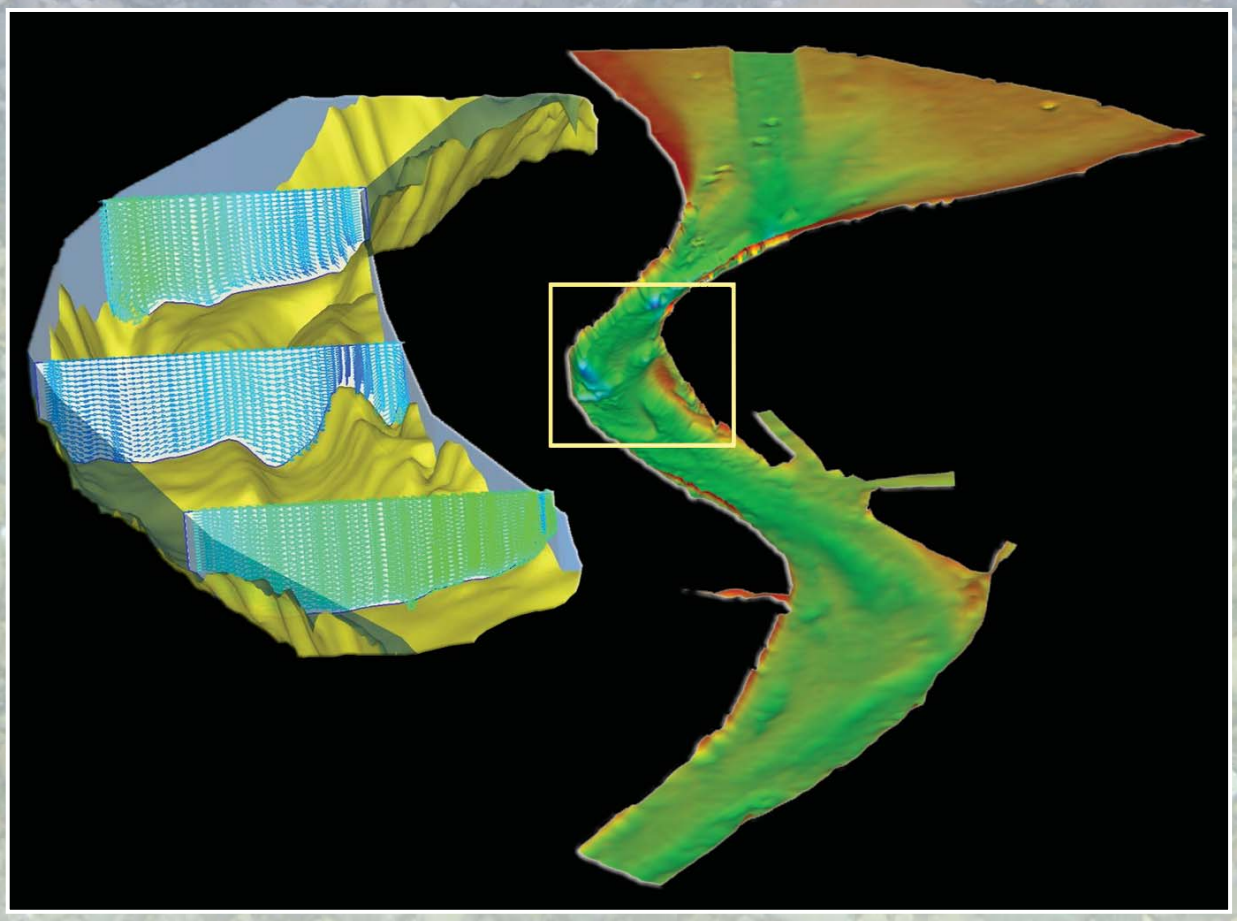
INTERNATIONAL
Upper Great Lakes
STUDY

Impacts on Upper Great Lakes Water Levels: St. Clair River

Summary Report



Final Report to the International Joint Commission
December 2009

Report Cover

The front cover shows two images of the St. Clair River prepared by the HydroSed2D model and Geographic Information System rendering based on data collected by underwater multi-beam sonar surveys of the river bed in the summer of 2008. The image to the right shows the channel morphology (depth and shape) from the mouth of the St. Clair River downstream for about 10 kilometres (6.2 miles). The yellow areas indicate shallower areas and there is a transition to blue, the deepest areas in the river. The image to the left illustrates typical velocities and flow directions in this first bend of the river. Green reflects higher velocities, while blue indicates lower velocities.

The background image of the cover, taken from an underwater video survey conducted in the summer of 2008 at depths of 12 to 14 metres (39 to 46 feet) shows the mostly gravel material found on the river bed in the upper reach of the St. Clair River.

Using data collected from these types of surveys, and applying the best available models, scientists and engineers have improved our understanding of the hydraulics and morphology of the St. Clair River and, in turn, the effects on the river of natural forces and recent human activities.

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Impacts on Upper Great Lakes Water Levels: St. Clair River

Impacts on Upper Great Lakes Water Levels: St. Clair River is the first of two major reports presenting the findings and recommendations of the bi-national International Upper Great Lakes Study (the Study). The Study is a five-year investigation launched by the International Joint Commission in 2007.

The St. Clair River part of the Study was established to address widespread concerns among governments at all levels, property owners and other interests about the long term economic and environmental effects of low water levels in the upper Great Lakes. Scheduling of the St. Clair River part was accelerated by nearly one year to address these concerns on an urgent basis.

A bi-national Study Board directed the work of nearly 100 scientists and engineers from governments, academia and the private sector in both countries. The Study benefitted from a high level of independent peer review. The Study's Public Interest Advisory Group played a significant role in the Study's public information and engagement effort. A draft report was made available for a 90-day public review and comment period.

This **Summary Report** provides a synthesis of the Study's approach, findings and recommendations. More information on the Study as well as the full scientific report and its 34 scientific/technical reports are available at the Study's website: **http://www.iugls.org**.

The Study Board concluded that:

1. The difference in water levels between Lake Michigan-Huron and Lake Erie has declined by about 23 centimetres (cm) (9 inches) between 1963 (following the last major navigational channel dredging in the St. Clair River) and 2006.

2. Three key factors contributed to this 23 cm (9 inches) change:

   - A change in the *conveyance* (water-carrying capacity) of the St. Clair River accounts for an estimated 7 to 14 cm (2.8 to 5.5 inches) of the decline.

   - *Glacial isostatic adjustment* (the uneven shifts of the earth's crust since the last period of continental glaciations ended) accounts for about 4 to 5 cm (1.6 to 2.0 inches) of the fall.

   - Changes in *climatic patterns* account for 9 to 17 cm (3.5 to 6.7 inches); this factor has become even more important in recent years, accounting for an estimated 58 to 76 percent of the decline between 1996 and 2005.

   Determining the total decline is not as simple as adding up the estimates of the three contributing factors. These estimates are highly dependent on the choice of the specific time period being analyzed within the 1963-2006 timeframe.

3. There has been no significant erosion of the channel along the length of the St. Clair River bed since at least 2000. Based on survey data collected in 1971, there appears to have been some enlargement of the channel between 1971 and 2000. However, the changes in the channel are within the error of the surveys. In addition, there are issues regarding the reliability of the 1971 data.

   On the basis of these findings and in accordance with its mandate, the Study Board recommends that:

   - *Remedial measures (to address past damages or adverse effects) not be undertaken in the St. Clair River at this time.*
   - *The need for mitigative measures (to address possible future changes that might result in adverse effects) in the St. Clair River be examined as part of the comprehensive assessment of the future effects of climate change on water supplies in the upper Great Lakes basin in Report 2 of the Study, on Lake Superior regulation, to be completed in 2012.*

   The Study Board also developed a set of recommendations addressing specific challenges in data collection, modelling and data management and coordination. Implementation of these measures by governments will be an important part of the legacy of the Study, helping provide water resource managers and policy makers with the information they need to regulate the upper Great Lakes more effectively under a changing climate regime and for adaptive management purposes.

For More Information

For more information on the International Upper Great Lakes Study, or to view the Study's 34 scientific/technical reports, please visit the Study's website: **www.iugls.org**

Information can also be obtained by writing to either of the following addresses:

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Summary Report
Table of Contents

1. The Ever-Changing Great Lakes

From any perspective – economic, social or environmental – the Great Lakes are of tremendous importance to Canada and the United States.

The Great Lakes region is home to millions of people who depend on the lakes as the largest single source of surface freshwater in the Western Hemisphere. The Great Lakes support rich ecosystems and diverse animal and plant species and are the foundation of major industries such as manufacturing, shipping, tourism, power generation and commercial fishing. Many Native American communities and First Nations rely on the natural resources provided by the Great Lakes to meet their economic, cultural, medicinal and spiritual needs.

The upper Great Lakes basin stretches from the headwaters of Lake Superior all the way downstream to Niagara Falls, an area of about 686,000 square kilometres (265,000 square miles) (Figure 1). The upper Great Lakes system encompasses Superior, Michigan, Huron (including

Figure 1 International Upper Great Lakes Basin

Changing lake water levels are of concern to many interests throughout the upper Great Lakes basin.

Georgian Bay) and Erie, and the connecting channels of the St. Marys River, the Straits of Mackinac, the St. Clair River system (consisting of the St. Clair River, Lake St. Clair and the Detroit River), and the Niagara River. (For study purposes, Lake Michigan and Lake Huron are considered a single lake, because they have the same surface water elevation due to their shared connection at the broad and deep Straits of Mackinac.)

Fluctuating lake levels are evidence of the continual changes underway in the Great Lakes.

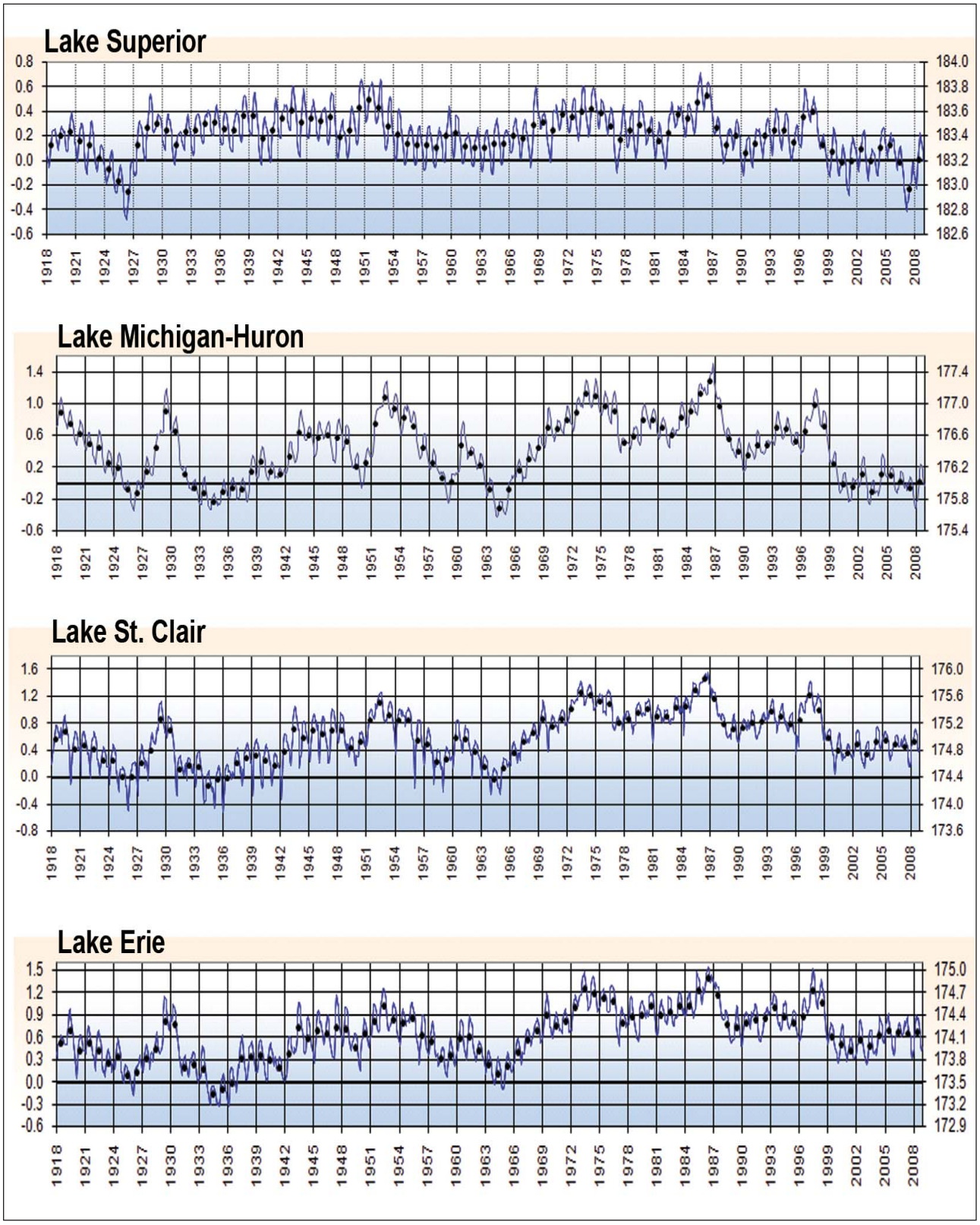
Many features of the Great Lakes – the lake and river beds, water supplies and outflows – are continually changing. Changes occur over a period of days, decades and millennia. Sometimes the changes are subtle, other times profound.

Fluctuating lake levels are dramatic evidence of such changes. In general, Great Lakes water levels depend on the storage capacity of the lakes, the outflow characteristics of the connecting channels, and the water supply received by each lake. Water enters a lake by way of precipitation, runoff from its drainage basin, diversions in, and inflow from the lake or river upstream. Water leaves a lake through evaporation, diversions out and outlets to the downstream lake. All of these processes vary over time.

Data for water level measurements on the Great Lakes are available only since about 1860, though there are questions about the reliability and comparability of some older data, given the various types of measurement used over the years. No precise patterns in fluctuating water levels are evident in the data records of the past century. As shown in Figure 2, there were record low water levels during the late 1920s and 1930s and again in the mid-1960s. Record high levels were seen in the early 1950s, in 1973, and again in 1985-1986. In the late 1990s, a nearly 30-year period of above-average water level conditions in the upper Great Lakes ended. Over the last 10 years, Lake Michigan-Huron and Lake Superior have experienced lower than average lake level conditions, with Lake Superior establishing record lows in August and September of 2007.

Water levels can also reverse quickly. For example, lake levels dropped from very high to very low levels in a matter of about two years from 1986 to 1988 and again from 1997 to 1998. Even within the last year, there has been a significant recovery of water levels on Lake Michigan-Huron and Lake Superior, though they remain below long-term averages.

Figure 2 **Upper Great Lakes Water Levels, 1918-2008**



Note: Water surface elevations at 0.0 are at Chart Datum on IGLD (1985); the black dots represent annual mean values.

The St. Clair River system plays an important role in determining the water levels of the upper Great Lakes.

Canada and the United States have only a very limited ability to regulate lake levels in the upper Great Lakes – on the St. Marys River, where the International Joint Commission has regulated Lake Superior outflows within a rule-based operation since 1921. This limited capacity to regulate flows in such a huge basin means that the natural flow from Lake Michigan-Huron to Lake Erie through the St. Clair River, Lake St. Clair and the Detroit River is a key factor in determining water levels of the upper Great Lakes.

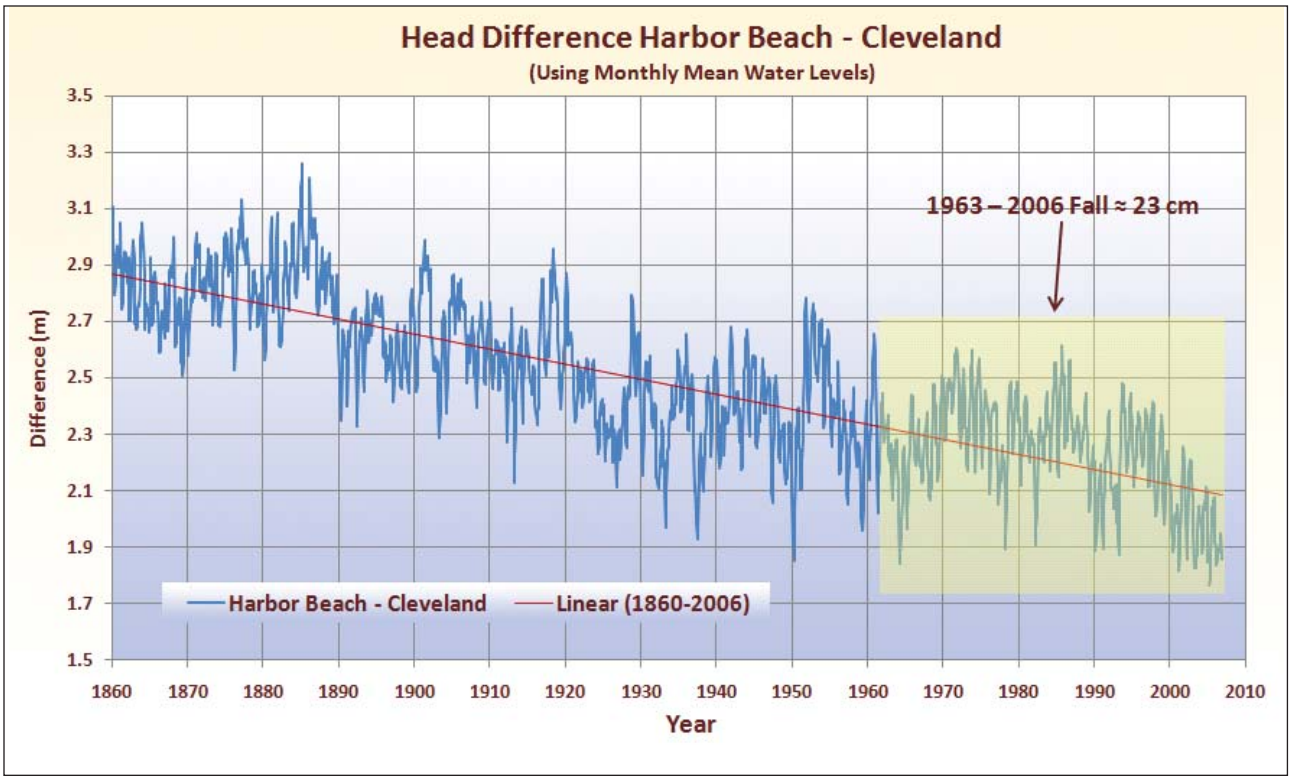
What drives the flow of the St. Clair River is the difference in the levels of Lake Michigan-Huron and Lake Erie (known as the ***head difference*** or the ***lake-to-lake fall***). Figure 3 illustrates how this difference has changed considerably from 1860 to the present day and how it can even fluctuate from year to year. Records of annual mean water levels recorded at Harbor Beach, Michigan on Lake Huron (about 100 kilometres [62 miles] north of the lake's outlet.) and Cleveland, Ohio on Lake Erie show that the head difference between the two lakes was about 2.9 metres (9.5 feet) between 1860 and 1880. The difference then decreased sharply through the turn of the century and generally continued to decline for more than 100 years. In 2008, the head difference was about 1.9 metres (6.2 feet). Between 1963 and 2006, the time period on which the Study focused, the head difference declined by about 23 centimetres (cm) (9 inches).

(Note that there is a distinction between the actual head difference in individual years, which can vary from one year to the next, and the trend line shown in Figure 3, which represents the best linear fit to the changes in the measured data over the longer time period.)

Natural forces and human activities can change the conveyance of the St. Clair River.

The connecting channels in the Great Lakes basin, including the St. Clair River, are subject to a range of physical forces, both natural and human-caused, that can contribute to changes in their conveyance (or water-carrying capacity). Natural forces can include sedimentation and bed erosion, aquatic vegetation growth or decline, fluctuations between extreme high and low water levels in the upper lakes, and seasonal ice cover and ice jams. Human activities can include dredging, shoreline protection works and obstructions in the river, such as bridges and shipwrecks.

Figure 3 **The Head Difference (Lake-to-Lake Fall) between Lake Michigan-Huron and Lake Erie**



Conveyance and Flow

A river's *conveyance* is not the same as its flow. Water flows can vary by day, month, season and year. Conveyance is a measure of the channel's capacity to carry water, regardless of how much water happens to be flowing through it at any particular time. Conveyance is determined by the physical features of the river's channel – such as depth, width and river bed features – and any natural or human-built obstructions that may be in the channel.

Dredging has altered the natural state of the St. Clair River more than any other human activity.

Dredging in the St. Clair River began in the late 1850s and has continued for the last 150 years. Most of this dredging was undertaken to support the rapid increase in commercial navigation on the Great Lakes. Additional material was removed in the early 1900s by commercial sand and gravel mining operations. These dredging projects were authorized by the United States Congress, following consultation between Canada and the United States and approval of both countries.

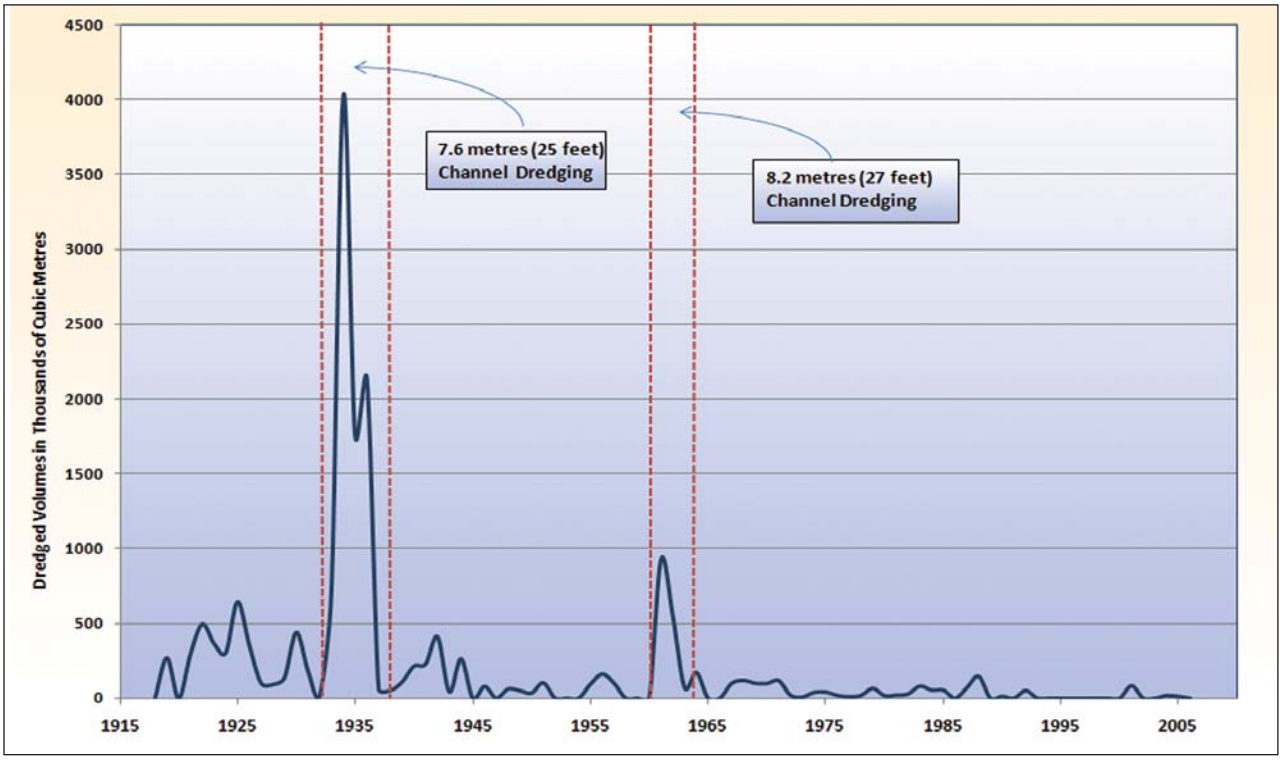
The largest dredging activity ever undertaken in the river occurred between 1933 and 1936, when 8.4 million cubic metres (11 million cubic yards) of material were excavated to deepen the channel to 7.6 metres (25 feet). This volume accounts for *one third* of the total volume of dredging that has taken place in the St. Clair River over the last 150 years.

The last major dredging in the St. Clair River was undertaken between 1960 and 1962, when the navigation channel was deepened again to 8.2 metres (27 feet) throughout the entire river. The total volume of dredging during this period was about 1.5 million cubic metres (2 million cubic yards) of material. This volume represents only about 18% of the total volume dredged between 1933 and 1936, and accounts for about 27% of the total volume dredged since 1936. Most of the dredged material was deposited in various locations within the river where it would not impede navigation.

Since 1962, all dredging in the St. Clair River has been related to maintenance dredging. This work involves the removal of relatively small volumes of sediment and obstructions to restore the channel bottom to its authorized navigation channel depths.

Figure 4 illustrates the volume of dredging in the St. Clair River since 1918, and indicates the relative magnitude of the 7.6 metres (25 feet) and 8.2 metres (27 feet) dredging projects undertaken in 1933-1936 and 1960-1962, respectively.

Figure 4 **Dredging Volumes in the St. Clair River, 1918-2006**



In the 1960s, Canada and the United States agreed to construct compensating works in the St. Clair River in response to water level concerns related to dredging of the channel. However, the works were never built, as the Great Lakes region moved from record low water levels in the mid-1960s to record highs by the mid-1970s and record highs again in the mid-1980s.

The uneven shifts in the earth's crust as it adjusts from the last period of continental glaciation affect water levels throughout the Great Lakes basin.

Another contributing factor to changing water levels is *glacial isostatic adjustment* (GIA). During the last period of continental glaciation, which ended in North America only about 10,000 years ago, the tremendous weight of the glacier that covered the Great Lakes region depressed the earth's crust underneath it. The weight also caused the crust beyond the edge of the ice sheet to bulge upwards (this area is known as the "forebulge").

When the glacier retreated, the crust, relieved of the weight, began to rebound. The glacier was thicker and remained longer over the areas that became the northern and eastern portions of the Great Lakes basin. As a result, the land in these regions is rising relative to the earth's core. At the same time, areas in the southern and western portions are falling, as the former "forebulge" area subsides.

This process continues today, though at different rates across the Great Lakes basin. GIA affects land-to-water relationships around each of the Great Lakes, as well as the elevation differences and hydraulic relationships between them.

Climate directly affects water levels in the upper Great Lakes.

The climate of the Great Lakes basin varies considerably due to the basin's north-south extent and the effects of the lakes on near-shore temperatures and precipitation. Over the long-term, regional climatic patterns affect the amount of water that can be stored in or released from a lake. Contributing climatic factors include the amount of water the lakes receive through precipitation and runoff from their drainage basins, water lost through evaporation, and the extent and timing of ice cover on the lakes and connecting channels.

In the past, water supplies to the upper Great Lakes basin have varied considerably, over periods of years, centuries and longer. Periods of higher and lower water supplies can be expected in the future due to climatic variations. Beyond these variations in climatic patterns are the still-uncertain implications of global climate change, particularly the effects of changing climatic patterns at the regional level.

2. Understanding the Ever-Changing Great Lakes: The International Upper Great Lakes Study

Objectives of the Study

Water levels in the upper Great Lakes are the focus of a five-year international study.

Canada and the United States have long recognized the need to cooperate on understanding and managing the special natural resource that they share, the Great Lakes. In 1909, the *Boundary Waters Treaty* established the International Joint Commission to prevent and resolve disputes regarding many of the lakes and rivers along their shared border. Among the responsibilities of the International Joint Commission is approving the construction and management of works that affect levels and flows in boundary waters.

Impacts on Upper Great Lakes Water Levels: St. Clair River is the first of two major reports of the *International Upper Great Lakes Study* (the Study) undertaken at the direction of the International Joint Commission. The five-year Study was launched in 2007, following extensive consultation with governments, organizations and individuals with an interest in the Great Lakes.

A cargo vessel enters the St. Clair River, passing under the International Blue Water Bridge. Report 1 of the Study addressed physical processes and possible ongoing changes in the river and their impacts on lake levels.

The Study has two major objectives:

1. Examine physical processes and possible ongoing changes in the St. Clair River and their impacts on levels of Lake Michigan-Huron and, if applicable, evaluate and recommend potential remedial options (**Report 1**); and
2. Review the regulation of Lake Superior outflows and assess the need for improvements to address both the changing conditions of the upper Great Lakes and the evolving needs of the many interests served by the system (**Report 2** of the Study, to be completed in early 2012).

The Study represents the most recent example of cooperation between Canada and the United States to improve our understanding of water levels in the Great Lakes basin – how they are changing and why, and what measures could be introduced to minimize adverse impacts from low and high levels.

The International Joint Commission appointed a 10-member bi-national Study Board to be responsible for the Study's overall planning and management. Members were drawn from the two federal governments, state and provincial governments, universities and the public.

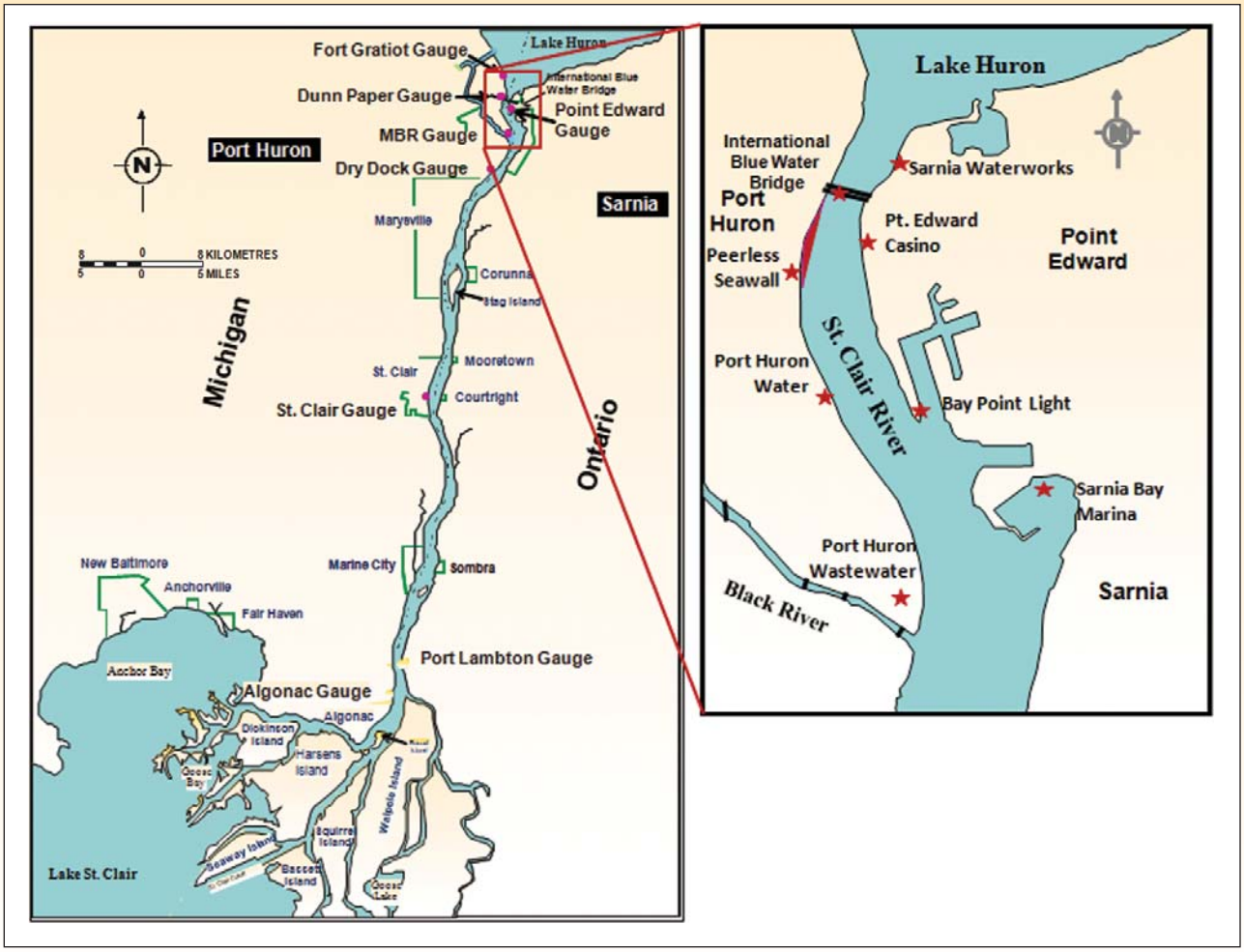
Figure 5 illustrates the geographical focus of the St. Clair River Study.

Study Approach

The Study approached the question of changes to the St. Clair River from several perspectives.

The central challenge of the St. Clair River part of the Study was to determine what factors are responsible for the change in lake-to-lake fall between Lake Michigan-Huron and Lake Erie. Answering these questions required an examination of the physical processes and possible ongoing changes in the St. Clair River and the effects of such changes on the level of Lake Michigan-Huron relative to Lake Erie (the *lake-to-lake fall*). Reviewing the number of

Figure 5 Focus of the St. Clair River Study



factors related to St. Clair River conveyance and upper Great Lakes water balance, the Study Board decided to address St. Clair River conveyance issues from several distinct but interrelated perspectives (Figure 6):

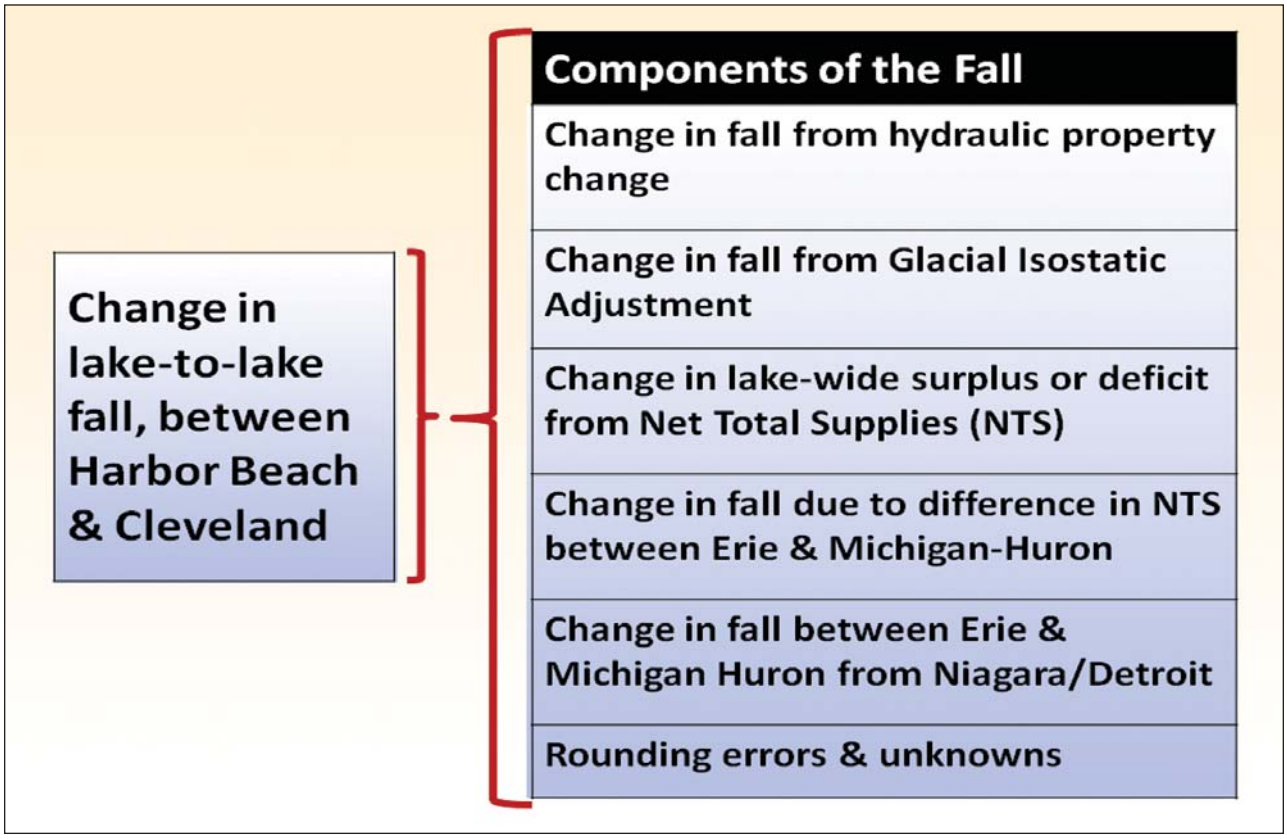
- ***sediment (morphology) regime***, examining the sediment processes in the St. Clair River to determine whether the river bed is eroding or stable;
- ***hydraulic regime***, focusing on understanding the relationships between levels and flows for the St. Clair River, how changes in the river bed (*e.g.*, changes to its geometry, scouring and deposition) have affected conveyance, and the effects on upper Great Lakes water balance;
- ***glacial isostatic adjustment***, addressing the implications on water balance calculations of the rise and fall of the earth's crust across the upper Great Lakes basin; and
- ***hydroclimatic patterns and trends***, examining the components in the water balance – precipitation, evaporation, runoff and other factors – to determine how they affect water levels and flows.

The Study formulated a series of science questions and undertook applied research projects to generate information needed to answer the questions. Some of the applied research projects were designed to address more than one science question, so that the Study could address a particular question from a number of perspectives.

Nearly 100 scientists and engineers from governments, academia and the private sector in both countries worked together, with input from the public, to plan and undertake the necessary investigations, analyze the results and prepare the Study's findings and recommendations. Their work drew on many disciplines, including engineering, hydrology, hydraulics, geology, sedimentology, physics and climatology.

The Study required data analysis and modelling efforts with a high level of precision and accuracy. One significant challenge identified early on was a lack of reliable historical data and the uncertainty associated with some early historical data on water levels, flows, and lake bed and river bed sediment. To address this problem, the Study collected new field data using the most advanced technology and

Figure 6 **Study Approach: What factors are responsible for the change in lake-to-lake fall?**



Note: The *hydroclimatic* analysis addressed three of the listed components – the two related to net total supplies of water and the one associated with any change in the conveyance of the Detroit or Niagara Rivers.

conducted a critical review of past historical data prior to their use in analytical and modelling tasks. The most recently developed and advanced models also were used in the Study. In addition, the Study included a comprehensive consideration of scientific uncertainty.

The St. Clair River Study accounted for about 25 percent of the Upper Great Lakes Study's total five-year budget of $17.5 million (CDN) or $14.6 million (US) (at 2005 exchange rates). The costs were shared equally by Canada and the United States.

The schedule of the St. Clair River part of the Study was accelerated by nearly one year to address growing public concerns about low water levels in the upper Great Lakes. The schedule was subsequently adjusted again to accommodate additional time needed for receipt of peer reviews, extended public comment and supplemental research projects.

Independent Peer Review

The Study was subject to a high level of independent peer review.

A major objective of the Study Board was to make the Study scientifically credible and accountable at all stages. The St. Clair River Report represented the first time in the history of the International Joint Commission that a bi-national study benefitted from ongoing independent peer review at all stages, from the development of the Study Strategy through to the completion of reports.

> *"Overall, we find the analyses, results and conclusions to be technically sound and consistent with the Study objectives."*
>
> *– Independent Peer Review Co-leads (August, 2009)*

Independent peer reviewers were engaged directly by the International Joint Commission and operated at arm's length from the Study Board. They reviewed the draft St. Clair River Report, drafts of the key scientific chapters, and eight of the major scientific/technical reports. The reviewers generally gave high ratings to these Study reports and provided specific suggestions for improvement. Peer reviewers identified a number of specific concerns regarding the various draft chapters, including the need for additional analysis and improved clarity of presentation. They also noted the need to quantify scientific uncertainty in the different areas.

The Study Board considered and responded to each comment from the peer reviewers. In some cases, the response required a simple clarification or rewording in the scientific/technical reports and Study report. In other cases, the responses required additional analysis and substantial revisions to the reports.

Independent Peer Review

Documents relating to the peer review process are available at the American Society of Civil Engineers-Environmental and Water Resources Institute website: **http://content.ewrinstitute.org/committees/IUGLS.cfm**

Public Information and Engagement

A Public Interest Advisory Group helped coordinate a comprehensive public information and engagement program.

Recognizing the many interests concerned with the future of water levels in the upper Great Lakes, the International Joint Commission appointed a bi-national Public Interest Advisory Group to provide advice to the Study Board on issues related to the Study and advice and support in the development and implementation of the Study Board's public information and engagement activities. Members were drawn from a wide range of public groups with an interest in the Great Lakes.

The Study Board, with the support and advice of the Public Interest Advisory Group, developed and implemented a comprehensive public information and engagement program during preparation of the St. Clair River Report. The program utilized public meetings, workshops, conferences, newsletters, email and the internet.

Public Information and Engagement Program

More information on the Study's public information and engagement program is available in a report prepared by the Public Interest Advisory Group, available through the Study website: **www.iugls.org**

The Study Board made the draft St. Clair River Report available for a 90-day period of public review and comment, from May 1st to August 1st, 2009. Interested members of the public had opportunities, either in person or via the internet, to access information and provide their views on the draft report.

In general, there appeared to be satisfaction on the part of the public that the Study's findings and recommendations were acceptable and the result of a technically sound and unbiased scientific process that engaged a wide range of interests. However, most respondents in the Georgian Bay region of Lake Huron and some commenters in parts of Wisconsin did not share this view.

Several broad areas of consensus emerged during the consultations.

During the consultations, consensus emerged in the following areas:

- that decisions at all levels of government be based on sound science;
- that the recommendation that the second phase of the Study, regarding possible improvements to Lake Superior outflow regulation, evaluate mitigation options in the St. Clair River based on additional analysis of the range of potential impacts of climate change;
- that any consideration of remedial options in the St. Clair River take into account the full range of economic, social and environmental interests in the entire upper Great Lakes basin, including Lake St. Clair and Lake Erie;
- the legacy recommendations involving continuing data collection and coordinated monitoring and modelling;
- the importance of maintaining the ability of large vessels to navigate and access ports;
- the need to protect habitat important to native species through natural water level fluctuations; and
- general opposition to a fixed permanent structure in the St. Clair River.

Dr. Alan Steinman, member of the Study's Public Interest Advisory Group, speaks to a public meeting in Muskegon, MI, during consultations on the draft report. The Study used videoconferencing technology, from five "hub" locations, so that residents in smaller communities around the upper Great Lakes had the opportunity to hear the presentations, present their views and hear the views of other interests.

Summary Results of the Study's Public Information and Engagement Activities

- 34 public meetings held in communities throughout the Study region, including 17 meetings during consultations regarding the draft report
- Nearly 2,000 people attended these public meetings, including more than 400 during the consultations
- Videoconferencing technology was used so that the Study could reach residents in smaller communities and connect upstream and downstream interests
- 41 written comments regarding the draft report
- 129 evaluations of the public meetings received
- Nearly 3 million "hits" or viewings of the Study's website, including more than 266,000 during May 2009, when the draft report was released
- More than 1,500 downloads of the draft Summary Report and nearly 1,000 of the draft full scientific report

There were differing views regarding several issues, including on the Study's primary recommendation that remedial measures in the St. Clair River not be considered at this time.

Many residents of coastal areas on Lake Michigan strongly agreed with the Study's primary recommendation regarding remedial measures, citing the potential for adverse effects if lake levels were to return to high levels such as those experienced in the mid-1980s. At the same time, Lake Superior residents expressed their opposition to any measures that might reduce levels on that lake to compensate for low levels in other lakes.

On the other hand, comments received from members of the public with an interest in the Georgian Bay region generally strongly disagreed with the recommendation, citing the adverse effects of low water on both the environment and economy in their area.

3. Understanding Changing Water Levels in the Upper Great Lakes: What Have We Learned?

St. Clair River Sediment Regime

The first step in the Study was to understand the changing St. Clair River. The Study carried out a range of projects to document and understand the sediment regime of the St. Clair River. They examined the geological history of the river, the type of material on and beneath the river bed, the river bed topography, changes to river bed topography since the 1962 deepening of the navigation channel, and the present-day patterns and rates of bed erosion, deposition and sediment transport along the river.

Has the "morphology" (the shape and composition of the river bed) of the St. Clair River been altered since the 1962 dredging? Specifically,

- Is the St. Clair River bed stable or eroding?
- If the bed of the St. Clair River is eroding, what initiated it, and when?

The key finding of the Study related to the sediment regime of the St. Clair River was that:

- ***The bed of the St. Clair River has not undergone any significant, general erosion since at least 2000.*** Based on the results of a 1971 survey, there appeared to be erosion throughout the river. But there are questions about the quality of data obtained in this earlier survey. Based on the results of more recent surveys using comparable technology and techniques, the Study found that there has been no significant erosion of the channel in the upper reach of the St. Clair River bed since at least 2000. These more recent surveys show some redistribution of sediments and in general deposition in the upper reach of the river. Sediment modelling also supported this conclusion.

St. Clair River Hydraulic Regime

The second step in understanding the changing St. Clair River was to look at the river's hydraulic regime – its water levels, flows and conveyance. Using information gained from the sediment component of the analysis, the Study carried out a series of hydraulic data analyses and modelling to assess whether conveyance has changed in the St. Clair River, establish when this change occurred, and determine the causes of any change.

What is causing the declining head difference between Lake Michigan-Huron and Lake Erie? Specifically,

- Has the conveyance of the St. Clair River changed since the 1962 dredging?
- If the conveyance has changed what were the causes?

The Study concluded that:

> ***An increase in the St. Clair River's conveyance accounts for 7 to 14 cm (2.8 to 5.5 inches) of the decline in the head difference between Lake Michigan-Huron and Lake Erie between 1963 and 2006, based on 15 different analyses.***

The Study Board has a high degree of confidence in this finding, because it is based on the results of extensive water data and flow analysis and modelling undertaken by the Study. This work included six modelling projects and five data and flow analysis projects. Each project looked at the same question from a different analytical approach. All 11 projects found a common direction and general magnitude of conveyance change. (In addition, four hydroclimatic modelling projects generated similar findings regarding the change in conveyance.)

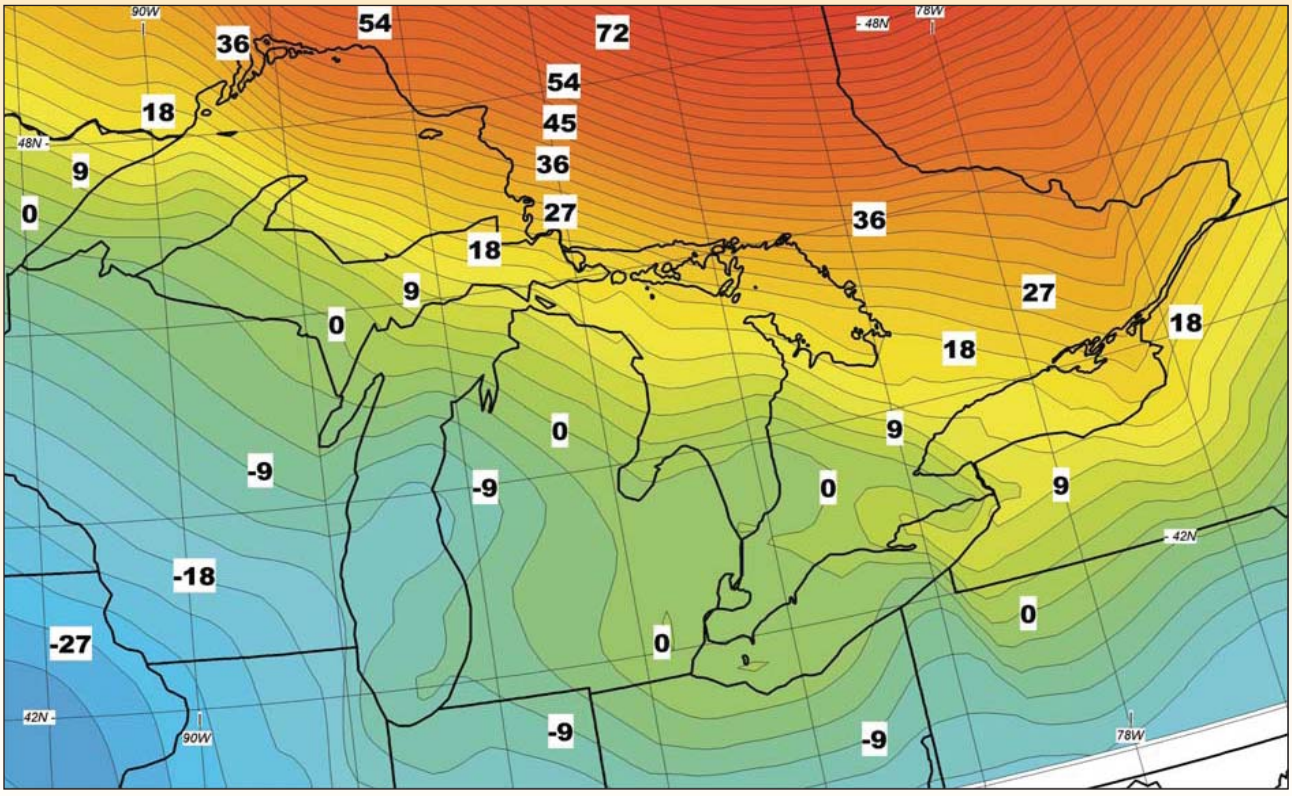
Other key findings of the Study related to the hydraulic regime of the St. Clair River were that:

- ***The increase in conveyance in the St. Clair River is not ongoing, and based on bathymetry from 2000 on, appears to have slightly decreased.*** The timing of when the conveyance change occurred is difficult to determine with certainty due to a lack of reliable historical data. Different analyses suggest that the change occurred in the mid- to late-1980s. Hydraulic modelling suggested that the conveyance of the St. Clair River may have decreased slightly since 2000, by 1 to 3 cm (0.4 to 1.2 inches).
- ***The changes in the river bed were not confined to a particular section of the river.*** Analysis and modelling using data collected at water level stations along the St. Clair River indicated that there were changes in conveyance in many, but not all, reaches of the river. In some of these reaches, conveyance increased over time, while in others conveyance decreased. Localized features of the channel, such as deep sections, have little effect on conveyance in the river. The conveyance in the St. Clair River is not controlled by any one section of the river.
- ***A number of factors likely have contributed to the change in the river's conveyance.*** The Study determined that while the record ice jam in 1984 was not the key contributing factor in the conveyance change of the St. Clair River, it did play some role. Fluctuations between extreme highs and lows of upper Great Lakes water levels, such as those experienced in the mid-1980s, also could have contributed to the increase in the river's conveyance. Other possible minor contributing factors include seasonal ice jams, maintenance dredging in the river, shipwrecks and the construction of shoreline protection works.

Glacial Isostatic Adjustment

By analyzing the available water level records since 1860 from gauges around the Great Lakes, researchers have been able to use models to compute the relative movement between any two gauge sites on the same lake, and to obtain relative velocities over the entire Great Lakes region. Figure 7 shows the estimated relative vertical motion velocity over the whole Great Lakes region, in cm per century, based on these analyses.

Figure 7 **Glacial Isostatic Adjustment in the Great Lakes Region**
(vertical movement [rising or subsiding] in cm/century)



Source: A. Mainville and M.R. Craymer, *Present-day tilting of the Great Lakes region based on water level gauges.* GSA Bulletin; July/August 2005.

Installed on a lighthouse in Lake Superior as part of the Study, this is one of two gauging stations collecting important new data on evaporation over the Great Lakes. The Study Board found strong support among many Great Lakes interests for continuing the operation of these stations after the Study is completed in 2012.

How has GIA affected the change in lake level relationship between Lake Michigan-Huron and Lake Erie?

The Study concluded that:

> ***GIA accounts for about 4 to 5 cm (1.6 to 2 inches) of the decline in the head difference between Lake Michigan-Huron and Lake Erie, based on a comprehensive analysis.***

Other key findings of the Study related to GIA in the upper Great Lakes Basin were that:

- ***There are two different types of GIA effects to consider:***
  - The *apparent* effect on water levels resulting from the change in the land-to-water relationship around each lake due to the "tilting" of the earth's crust; and
  - The *physical* effects of GIA due to the impact of movement of the earth's crust on the actual water levels of the two lakes (i.e., their surface elevation relative to true mean sea level at any given time).
- ***Despite data challenges, GIA effects will need to be better understood to support future management decisions on Lake Superior regulation.*** For example, public concerns about declining or rising water levels on shorelines, and declines in water levels in the upper Great Lakes as a result of climate change will be exacerbated by the effects of GIA.

Climate

The Study examined the hydroclimatic regime of the upper Great Lakes and considered how the various hydrological factors affect water supplies and Great Lakes water levels. The Study undertook an integrated approach that focused on comparative and statistical hydrological data analyses, focusing on over-lake precipitation, basin runoff and lake evaporation as the major contributors to the net basin supply.

How has climate affected the change in lake level relationship between Lake Michigan-Huron and Lake Erie?

The Study concluded that:

> ***Hydroclimatic factors account for 9 to 17 cm (3.5 to 6.7 inches) of the decline in the head difference between Lake Michigan-Huron and Lake Erie.***

The effects of climate vary widely depending on the time intervals used within the 1963-2006 timeframe, and thus the wide range in estimates.

Other key findings of the Study related to the hydroclimatic regime in the upper Great Lakes Basin were that:

- ***Climate is the main driver of the lake level relationships between lakes over time.*** Although the water levels of the Great Lakes in the latter half of the twentieth century were higher compared to the first half, there has been a persistent decline in net total supply of water to Lake Superior and Lake Michigan-Huron over the past two decades. This has led to declining levels in the lakes.
- ***Changing hydroclimatic conditions (particularly a substantial decline in Lake Michigan-Huron net total supplies of water) increasingly have been major factors in the decline in the head difference.*** Hydroclimatic factors accounted for 40 to 74 percent, or about 9 to 17 cm (3.5 to 6.7 in), of the decline over this full 43-year period. The influence of hydroclimatic factors appears to be increasing in more recent years, however, accounting for 58 to 76 percent of the decline in the 1996-2005 period.
- ***There is a clear need for more accurate estimates and continual monitoring and analysis of Great Lakes water supplies and connecting channel flows.*** This need will become particularly important as part of an ongoing adaptive management effort to deal with the emerging but, as yet, uncertain effects of climate change. Similarly, new hydroclimatic models are required to better predict climate effects on lake levels.

Putting it Together: What Did the Study Find?

The Study has greatly advanced the understanding of how the St. Clair River works and the forces that have changed it.

The Study has contributed to a significantly improved level of understanding of the St. Clair River – its geology, sediment transport and flow, and the river's effect on water levels in the upper Great Lakes. The Study has brought into focus how various natural forces and human activities have changed the St. Clair River since the last major expansion of the channel by dredging in 1962.

Three key factors have contributed to the 23 cm (9 inches) decline in head difference between Lake Michigan-Huron and Lake Erie.

The Study estimated that there was a decline in the head difference of about 23 cm (9 inches) between Lake Michigan-Huron and Lake Erie between 1963 and 2006. The Study also concluded that the decline in the head difference is not the result of any single factor. Rather, several physical forces have contributed to the decline:

- a *change in the conveyance* of the St. Clair River accounts for an estimated ***7 to 14 cm (2.8 to 5.5 inches)*** of the decline in the head difference;
- *glacial isostatic adjustment* in the upper Great Lakes basin is responsible for about ***4 to 5 cm (1.6 to 2.0 inches)*** of the change; and
- *changes in climatic patterns* account for ***9 to 17 cm (3.5 to 6.7 inches)*** of the decline, though the relative importance of this factor has increased sharply in recent years.

Figure 8 illustrates this synthesis of the Study's findings.

Determining the total decline in head difference is not as simple as adding up the estimates of the three contributing factors. Estimates of the relative contributions of each of the factors, and thus of the overall decline, are highly dependent on the choice of the time period being analyzed. Within the 1963-2006 timeframe, for example, there are several periods during which the decline was actually higher than 23 cm (9 inches).

The lakes adjust to a new hydraulic regime relatively quickly after any change in conveyance in the St. Clair River.

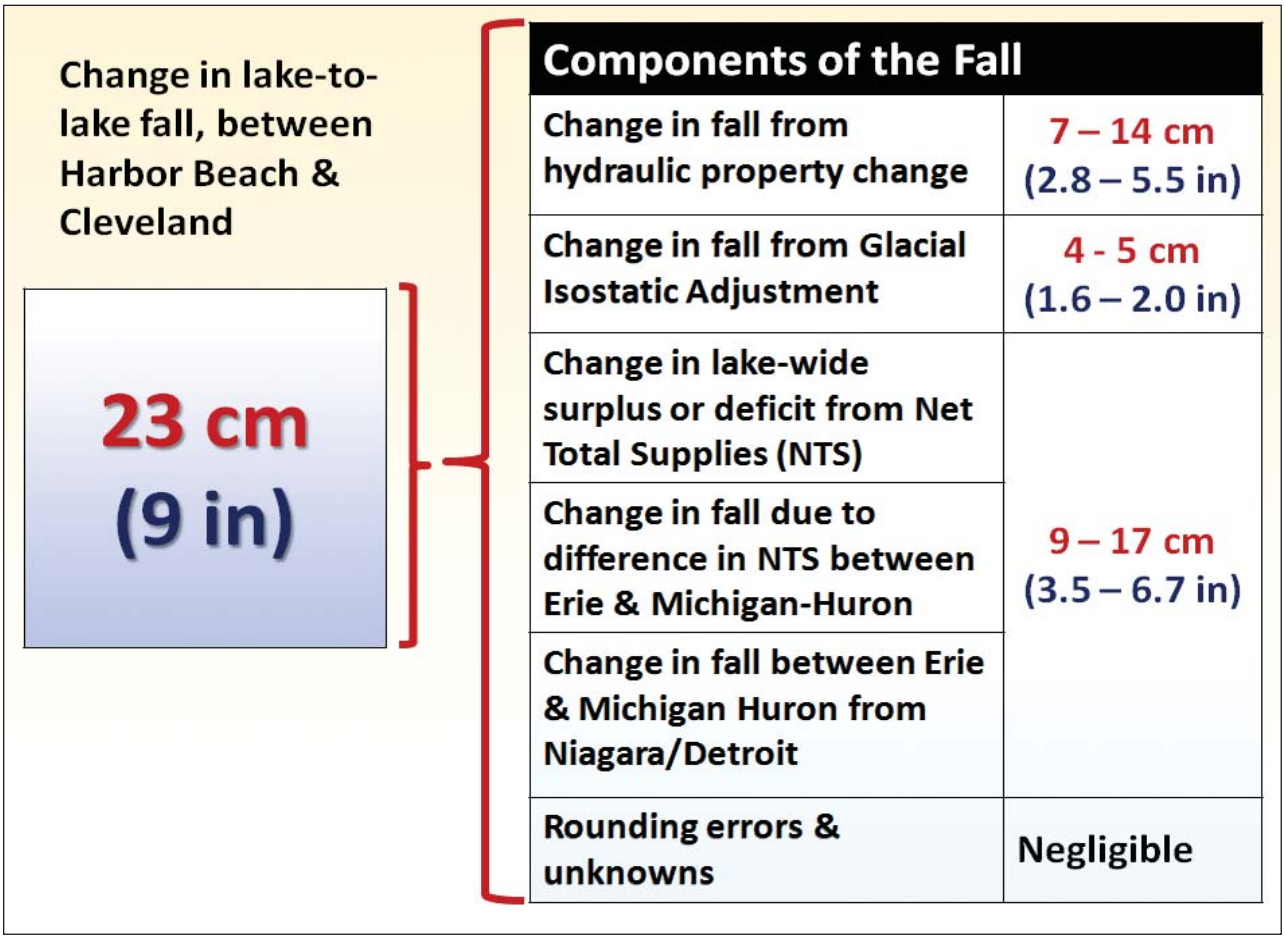
The Study concluded that, assuming the same water level conditions in Lake Michigan-Huron, Lake St. Clair and Lake Erie (under constrained "steady state" conditions), the St. Clair River can discharge about 140 to 320 m^3/s (4,940 to 11,292 ft^3/s) more water than it could in 1971. However, the hydraulic relationship among the lakes is dynamic, and the relative levels between the lakes adjust to a new hydraulic regime relatively quickly. In fact, a new lower water level equilibrium is established, typically within two to three years following any change in conveyance.

It is important to note that even the "steady state" estimates of changes in the river's discharge from 1971 represent about 3 to 5 percent of the river's mean annual flow, and are within the range of measurement accuracy. A series of simulations of the mid-lakes hydrology, undertaken by the Study, estimated the actual change to be much lower than 3 percent, due to the dynamic nature of the lakes.

In accordance with its directive from the International Joint Commission, the Study analyzed options for remedial measures for the St. Clair River.

As part of its mandate, the Study reviewed past proposed remedial works and new innovative approaches to modifying flows in the St. Clair River. With this information, the Study identified a range of options that might be employed if remediation were deemed necessary. In addition, work was undertaken to determine the institutional, legal and environmental requirements that would have to be considered in implementing any of these options.

Figure 8 **Study Findings:** What factors are responsible for the change in lake-to-lake fall?



4. Changing Water Levels in the Upper Great Lakes: The Study's Recommendations

The International Joint Commission has the authority, under the Boundary Waters Treaty of 1909, to recommend that the Canadian and U.S. governments undertake compensation measures in boundary waters. Compensation measures can include *remedial* measures to address past damages or adverse effects and *mitigative* measures to address future changes that might result in adverse effects.

The Study Board developed two sets of recommendations based on the Study's findings and in accordance with its mandate.

Principal Recommendations

1. Compensation Measures

The Study Board recommends that remedial measures not be undertaken in the St. Clair River at this time.

The Study's findings indicated that the increase in conveyance in the St. Clair River is not ongoing, and that, based on bathymetry from 2000 on, conveyance has slightly decreased. In addition, the change is small relative to the degree of scientific uncertainty associated with the various analyses and data measurements. Furthermore, the conveyance change is likely the result of a combination of factors, rather than any single factor.

Given these findings and in accordance with its mandate, the Study Board concluded that remedial measures to address changes in the St. Clair River since the navigational dredging in 1962 are not warranted at this time.

2. Addressing Effects of Long-Term Climate Change

The Study Board recommends that the need for mitigative measures in the St. Clair River be examined as part of the comprehensive assessment of the future effects of climate change on water supplies in the upper Great Lakes basin in Report 2 of the Study, on Lake Superior regulation.

There is general world-wide consensus among scientists that climate change, driven by increasing concentrations of greenhouse gases in the atmosphere, is occurring and will continue. The regional effects of climate change are expected to differ from one region to another. Understanding the effects of climate change is essential to the management of the Great Lakes, including government and community efforts to reduce and adapt to those effects.

The second part of the Study, now underway, is examining current and emerging issues related to the regulation of Lake Superior, including the effects of climate change on water supplies in the upper Great Lakes basin. It is appropriate, therefore, to consider any possible future mitigative measures in the St. Clair River in the context of this broader assessment of future water supplies in the entire upper Great Lakes.

Compensation Measures

Remedial measures are those designed to address past damages or adverse effects.

Mitigative measures are those designed to address possible future changes that might result in adverse effects.

A new hydrometric (water quantity) gauging station on the St. Marys River, one of four new stations on the connecting channels of the upper Great Lakes installed under the Study. Government support for the continued operation of these stations after the Study is completed will provide key data to help Canada and the U.S. manage the Great Lakes under a changing climate regime.

"Legacy" Recommendations

Over the course of the St. Clair River part of the Study, investigators identified serious barriers to their work. These barriers included a lack of reliable data and a lack of standardization of data collection and reporting among the many federal, state, provincial and local agencies and organizations responsible for managing various components of the Great Lakes' waters and related water resources sectors. Together, these barriers reduce our capacity to understand and manage the complex systems affecting the Great Lakes.

Recognizing these concerns, the Study Board developed a series of secondary recommendations to the International Joint Commission identifying specific needs in the areas of data collection, modelling and coordination. These include specific recommendations that:

- Bathymetric surveys be conducted every five years to monitor any changes in the bed of the St. Clair River;
- The four new stream flow gauging stations and the two eddy co-variance (evaporation) gauging stations installed as part of the Study be maintained following the completion of the Study in 2012.
- Accountability and coordination in the collection and management of essential data on the Great Lakes be strengthened by formalizing the mandate of the bi-national Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data and having the Committee formally report to the International Joint Commission.

Implementation of these measures by governments will be an important part of the legacy of the Study, helping provide water resource managers and policy makers with the essential information they need to manage the upper Great Lakes more effectively under a changing climate regime.

5. Looking Ahead: Where Do We Go From Here?

The completion of ***Impacts on Upper Great Lakes Water Levels: St. Clair River*** and its submission to the International Joint Commission mark important milestones in the International Upper Great Lakes Study. But considerable work remains to be done.

The next steps in the Study process are:

- The International Joint Commission will convene public hearings in the spring of 2010 in both Canada and the United States to receive further public comments on the St. Clair River Report.
- Based on its review of the findings, peer review, public comment and other consultations, the International Joint Commission will recommend a course of action to the governments of Canada and the United States.
- In the meantime, work already underway on the second part of the Study, on Lake Superior regulation, will continue over the next two years. The Study Board will submit its Lake Superior report by March 2012. The Study will end with the submission of that final report to the International Joint Commission.[1]

The second part of the Study is addressing the changing conditions of the upper Great Lakes and the evolving needs of the many interests served by the Great Lakes system.

1 Information on the Lake Superior regulation part of the Study is available at the Study's website: **www.iugls.org**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