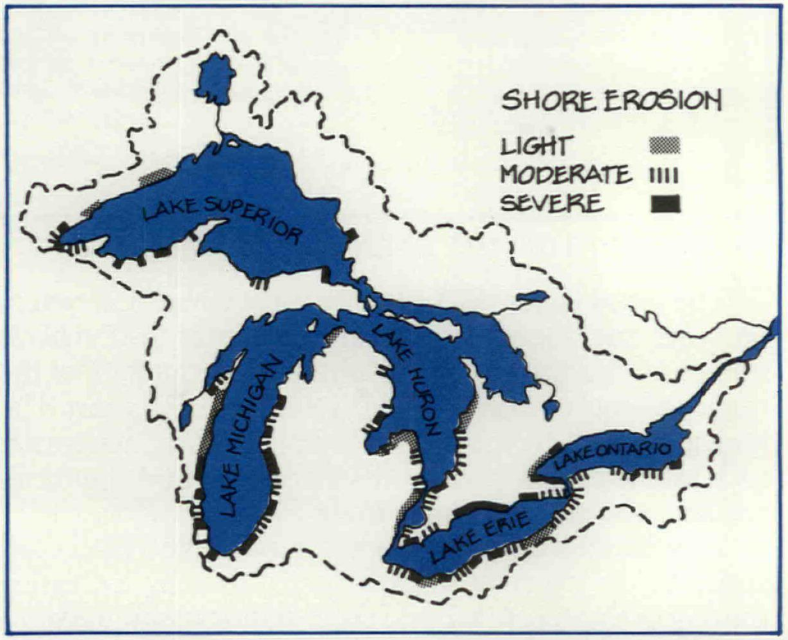
The Great Lakes shoreline characteristics range from extreme flat lowland areas, highly susceptible to flooding (such as the St. Clair Flats), to high bluff areas, some of which are highly erodible. A major use of the Great Lakes coastal land is for residential purposes. Other uses include industry, recreation, parks, beaches, boating facilities and forest preserves. All these areas are affected by fluctuating lake levels. Residential areas incur most of the damage from storms due to their relatively high investment value and man's habit of building close to a bluff edge or on low flat shorelines.

Flooding and erosion are natural processes. However, they represent continuing problems in the Great Lakes, compounded by mismanagement of shorelands. Floods and erosion cause extensive damages every year. Ignoring the reality of Great Lakes water level fluctuation, high water levels and storms in the future could lead to more damages because of high erosion rates, flood susceptibility and structures built too close to the shore.

In 1972-73, record high water levels in the Great Lakes caused extensive shore property damages. The Govern-



GREAT LAKES SHORELINE SUSCEPTIBLE TO FLOODING



GREAT LAKES SHORELINE SUSCEPTIBLE TO EROSION

ments of Canada and Ontario surveyed the shoreline and subsequently prepared a report compiling details of areas where flood and erosion risk are highest and recommended how future damage might be reduced. Reports from several recent international and federal-provincial studies also concluded that the best way to reduce future flood and erosion losses is to control future shoreline development.

If you are planning to purchase shore property and would like to be aware of its potential hazards, or if you own property on the shore and are seeking advice on how to deal with flooding and erosion problems, several booklets and pamphlets are available. A list of these can be found in the reference section of this brochure.

SOME QUESTIONS AND ANSWERS

Question: Can improvement in the present methods of Lake Superior and Lake Ontario regulation further reduce flood and erosion damage to the Great Lakes?

Answer: To a large extent no because the capacities of the Great Lakes outlet channels limit the amount of outflows that can be released. Any further increase or reduction in outflow can only be possible with major and costly channel enlargements and modifications to some of the control structures.

Reduction in the range of water levels on the Great Lakes might be possible if more accurate long-term weather forecasts were available. But such forecasts are still not possible at this time. Research efforts are continuing on weather forecasting procedures, hydrologic modelling and on techniques for collecting snow water equivalent and soil moisture contents in the Great Lakes basin. Accurate new information will make it possible to improve forecasts of the amount of runoff which in turn could improve regulation decisions.

Question: Can manipulation of the existing major diversions in the Great Lakes alleviate the problems of extreme high and low water levels?

Answer: The results of a recent international study show that the existing major diversions cannot be altered to reduce extreme high levels or increase extreme low levels without causing adverse environmental effects and economic loss.

Even if existing diversions were to be altered to the extreme, improvements in the Great Lakes levels would be minimal. For example, if the existing Long Lac and Ogoki diversions were stopped, and both the Chicago and Welland Canal diversions increased to about 250 cubic metres per second each, Lake Superior would be lowered by only 0.05 metre, Lakes Michigan and Huron by 0.11 metre, Lake Erie 0.09 metre, and Ontario 0.05 metre.

Question: Can the other Great Lakes be regulated?

Answer: The possibilities of regulating the water levels of Lakes Michigan, Huron and Erie were examined in two recent international studies. One study was completed in 1973 and the other in 1981. They both found that it would be very costly to regulate these lakes and the expected benefits would not offset the costs. Furthermore, the effects of such regulation would be generally undesirable for the wetlands and wildlife environment in the Great Lakes.

Question: Can the structure, which is located partly across the river above Niagara Falls, be used to regulate the water levels of Lake Erie?

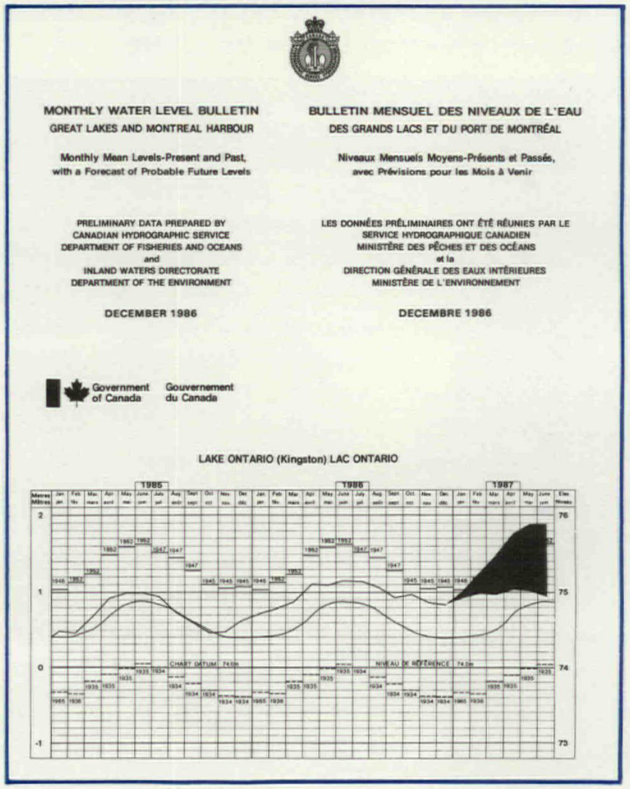
Answer: This structure controls the distribution of river flow between the hydro-electric power plants in each country and the flow over the Niagara Falls for purposes of the 1950 Niagara River Treaty between Canada and the United States. Studies and tests in the past have found that the operation of this control structure has only an extremely small effect on the outflows of Lake Erie and hence, it would not be effective to regulate Lake Erie's level.

Question: What can one expect of the 'Green House Effect' on lake levels?

Answer: The 'Green House' effect, caused by an increase of carbon dioxide in the earth's atmosphere, is the subject of intense study by scientists around the world. While different researchers have different opinions, they tend to predict a slight increase in precipitation and air temperature. Evaporation and transpiration (a process by which plants dissipate water into the atmosphere) would also increase, while streamflow to the Great Lakes could be reduced. The overall impact could be a reduction in lake levels and outflows.

FORECAST OF GREAT LAKES WATER LEVELS – A LOOK AT THE FUTURE

The Monthly Water Level Bulletin, published by the Department of Fisheries and Oceans and Environment Canada, includes a six-month forecast of Great Lakes water levels. These forecasts are presented as the probable levels based on certain assumed hydrologic conditions over the six month forecast period.



Copies of the Monthly Water Level Bulletin can be obtained by writing to:

Environment Canada
Inland Waters Directorate
867 Lakeshore Road
P. O. Box 5050
Burlington, Ontario.
L7R 4A6

Additional information on the subjects covered in this brochure can be obtained from the Water Planning and Management Branch of Environment Canada at the above address.

CONVERSION TABLE

Metric to British Units (approximation only)

1 cubic metre per second =35.31 cubic feet per second

1 metre = 3.28 feet

1 kilometre = 0.621 mile

1 kilogram = 2.2 pounds

1 square kilometre = 0.386 square mile

1 cubic kilometre = 0.240 cubic mile

1 litre = 0.22 gallon (Imperial)

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