Expedited Review of Plan 2014, Phase 1: Informing Plan 2014 Deviation Decisions Under Extreme Conditions

A report to the International Lake Ontario - St. Lawrence River Board and the International Joint Commission

NOVEMBER 19, 2021

GLAM GREAT LAKES – ST. LAWRENCE RIVER ADAPTIVE MANAGEMENT COMMITTEE

GLAM Committee membership

Canada	United States
Co-Chairs	
Wendy Leger Environment and Climate Change Canada	**John Allis** US Army Corps of Engineers, Detroit District
Members	
Jacob Bruxer Environment and Climate Change Canada	**Dena Abou** US Army Corps of Engineers, Chicago District
Patricia Clavet Quebec Ministry of Sustainable Development, Environment and Climate Change	**Mary E. Austerman** New York Sea Grant
Linda Debassige Ogimaa Kwe (Chief), M'Chigeeng First Nation	**Lauren Fry** National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory
Susan Doka Fisheries and Oceans Canada	**Keith Koralewski** US Army Corps of Engineers, Buffalo District
Jean Morin Environment and Climate Change Canada	**Scudder D. Mackey** Ohio Department of Natural Resources
Frank Seglenieks Environment and Climate Change Canada	**Bill Werick** Water resources consultant
Jonathan Staples Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry	Vacant
Co-Secretaries	
Mike Shantz Environment and Climate Change Canada	**Missy Kropfreiter** US Army Corps of Engineers, Detroit District

Credits and Acknowledgements

The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee would like to acknowledge the significant contributions from a wide range of individuals and groups in support of the Phase 1 effort (Please refer to Appendix 1 for a full list of contributors).

The International Joint Commission provided funding and oversight.

Members of the International Lake Ontario-St. Lawrence River Board provided oversight and input throughout the process, including through a series of workshops.

The individual technical studies and development of the Decision Support Tool were supported by project leads and contributors from numerous agencies and organizations represented on the GLAM Committee with particular note to Environment and Climate

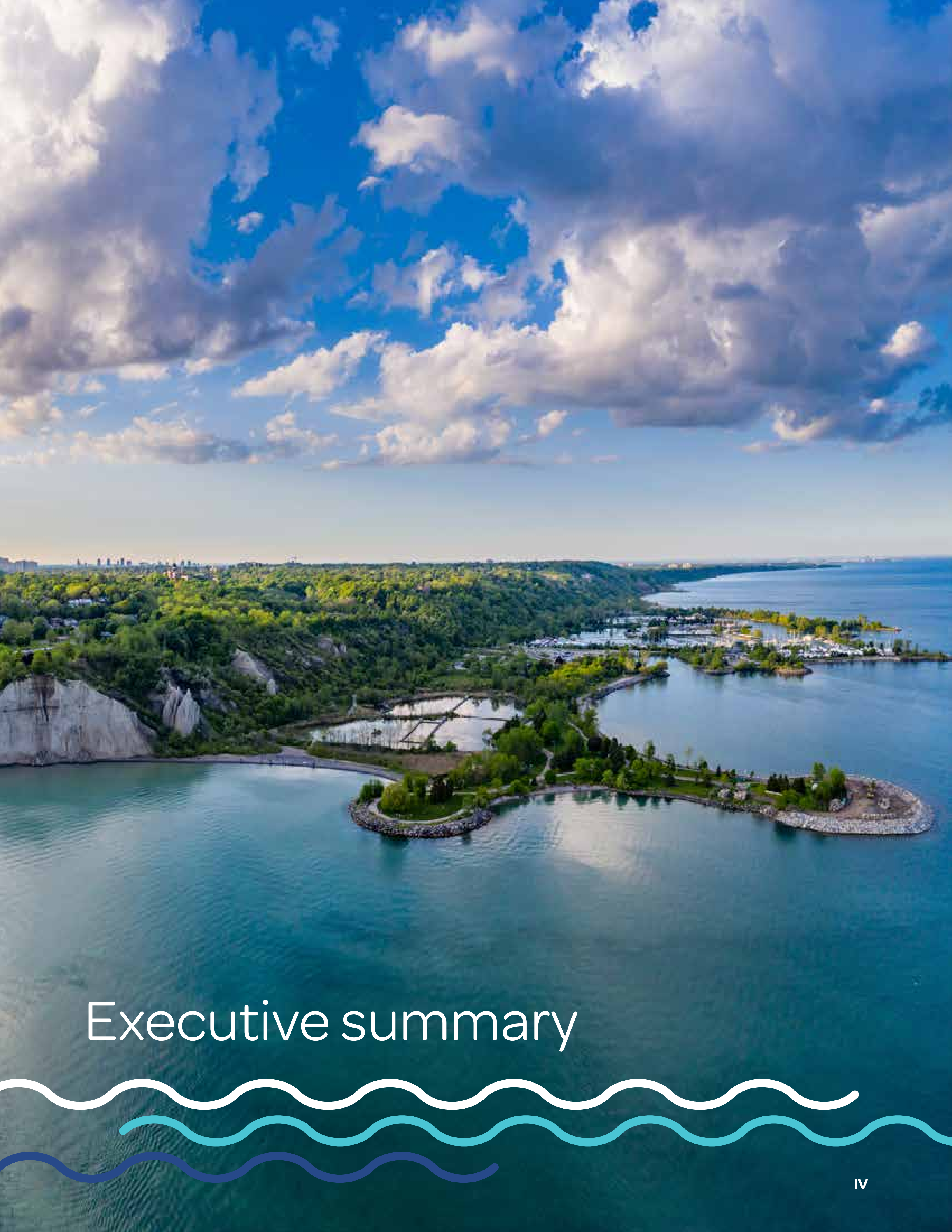
Change Canada and the US Army Corps of Engineers. Many of those technical studies involved additional outreach to countless agencies, organizations and individuals who contributed their perspectives and experiences related to high water impacts. Numerous contractors hired to assist with the technical work provided important deliverables to the effort.

Volunteer members of the Public Advisory Group contributed many hours of their time learning about the system and contributing their knowledge and perspectives on the GLAM Committee's work.

Valuable and constructive feedback was provided by the Independent Review Group, established by the International Joint Commission to review various aspects of the GLAM Committee's work.

Finally, the GLAM Committee would like to thank science writer Steve Orr, who led the development of this final Phase 1 report.

Lake Ontario at Rochester, NY, USA



Executive summary

Executive summary

Overview

In the spring of 2017, mere months after the outflow regulations known as Plan 2014 went into effect, extremely wet conditions across the Lake Ontario and St. Lawrence River basins caused water levels to rise to record heights over the course of a few weeks. Severe flooding struck the shoreline of both Lake Ontario and the St. Lawrence River, impacting many shoreline residents and businesspeople. High water also caused major difficulties for Indigenous Nations, boaters, commercial shippers, farmers and other interests.

Flood waters returned in the spring of 2019 with water levels breaking the records set just two years earlier, disrupting commercial navigation, damaging shorelines yet again, and harming most, if not all, water uses and interests. The period from late May through the beginning of August 2019 was the worst extended period of high water since record-keeping began more than a century ago. Governments, insurers and private parties spent hundreds of millions of dollars on recovery and resilience work after the two floods. The lives and livelihoods of thousands of people and the operations of many businesses, farms and local governments were disrupted for weeks and months. Some angry parties blamed Plan 2014 for the damaging high water, though technical reviews showed that without the infrastructure and operations under Plan 2014 water levels would have been higher. Others pointed fingers at the appointed International Lake Ontario-St. Lawrence River Board (Board) that can deviate from the rules of Plan 2014 when levels are extreme. A few claimed the Board unfairly deviated too much to help one interest or not enough to help another.

The Board employed several strategies to try and balance the interests of different sectors of the lake-river system between 2017 and 2020, but no regulation of outflows can prevent flooding when the events are so extreme. Members believe that the decisions

SNAPSHOT

- After two years of damaging high water on Lake Ontario and the St. Lawrence River, The International Joint Commission (IJC) ordered an immediate, expedited review of Plan 2014, the outflow regulations for the lake. The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee, established by the IJC, is conducting the review.
- Phase 1 of that Expedited review, the focus of this report, makes significant steps forward for the IJC's International Lake Ontario-St. Lawrence River Board (Board). The Board oversees the operation of Plan 2014 and has the authority to deviate from the plan's provisions during times of extreme high or low water.
- Working on a compressed timetable, the GLAM Committee has examined the ways the Board has selected deviations in the past, gathered considerable data and information on the impacts of extremely high water levels, and analyzed the Plan 2014 limits from which the Board often deviates. The GLAM Committee has used that information to uncover possible new deviation strategies and to create an interactive Decision Support Tool (DST) to inform Board decision-making.
- The DST illustrates the uncertainties and risks inherent in the decision process. It provides the Board with a wealth of information that reduces some of those uncertainties. It also informs the Board about tradeoffs — the benefits and harms that changes in water levels and flows can bring about for competing interests on Lake Ontario and the St. Lawrence River. The DST informs the Board's decision making, but does not make decisions for the Board.

they made with the information they had available at the time were reasonable and warranted. However, in the wake of those two high-water episodes, Board members have said they could use more information on the incremental impacts to interests and regions of the deviations they considered, particularly information that can inform decisions at the pace with which they need to be made. They asked for more insight and confidence in the potential consequences of their actions. The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee, which is conducting a two phased expedited review of Plan 2014, has been working to give the Board what it asked for.

As detailed in this Phase 1 report, the GLAM Committee has produced an innovative Decision Support Tool (DST) designed to give the Board objective information about deviation outcomes. The tool provides broad-based metrics and up-close data about the potential impacts of deviation decisions across interest groups and geographic areas. The DST will not give the Board the power to eliminate extreme high or low water, nor will it make decisions for the Board. The Board will continue to have only a modest ability to influence water levels. Nevertheless, the DST will inform the Board so that it better understands the impacts and uncertainties of deviation options, and thus enables them to make effective decisions while maintaining their ability to be as fair and impartial as possible within the context of the *Boundary Waters Treaty* (https://www.ijc.org/en/who/mission/bwt) and 2016 Supplementary Order of Approval (https://ijc.org/en/68a).

Why an expedited review of Plan 2014

The 2017 and 2019-2020 high-water events were the result of a confluence of natural occurrences, including excessive precipitation in the Lake Ontario and St. Lawrence River basins and extreme inflows from Lake Erie as well as the Ottawa River, which enters the St. Lawrence River at Montréal. No regulation plan could have prevented flooding in the face of such extraordinary water supplies beyond the design capacity of the St. Lawrence River system. However, the unprecedented nature of the high-water events and the possibility of recurrence, plus a degree of public distrust of Plan 2014, prompted the IJC commissioners to speed up the timetable for a review of the plan by an internal body dedicated to such work — the GLAM Committee. The IJC ordered the expedited review in February 2020 and the GLAM Committee was instructed to explore how Plan 2014 addresses extreme high or low water levels and consider whether the plan's regulatory processes should be improved or supplemented to better deal with such extreme events. The GLAM Committee also is considering whether the assumptions made about future water supplies for Lake Ontario and the St. Lawrence River should be revisited due to the impacts of climate change.

To assist the GLAM Committee with its review, the IJC named an 18-member Public Advisory Group (PAG), made up of representatives of uses and interests from throughout the St. Lawrence River and Lake Ontario system. The advisory group offered valuable advice to the GLAM Committee during the Phase 1 effort. Through their contributions the PAG increased transparency in the process, provided a detailed assessment of the Phase 1 engagement process, and gained insights and empathy of the impacts and experiences of interests across the entire system.

The GLAM Committee undertook a two-phased approach. Phase 1 of the expedited review had a more narrow and urgent purpose as explained below and was completed in early November 2021. Phase 2 of the expedited review will examine Plan 2014's response to extreme high and low water on a broader basis, gather more information, continue critical research, and explore the need for any modifications to the regulatory plan. Phase 2 is tentatively scheduled for completion in the fourth quarter of 2024.

The GLAM Committee's Phase 1 focus: Board deviations

Amid the clamor over two record-breaking floods in a three-year period, and with more high water looming, the IJC directed that Phase 1 of the expedited review focus on a single element: providing Board members with more insight when they made deviation decisions. At the time the Phase 1 effort began, the level of Lake Ontario remained high and water was flowing into Lake Ontario from Lake Erie in near-record volumes. It seemed possible that water supplies would remain perilously high for at least several more years. Increasing the level of confidence in deviation decisions was deemed the most expedient way to prepare for what was feared could be an imminent recurrence of damaging high water. As it turned out, an unusually dry period in the Lake Ontario and Lake Erie basins in 2020-2021 alleviated the immediate threat of high water over that period.

The focus of Phase 1, then, was on providing the best information possible to assist the six-member International Lake Ontario-St. Lawrence River Board (Board), an appointed body that oversees the operation of Plan 2014. The Board has the authority to change the planned outflow, or "deviate" from Plan 2014's provisions when the water reaches extreme high or low levels.

Outflow regulation, even in the absence of extreme high water, is not a simple task. Lake Ontario's level can be influenced by adjusting the outflow of water through the Moses-Saunders Power Dam on the St. Lawrence River. Outflow adjustments tend to have a moderating effect on Lake Ontario levels, reducing the rate or extent of a rise or fall, though levels cannot be controlled entirely. The vast lake reacts very slowly to changes in outflow, while the St. Lawrence River has multiple hydraulic zones, each of which reacts differently to outflow alterations. When water levels are not extremely high or low, Plan 2014's rule curve governs the outflow. When water pushes toward an extreme, one of the five limits built into Plan 2014 can govern outflows. The limits are intended to protect interests on Lake Ontario and the St. Lawrence River such as shoreline property owners, hydropower producers or commercial shippers.

If the lake level reaches pre-determined extreme high or low "trigger levels," the Board is authorized to deviate from Plan 2014's rule curve or limits by ordering outflow changes. Per criterion H14 of the 2016 Supplementary Order of Approval, when high level triggers are exceeded the works are to be operated so as to provide all possible relief to riparian owners upstream and downstream, and when water falls below the low level triggers, the works are to be operated so as to provide all possible relief for municipal water intakes, navigation and power purposes, upstream and downstream. These changes are intended to lessen the impact of extreme water levels. The Board also can deviate in certain other cases as per their directives from the IJC. During the high water in 2017, 2019 and early 2020, the Board was regularly under deviation authority and making decisions that resulted in deviations occurring almost half the time from 2017 through the end of 2020. That is, during these periods of high water, the system was managed as often under deviations as it was under normal plan operations. Deviations cannot eliminate extreme high or low water, but they can make a measurable difference in some cases. For example, in the summer of 2017, after the Lake Ontario level had begun to recede from its peak, the Board was able to remove an additional fifteen centimeters (six inches) of water from Lake Ontario. But, as happened frequently in 2017 and 2019-2020, interests on the river and lake sometimes plead with the Board to do more.

Board members found that during these periods of extreme high water they could have made use of more information about potential outcomes of their decisions. Some of these information gaps pertain to tradeoffs — that is, situations in which alleviating the impact of extreme water levels on one interest or region worsens the impact on another interest or region. The Board has struggled to weigh respective impacts in these cases, which are happening in real time and often are accompanied by public outcry from the competing interests. As well, the Board members said they could not judge long-term impacts of possible deviation strategies because of uncertainty about water supplies in the coming weeks and months, a challenge exacerbated by the changing climate.

The Phase 1 effort by the GLAM Committee was aimed at finding ways to improve deviation decisions by providing the Board with better information, including better ability to inform real-time decision-making. Working on a compressed schedule, the GLAM Committee conducted or sponsored targeted research to address key gaps in knowledge, and also developed the DST to consolidate, summarize and visualize that information to support Board decision-making.

Research accomplishments

The GLAM Committee worked to fill information gaps and address uncertainties about deviation-decision outcomes. Its data collection and analysis will inform both the Board and the public of the risks and tradeoffs associated with regulating under extreme high water. The data was used to create the DST and to provide insights into possible new deviation strategies. The DST also can be updated as better information and understanding is developed through the ongoing research programs.

Much of the research conducted or sponsored by the GLAM Committee focused on the impacts of extreme high water on six identified uses and interests on the lake-river complex: municipal and industrial water systems; commercial navigation; hydropower production; lake and river shoreline properties; lake and river ecosystems, and recreational boating and tourism. The GLAM Committee and the IJC also respect and recognize that Indigenous Nations must be included in the review of regulation plans, in addition to the six other key interests, to ensure that Indigenous knowledge and perspectives are part of the plan review process. Engagement and fact-finding about impacts of water-level changes on these communities began in Phase 1 of the Plan 2014 expedited review and will continue in Phase 2. Likewise, public engagement efforts initiated through the PAG in Phase 1 are important to informing critical research.

Among the Phase 1 research efforts:

- The GLAM Committee identified possible new strategies for deviating from Plan 2014's flow limits by researching the history and functioning of the limits throughout the extreme water conditions and examining opportunities for incremental improvements.

- The GLAM Committee commissioned LURA Consulting to document the impact of high water on municipal and industrial water systems on the river and lake. A separate study by Polytechnique Montréal examined potential impacts on water systems of low wintertime flows on Lake St. Lawrence, the broad section of the river upstream from the Moses-Saunders dam.

- A study by the US Army Corps of Engineers' Institute for Water Resources provided independent estimates of the impacts of extreme high outflows on the commercial navigation industry. The research examined nine navigation-interruption scenarios that could result from Board deviations and produced estimates of the tons of cargo delayed and financial cost under each scenario. The study and a GLAM Committee workshop with navigation industry representatives identified how harmful stoppages would be from the industry's perspective.

- A Clarkson University study of winter flows through the Moses-Saunders dam found that in some situations the Board might be able to deviate more aggressively from the I Limit, which promotes stable ice cover on critical areas of the St. Lawrence River. Separately, River Institute researchers documented that extreme reduction of winter water levels in Lake St. Lawrence of the sort that might result from more aggressive Board deviations could harm a wide range of aquatic organisms.

- GLAM Committee members and researchers at Environment and Climate Change Canada, the US Army Corps of Engineers and other organizations collected and analyzed data on the extreme high water events in 2017, 2019 and early 2020 including the detailed analyses of aerial imagery, municipal damage reports, media reports, and questionnaire responses from over 3000 shoreline property owners. Researchers also conducted detailed analyses of shoreline building footprints and assessed shoreline impacts against the water levels at the time those impacts occurred. The work measured impacts on residential and business properties, marinas and yacht clubs, municipalities and recreational boaters at many locations.

- The GLAM Committee worked with contractors Copticom Stratégies et Relations Publiques, Kennedy Consulting, and USACE-Buffalo to undertake outreach activities to staff from municipalities, conservation authorities and other local governments in Ontario, Quebec and New York to gather additional shoreline impact information. People Plan Community and associates were also contracted to work with the GLAM Committee to engage First Nations, Tribal Nations and the Métis Nation that may be impacted by fluctuating Lake Ontario and St. Lawrence River water levels and listen to impacts, experiences and knowledge.

- The US Army Corps of Engineers and the National Research Council Canada developed models that correlated water levels with the number of buildings that would be inundated along the upper St. Lawrence River and Lake Ontario shorelines. The impact of waves and storm surge were estimated as well. Simulations of inundated buildings were also done for the lower St. Lawrence River by Environment and Climate Change Canada.

The Decision Support Tool

A significant Phase 1 accomplishment was creation of a working prototype DST to provide the Board with new insights into and ways to visualize the uncertainties and impacts of possible deviations and the tradeoffs associated with them. Interactive tools such as this are becoming more common in many fields, from sports to health care to water-resource management.

The computer-based DST allows the Board to test the outcome of possible deviation strategies that are presented to them by representatives of the agencies that support the regulation of outflows from Lake Ontario. Until now, information available to the Board during extreme conditions was limited, and was spread across multiple platforms and output types. The approach adopted through the use of the DST is to summarize, synthesize, and create visualizations of a range of metrics across all interests and across a wide range of geographic regions. This information is presented through broad-based metrics that show, for example, the number of shoreline and near-shore buildings on Lake Ontario and the St. Lawrence River that could be inundated by the water levels associated with a proposed deviation, or show the tons of cargo affected and the financial cost if a proposed deviation strategy were to cause flows unsafe for navigation leading to a temporary closure. Both values are plotted over time.

Results can also be displayed through location-specific metrics that define impacts by water level ranges known as "impact zones." These have been developed to show on-the-ground impacts of proposed deviations for a series of shoreline communities — seven on the Lake Ontario shore, two on the upper St. Lawrence River and two on the lower river. These metrics reflect impacts on residential and business properties; marinas and yacht clubs; recreational boaters; parks, roads and other municipal infrastructure, public and private water systems and agricultural land on the lower river. This approach allows the Board to compare impacts of proposed outflow strategies at multiple locations on the St. Lawrence River and Lake Ontario and understand the tradeoffs inherent in any deviation decision, whether those tradeoffs are between interest groups or between geographic regions.

Along with the challenges of assessing tradeoffs, Board members have long faced uncertainty about future water-supply conditions, a consequence of the fact that long-term weather patterns cannot be accurately predicted. This has made it impossible to be sure that a deviation will play out the way the Board intended increasing the challenges faced by the Board when considering the impacts of any outflow strategy. The DST addresses that uncertainty by providing a range of possible water-supply scenarios and showing the associated impacts so the Board can get a sense of the short-term and longer-term effect of deviations. The Board may test deviation outcomes using the six-month forecast provided by the responsible government agencies in Canada and the United States. They can test the levels that would occur if there were no regulation of outflows or in dozens of other wet or dry scenarios based on the historical record. The Board may even choose from "more extreme-case" scenarios in which the water supply and resulting water levels would exceed those of 2017 and 2019. While there is no guarantee that any of those scenarios will come to pass, the use of variable water-supply scenarios allows Board members to judge what effect a possible deviation could have in the coming months.

Importantly, the DST will not make decisions for the Board, and it cannot eliminate the impacts of extreme high or low water, nor can it eliminate uncertainty associated with such a large, hydrologically dynamic system. However the DST does allow for more informed decision-making, particularly related to how a decision impacts multiple interests across widely separate geographic regions. Board members have tested the DST and found the information it provides to be useful in better understanding risks and tradeoffs. The utility of the DST will only increase as it incorporates more information and as Board members gain more familiarity with it, particularly during real-time, decision-making situations.

Findings and recommendations

This first phase of the expedited review of Plan 2014 serves as a good example of adaptive management, which draws on new data and research to adjust management of a system to changing conditions. Information was gathered from people, businesses and institutions that were directly impacted by the extreme high water in 2017, 2019 and early 2020. Technical studies focused on the impact of high water on other uses and interests, and also how this information could be used by the Board in making decisions around deviations from the Plan 2014 rules and limits.

Much of this information formed the underpinnings of the DST, which will help the Board assess impacts, tradeoffs and uncertainties associated with extreme high water and the potential outcomes from deviations strategies with the goal of enabling the Board to make decisions in future high-water and low-water situations that are better-informed and more effective.

Through the Phase 1 effort the GLAM Committee established a number of key findings (see side box) that will help frame activities to be carried out to further inform Board deviation decision-making and in setting priorities for Phase 2 of the expedited review.

As the Phase 1 effort ended in the fall of 2021, the GLAM Committee has identified six recommendations to the IJC as the expedited review moves into Phase 2.

A. Indigenous Relations Building continue into Phase 2 and beyond.

B. Public Outreach and Engagement continue in Phase 2 and for the longer-term adaptive management process.

C. The DST should be considered a dynamic tool that needs continual updates and improvements. Resources need to be dedicated to this.

D. The Board should use the DST to prepare for the next crisis situation. Board members should continue learning how to make use of the DST.

E. Data gaps should continue to be filled and new technologies explored.

F. Phase 2 of the Expedited Review should provide for a fulsome review of Plan 2014.

Phase 2 of the expedited review of Plan 2014 will include analysis of possible changes to the plan's outflow rules, limits and "trigger levels" for Board intervention. It is expected to be completed in approximately three years.

KEY FINDINGS

1. Inclusion of Indigenous peoples' perspectives and traditional ways of knowing are important to the adaptive management process and the on-going review of the regulation plans. (Sections 2.8 and 4.7)
2. The Public Advisory Group was integral in the development of the DST and has informed on-going public engagement. (Sections 3.2.3 and 6.0)
3. Uncertainty in forecasted conditions will remain an issue for the Board, especially with climate changes. The use of water supply scenario testing can help better understand the probabilities and consequences. (Sections 3.2.2 and 5.1)
4. The Board needed information on how deviation decisions might shift risks/impacts between interests and locations. The GLAM Committee's work to characterize the type, breadth and severity of impacts across a number of interests and geographies is helpful. (Sections 3.2.3 and 5.5)
5. New information may allow limits and deviations from them to be changed. This provides some possible options for deviations in the future as well as possible plan alternatives to explore in Phase 2. (Sections 3.3 and 4.0)
6. Risk and uncertainty surround Board deviation decision-making. Adaptive management attempts to identify the risks and reduce the level of uncertainty as much as possible through on-going monitoring, modeling and verification. (Section 5.5)
7. The DST better informs the Board by allowing them to examine impacts of deviation strategies across interests and regions, but it cannot eliminate impacts or assure an objective will be met. The Board must still make the decision consistent with the 2016 Order and IJC Directives. (Section 5.0)
8. The DST remains a work in progress with a number of data gaps still to be filled including low water impacts. (Section 5.4)

Contents

List of Figures

List of Tables

1

Introduction

1.0 Introduction

In the face of two years of record-setting high water on Lake Ontario and the St. Lawrence River, the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee was directed by the International Joint Commission (IJC) to conduct an expedited review of Plan 2014, the outflow management regulations for Lake Ontario (see Appendix 2).

This is the report on Phase 1 of that expedited review. This first phase was given a narrow and urgent focus: Exploring whether there are new and better ways for the International Lake Ontario-St. Lawrence River Board (Board) to respond to a repeat of the exceptional hydrologic conditions and extreme high water levels on Lake Ontario and the St. Lawrence River that caused severe impacts in 2017 and 2019. To achieve this, the GLAM Committee has built on existing information and compiled a great deal of new information about the impact of extreme high water. The GLAM Committee has also worked closely with the Board to learn more about the practices it uses to address extreme high-water events on Lake Ontario and the St. Lawrence River by adjusting outflows, overriding, or deviating from, the provisions of Plan 2014. That information has been used to produce an innovative interactive tool that will provide the Board with valuable insight into potential risks and potential benefits when it responds to future extreme water events.

1.1 Purpose

The GLAM Committee was established by the IJC in January 2015 to systematically review outflow management plans from Lake Ontario and Lake Superior (IJC, 2015). The committee was given a 15-year timetable to complete its reviews — but the IJC advanced the timetable for the review of the Lake Ontario-St. Lawrence River outflow regulations, known as Plan 2014, because some members of the public and some elected officials questioned whether the plan and Board had responded appropriately to the repeated rounds of extreme high water (GLAM, 2018; Global News, 2020; Auburn Citizen, 2020).

The decision in February 2020 to focus Phase 1 of the expedited review on trying to find more effective ways for the Board to deviate to help reduce flooding was driven by memory of the two flood years on Lake Ontario and the St. Lawrence River. As well, there were record or near-record water levels on the upper Great Lakes, including Lake Erie, which feeds through the Niagara River and the Welland Canal directly into Lake Ontario (ECCC, 2020). There are no dams on Lake Erie or the Niagara River to control the flow into Lake Ontario (INBC, 2021). With continued high unregulated inflow from Lake Erie, there was an elevated risk of similar or even worse extreme high water on Lake Ontario in coming years. Considering this, the IJC felt that the first step it should take was to help the Board refine its decision-making as soon as practical in case high water were to recur in the near term.

As Board members told the GLAM Committee during preparation of this report, Board members have felt the need for more information on the impacts of their deviation decisions during recent high-water years and have found it challenging to make these decisions without full knowledge of the risks and uncertainties associated with their decisions (GLAM, 2020a). The Board members' concerns about limited information are of great interest to the IJC and the various uses and interests, particularly given the unprecedented nature of the recent flood events and the potential future impact of climate change.

1.2 Research leads to a Decision Support Tool

Even before Lake Ontario's waters began to recede from their peak levels in 2017 and 2019, the GLAM Committee and its partners had started gathering data on the impacts of high water on six uses and interests throughout the Lake Ontario and St. Lawrence River system as defined by the IJC in the report on Plan 2014 (IJC, 2014). Detailed information was collected on shoreline damage, commercial-shipping effects and impacts to the river ecosystem, hydropower, municipal water intakes and recreational boating (GLAM, 2018).

More recently, the GLAM Committee has begun gathering information on impacts on Indigenous communities on the St. Lawrence River and Lake Ontario. The GLAM Committee asked Board members what information is needed to support decision-making. GLAM Committee members and associates studied the regulatory framework and explored alternative deviation strategies that could be employed. A Public Advisory Group (pag), made up of representatives from a broad range of sectors and interests (Table 1) on Lake Ontario and the St. Lawrence River, was established and has provided the GLAM Committee with useful advice and input on the effects of extreme high water on their constituencies (IJC, 2020b). This new data and insight have allowed the GLAM Committee to develop an interactive tool that will synthesize and present a wealth of objective data to the Board about the tradeoffs across interests and geographies that are inherent in many deviation decisions. The Decision Support Tool (DST) will systematically provide Board members with information that will help them compare the impacts of possible deviations on the various uses and interests.

Table 1:

LIST OF SIX USES AND INTERESTS AS IDENTIFIED IN ILOSLRSB, 2006 AND IJC, 2014

- Municipal and industrial water systems
- Commercial navigation
- Hydropower generation
- Lake and river shoreline properties (including agriculture)
- Lake river ecosystems
- Recreational boating and tourism

**Indigenous Nations are being considered by the GLAM Committee in the adaptive management process*

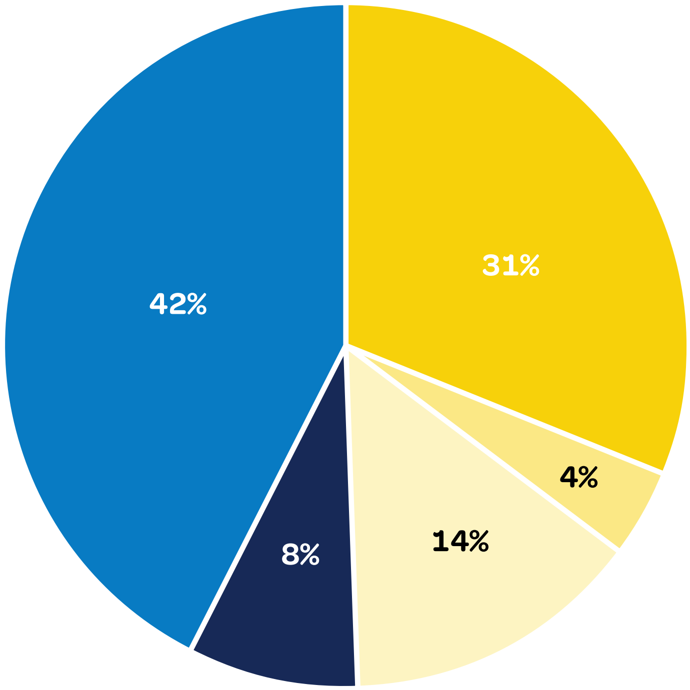


Figure 1:

FRACTION OF THE TIME THAT PLAN 2014 RULE CURVE OR LIMITS WERE APPLIED VERSUS THE FRACTION OF TIME THAT DEVIATIONS WERE CONDUCTED IN 2017 THROUGH 2020

- Plan 2014 Rule Curve
- Plan 2014 Limits
- Major (Criterion H14) Deviations
- Condition J Deviations
- Minor Deviations

Uncertainties about upcoming hydrologic conditions can be addressed by testing deviation strategies under a variety of possible future water supplies.

During extreme water-level situations on Lake Ontario the flow releases may be set off-regulation plan and still be in compliance with the 2016 Order. The Board is authorized to use its discretion to set flows in such conditions and to deviate from the usual rules and limits in the approved plan to provide relief to the degree possible upstream and downstream. Its deviations can alter the water level — in the realm of centimeters or inches, not meters or feet — by adjusting the flows out of Lake Ontario and through the St. Lawrence River. Water supply conditions were such that the flow releases were off-plan repeatedly during the recent extreme high water; discretionary deviation decisions dictated the outflow through the St. Lawrence River for approximately half of the time from January 2017 to December 2020 (Figure 1, see more detailed discussion in Section 3.0).

While the DST should be an effective aid, it will neither make deviations decisions for the Board nor give the Board new powers to address threatening extreme water levels. Often when the Board is called upon to act, serious impacts will have already begun (Figure 2). The Board has little leeway; it can take steps to lessen those impacts slightly but it cannot make them disappear.

Studies[1] by the Board (ILOSLRB, 2017), the GLAM Committee (GLAM, 2018), the IJC and others have shown that extraordinarily heavy and persistent precipitation and other natural occurrences led to the high water level in 2017, 2019 and early 2020 (Figure 3). Those studies have demonstrated that neither Plan 2014 nor any other regulatory plan could have prevented the flood damage that occurred.

However, abiding concern about the impacts of extreme high water in 2017 and 2019 caused the IJC and the two national governments to reassess the need to analyze Plan 2014 in the near term. As a result, Canada and the United States provided funding for an expedited review of the plan.

In the winter of 2019-2020, continued high inflows from Lake Erie and high local Lake Ontario-St. Lawrence

[1] The International Lake Ontario St. Lawrence River Board and the GLAM Committee produced reports regarding the 2017 event and other information from 2019 can be found on the Board website at https://ijc.org/en/loslrb/watershed/2017-and-2019-high-water-events

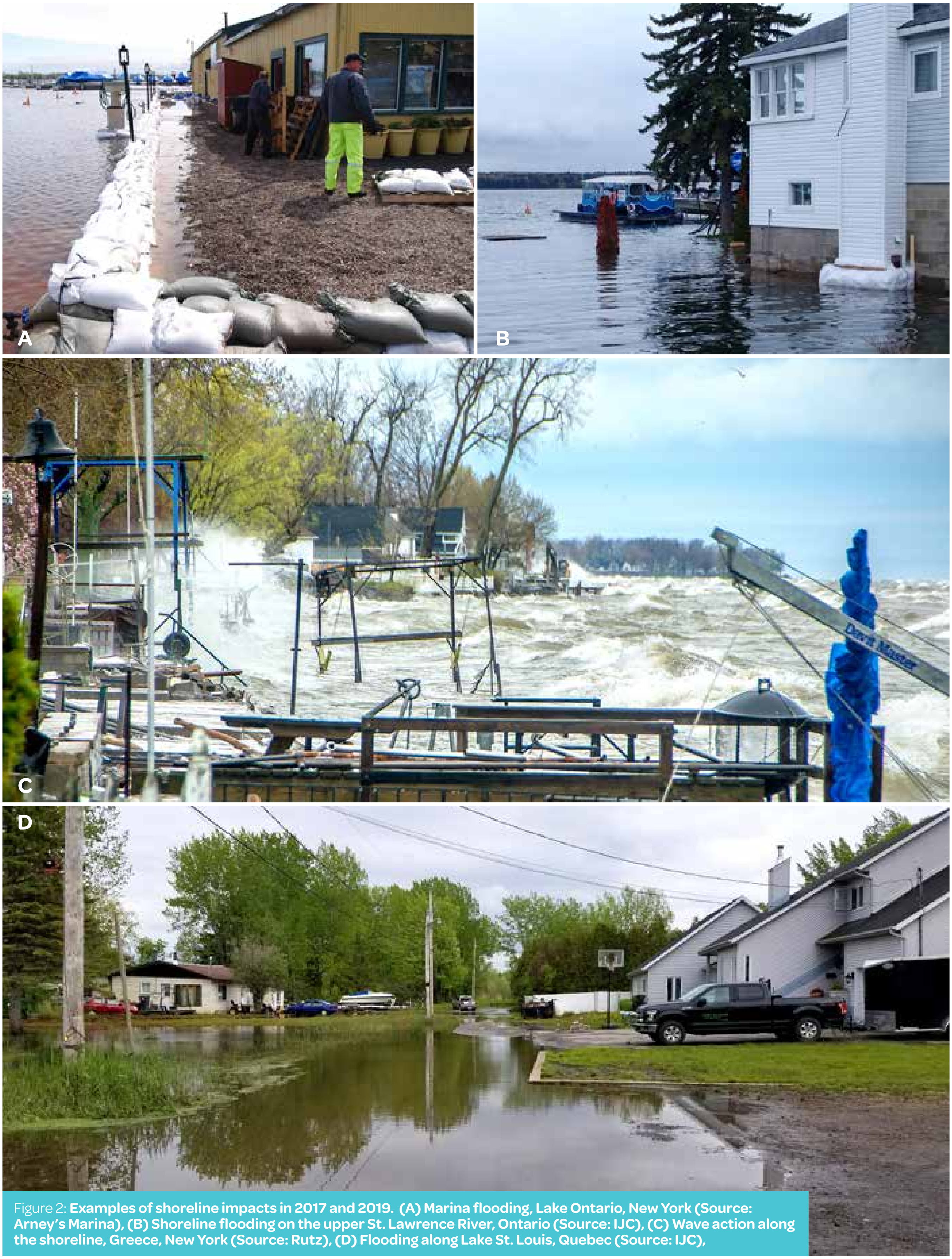


Figure 2: **Examples of shoreline impacts in 2017 and 2019. (A) Marina flooding, Lake Ontario, New York (Source: Arney's Marina), (B) Shoreline flooding on the upper St. Lawrence River, Ontario (Source: IJC), (C) Wave action along the shoreline, Greece, New York (Source: Rutz), (D) Flooding along Lake St. Louis, Quebec (Source: IJC),**

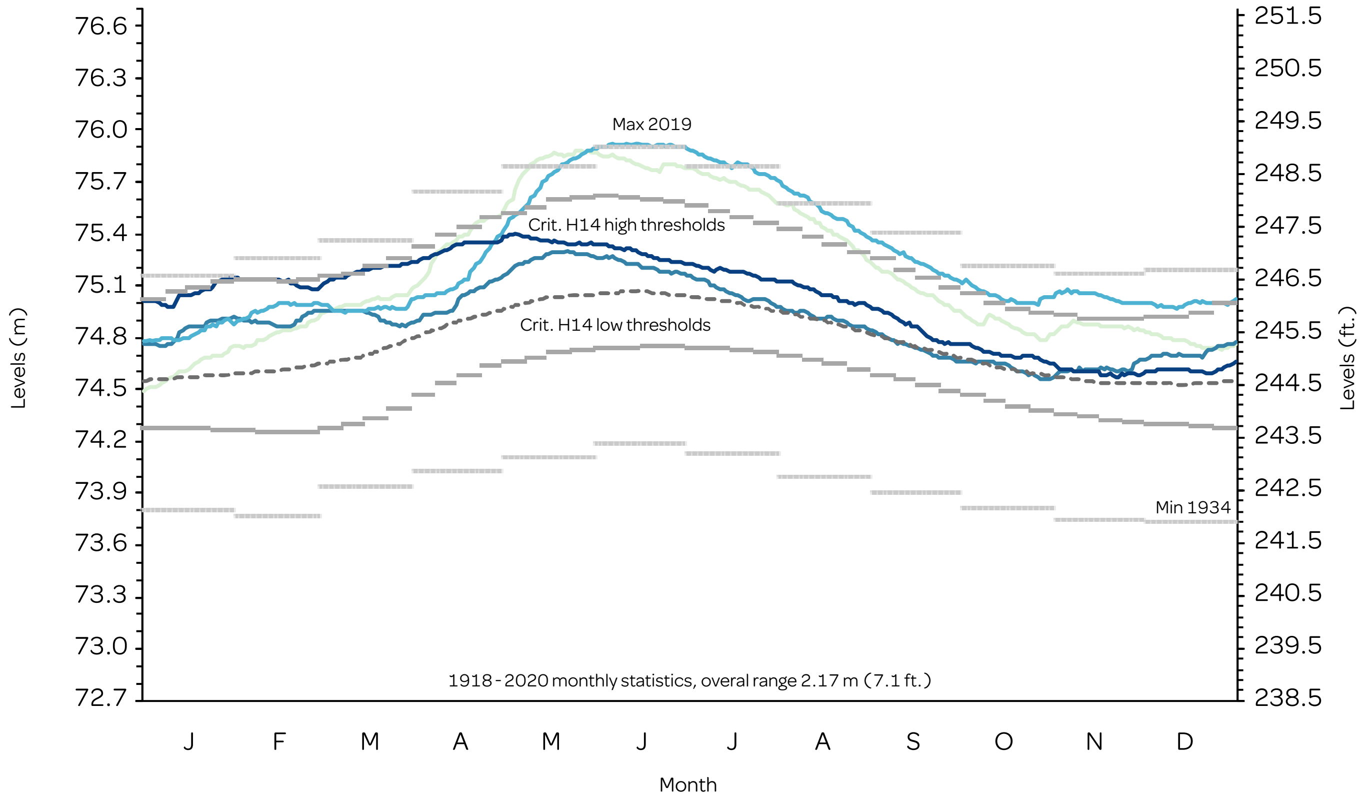


Figure 3:

LAKE ONTARIO WATER LEVELS[2], 2017-2020

(Source: International Lake Ontario – St. Lawrence River Board)

2017 2018 2019 2020 Min Max Average

River basin water supplies kept levels of Lake Ontario near or above the extreme high water levels and the point where Board deviations from Plan 2014 were authorized. Favorable weather-driven ice conditions on the river enabled deviations from the plan and release of extraordinarily high winter outflows from Lake Ontario that helped keep the winter lake level from rising higher. Lake levels began to moderate in March 2020 and, primarily due to a lack of spring precipitation and snowmelt runoff in the basin, lake and river levels peaked below the high thresholds in 2020.

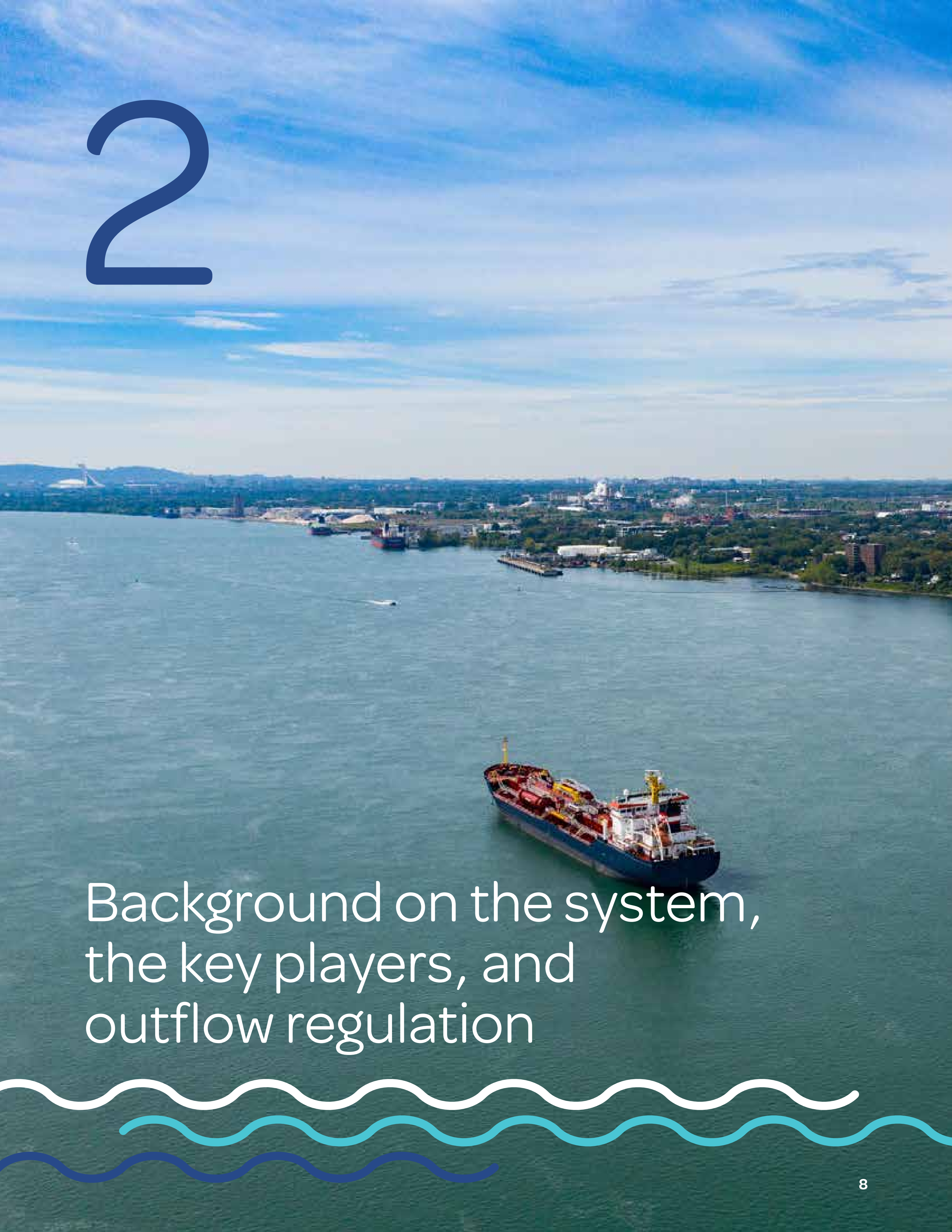
In a telling example of the uncertainty about future water supplies that the Board faces, Lake Ontario fluctuated through 2021. The lake's level quickly fell below the long-term average in the early part of the year and an unusual spring drought began in parts of the lake-river basin. Just months after concern had centered on possible high water, Lake Ontario levels declined to the point that the Board was authorized to begin deviating to address low-water conditions. In late May 2021, the Board reduced outflow from Lake Ontario below those specified by Plan 2014 to provide all possible relief from the potential impacts on municipal water intakes, navigation and power purposes, upstream and downstream. Nonetheless, Lakes Michigan, Huron and Erie remained well above average in the summer of 2021 and the drought in the Lake Ontario basin broke with several months of above-average precipitation. In early October, Lake Ontario's level moved back above the long-term average point (ECCC, 2021).

[2] All water level elevations listed in this report are referenced to the International Great Lakes Datum of 1985 or IGLD1985

In light of this, and given the variability and uncertainty in Lake Ontario water supplies and other hydrologic factors, the rationale for focusing Phase 1 on the Board's ability to address extreme high water through deviations remains well-founded. The low water levels in the spring and early summer of 2021 and the rapid recovery from those low levels also point to the importance of adaptive management to address changing conditions over the short and long term. The purpose of Phase 1 was not to end up with an overall recommendation for how to deviate, nor to provide a system optimization. Rather, it was to gather, process and present the information needed by the Board to assist them with their decision-making.

A broader exploration of Plan 2014 under both high and low water extremes and the need for any modifications will be the subject of the Phase 2 report on the expedited review of the plan. Work on Phase 2 of the expedited review is tentatively scheduled to be completed in the fourth quarter of 2024.

More on the expedited review of Plan 2014:
https://ijc.org/en/glam/expedited-review



2

Background on the system, the key players, and outflow regulation

2.0 Background on the system, the key players, and outflow regulation

The Lake Ontario-St. Lawrence River is a complex, dynamic system with many unique natural features and with engineered structures that are used to regulate flows through the interconnected lake and river system. The International Joint Commission (IJC) and their International Lake Ontario-St. Lawrence River Board (Board) serve to manage the outflows of Lake Ontario in accordance with Orders of Approval issued by the IJC. Outflows are managed under widely varying hydrological and climatic conditions, including changes in precipitation and temperature, which are two primary drivers of water levels in the system. The intent of outflow management is to achieve expected outcomes in consideration of a wide range of interests, and to the benefit of both Canada and the US.

2.1 Lake Ontario and the St. Lawrence River

The Lake Ontario-St. Lawrence River system, for the purposes of outflow regulation, extends from the lower Niagara River through Lake Ontario and as far down the St. Lawrence River as Trois-Rivières, Quebec, which is about 140 km (87 mi.) downstream of Montréal (Figure 4).

Lake Ontario is the easternmost and lowest of the five interconnected Great Lakes (Figure 5); the accumulated water from the four upper lakes enters Lake Ontario through the Niagara River and the Welland Canal. By surface area, Lake Ontario is the 12th largest freshwater lake on Earth (19,011 km^2 or 7,340 mi^2), but is the smallest of the five Great Lakes. By volume it is the fourth smallest, ahead of Lake Erie. Lake Ontario is 311 km (193 mi) long and 85 km (53 mi) wide at its widest. The border between the United States and Canada runs roughly through its center, with 54 percent of its shoreline in Canada (CCGLBHHD, 1977).

The Great Lakes represent the largest freshwater system in the world. With abundant biodiversity, they

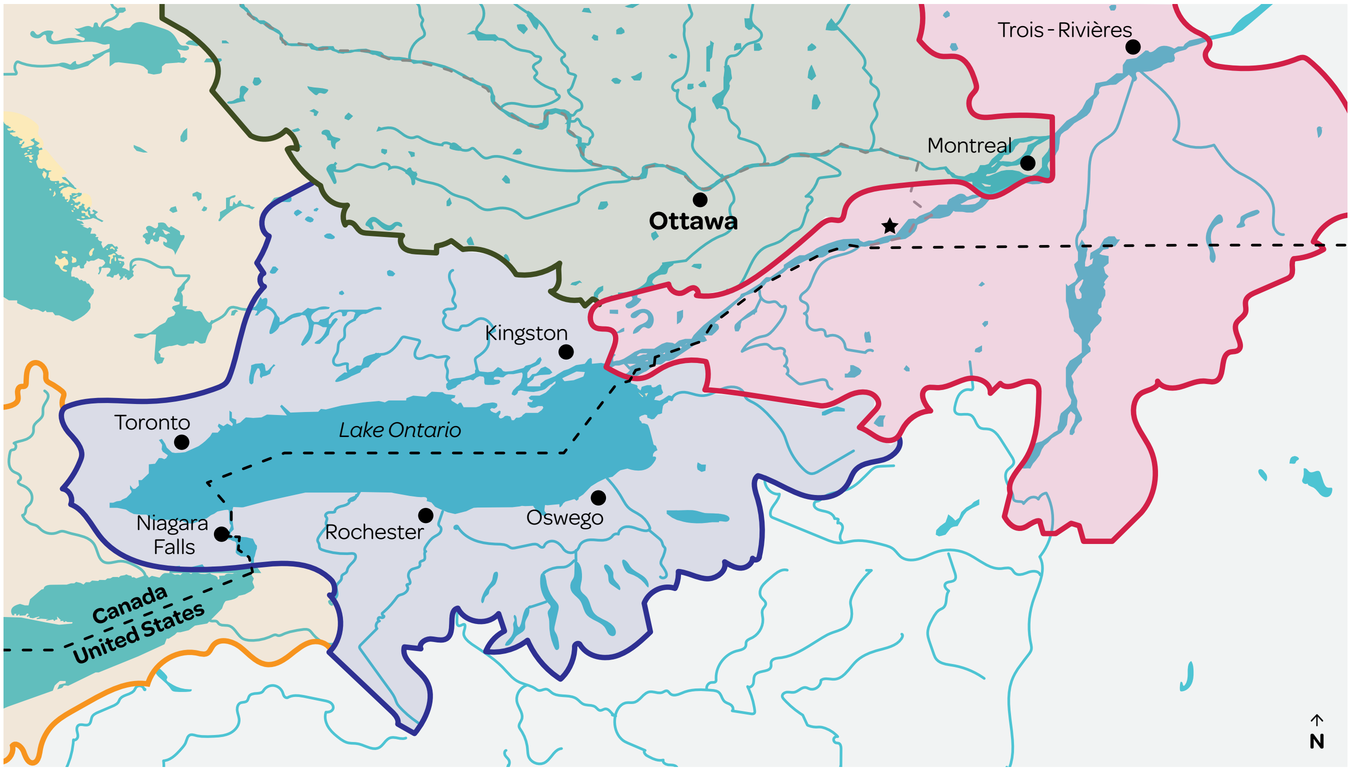


Figure 4:

MAP OF LAKE ONTARIO AND THE ST. LAWRENCE RIVER

Upper Great Lakes Watershed — Lake Ontario Watershed — St. Lawrence River Watershed

Sub-watershed of the St. Lawrence River — ★ Moses-Saunders Power Dam

Provincial border — International border

are home to approximately 3,500 species of plants and animals and provide 20 percent of the world's freshwater supply (NOAA, https://www.noaa.gov/education/resource-collections/freshwater/great-lakes-ecoregion).

As the traditional territory and Treaty territory for diverse Indigenous Peoples including the Anishinaabe, the Haudenosaunee, the Wendat, the Métis and others, the Great Lakes have always been a center of habitation and trade.

Today, about 8.75 million people live in municipalities that abut Lake Ontario, and tens of thousands of households are located on or near the lake shore. The greatest concentration of shoreline development is in the heavily urbanized Greater Golden Horseshoe region stretching from Niagara Falls around the western end of the lake through Toronto, Canada's largest city. Rochester, New York, has the largest concentration of shoreline residents on the United States side (Figure 4).

Lake Ontario empties into the St. Lawrence River, which by discharge volume is the 13th largest river in the world (Benke et al., 2005). The St. Lawrence River runs 1,191 km (740 mi) before emptying into the Atlantic Ocean; the first 450 km (280 mi), from the head of the river at Cape Vincent, New York and Kingston, Ontario downstream to Trois-Rivières, Quebec, is influenced by changes in outflow from Lake Ontario as addressed by Plan 2014. The stretch of the St. Lawrence River immediately upstream of the Moses-Saunders Power Dam located at Cornwall, Ontario and Massena, New York is known as Lake St. Lawrence, which was created when the Moses-Saunders Dam went into operation in 1958. Lake St. Lawrence serves as a forebay for the dam.

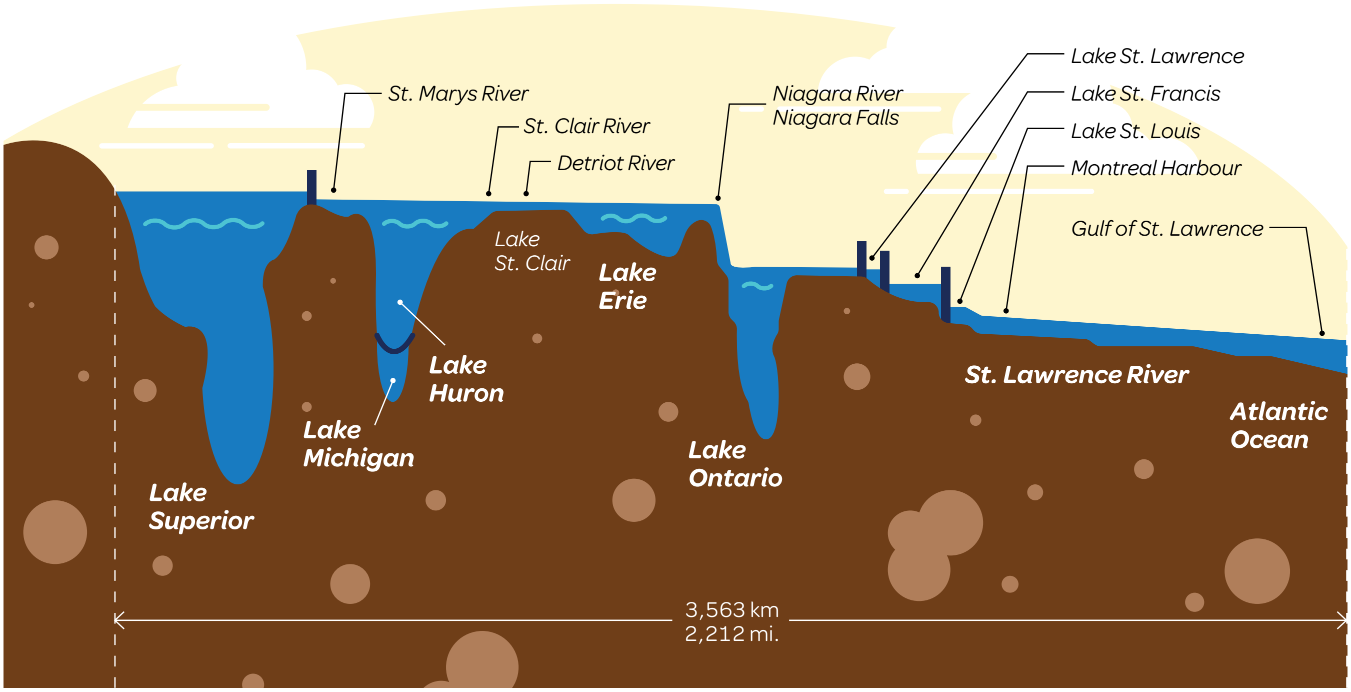


Figure 5:

WATER SURFACE PROFILE OF THE GREAT LAKES SYSTEM (Source: IUGLS, 2012)

At Montréal, the St. Lawrence River is joined by its largest tributary, the Ottawa River, which drains a basin more than twice the size as that of Lake Ontario. During the spring melt, large quantities of water that are stored in the snowpack are released and can combine with rainfall, which can lead to heavy spring flow and flooding. This is called a freshet. Generally there are two distinct flood peaks on the Ottawa River in the spring, about three weeks apart. The first spring flood peak in the Ottawa River originates from unregulated flows from its southern tributaries. The second peak results from a combination of high flows from the northern tributaries together with flows from headwater areas, and is partially regulated. The spring freshet can have a big impact on the levels and flows on the lower St. Lawrence River, however, the IJC has no oversight of that river's flow and does not set conditions for operation of the dams in the Ottawa River basin (https://ottawariver.ca).

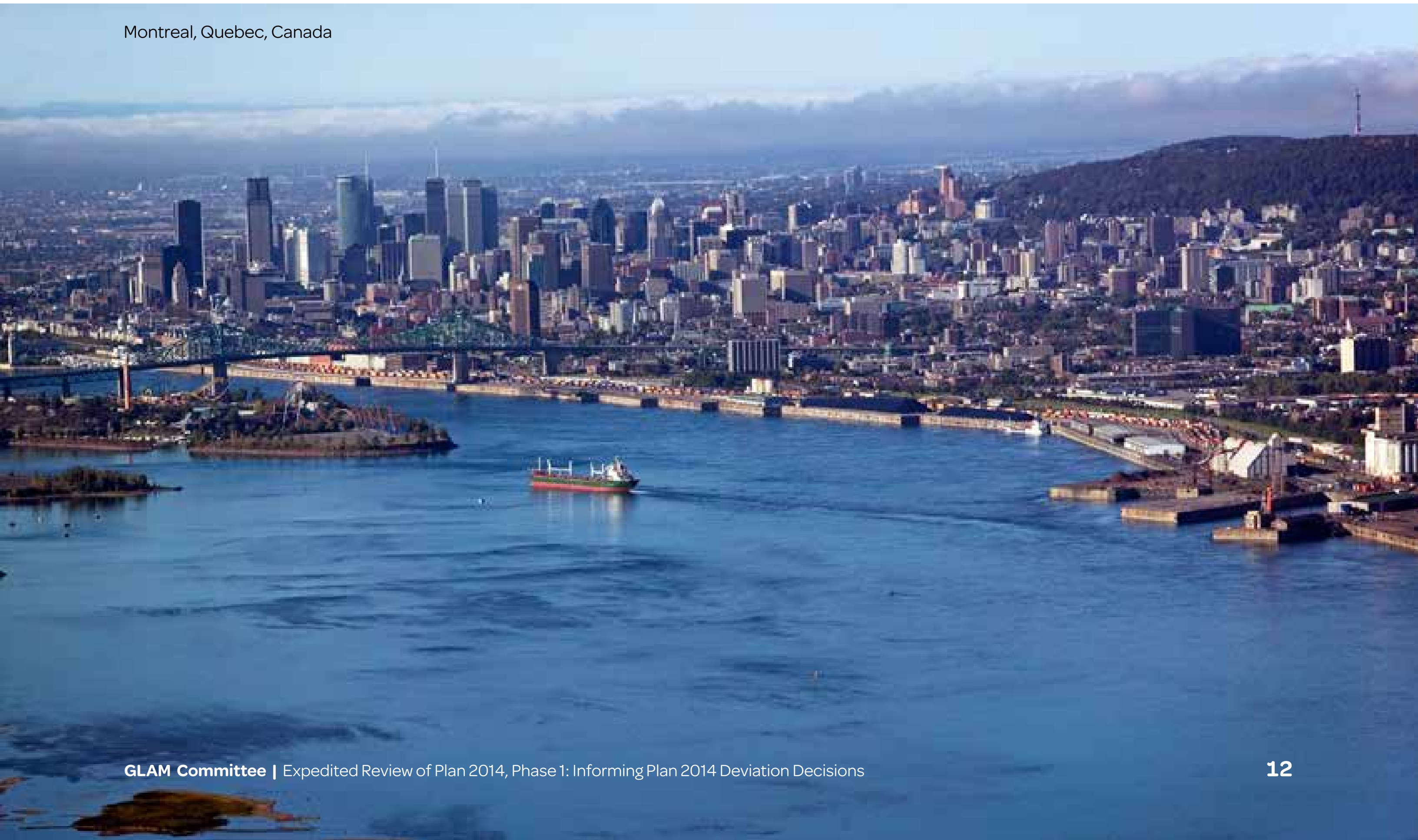
Approximately 4.7 million people live in municipalities that border the St. Lawrence River between Cape Vincent and Trois-Rivières. The bulk of the shoreline lies in Quebec and the dominant population center is Montréal, Canada's second-largest city. The river elevation naturally dropped roughly 69 m (226 ft) between Cape Vincent and Montréal, and originally several rap ids in that section of the river had made it impassable to large vessels. However, this fall of water offered substantial hydropower potential. After decades of discussion between officials in Canada and the United States, in 1952 the two nations submitted an application for a hydroelectric project to the IJC for approval in accordance with the *Boundary Water Treaty of 1909*. The design of the hydropower project that would straddle the St. Lawrence River near Cornwall, ON and Massena, NY was required to also facilitate the construction of the Seaway navigation system that was agreed to shortly afterwards by the two Governments. In October 1952 the project was approved (IJC, 1952).

Also in 1952, in the midst of flooding on Lake Ontario, the two national governments asked the IJC to determine, “having regard for all other interests”, whether measures could be taken to regulate the level of Lake Ontario for the benefit of property owners on the shores Lake Ontario, “having in mind the order of precedence to be observed in the uses of boundary waters as provided in Article VIII of the *Boundary Waters Treaty of 1909*” (ILOBE, 1957). The Lake Ontario monthly average level had reached as high as 75.76 m (248.6 ft) in June of 1952, the historical maximum record. After several years of study, and government concurrence, the IJC approved a design range of Lake Ontario levels that would reduce the peak level by 0.24 m (0.8 ft), provided that natural water supplies were no more extreme than those experienced in the past (ILOBE, 1957). To enable this reduction in Lake Ontario levels for the benefit of shoreline property owners required additional dredging in parts of the upper St. Lawrence River to increase the outflow capacity while allowing safe velocities for navigation to be maintained. This added channel flow capacity would enable a “considerable decrease” in future Lake Ontario shore property damage but not enable all such damage to be eliminated (ILOBE, 1957), nor would it prevent greater shoreline damages if water supplies to the lake were more extreme than historical.

The 7-year construction of the hydropower project included the Moses-Saunders dam, the Long Sault Dam, the Iroquois Dam, the Massena Intake, and 18 km (11.2 mi) of dikes (Macfarlane, 2014). The channel enlargements in the river required removal of over 53,500,000 cubic metres (70,000,000 cubic yards) of material (Bryce, 1982). The construction of the project resulted in the generation capacity of 1,957 megawatts of hydropower, enough energy to meet the needs of about two million homes. The hydropower project, together with the locks and additional channel dredging of the Seaway project, allowed deep-water vessels to navigate the river, thus opening the Great Lakes to ocean-going freighters. Outflow regulation was enabled by the St. Lawrence hydropower project. The increased channel capacity of the upper St. Lawrence River together with the dams allowed both higher and lower than natural outflows to be released from Lake Ontario and provided a measure of flood mitigation.

A visual tour of the Lake Ontario-St. Lawrence River system: https://storymaps.arcgis.com/stories/3dfcb1b201cd4a9f9424719976beecf5

Montreal, Quebec, Canada



2.2

The International Joint Commission

**The IJC was created by the1909 *Boundary Waters* ***Treaty* between Canada and the United States and it is now considered one of the world's oldest international organizations.

The IJC's purpose is to prevent or resolve disputes over the uses of the lakes and rivers that either form part of the boundary, or cross the boundary, between Canada and the United States. In many cases, the IJC has been called upon by Governments to set conditions for the construction, operation and maintenance of any dam or diversion that would affect water levels and flows across the international boundary. The IJC has set conditions for uses, diversions and obstructions of boundary waters and recommended water apportionment measures on numerous bodies of water along the boundary or that cross the boundary between the United States and Canada and often maintains oversight of water outflows and water uses in those cases.

On the Great Lakes, the outflow of Lake Superior is regulated through dams on the St. Marys River and the outflow of Lake Ontario is regulated through dams on the St. Lawrence River under IJC supervision. The IJC has established boards to oversee the regulations at each of these locations. The IJC's mission also includes ice management and the management of flows and levels in the Chippawa-Grass Island pool on the Niagara River as well as Great Lakes water-quality issues.

The IJC comprises three members from each country that are appointed by their federal governments. The IJC has a professional staff in United States and Canada numbering about three dozen and also relies on the support of government partner agencies in both countries.

The membership of the IJC can be found on the IJC website: https://ijc.org/en/who/people/commissioners

More on the Commission: www.ijc.org

Moses-Saunders Dam

2.3 The International Lake Ontario-St. Lawrence River Board

The Board oversees the operations of Plan 2014 on Lake Ontario and the St. Lawrence River. This report has been prepared for use by the Board to help it carry out its mission and meet its obligations under the 2016 Supplementary Order of Approval (https://ijc.org/en/68a) and associated directives.

The Board consists of six members who are appointed by the IJC. Each national government nominates one member, as do the provinces of Quebec and Ontario and the state of New York. To maintain parity a sixth U.S. member is appointed by the IJC. All appointees are professionals with expertise in water-related matters. The Board is aided by an Interim Advisory Group, which is meant to ensure that Board members have benefit of input from a broad group of stakeholders. At present the advisory group comprises six individuals, three from the United States and three from Canada, who had served on the Board itself until a December 2020 restructuring.

The Board supervises the regular workings of Plan 2014, which responds automatically to fluctuating water supplies by increasing or decreasing the outflow from Lake Ontario through the Moses-Saunders Power Dam and at times of maintenance or to supplement flows, a dam at Long Sault on the St. Lawrence River (see Figure 10 in Section 2.7.3 for reference). The Board reports semi-annually to the IJC on their activities and water levels. The Board has a number of sub-committees and staff who support it. The roles and responsibilities of these groups are outlined on Figure 6 and further described on the Board's website (https://ijc.org/en/loslrb/lake-ontario-st-lawrence-river-regulation).

Much of the time the Board's role is to monitor outflows and water levels as they fluctuate up or down in response to inflows from Lake Erie and weather–driven water supplies and to ensure that the outflows from Lake Ontario are set in accordance with Plan 2014. When water supplies are such that the level in Lake Ontario rises or falls to pre-determined "trigger levels" that are laid out in the *Directive on Operational Adjustments, Deviations and Extreme Conditions*, (https://ijc.org/en/loslrb/who/directives/deviations) the works are to be operated to provide all possible relief upstream and downstream. The Board is authorized to use its discretion to set flows under extreme conditions and to deviate from the plan to help lessen the impact of extreme water levels. (The board that existed under the previous regulation plan had similar, though not identical, authority.)

When deviating in times of extreme low water, as it did in the spring and early summer of 2021, the 2016 Supplementary Order of Approval requires the Board to give priority to protecting municipal and industrial water intakes, commercial shipping and hydropower production. When deviating during times of extreme high water, the 2016 Order requires the Board to give priority to protecting riparians (shoreline property owners), with consideration given toward those who are upstream along Lake Ontario and the upper St. Lawrence River above the dams and downstream along the lower St. Lawrence River shore. The high-end "trigger levels" (refer to Figure 3) are the levels that are expected to be exceeded 2 percent of the time; the low-end "trigger levels" are points below which the level is expected to fall 10 percent of the time.

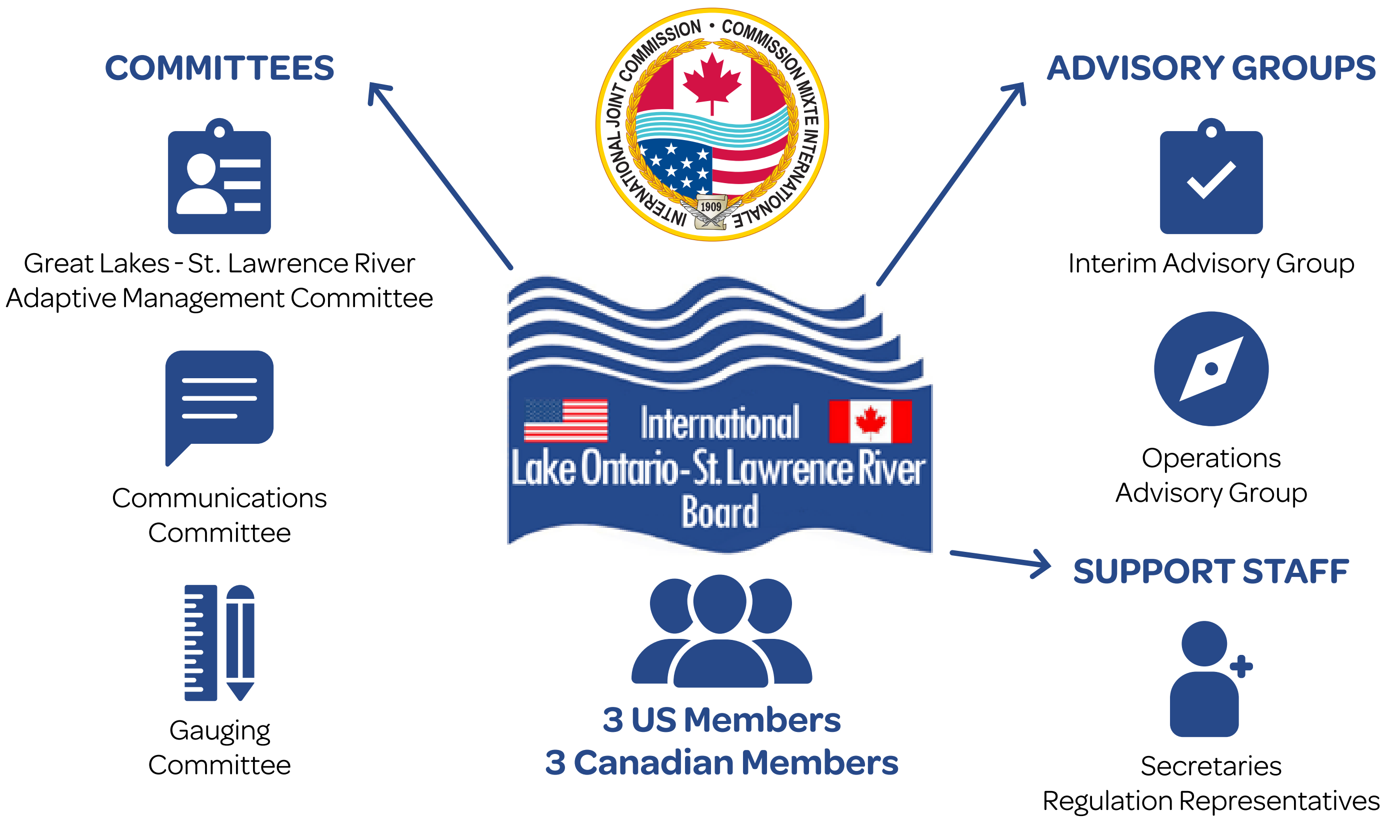


Figure 6:

ROLES AND RESPONSIBILTIES OF THE INTERNATIONAL LAKE ONTARIO-ST. LAWRENCE RIVER BOARD

The interventions that are taken once "trigger levels" are reached are known as major deviations from the plan. Major deviations alter the rate of outflow to try to bring about a desired change in the water level on Lake Ontario or the St. Lawrence River. The Board's authority to deviate from the plan remains active so long as the water level of Lake Ontario continues to be above the high-water "trigger levels" or below the low-water "trigger levels".

As extreme water levels ease and there no longer is need for a major deviation, the Board is required to outline for the IJC its strategy for returning to Plan 2014 outflows. The Board also must consider whether it is beneficial to make outflow changes in the future to offset, or "pay back," the water that was released from Lake Ontario beyond what Plan 2014 would have specified. (If the Board was dealing with a low-water situation, the same applies to any "extra" water that was held on Lake Ontario.) The IJC decides, based on recommendations from the Board, on a case-by-case basis, whether pay-back deviations are needed. This is most often based on the current conditions and forecasts. As an example, beginning in October, 2021 the Board increased Lake Ontario outflows by up to 200 m^3/s (7,100 cfs) above the amount set by Plan 2014 for approximately eight weeks to return Lake Ontario's water level to the level it would have been if the Board had not made outflow deviations earlier in the spring/early summer of that year (late May through mid-July), but had instead strictly followed those specified by Plan 2014. The effect of this was to try and reduce Lake Ontario water levels by 4 cm by mid-December, 2021 to offset the amount that had been added to the lake as a result of the earlier deviation when the low criterion H14 "trigger levels" had been crossed.

The Board supervises the regular workings of Plan 2014, which responds automatically to fluctuating water supplies by increasing or decreasing the outflow from Lake Ontario through the Moses-Saunders Power Dam and at times of maintenance or to supplement flows, a dam at Long Sault on the St. Lawrence River

The Board also may engage in short-term "minor" deviations that aid one use or interest without unduly harming any others. For example, if conditions warrant the Board temporarily raises levels for a few days in the fall in the forebay of the dam so that boats on Lake St. Lawrence can be readily removed for the season.

Subject to the requirements of the 2016 Order, the IJC may also authorize the Board to temporarily make minor modifications to the regulated outflows under a section of the 2016 Supplementary Order of Approval known as Condition J. These authorizations allow the Board to temporarily make minor modifications or changes to the regulated outflows from Lake Ontario for the purpose of determining modifications or changes in the regulation plan that may be advisable. The Board is required to report to the IJC the results of such temporary changes or modifications, together with any recommendations arising from such, and the IJC may accept or reject any such recommendations.

In the winter of 2019-2020 and 2020-2021, the IJC authorized the Board under Condition J to test viability of outflows that were greater than the plan's winter operational limits provided they had little or no negative impact on other interests such as ice formation.

Deviation under any circumstances can be difficult given the complexities and uncertainties of the system. For example, increasing outflow to reduce flooding impacts on the Lake Ontario shoreline can increase the risk of flooding on some parts of the St. Lawrence River shoreline downstream of the dams. At the same time, those increased outflows can also cause water levels to plummet on other parts of the St. Lawrence River, such as Lake St. Lawrence. Conversely, large reductions in outflows result in large and rapid water level rises on Lake St. Lawrence and a corresponding drop in levels downstream of the dams (refer to Figure 27 and discussion in Section 3.2.2).

The deviation process, then, is a balancing act in which the Board must be mindful of the impact of its decisions not just on shoreline properties but on other uses and interests such as commercial navigation, the lake and river ecosystems and the need for stable ice cover on sensitive sections of the river as outlined in the 2016 Supplementary Order of Approval and the *Directive on Operational Adjustments, Deviations and Extreme Conditions*. This delicate give-and-take can lead to differences of opinion among parties who believe their interest or region was shortchanged by a deviation decision.

As was made clear by the experience in 2017 and 2019-2020, no deviation strategy or any other regulation action can prevent extreme high water in the face of unpredictable excessive precipitation, late snowmelt and other confounding factors such as high inflows from the Ottawa River in the spring (refer to Section 3.2.2 for more discussion on factors that complicate deviation decisions).

More on the Board: https://ijc.org/en/loslrb

2.4 The Great Lakes - St. Lawrence River Adaptive Management Committee

The Great Lakes–St. Lawrence River Adaptive Management (GLAM) Committee was created by the IJC in January 2015. Through its directive (https://ijc.org/en/glam/who/directive), the Committee is charged with evaluating and supporting the outflow regulation plans for Lake Ontario and Lake Superior, and the management of water levels and flows in the Niagara River (specifically the Chippawa-Grass Island Pool). The GLAM Committee reports to the Boards that are responsible for those operations. This expedited review of the Lake Ontario management plan is the first such review to be concluded by the GLAM Committee. The GLAM Committee is made up of nine technical experts from each country appointed by the IJC, plus supporting secretaries.

As its name indicates, the GLAM Committee employs adaptive management — an approach that replaces static oversight with a dynamic process. The committee employs monitoring, modeling and analysis of new evidence on a continuing, iterative basis to recommend ways to improve the outflow regulation plans and adapt them to changing circumstances, including climate change. The GLAM Committee developed a short and long-term strategy document (GLAM, 2020b) to guide the adaptive management process and the expedited review of Plan 2014. The strategy outlines the critical components in the adaptive management process as well as the priorities for Phase 1 and Phase 2 of the expedited review of Plan 2014. The strategy was modified to address feedback provided to the IJC within the US Government Accountability Office report (GAO-20-529, July 2020).

More on the Committee: https://ijc.org/en/glam

2.5 Public Advisory Group for phase 1 of the expedited review of Plan 2014

In May 2020, the IJC appointed an 18-member Public Advisory Group (PAG) to help the GLAM Committee in Phase 1 of the expedited review of Plan 2014. The group's 18 members, drawn from First Nations, citizen associations, business and recreational groups, environmental advocacy organizations, and local government entities, represent the uses and interests on Lake Ontario and the St. Lawrence River. They began twice-monthly virtual meetings in June 2020.

Members serve in a voluntary capacity and have contributed significant time to attend about two dozen virtual meetings, many jointly with GLAM Committee and Board staff, and others separately. The PAG was tasked with advising the GLAM Committee on the information, tools and criteria used to assist the Board with deviation decisions. The PAG brought transparency to the process and ensured that the Board received the most pertinent information to assist it with decision-making, something encouraged by the US Government Accountability Office in their July 2020 report (GAO-20-529, 2020). The PAG did not have direct access or influence on the Board's decisions, but its members provided valuable input about the impact of high water on the sectors and interests they represent and aided greatly in the development of the Decision Support Tool (DST). In the process, they gained a greater understanding and empathy for the issues and experiences of the other interests and regions and the complexity of the Lake Ontario-St. Lawrence River system.

The PAG consisted of people representing the following organizations or parties: Ault Island residents (Ontario); Beaconsfield Yacht Club (Quebec); Boating Ontario Association; Communauté métropolitaine de Montréal; Jefferson County Legislature (New York); Mohawk Council of Akwesasne; Montreal Port Authority/RUSL; New York Power Authority; Niagara County government (New York); Rochester-area shoreline residents (New York); St. Lawrence Seaway Pilots Association; Save our Sodus (New York); Save the River/Upper St. Lawrence Riverkeeper; The Nature Conservancy; Thousand Islands International Tourism Council; Union des producteurs agricoles; United Shoreline Ontario; Université du Québec à Trois-Rivières.

See Section 6.0 of this report for further discussion and visit: https://ijc.org/en/glam/expedited-review/public-involvement

2.6 Plan 2014 outflow regulation

An updated regulation plan for Lake Ontario and the adjoining portion of the St. Lawrence River, known as Plan 2014, was adopted by the IJC following concurrence from the Governments of Canada and the United States in its December 8, 2016 Supplementary Order of Approval. Releases of water in accordance with the 2016 Order and Plan 2014 were effective by the end of January 2017, and replaced the previous regulation plan (Plan 1958-D) which had been in use since 1963. Plan 2014, designed to accommodate a broader range of hydrologic conditions than its predecessor, was the culmination of over 16 years of study, public consultation and revision (IJC, 2014).

Fundamentally, the plan dictates how much water should be released from the Moses-Saunders Power Dam and its spillway, the Long Sault Dam, located about 160 km (100 mi) downstream of Lake Ontario's eastern end. Plan 2014 is expected to maintain the water levels on Lake Ontario and the St. Lawrence River for much of the time within the range of water levels experienced over the past century. But neither it nor any other outflow management action can control water levels and prevent serious impacts when excessive precipitation, high inflows and other unforeseeable natural factors send waters to extreme high levels or when drought conditions send waters to extreme lows.

Lake Ontario level (IGLD 1985)	Pointe Claire level (IGLD 1985)
< 75.30 m (247.05 ft)	22.10 m (72.51 ft)
≥ 75.30 m (247.05 ft) and < 75.37 m (247.28 ft)	22.20 m (72.83 ft)
≥ 75.37 m (247.28 ft) and < 75.50 m (247.70 ft)	22.33 m (73.26 ft)
≥ 75.50 m (247.70 ft) and < 75.60 m (248.03 ft)	22.40 m (73.49 ft)
≥ 75.60 m (248.03 ft)	22.48 m (73.75 ft)

Table 2:

LAKE ST. LOUIS (POINTE CLAIRE) LEVELS CORRESPONDING TO LAKE ONTARIO LEVELS FOR LIMITING LOWER ST. LAWRENCE RIVER FLOODING DAMAGES (F LIMIT).

Plan 2014 typically prescribes the outflow from Lake Ontario on a week-to-week basis. Lake releases for Plan 2014 begin with a sliding rule curve based on the pre-project stage-discharge relationship such that as Lake Ontario levels or water supplies increase, outflows increase and as water levels or supplies decrease, outflows decrease (GLAM, 2018). The rule curve takes into account the present-day lake levels as well as the recent and estimated near-future supply of water in Lake Ontario. Under historical water supply conditions, the plan generally keeps the lake and river within the historic range of seasonal levels. The plan also was designed to achieve certain specific socioeconomic and environmental objectives, such as providing conditions that are beneficial to shoreline wetlands and recreational boating, while also complying with the Treaty order of precedence of uses[3] and supporting other uses and interests (IJC, 2014).

The plan contains a series of limits that restrict or increase outflow from the lake under certain conditions to address specific uses and interests that can be affected by water levels and flows (IJC, 2014 – Annex B). These flow limits were developed from those used in Plan 1958-D, the former regulation plan, and what had been learned through operations with the decades of experience with deviations from that plan.

Plan 2014 Limits:

- **The F Limit,** which is designed to balance high water and the risk of flooding and erosion both upstream on Lake Ontario and downstream on the St. Lawrence River by adjusting Lake Ontario outflows to target increasingly higher water levels downstream at Lake St. Louis near Montréal as water levels upstream on Lake Ontario also increase (Table 2).
- **The I Limit,** which is meant to foster the establishment of a stable ice cover on portions of the St. Lawrence River in the wintertime. Stable ice cover prevents ice jams that can cause localized flooding and restrict flow in some areas to the point where municipal water intakes might become unusable.
- **The L Limit,** which is meant to keep levels and flow velocities in the St. Lawrence River within the range needed for safe navigation by commercial freighters (refer to Figure 23 in Section 3.1.2).
- **The J Limit,** which, unless another limit takes priority, restricts the scope of any increase or decrease in flow from one week to the next. The limit is meant to prevent rapid changes in currents or water levels in the St. Lawrence River.
- **The M Limit,** which applies during times of extreme low water by balancing levels between Lake Ontario and Lake St. Louis much like the F Limit does in times of high water. The M Limit acts to protect commercial shipping, hydropower production and water systems.

[3] Under Article VIII of the Boundary Waters Treaty, the following order of precedence of uses of boundary waters shall be observed by the IJC when considering projects: (1) Uses for domestic and sanitary, (2) uses for navigation, including the service of canals, and (3) uses of power and irrigation purposes.

The limits are looked at collectively. If two limits apply at the same time, operations would be such as to respect both limits as much as possible.

As noted in Section 2.3, Plan 2014's rule curve and limits may be deviated from under certain conditions as per the 2016 Supplementary Order of Approval and *Directive on Operational Adjustments, Deviations and Extreme Conditions*. When Lake Ontario's water levels reach or exceed extreme high "trigger levels" and when Lake Ontario's water levels reach or fall below the extreme low "trigger levels" major deviations are authorized. Other circumstances may necessitate operational adjustments or minor deviations. As discussed in the next section, the Board is obligated to abide by the conditions laid out in the 2016 Supplementary Order of Approval when making deviation decisions.

Relative to the regulation of Lake Ontario outflows, the inflow from the Ottawa River can have a profound effect on conditions in the lower St. Lawrence River. As noted earlier, the IJC and Board have no regulatory authority over the Ottawa River's flow and do not control the dams in the Ottawa River basin. However, the Board works closely with the Canadian domestic Ottawa River Regulation Planning Board (https://ottawariver.ca) to integrate current and forecasted flows from the Ottawa River basin into the Board's Lake Ontario outflow strategy.

While the storage capacity of reservoirs in the Ottawa River basin is relatively small compared to the water volume during the freshet time, the Ottawa River Regulation Planning Board takes every measure possible to try to optimize discharges from upstream reservoirs in order to reduce peak levels and flows along the Ottawa River. In doing so, peak flows into the St. Lawrence River are also reduced to a certain extent. While there is coordination and communication the two systems are operated independently.

More on Plan 2014:

- https://ijc.org/sites/default/files/Plan2014_Compendium Report.pdf
- https://www.ijc.org/sites/default/files/2019-04/Plan2014.pdf

More on Frequently Asked Questions about Board operations:
https://ijc.org/en/loslrb/causes-2017-high-water-event

More on the Ottawa River Regulation Planning Board:
https://ottawariver.ca

2.7 The uses and interests of Lake Ontario and the St. Lawrence River

Plan 2014, like the regulation plan before it, considers the needs of the groups of people and the business sectors that rely on Lake Ontario and the St. Lawrence River and have a strong interest in the water levels there. Elements of the plan rule curve and its limits were specifically designed to support and protect these uses and interests. Plan 2014 was also designed to provide for more natural variations of water levels of Lake Ontario and the St. Lawrence River relative to the previous regulation plan, which are needed to restore ecosystem health while continuing to moderate extreme high and low levels (ILOSLRSB, 2006; IJC, 2014).

The LOSLR Study Board Report (ILOSLRSB, 2006) identified six uses and interests in the region that live or work along the shore or use the lake and river for recreation or business and that potentially would be affected by new regulatory rules: (1) coastal development, (2) commercial navigation, (3) ecosystems, (4) hydropower, (5) municipal and industrial water use, and (6) recreational boating. Previous IJC studies (ILOSLRSB, 2006; IJC 2014) developed performance metrics to measure the impacts of water fluctuations on each of the six uses and interests and developed models to test the impacts in a variety of potential scenarios, including extreme high and low water levels and potential changes from climate change.

Because the Lake Ontario and the St. Lawrence River comprise a dynamic system whose levels ultimately are determined by the amounts of water that enter the system naturally, uses and interests can find themselves at risk from high or low water levels. Water levels and flows that benefits one interest can at times disadvantage another. Swimmers may appreciate lower water levels and wide sandy beaches, for example, while recreational boaters struggle to access docks or navigate between marinas and open water. Such situations can lead to tensions between the various interests and regions.

The order of precedence of uses which is followed in setting conditions for uses, obstructions and diversions of boundary waters dates to the *1909 Boundary Waters Treaty* (https://www.ijc.org/en/who/mission/bwt) between the United States and Great Britain on behalf of Canada, which created the IJC. Article VIII of the Treaty lists, in order of precedence, three uses: domestic and sanitary purposes, navigation, and power production and irrigation. The Treaty states that "no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence." In a separate paragraph of Article VIII, the Treaty says that approval of projects by the IJC is conditional on suitable and adequate provision for the protection and indemnification of all interests on the other side of the line which may be injured by a project.

The IJC's 2016 Supplementary Order of Approval and associated directives provide the guidance and criteria for the Board to follow when making outflow decisions. The 2016 Order respects the order of precedence of uses and provides protection of interests as required by the Treaty including the requirement for flood protection identified in the 1956 Order.

More on the 2016 Supplementary Order of Approval:
https://ijc.org/en/loslrb/who/orders


Swimming and boating on Lake Ontario in Toronto, Ontario, Canada

2.7.1

Municipal and industrial water systems

Numerous municipalities, industrial facilities and other private parties draw water from the St. Lawrence River and Lake Ontario. The submerged intakes through which they pull in water are critical assets that are vulnerable to extreme low water levels. Some municipal and industrial water infrastructure located near the shoreline, such as pump stations and water mains, are subject to impacts from extreme high water as well (Figure 7).

The 2016 Supplementary Order of Approval does not specifically mention wastewater treatment plants, but they are included in this category as well. Treatment plants and the underwater outfalls through which they discharge wastewater also can be vulnerable to extreme high and low water levels.

Plan 2014 was crafted to keep water intakes and wastewater outfalls well-submerged. During wintertime, the I Limit, which primarily is intended to encourage the formation of stable ice cover on the St. Lawrence River, also prevents levels there from falling below the point traditionally believed to hamper operation of the intakes. The M Limit prescribes flows to balance low levels of Lake Ontario and Lake St. Louis to lessen impacts to certain interests including municipal water systems.

Should the Board be authorized to deviate from Plan 2014 because the lake level has hit the low “trigger levels”, the 2016 Supplementary Order of Approval requires the works to be operated to make all possible efforts to protect municipal water facilities, commercial shipping and hydropower production upstream and downstream. In that setting, the Board must do everything it possibly can to keep levels high enough in the river and the lake that the intakes can function properly.

On occasions when the lake level reaches or exceeds the high “trigger levels” as it did in 2017 and 2019-2020, the Board is mindful that water-facility infrastructure on the shoreline can be placed at risk of flooding. The Board also considers the fact that when already-high outflows from the Moses-Saunders dam are increased, the water level in Lake St. Lawrence just upstream of the dam can fall quickly. In those instances, care must be taken to protect the water-system intakes in that stretch of the St. Lawrence River.

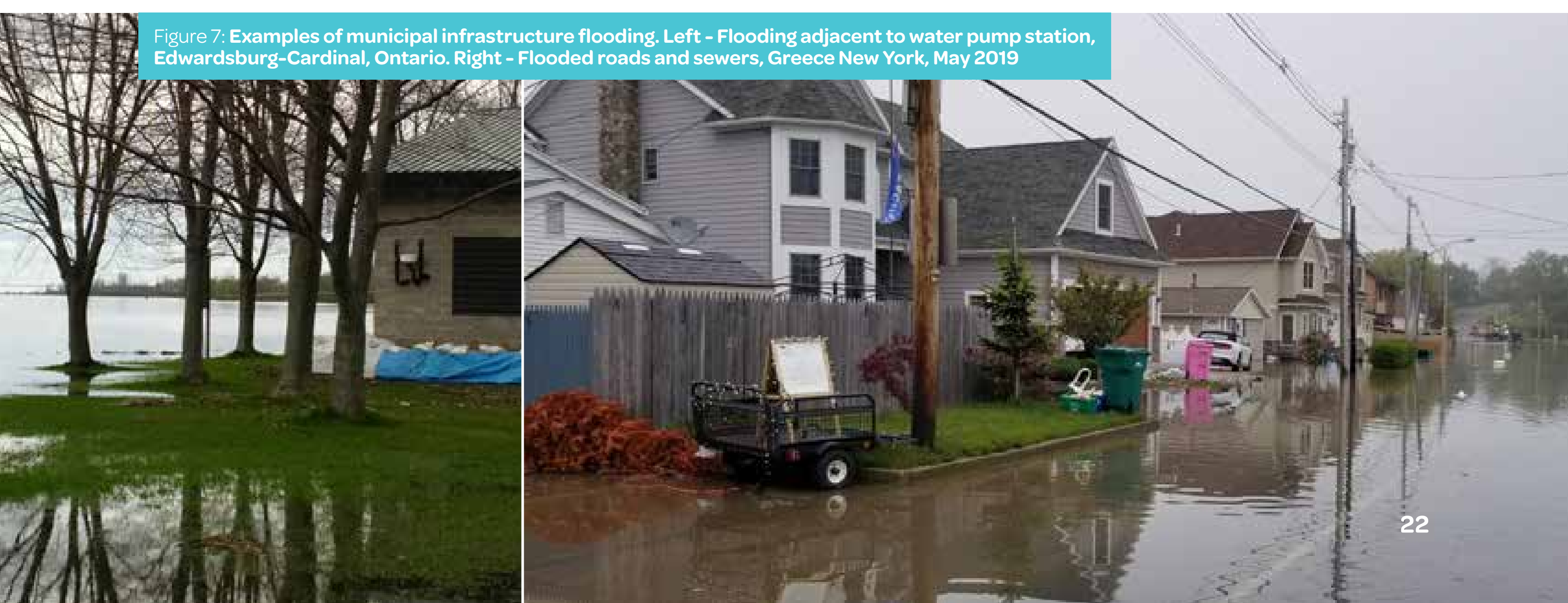


Figure 7: **Examples of municipal infrastructure flooding. Left - Flooding adjacent to water pump station, Edwardsburg-Cardinal, Ontario. Right - Flooded roads and sewers, Greece New York, May 2019**

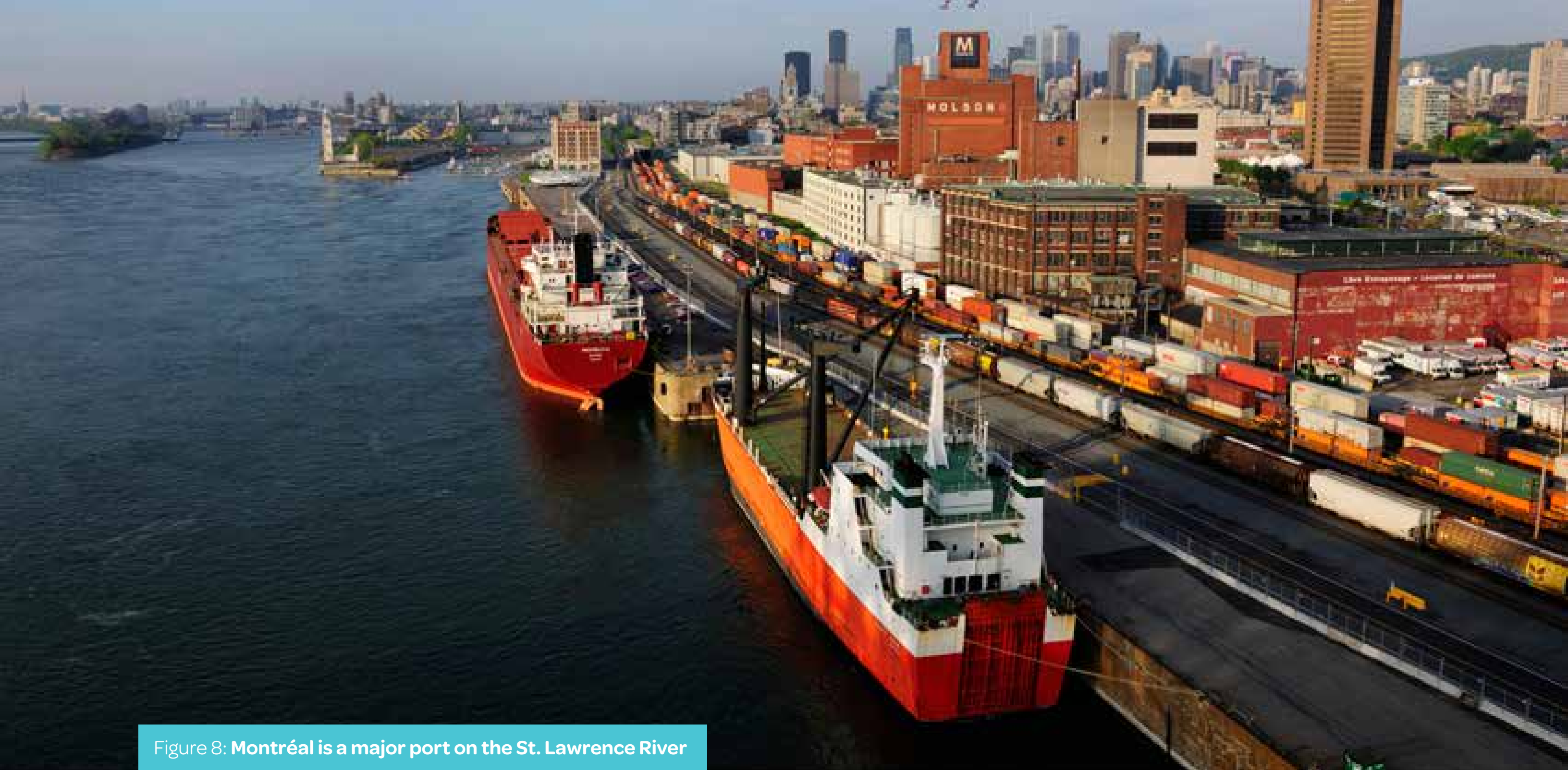


Figure 8: **Montréal is a major port on the St. Lawrence River**

2.7.2
Commercial navigation

Ocean-going and domestic vessels move regularly through the St. Lawrence River and Lake Ontario, and can then travel through the Welland Canal into Lake Erie and from there into the upper Great Lakes. Montréal is a major port on the St. Lawrence River (Figure 8); Hamilton and Toronto are major ports on Lake Ontario. Oswego in New York, Oshawa and Picton in Ontario are among a number of other ports on the lake and river that also receive commercial freighters (Chamber of Marine Commerce, https://www.marinedelivers.com/great-lakes-st-lawrence-shipping).

Commercial vessels require water levels that are neither extremely low nor extremely high. They also require flows in the river to be limited to prevent unsafe currents. Extreme low levels could restrict passage through parts of the St. Lawrence River. Plan 2014's rules aim to maintain conditions in the river that allow commercial navigation to occur: if water levels veer toward very high or very low points, the L and M Limits built into the plan are meant to maintain conditions in the river that allow continued navigation.

If the Board is deviating because the lake has hit a low "trigger level", the 2016 Supplementary Order of Approval requires the works to be operated to make all efforts to keep levels high enough to protect municipal water facilities, commercial shipping and hydropower production.

If the Board has deviation authority because water levels have reached or exceeded a high "trigger level", the Board may direct the increase of outflows through the Moses-Saunders dam beyond what is prescribed by the plan and the L Limit to lower the level of Lake Ontario to provide all possible relief upstream and downstream. In setting flows during periods of crises, the Board must be sensitive to the nature and extent of the potential adverse effect of its decision. At the same time it must take into account the nature and extent of the relief it is attempting to provide. On those occasions, however, the Board must take into consideration the fact that very high outflows create currents that can make navigation by large vessels difficult or impossible on portions of the St. Lawrence River.

2.7.3
Hydropower production

Three large hydropower facilities located on the St. Lawrence River are directly dependent on Lake Ontario outflows. The Moses-Saunders Power Dam (Figure 9) is located at the foot of Lake St. Lawrence (Figure 10). The dam is comprised of two adjacent power plants, the Saunders Generating Station in Ontario and the St. Lawrence-FDR Power Project in New York. The power dam, along with the nearby Long Sault Dam spillway are the locations at which the Lake Ontario outflow can be increased or decreased, and where the Board-specified outflows are set. The I Limit is intended to restrict flow so that a stable ice cover forms in Lake St. Lawrence and at other critical parts of the river that, once formed, allows for higher flows and prevents ice jams that can cause flooding. The Board, if deviating in winter to maximize outflows, is cognizant of the ice cover and loss of hydroelectric generation that an ice jam would cause, along with potential damages to other local and Lake Ontario interests, if the jam is prolonged.

Further downstream, two additional facilities, Beauharnois and Coteau-Les Cèdres, are located near the head of Lake St. Louis, a section of the St. Lawrence

Figure 9: **Moses-Saunders Power Dam on the St. Lawrence River, used to regulate outflows from Lake Ontario**

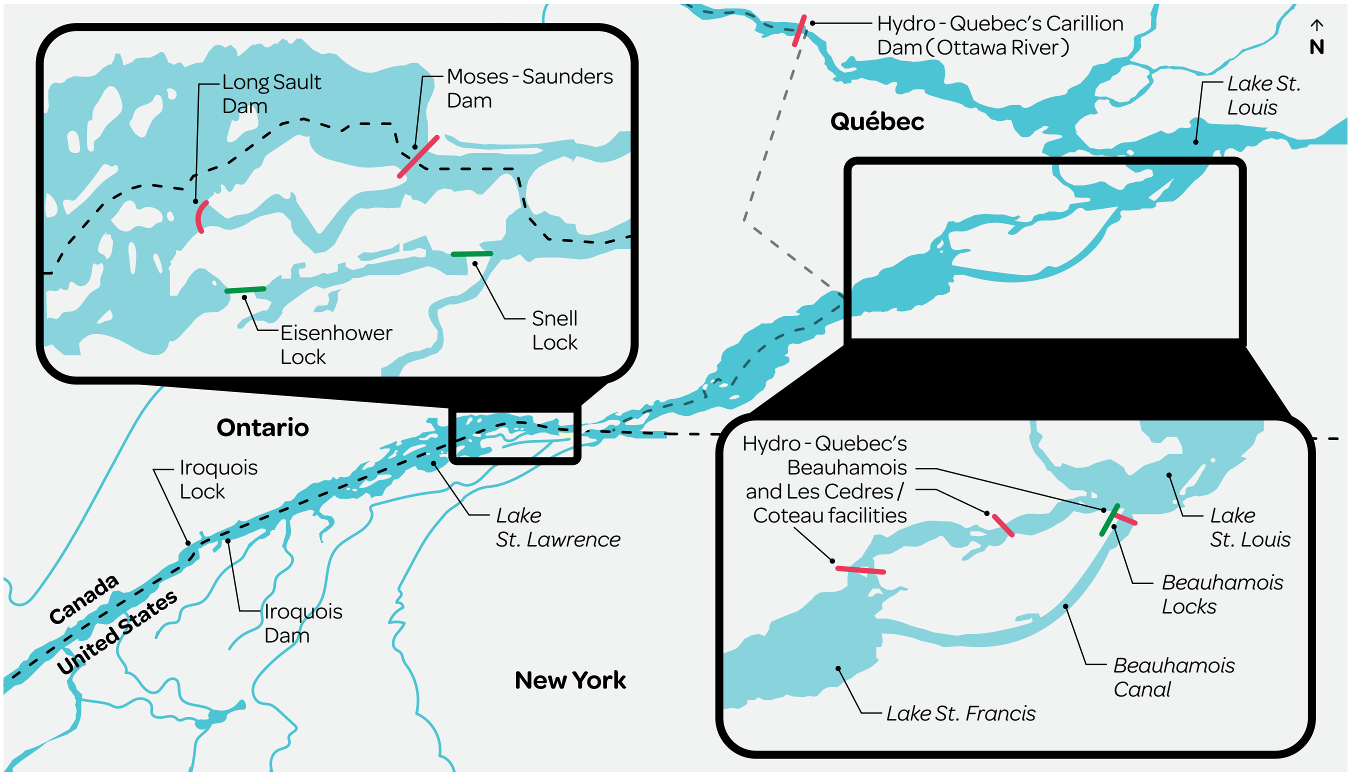


Figure 10:

MAP OF THE ST. LAWRENCE BETWEEN IROQUOIS, ONTARIO AND LAKE ST. LOUIS, QUEBEC INCLUDING MAIN FACILITIES

Dam Lock Provincial border International border

River just above Montréal (Figure 10). Both are run-of-river plants, meaning they do not impound water upstream of the facility and releases are typically set to match those set upstream through the Moses-Saunders dam. Ice forms on the river upstream of the two plants and the I Limit was designed to take into account the need to form and maintain ice cover there and also on Lake St. Lawrence. As well, the L Limit was written to safeguard the two facilities; the maximum flow allowed by the L Limit in non-navigation season was selected because that is the combined physical capacity of Beauharnois and Coteau-Les Cèdres.

When the Board is deviating from Plan 2014 because the lake level has hit low-water "trigger levels", it must abide by the requirement that it make all efforts to protect municipal water facilities, commercial shipping and hydropower production.

Figure 11: **Sandbanks Provincial Park, Prince Edward County, Ontario**

2.7.4 River and lake shoreline properties

Thousands of parcels of land line the shores Lake Ontario and the St. Lawrence River. Many are privately owned and used for year-round or seasonal homes by individuals or families, or for businesses that range in size from small marinas to nuclear power complexes. In some areas, particularly downstream adjacent to Lake St. Pierre in Quebec, land adjacent to the shoreline is used for agriculture. Municipalities, conservation authorities, the provinces of Quebec and Ontario, the state of New York and the two federal governments own considerable land as well, with much of it set aside for recreational purposes (Figure 11).

Shoreline interests are vulnerable to both very high and very low water. The plan's rules are meant to help reduce the frequency and duration of extreme highs or lows relative to pre-project channel conditions (i.e. if outflows were not regulated). If the water supply increases and the water level rises enough, the F Limit will govern Lake Ontario outflows in such a way as to try and balance flood risk between upstream and downstream interests. If the water level is low enough, the M Limit does the same for the risk of low water. The Board is authorized to deviate from these rules and limits when the high or low "trigger levels" are reached.

When levels reach or exceed the high "trigger levels", the Board deviations are primarily driven by concerns about shoreline impacts. The Board also must balance risks between different parts of the system, including shoreline properties on the lake and those along the river as defined in the 2016 Order — which may have diverging interests when it comes to how much flow should be released.

Not all shoreline parcels are equally vulnerable to extreme high water. Some stretches of Lake Ontario and St. Lawrence River shoreline are highly susceptible to flooding or erosion by nature of their location and the local geology, while others are not. Many but not all developed parcels feature revetments, bulkheads or other structures meant to reduce flooding and erosion impacts, though they vary in effectiveness against extreme high water or large waves. The planning and regulation of development in vulnerable areas is subject to state or provincial as well as local jurisdictions.

2.7.5

St. Lawrence River and Lake Ontario ecosystems

A vast interconnected community of mammals, fish, birds, reptiles, amphibians, invertebrates, microbes, land-based and aquatic plants, algae and other organisms live in the ecosystems of Lake Ontario and the St. Lawrence River (Figure 12).

The ecosystems appear to have been overlooked in the 1952 and 1956 Orders as something that could be affected by management of outflows from Lake Ontario and the St. Lawrence River. The many organisms that live in and around the water were not taken into consideration in the development of the 1952 and 1956 Orders (IJC, 2014).

Over time, scientists learned that regulation of Lake Ontario outflows was harming the ecosystems of Lake Ontario and the St. Lawrence River, primarily by narrowing the natural range of year-to-year fluctuations of water levels on the lake and upper river compared to what would have occurred naturally (ILOSLRSB, 2006).

Research done prior to the development of Plan 2014 found that about 26,000 hectares (64,250 acres) of shoreline wetlands had lost diversity and that undesirable cattail monocultures have become more common due to regulation that eliminated the natural occurrence of extended periods of lower water (Wilcox, et al. 2005). The situation may be exacerbated by regulation that encourages lower water levels on Lake Ontario and the upper St. Lawrence River in winter and early spring. This harms a number of native animal species; one of them, muskrats which plays a role in limiting the spread of cattails (ILOSLRSB, 2006).

Parts of the ecosystem in Lake St. Lawrence haves a different problem; large rapid drops in water level can cause immediate harm to aquatic organisms especially if they are exposed to freezing in the winter. Rapidly increasing outflows through the Moses-Saunders or Long Sault dams can cause these large drops in levels, as can sudden flow restrictions due to changing upstream ice conditions. The I Limit, which moderates flows and water levels in the St. Lawrence River to promote stable ice formation, serves to keep levels on Lake St. Lawrence from dipping to extreme lows in the winter. During times of extreme high water on Lake

Figure 12: **Great egret hunting in a marsh of the St. Lawrence River**

Ontario when the Board has the authority to deviate from the I Limit, its members are mindful of concerns that the ecosystem in Lake St. Lawrence can be damaged if levels fall too low.

Downstream on the lower St. Lawrence River, the spring and early summer season is a critical period for reproduction for several bird, fish and turtle species. Increases in outflows that result in a quick changes in levels (e.g. >20 cm (8 in.)) during critical nesting stages can risk having detrimental effects on the reproduction of several groups, especially several endangered species (Talbot, 2006).

During times of very low water on Lake Ontario, the Board may feel pressure to further reduce outflow to raise the lake level — which could perpetuate the damage to shoreline wetlands. This situation, like the Lake St. Lawrence winter scenario, and the timing of outflows for the lower St. Lawrence River cited above, highlight a difficulty in assessing ecosystem impacts: In most cases, positive or negative changes to shoreline wetlands and other ecosystem indicators manifest themselves over periods of months or years, long after a single deviation has run its course. The Board has had little information about how such a deviation can impact an ecosystem.

Plan 2014 was written, in part, to address ecosystem degradation by allowing more natural fluctuations in water levels. As noted earlier in this section, the Lake Ontario and St. Lawrence River ecosystems were recognized in the 2016 Supplementary Order of Approval.

2.7.6 Recreational boating and tourism

Recreational boating and shoreline tourism can be negatively impacted by both high and low water levels. Extreme high water can force closure of marinas, beaches and parks, and can submerge docks and boat launches.

Extreme low water can make docks and boat launches inaccessible or unusable. It also can make channels that connect dockage with the lake or river difficult if not impossible to navigate. These are not-infrequent problems on the upper and lower St. Lawrence River. Lake St. Lawrence, where high outflows through the Moses-Saunders dam lower water levels, has particularly been affected in recent years.

Major deviations from the F or L limits to increase already-high outflows could lower the water level enough in Lake St. Lawrence to pose problems for boaters there. In an example of the difficult tradeoffs that the Board often faces, such deviations would lower levels on Lake Ontario, which could help boaters and tourism there. As noted, recreational boating was first recognized in the 2016 Supplementary Order of Approval.


Boating along the St. Lawrence Seaway, New York

2.8

Indigenous Nations

Members of First Nations, Tribal Nations and the Métis Nation have lived alongside Lake Ontario and the St. Lawrence River for millennia. Interacting with the natural world through a spirit of kinship, twinned with a sense of responsibility, Indigenous Peoples are intertwined with the region's lands and water. As guardians of the landscape, they have relied on shorelines, rivers and wetlands of the Great Lakes-St. Lawrence River region for livelihood through traditional practices such as hunting, gathering, subsistence agriculture and fishing[4].

Lake Ontario along with the St. Lawrence River from Lake Ontario through to Trois Rivières is a vibrant watercourse of cultural heritage and economic exchange.

In total, the GLAM Committee identified twenty-two Indigenous Nations that have interest in the shorelines of Lake Ontario and the St. Lawrence River. Out of these, there are six communities that reside directly along the shoreline and 16 communities with an interest in the shorelines (Table 3).

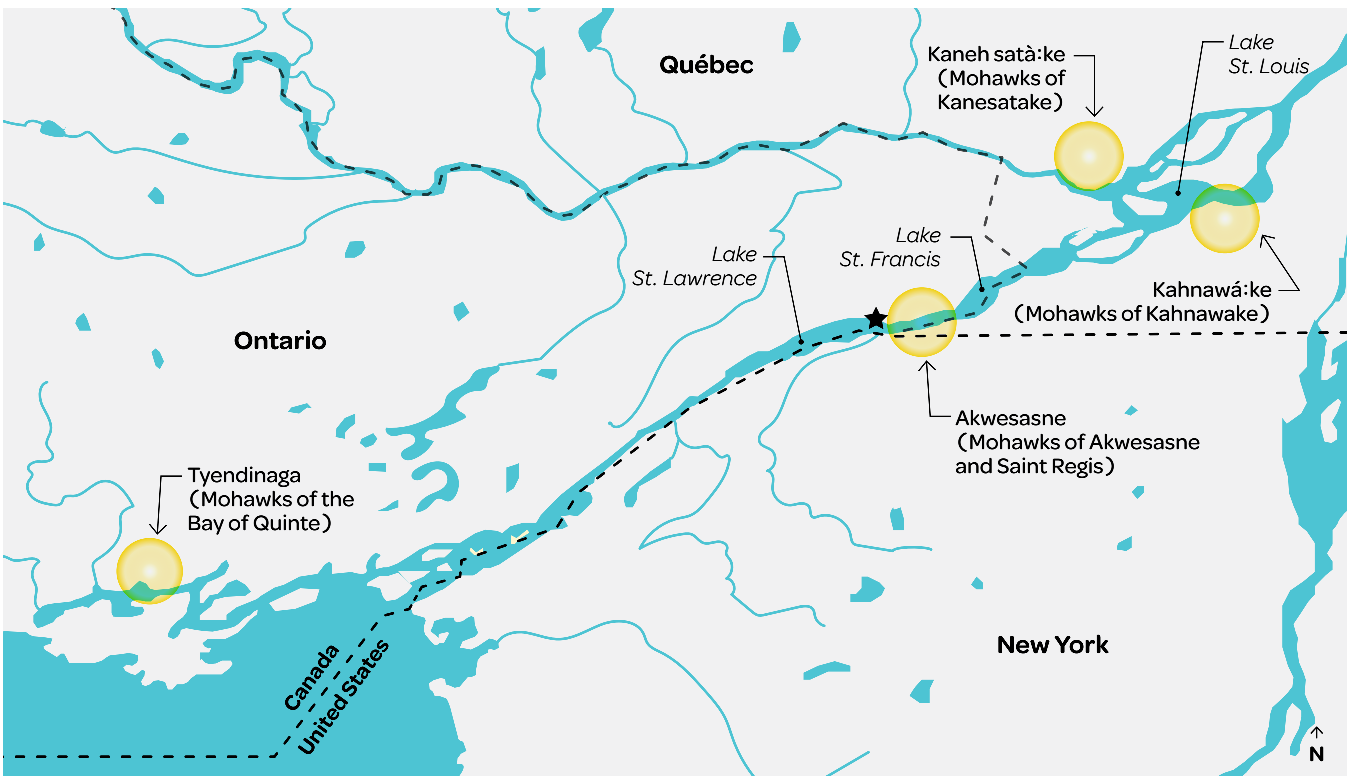


Figure 13:

FEDERALLY-RECOGNIZED INDIGENOUS LANDS DIRECTLY ADJACENT TO THE SHORELINE LAKE ONTARIO OR THE ST. LAWRENCE RIVER

● Federally - recognized Indigenous Lands ★ Moses - Saunders Power Dam

Provincial border International border

[4] The following is from wisdom gained through the GLAM Committee's Indigenous Engagement Planting a Relationship sessions, particularly from those who shared generously with GLAM, including the Water Walkers and Hiawatha First Nation.

Table 3:

INDIGENOUS NATIONS AND KEY WATERSHEDS/WATERWAYS

Indigenous Nation	Watershed / waterway
Residing Directly on the Shoreline	
Mohawks of the Bay of Quinte	Lake Ontario
Mohawk Nation Council of Chiefs	St. Lawrence River
Mohawk Council of Akwesasne	St. Lawrence River, CAN
Saint Regis Mohawk Tribe	St. Lawrence River, USA
Mohawks of Kahnawake	St. Lawrence River
Mohawks of Kanesatake	Ottawa River / St. Lawrence River
Interest in the Shoreline	
Mississaugas of the Credit First Nation	Shore and water of Lake Ontario
Williams Treaty First Nations	Lake Ontario
Alderville First Nation[5]	Lake Ontario watershed
Hiawatha First Nation	Lake Ontario watershed
Curve Lake First Nation	Lake Ontario watershed
Scugog Island First Nation	Lake Ontario watershed
Algonquin of Pikwakanagan First Nation	Ottawa River & St. Lawrence River
Conseil des Abénakis d'Odanak	St. Lawrence River
Conseil des Abénakis de Wôlinak	St. Lawrence River
La Nationne Huron Wendat	Lake Ontario & St. Lawrence River
Métis Nation of Ontario	Lake Ontario, Ottawa River & St. Lawrence River
Nation Métis Québec	Ottawa River & St. Lawrence River
Tribal Nation	**Location**
Tuscarora Nation	USA, Lake Ontario watershed
Seneca Nation	USA, Lake Ontario watershed
Onondaga Nation	USA, Lake Ontario watershed
Oneida Nation	USA, Lake Ontario watershed

The fluctuation of Lake Ontario and St. Lawrence River water levels does affect First Nations, Tribal Nations, and the Métis Nation in various ways, including impacts to their traditional and cultural practices and Indigenous rights. For example, outflow management decisions directly affect the Mohawks of Akwesasne as the Moses-Saunders and Long Sault dams are immediately upstream of the Akwesasne Mohawk Territory. This Mohawk community is represented by the Saint Regis Mohawk Tribe in the southern portion, the Mohawk Council of Akwesasne First Nation for the northern portion and the traditional leadership of the Mohawk Nation Council of Chiefs.

Additional Mohawk communities such as the Mohawks of the Bay of Quinte (within the Tyendinaga Mohawk

[5] There are seven First Nations within the Williams Treaty Nations, which include: Beausoleil First Nation, Chippewas of Rama First Nation, Georgina Island First Nation, Mississaugas of Scugog Island First Nation, Curve Lake First Nation, Alderville First Nation, and Hiawatha First Nation. For the purposes of the GLAM Committee's work for Lake Ontario and the St. Lawrence River shoreline, the last four listed are included in the table.

Figure 14: **Flooding of homes along the shoreline within the Tyendinaga Mohawk Territory, May 2017**

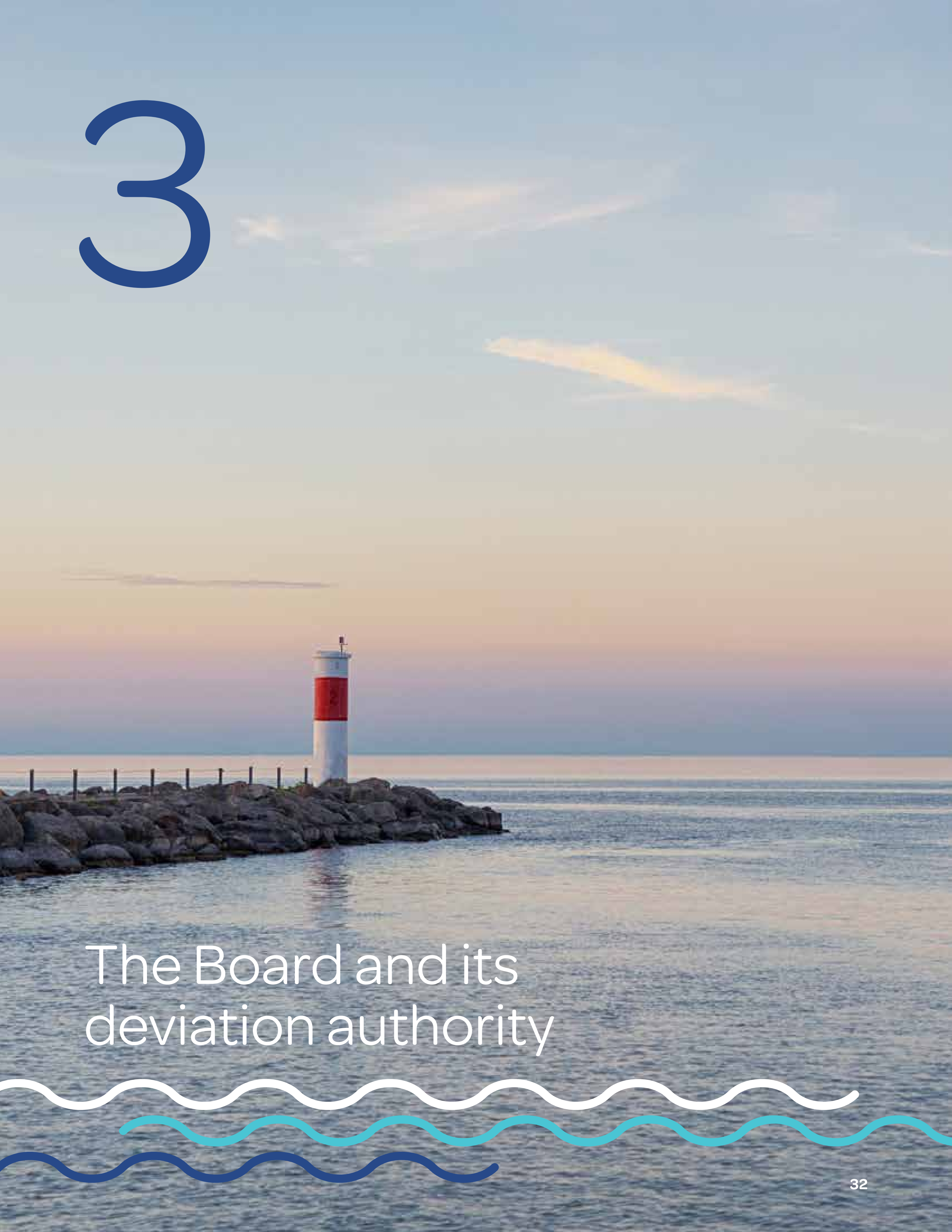
Territory, Lake Ontario) (Figure 14), the Mohawks of Kahnawake (Lake St. Louis - St. Lawrence River), and Mohawks of Kanesatake (Lake of Two Mountains, where the Ottawa River meets the St. Lawrence River) are geographically situated along the Lake Ontario and St. Lawrence River shoreline (Figure 13). They are also affected by changing water levels and flows based on their location in the system.

Signed in 1909, the *Boundary Waters Treaty* between Canada and the United States does not explicitly reference Indigenous Nations or their relationship with the IJC. In any proceeding, inquiry, or matter before the IJC, however, the Treaty requires all interested parties be offered a convenient opportunity to be heard. For much of its early history, however, the IJC did not proactively invite Indigenous Nations to engage in its work, deferring instead to the governments of Canada and the United States to assume this role.

In recent decades, and at the request of governments, the IJC has sought to more formally include Indigenous perspectives in its activities. Across the United States-Canada boundary, the IJC has been actively engaging with First Nations, Tribal Nations, and the Métis Nation to ensure that their unique perspectives, ways of knowing and traditional knowledge are reflected in the work of the IJC. Through the work of the Expedited Review of Plan 2014, the GLAM Committee is engaging with First Nations, Tribal Nations and Métis Nations in the Lake Ontario-St. Lawrence River system, to initiate a conversation about how these Indigenous Nations experience changing lake levels and river flows. This work is seen as a first step in a longer-term effort to incorporate Indigenous knowledge and perspectives into the work of the GLAM Committee in support of the review of outflow regulation plans.

Insight

Outreach and inclusion of Indigenous peoples is important for ongoing regulation plan review.



3

The Board and its deviation authority

3.0
The Board and its deviation authority

The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee has examined the recent history of deviations to look for instances when different actions might have been possible. Committee representatives interviewed past and present International Lake Ontario – St. Lawrence River Board (Board) members and documented information gaps that contributed to uncertainty. The GLAM Committee documented the Board's desire for more data on risks and rewards of deviation options. Knowing that the Board often faces questions about when to deviate from Plan 2014's limits, which cap outflow in some circumstances, the GLAM Committee studied the history and function of those limits to explore alternative deviation possibilities.

The aim was to provide the Board with objective, relevant information to support its decision-making. This work, in which the Public Advisory Group (pag) was also involved, was integral to the GLAM Committee's creation of the Decision Support Tool (DST). The tool illustrates the benefits and harms that deviations might cause to various uses and interests and helps the Board better understand possible outcomes in the face of uncertainty about future water supplies.

3.1
The Board and extreme high water in 2017 and 2019-2020

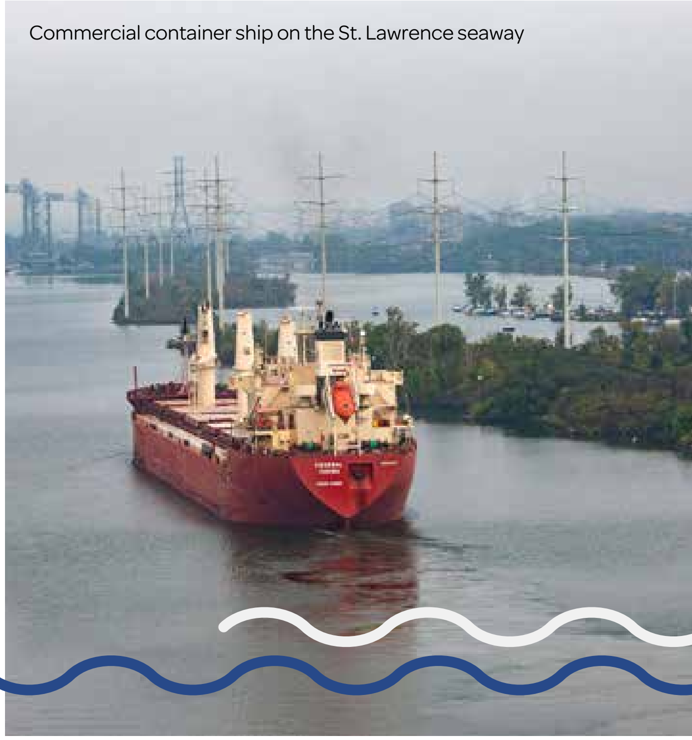
The first four years that Plan 2014 was in use, beginning in January 2017 and ending in December 2020, was one of the most active periods in the 61-year history of the Board. Due to the extreme water supplies in 2017 and again in 2019 and early 2020, Board deviations governed outflows from Lake Ontario for 103 weeks, or nearly half the weeks in those four years (see Figure 1 in Section 1.2).

The Board employed several strategies to balance the interests of different sectors of the lake-river system. In both 2017 and 2019, in the face of damaging floods on the shorelines of Lake Ontario and both the upper and lower St. Lawrence River, the Board chose to follow the F Limit as it tried to balance the impacts of high water both upstream and downstream, even when it did have the authority to deviate from that limit. With heightened flood risk again in the spring of 2020, the Board, having the authority to deviate, chose to deviate above the lowest tiers of the F Limit in March.

As well, Board deviations from the L Limit significantly impacted the commercial shipping industry during both high-water events. In the summers of 2017 and

2019 when outflows were set above the L Limit, higher water velocities in the St. Lawrence River led the shipping authorities to institute mitigation measures such as speed, passing and draft restrictions, to ensure safe navigation (GLAM, 2018). In March 2020, the Seaway corporations chose to delay the opening of the shipping season, providing the Board an opportunity to maximize outflows from Lake Ontario in an effort to reduce the flood risk on the shore.

The Board's deviation decisions were based on the best information available at the time and their experience and judgement. Inevitably, though, the deviation decisions stirred controversy along the shore of Lake Ontario and the St. Lawrence River, and among navigation interests, many of whom felt at times that the Board should have done more to help their interests or regions during the crises.


Commercial container ship on the St. Lawrence seaway

3.1.1 High water in 2017

In 2017, the lake level first reached the criterion H14 "trigger levels" on April 28. The lake level had reached such an extreme point largely because of record-breaking spring rains in the Lake Ontario, St. Lawrence River, Ottawa River and Lake Erie basins (e.g. Figure 15 and Figure 16). When lake levels exceed the "trigger levels", the Board is directed to manage flows to provide relief from extreme levels both upstream and downstream. That allowed the Board to deviate from the plan's F Limit, which was governing outflows at the time, though Board members chose to continue following the F Limit to balance flood levels occurring upstream and downstream. The Board did not have sufficient information to know whether a better balance might be achievable.

Lake Ontario's level peaked in late May at 75.88 m (248.95 ft), the highest level observed since reliable records began in 1918. At the same time, levels on the St. Lawrence River downstream approached or exceeded records. In part this was due to extreme flow from the Ottawa River.

Shoreline communities in the Montréal region and downstream on Lake St. Pierre were hit by severe flooding that forced evacuations and impacted hundreds of homes (Ministère de la Sécurité publique, 2017). Thousands of private dwellings, businesses and public facilities on both sides of Lake Ontario and the upper river were heavily impacted, with many buildings and shoreline protective structures damaged by high water and waves that accompanied a series of moderate windstorms.

The F Limit governed outflows from April 5th to the end of May as water levels were rising and eventually reached extreme highs. The limit manages outflow so that as Lake Ontario's level rises, so does the level maintained on Lake St. Louis, a section of the St. Lawrence River near Montréal. Figure 17 and Figure 18 illustrate 2017 outflows and Lake Ontario water levels, highlighting when different flow limits applied, as well as when major and minor deviations occurred.

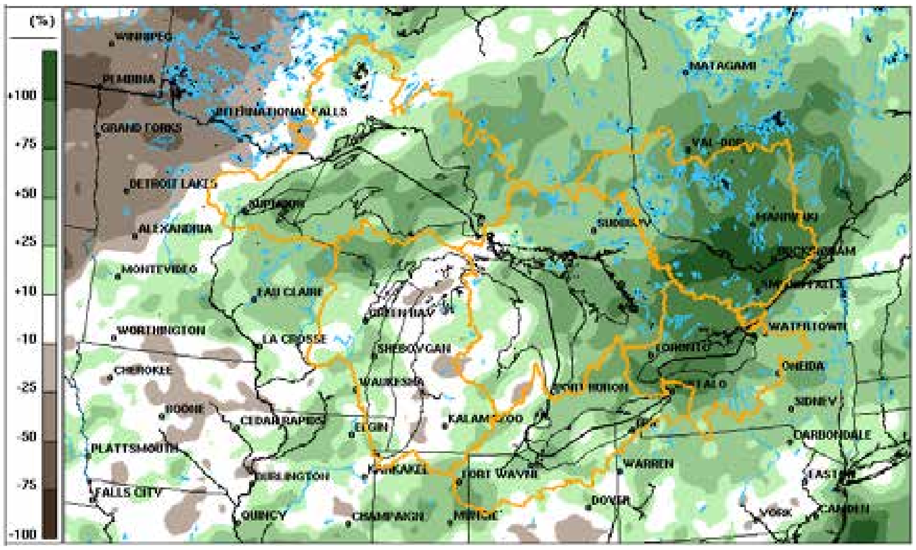


Figure 15:

TOTAL PRECIPITATION ACCUMULATION IN APRIL AND MAY 2017 BASED ON PERCENT DEPARTURE FROM THE 2002-2016 MEAN.

(Source: ECCC - Meteorological Service of Canada)

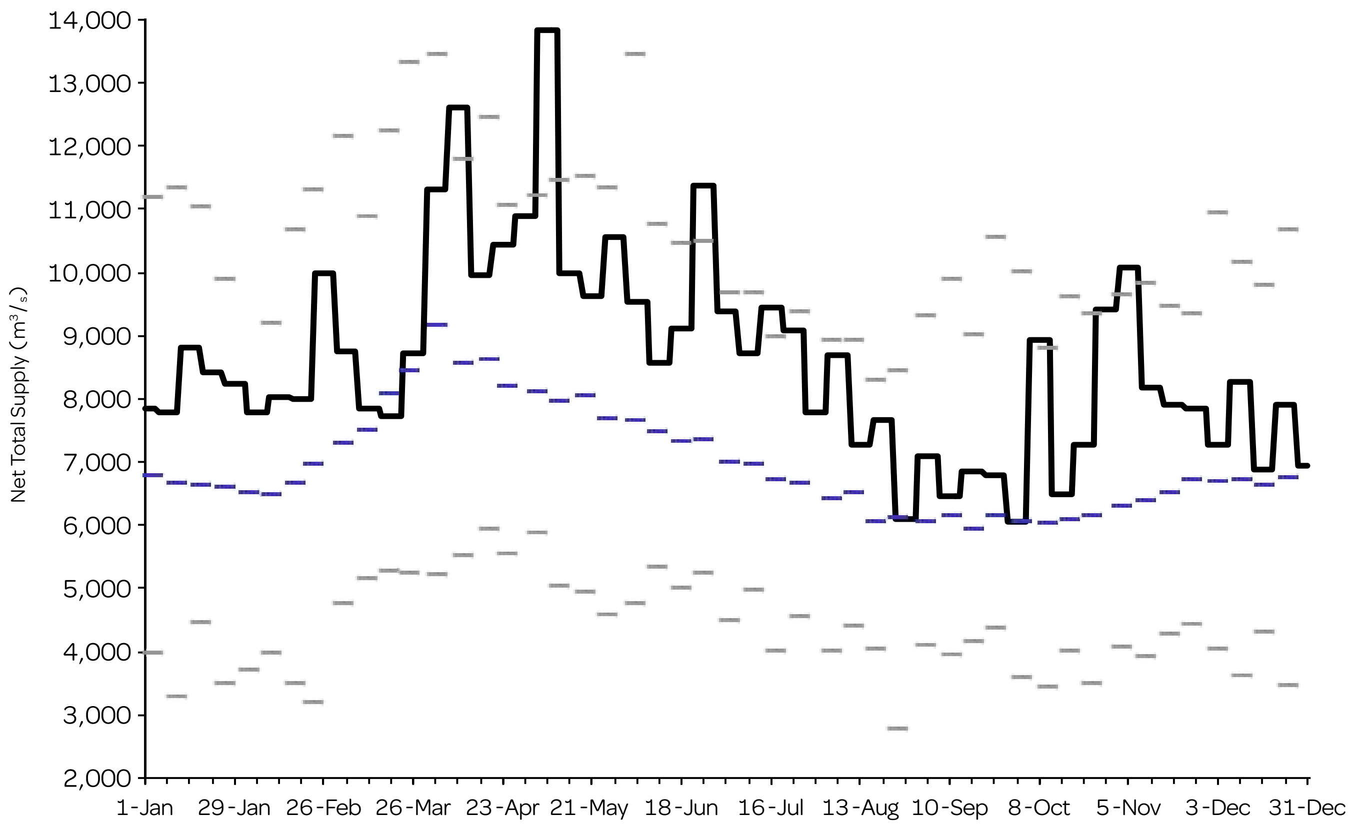


Figure 16:

WEEKLY NET TOTAL SUPPLIES FOR THE LAKE ONTARIO BASIN IN 2017, COMPARED TO RECORD HIGHS, LOWS AND LONG-TERM AVERAGE.

(Source: International Lake Ontario – St. Lawrence River Board)

Figure 17:

LAKE ONTARIO OUTFLOWS IN 2017, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED

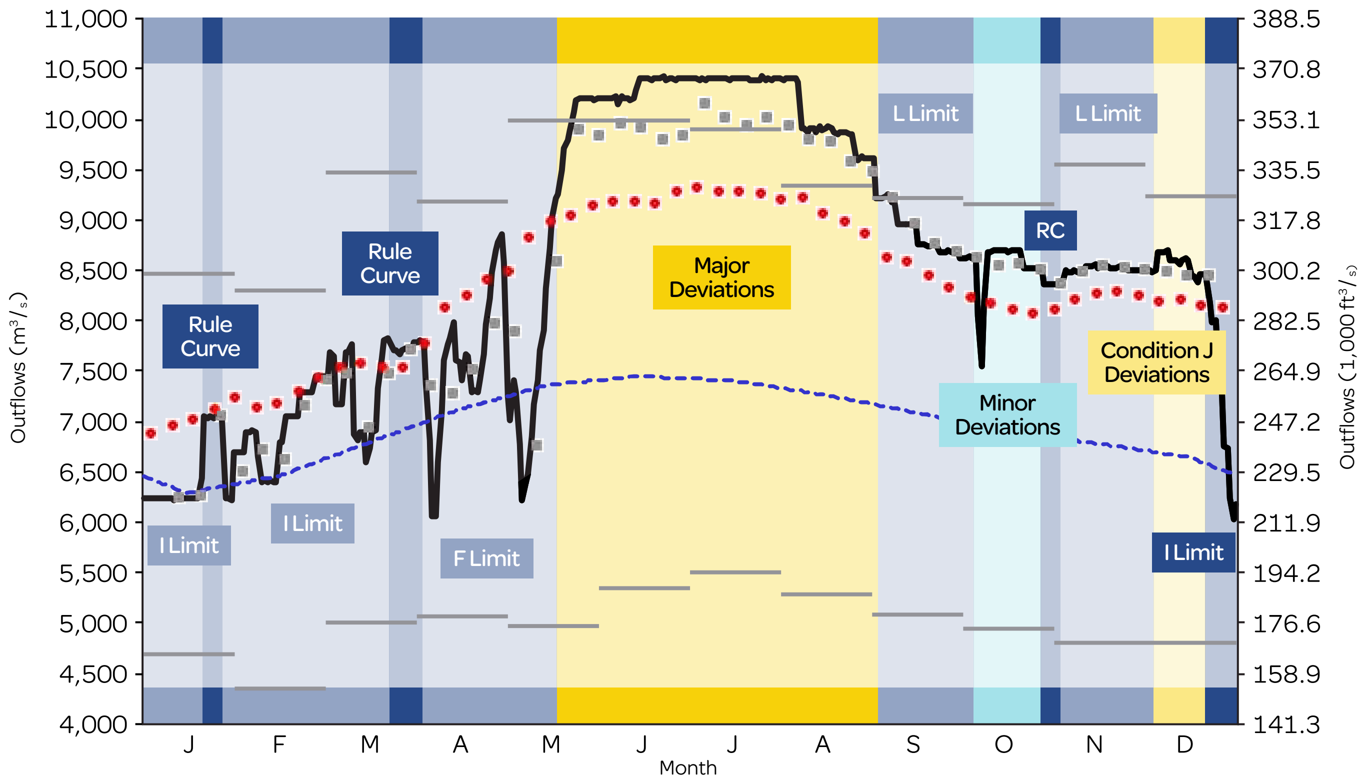
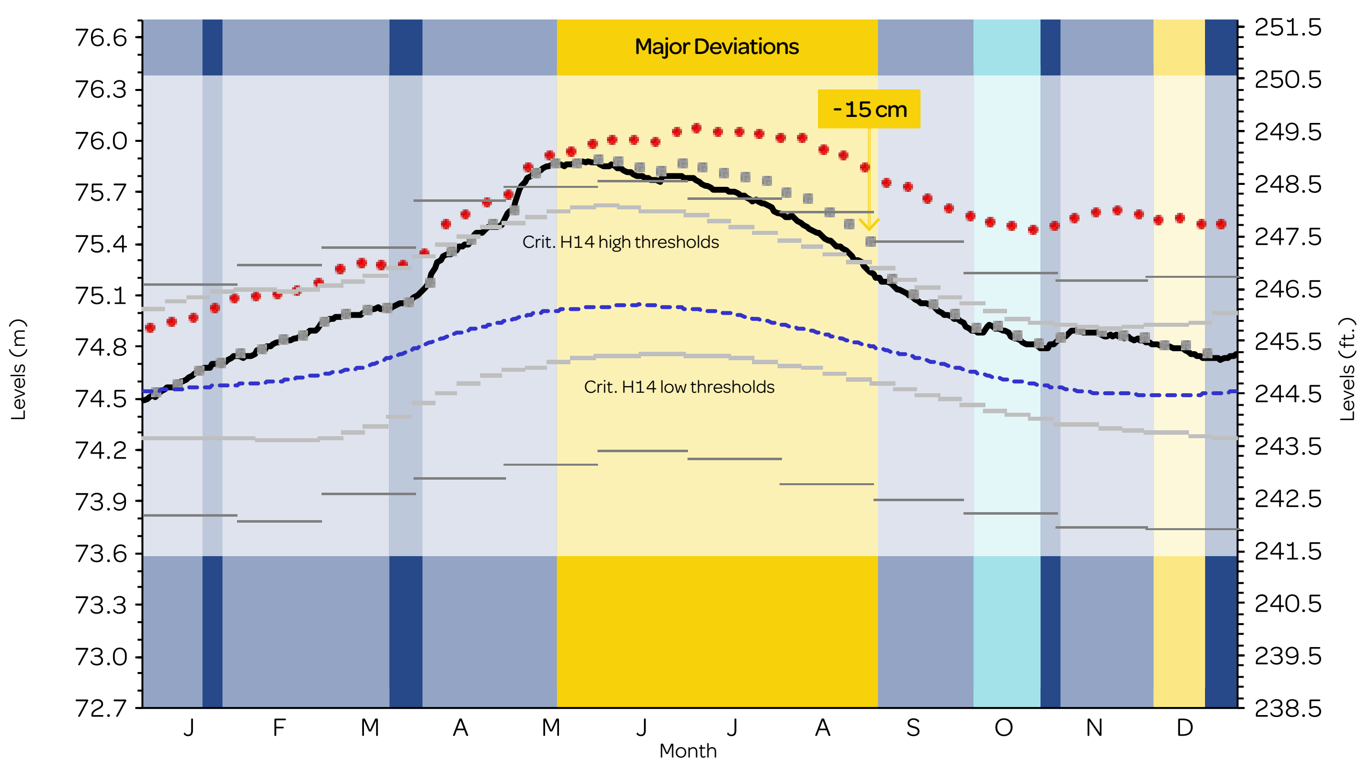


Figure 18:

LAKE ONTARIO WATER LEVELS IN 2017, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED



● Preproject ■ Plan 2014 ■ Plan 2014 Rule Curve ■ Major (Criterion H14) Deviations
■ Minor Deviations ■ Condition J Deviations ■ Plan 2014 Limits — Actual - - Average

The F Limit prescribes a maximum level for Lake St. Louis of 22.48 m (73.75 ft) once Lake Ontario reaches 75.60 m (248.03 ft), at which point the Board typically has the authority to deviate above this level on Lake St. Louis if it so chooses.

The Board did not deviate from the F Limit because its members believed the limit was balancing upstream-downstream flooding and the Board members did not feel they had sufficient information on impacts to know whether any improvement could be achieved upstream (Lake Ontario and the upper St. Lawrence River) through deviations without significantly harming downstream (St. Lawrence River in Quebec) interests, or vice-versa. The Board was aware that damaging flooding was occurring to properties both upstream and downstream. It did not know how many properties would be affected either upstream or downstream with an incremental change in flow from the F Limit. The Board did understand that a deviation from the F Limit that raised downstream levels by 8 to 14 centimeters (3 to 5 ½ in.) for a week would allow one additional centimeter of water to be removed from Lake Ontario by the end of that week, but it was unsure if such a change would result in more or less flood damage overall.

On May 24, when circumstances had eased slightly along the lower St. Lawrence River as the spring flows from the Ottawa River began to subside, the Board began to deviate from the plan flow to extend additional relief to the Lake Ontario shore. By this time, the outflows according to the F Limit had increased to the point where the L Limit governed. The L Limit specifies outflow to allow large commercial freighters to safely navigate the St. Lawrence River upstream of Montréal. The Board set outflows at 10,200 m^3/s (360,000 cfs), which is the maximum specified by the L Limits when the Lake Ontario level is between 75.7 m and 76.0 m (248.36 and 249.34 ft). A sustained outflow rate that high had been employed only twice since regulation of outflows began in 1960. Commercial vessels continued to transit the river but with speed and passing restrictions in place on the Seaway.

On June 14, as damaging high water persisted on Lake Ontario, the Board increased outflow beyond the L Limit to 10,400 m^3/s (367,000 cfs), the highest sustained rate on record. The Seaway corporations placed commercial vessels under additional restrictions and called in tugboats to assist ships at critical high-current locations, allowing ships to continue operating. The record outflow continued until August 8, when the Lake Ontario level had dropped to 75.50 m (247.70 ft) and the Board began reducing the rate of discharge according to the L Limit of the plan. On September 2, 2017, the Board's major deviation authority ended when the lake level dropped below the criterion H14 "trigger levels".

More on 2017 high water:

- https://ijc.org/en/loslrb/observed-conditions-regulated-outflows-2017
- https://ijc.org/en/loslrb/watershed/2017-high-water_Q-and-As

3.1.2 High water in 2019-2020

Carillon dam, Ottawa River

Two years later, the scenario was not dissimilar. The Lake Ontario level had fallen until it was relatively close to the long-term average through much of 2018. It rose somewhat in the winter but in late April 2019, the water supplies and levels shot up rapidly. Precipitation in the Lake Ontario basin was significant and persistent from late April into June, and the inflow from Lake Erie was relentless, with water levels and inflows reaching record highs.

Perhaps the most exceptional circumstances played out along the downstream section of the St. Lawrence and Ottawa rivers in Canada. The Ottawa River, which drains a vast area of Quebec and Ontario, was swollen with late, heavy snowmelt and spring rain. It overshot its own banks and its volume eclipsed records set just two years earlier. That water surged into the St. Lawrence River near Montréal for an extended period (Figure 19) and for the second time in three years, severe flooding hit communities along the St. Lawrence River (e.g. Figure 20).

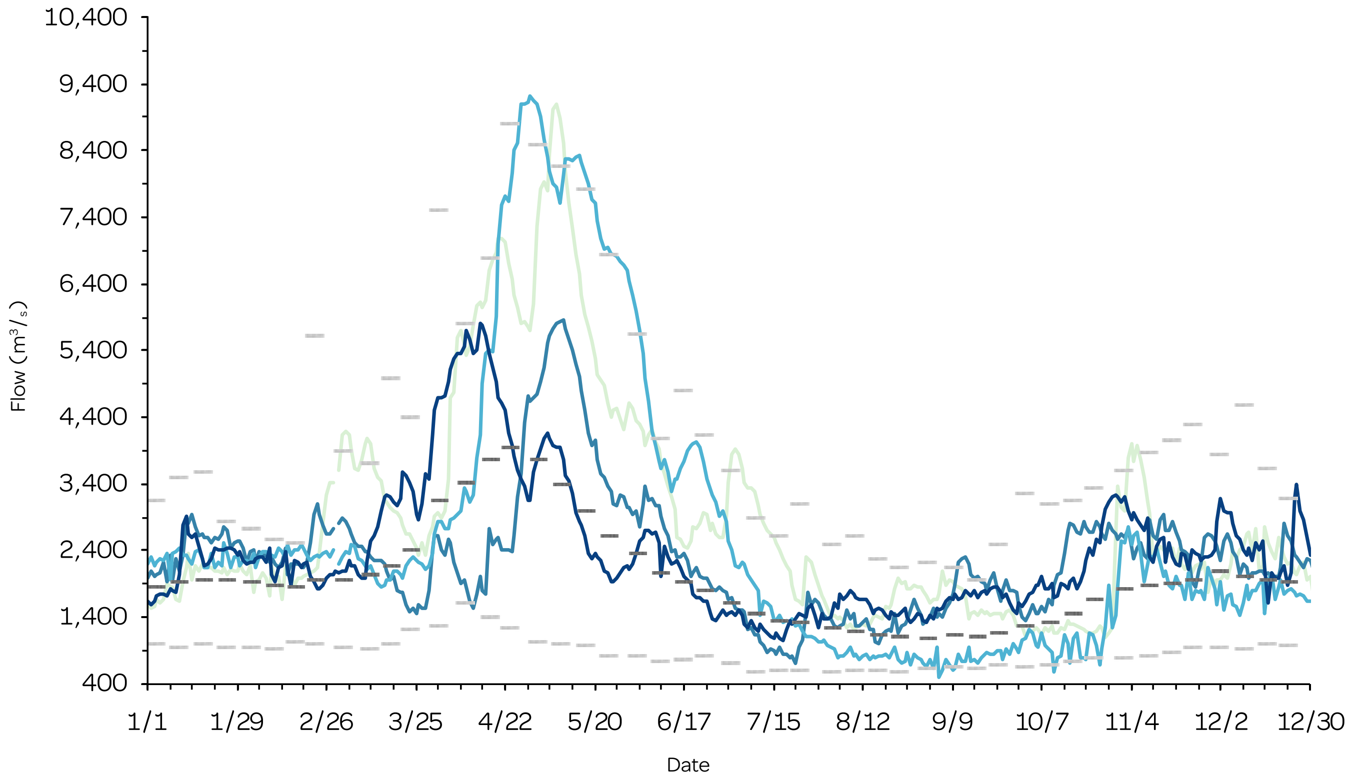


Figure 19:

OTTAWA RIVER FLOW INTO THE ST. LAWRENCE RIVER, 2017-2020

(Source: International Lake Ontario – St. Lawrence River Board)

Min — Max — Avg (1963-2019) — 2017 — 2018 — 2019 — 2020

Figure 20: **Residential and agricultural flooding along the shoreline of the St. Lawrence River near Maskinongé, Quebec**

The criterion H14 "trigger levels" had been reached in early May 2019, meaning the Board had the ability to deviate from the plan's specified discharge. Just as in 2017, the Board elected to follow the F Limit and not increase outflows beyond that because Board members had limited detailed information about whether such deviations could reasonably be expected to significantly reduce upstream levels and impacts without unfairly increasing harm to downstream riparians, including those on Lake St. Pierre, or, conversely, whether reducing outflows temporarily could significantly reduce downstream impacts without unfairly increasing harm upstream. Figure 21 and Figure 22 illustrate 2019 outflows and Lake Ontario water levels, highlighting when different flow limits applied, as well as when major and minor deviations occurred.

By the start of June, flooding had begun to ease along the lower St. Lawrence River and the L Limit was setting the outflow at 10,200 m^3/s (360,000 cfs), the maximum allowed under the sliding scale built into the limit.

On June 10, 2019, the Board began using its ability to deviate by directing that outflow be increased to 10,400 m^3/s (367,000 cfs), just as it had done in 2017. The discharge remained at that elevated rate until August 21, when the lake level had subsided to 75.50 m (247.7 ft). The Board continued to deviate, however, by keeping the outflow 200 m^3/s (7,100 cfs) above the maximum allowed by Plan 2014's L Limit (Figure 23).

In October 2019, anticipating that Lake Ontario levels may soon fall below criterion H14 "trigger levels" and thus end the Board's authority to enact major deviations, the IJC granted the Board's request for special authority to continue deviating consistent with Condition J of the 2016 Supplementary Order of Approval. Condition J allows deviations to test modifications to the plan rules provided they are consistent with other conditions in the 2016 Order. The IJC authorized the Board to test the plan rules because of abiding concern about the extremely high inflow from Lake Erie and possibility of extreme high water on Lake Ontario again in 2020.

Figure 21:

LAKE ONTARIO OUTFLOWS IN 2019, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED

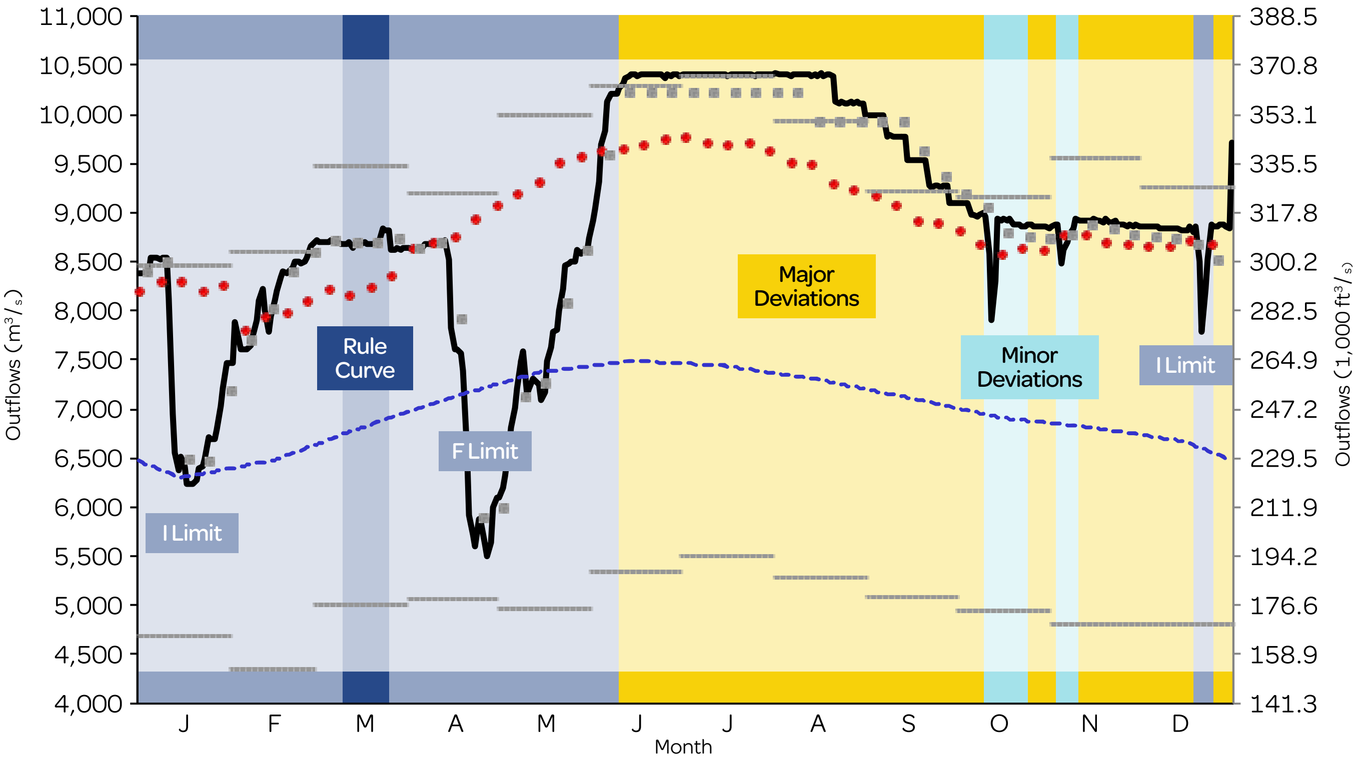
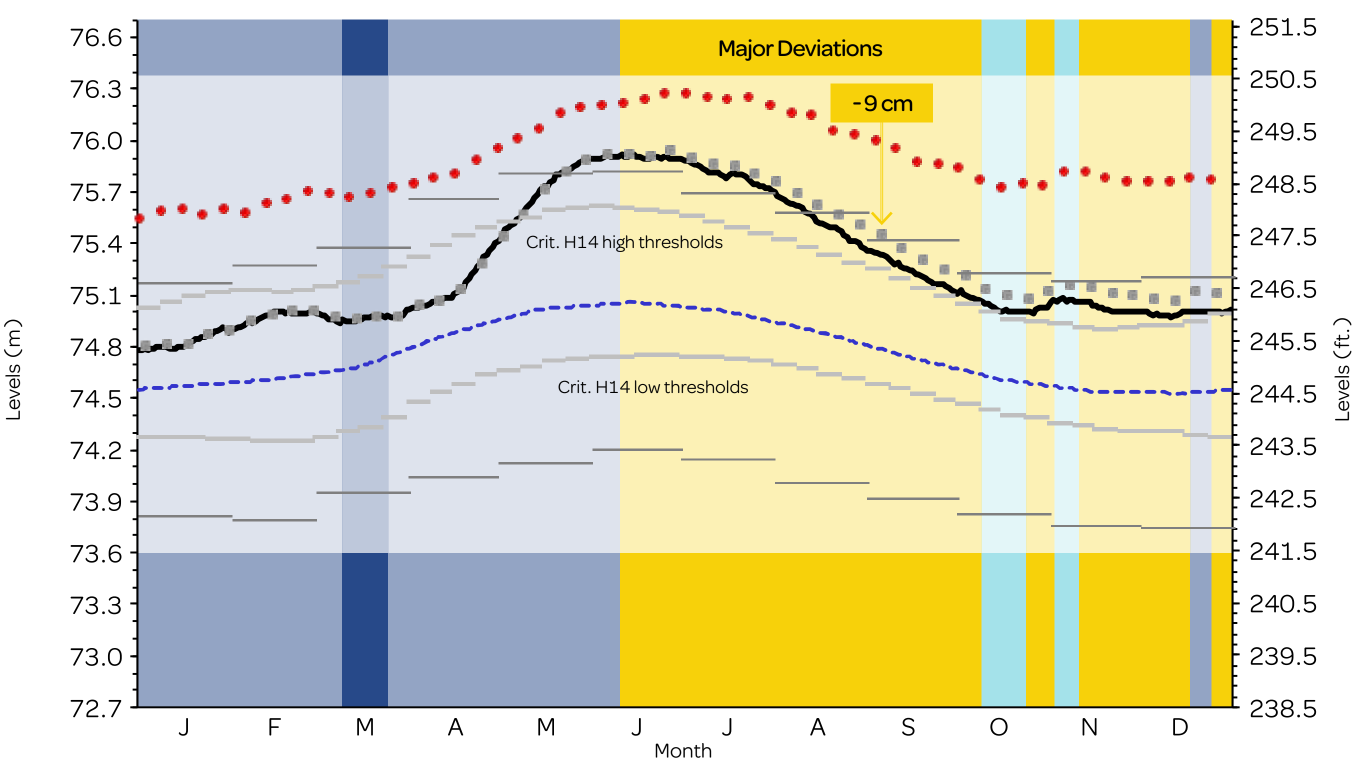


Figure 22:

LAKE ONTARIO WATER LEVELS IN 2019, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED



Preproject | Plan 2014 | Plan 2014 Rule Curve | Major (Criterion H14) Deviations
Minor Deviations | Condition J Deviations | Plan 2014 Limits | Actual | Average

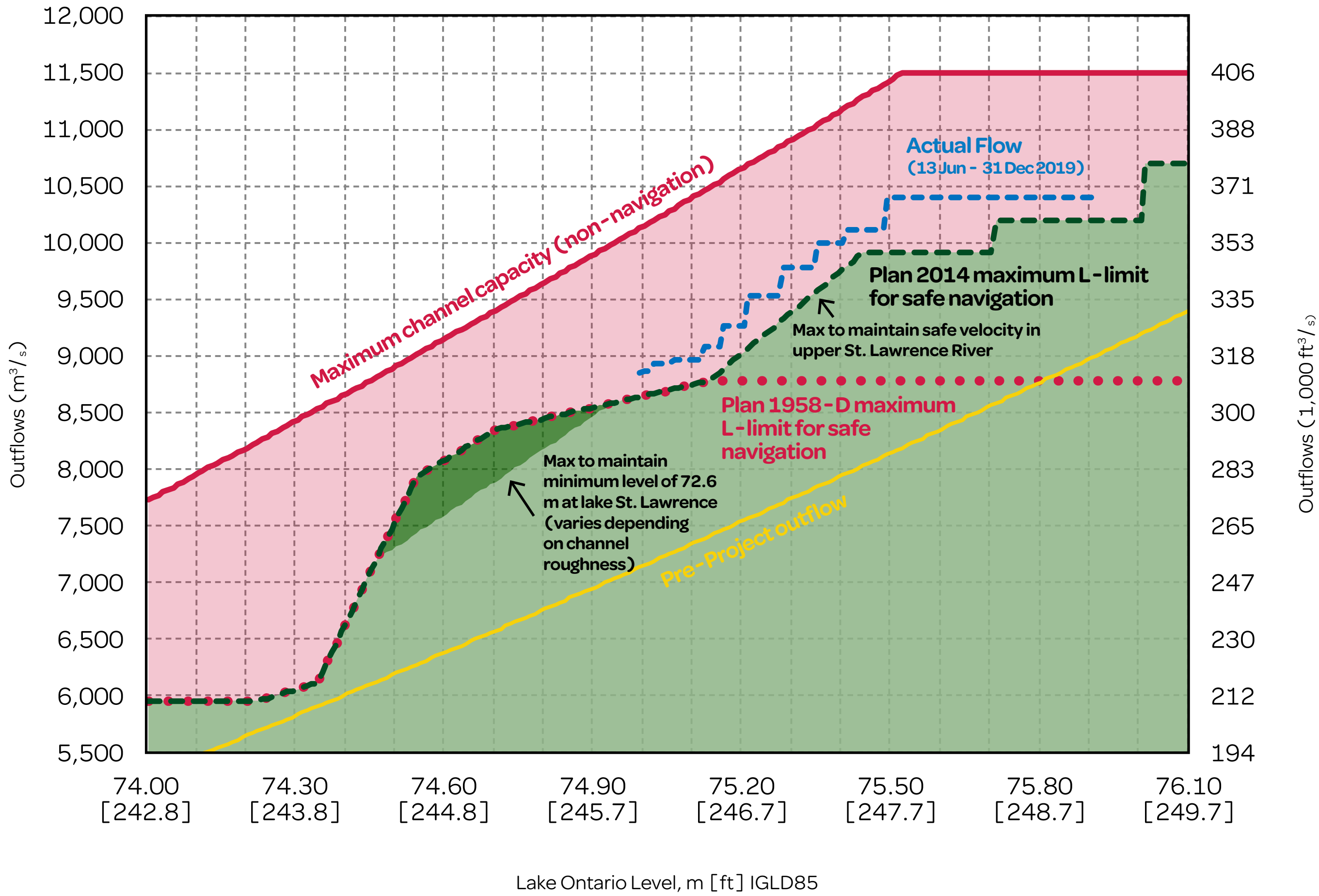


Figure 23:

PLAN 2014 MAXIMUM L LIMIT SHOWING ACTUAL FLOWS IN 2019 WHICH EXCEEDED THE LIMIT BY 200 M3/S (7,100 CFS) AS LAKE ONTARIO LEVELS DROPPED.

The Board continued to direct high discharges, often above the plan-prescribed "rule curve" flow, through the winter, setting records for outflow in January, February and March. In March and April 2020, seeing that it was likely that the third tier of the F Limit would be reached that spring, the Board decided to skip the first two F Limit tiers and set outflows that would allow Lake St. Louis levels to rise as high as 22.33 m (73.26 ft) even though Lake Ontario had not yet reached its corresponding level of 75.37 m (247.28 ft) in the F Limit. Further, the Board agreed that due to the risk of damage from ice movement on Lake St. Louis at such high levels, that the second tier of the F Limit level of 22.20 m (72.83 ft) would be targeted while significant ice remained.

The Board agreed that levels on the St. Lawrence River downstream of Lake St. Louis were to be monitored and outflows were to revert to the applicable lower F Limit tiers if significant flooding was occurring at Lake St. Pierre. As it turned out, more modest precipitation and snowmelt runoff conditions that spring did not necessitate going any higher than this 22.33 m (73.26 ft) level on Lake St. Louis as Lake Ontario peaked at 75.40 m (247.38 ft), well within the third-tier range.

During the early spring of 2020, the Board also consulted the Seaway corporations about delaying the start of navigation season by 12 days, until April 1, so that spring outflows could be maximized through

Figure 24:

LAKE ONTARIO OUTFLOWS IN 2020, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED

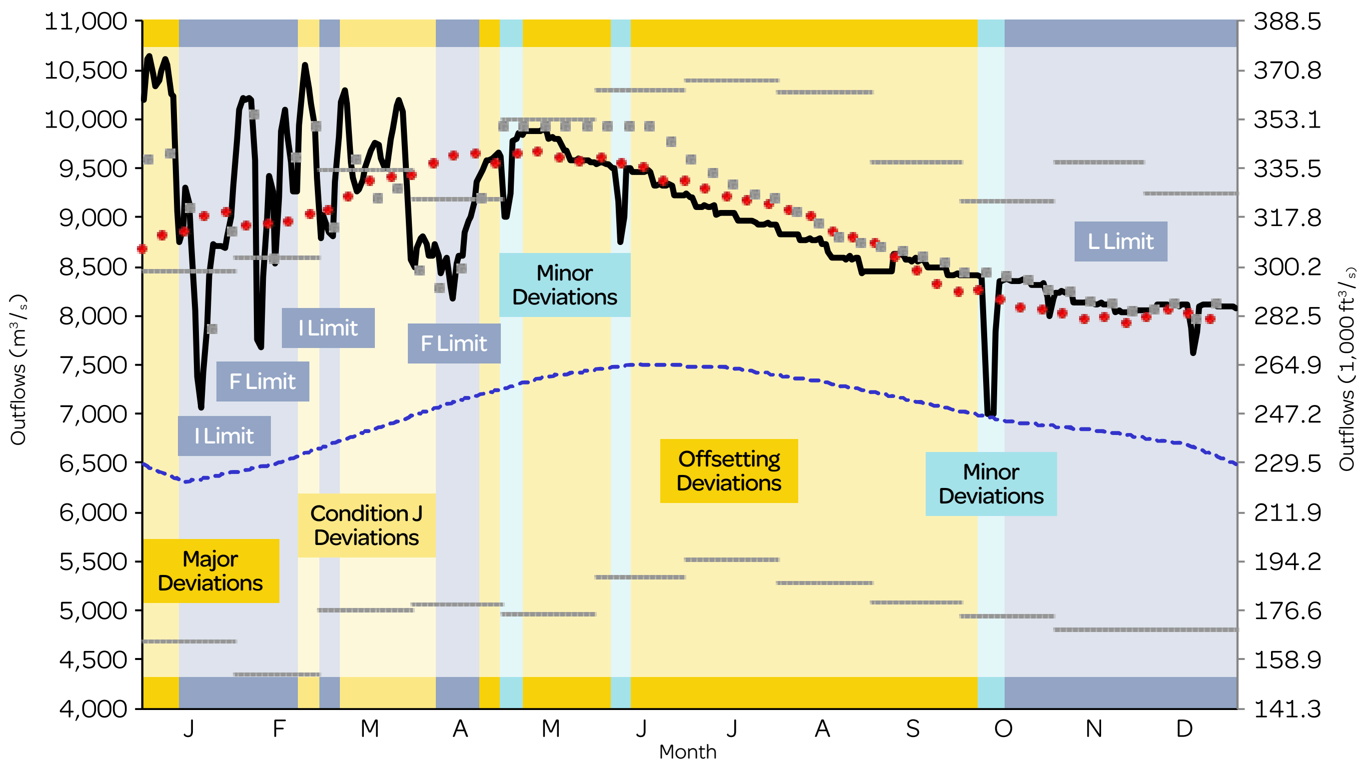
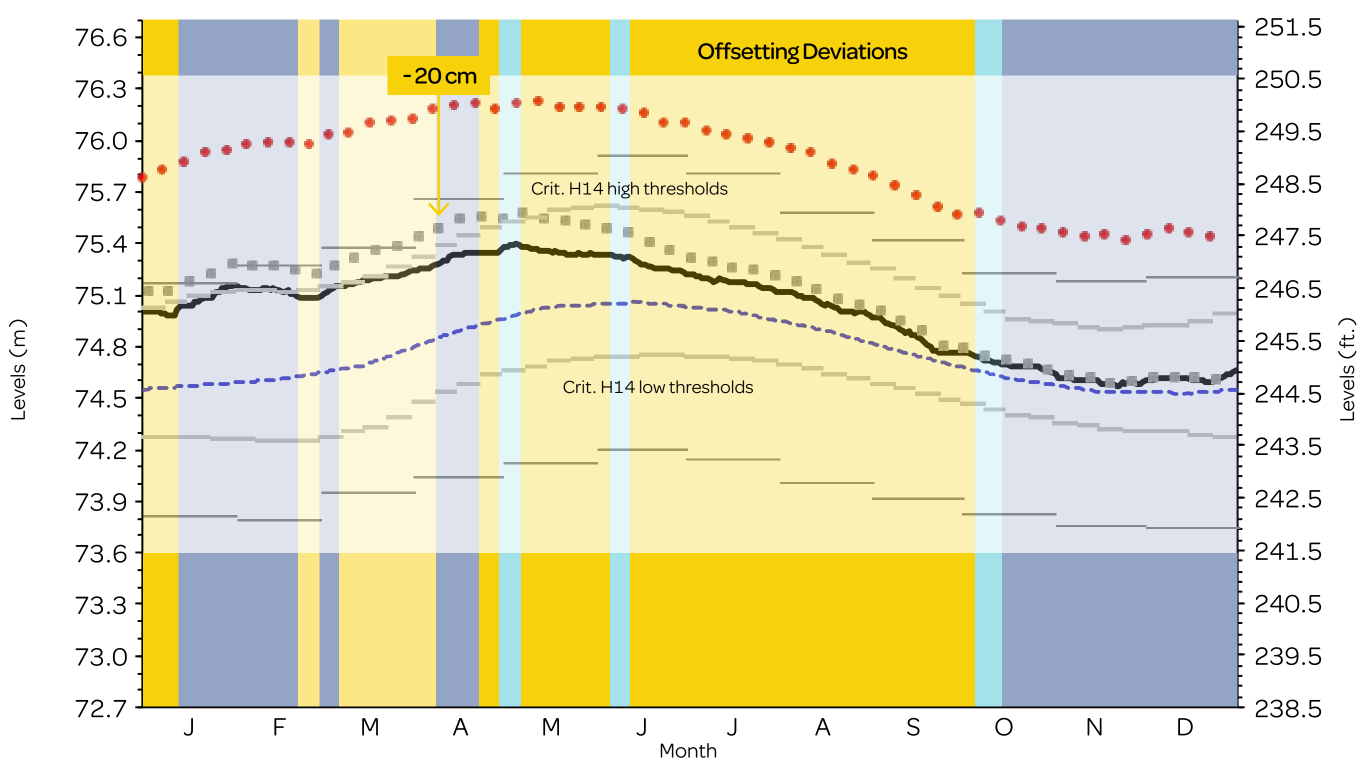


Figure 25

LAKE ONTARIO WATER LEVELS IN 2020, SHOWING WHEN LIMITS AND BOARD DEVIATIONS APPLIED



Preproject | Plan 2014 | Plan 2014 Rule Curve | Major (Criterion H14) Deviations
Minor Deviations | Condition J Deviations | Plan 2014 Limits | Actual | Average

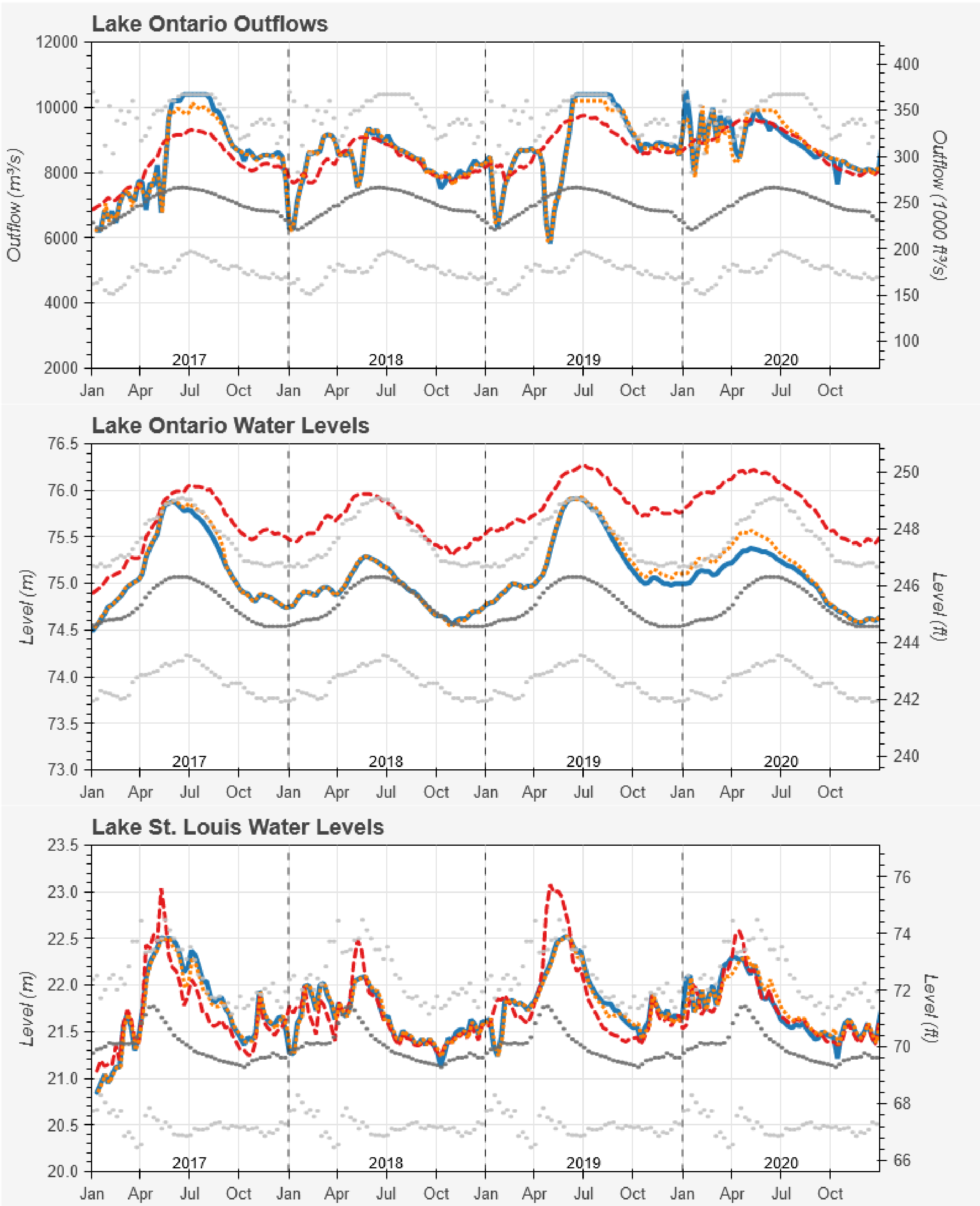


Figure 26:

ACTUAL (OBSERVED) VERSUS PRE-PROJECT (SIMULATED) CONDITIONS FROM 2017 THROUGH 2020

Actual Conditions — Pre-project Conditions — Plan 2014 — Average — Max / Min this date. The Board continued to maximize outflows in May. In consultation with the Seaway corporations, who were receiving feedback from mariners, outflows were set 70 m3/s above to as much as 180 m3/s above the L Limit until late May. While the Lake Ontario level had been high in the spring of 2020, the peak was 51 cm (20 in) lower than the previous year and there was no appreciable flooding. Figure 24 and Figure 25 illustrate 2020 outflows and Lake Ontario water levels, highlighting when different flow limits applied, as well as when major and minor deviations occurred.

In addition to the construction of Moses-Saunders Dam the St. Lawrence hydropower project required significant dredging in the upper St. Lawrence River. This makes it physically possible to release higher outflows now than prior to the project. The outflow conditions that would occur without the project can be simulated using a relationship between the observed water levels and flows that occurred prior to the construction of the project; this relationship is known as the pre-project relation. As shown in Figure 26, in both 2017 and 2019, the project allowed extremely high outflows to be released and this reduced the peak and duration of flooding that occurred.

More on high water in 2017 and 2019-20:

- https://ijc.org/en/loslrb/watershed/2017-and-2019-high-water-events
- https://ijc.org/en/loslrb/watershed/2019-high-water_Q-and-As

Insight

The Board wanted more information on the incremental impacts of deviation decisions and whether they could deviate without disproportionately harming Lake Ontario or St. Lawrence River interests.

3.2 The Board and GLAM Committee collaborate

In both 2017 and 2019-2020, the Board hit decision points where it opted not to deviate from the plan's built-in limits because members lacked enough certainty about whether they could deviate without disproportionately harming Lake Ontario or St. Lawrence River interests.

By definition, the F, L and I limits tend to apply when outflows are quite high, and the Board often finds itself considering deviating from a limit. But uncertainty about the repercussions of straying from these limits makes it more difficult for the Board to develop a deviation strategy. That is what led the GLAM Committee to study Plan 2014's limits and gather more information on impacts — in hopes of finding alternative tactics that the Board can someday apply when it considers deviating from the limits.

Working together, the GLAM Committee and Board discussed and analyzed the Board's previous deviations. The analysis focused not just on *what* deviations had been made but on *why* and *how* the deviation decisions were made, and looked into regulatory factors that came into play in making deviation decisions. The goal was to learn what metrics and other information should be included in the DST. Those discussions involved GLAM Committee members and their professional associates, the six current Board members, the six members of the Board's Interim Advisory Group, and 18 members of the PAG who represent many of the uses and interests in the Lake Ontario and St. Lawrence River systems. The effort used shared vision planning, a collaborative approach for water management that was developed by the US Army Corps of Engineers (USACE) and has been used by the IJC and the GLAM Committee in the past.

3.2.1 How the Board works

When the Board gathers to consider deviations, its Regulation Representatives (technical experts from the government agencies that support the Board) will brief Board and Interim Advisory Group members on current conditions and the forecasts of weather and water supplies and near-term water levels. After discussions and guidance from the Board, the Regulation Representatives develop and present Board members with a range of possible deviation strategies to consider.

Board members draw on what they have learned from the briefing, on their own knowledge of current and potential impacts, and their own experience. As per an IJC policy directive, Board members are selected by the IJC on their ability to act impartially and effectively with good judgement and with a desire to work towards consensus. After discussion and debate of the available options, the Board co-chairs will poll its members to seek agreement on a specific strategy. In the rare event that the Board is unable to reach consensus, the Board is required to defer to the IJC for clarification and/or guidance.

After discussions and guidance from the Board, the Regulation Representatives develop and present Board members with a range of possible deviation strategies to consider.

These proposed deviation strategies have been tested by the Regulation Representatives and shown to be physically feasible. Each strategy comes with an estimate of the change it will have on the forecasted range of lake and river levels over the next several months. In the past couple of years, leaders of the GLAM Committee also have provided the Board with useful, albeit limited, information on the possible deviations' impacts on the various uses and interests.

Board members are realistic about the improvements that deviations can bring about. They know that once damaging high lake levels set in as a result of excessive precipitation, high snowmelt runoff and/or high inflows from Lake Erie, there is no quick way to bring water levels down again. As was the case in 2017 and

2019-2020, it takes months of careful outflow management plus favorable weather conditions to reduce or eliminate impacts on the shorelines and shoreline properties of Lake Ontario and the St. Lawrence River, on recreational boaters, commercial shippers and other interests.

Typically, the Board's deviations can do no more than lower (or raise) lake levels in small increments; this is because of the limitations of the system and because the rules of the regulation plan are also working to prevent extremes. In the summer of 2017, for instance, it took more than two and a half months of flow increase deviations to lower Lake Ontario 15 cm (6 in.) more than would have been the case had Plan 2014's regulation rules been strictly followed. Lake Ontario had peaked about 80 cm (31 in.) above the long-term average in May of that year.

The Board also must face a lack of certainty in future conditions. Owing to the variability and unpredictability of the weather-driven Lake Ontario water supply, there is considerable uncertainty not just in forecasted water levels but also in the effects future water levels will have on various interests, uses and regions.

3.2.2 Factors that complicate deviation decisions

The GLAM Committee and Board members identified factors that make it difficult for the Board to make deviation decisions. Some are self-evident, others are not, and a changing climate potentially exacerbates a number of these factors.

Future water supply conditions are uncertain: Precipitation in the Lake Ontario and St. Lawrence River basins, as well as in the basins of Lake Erie and the Ottawa River, is a primary driver of water level fluctuations – but reliable precipitation forecasts are available for only a few days into the future. Under most circumstances the bulk of the water entering Lake Ontario flows in from Lake Erie. That supply is predictable to a point, but precipitation variations in the Lake Erie basin can alter that inflow relatively quickly. Rain and snow within the Lake Ontario basin itself also contribute appreciably to the lake level, and that cannot be predicted well. The benefits to interests and regions that come from Board deviation decisions are dependent on the water supply in the coming weeks and months. A period of heavy rain or a drought can easily erase a deviation's benefit. Climate changes only exacerbate this uncertainty.

Outflow deviations may lead to only incremental improvements for one interest or region but have a more significant impact elsewhere: By definition, natural water supplies and resulting levels are already extremely high or low when major deviation authority granted by criterion H14 "trigger levels" kick in and impacts are occurring in multiple places in the system. Any deviation in outflow the Board can make will lead only to small changes in levels on Lake Ontario and incremental improvements to some uses and interests. In some circumstances, an incremental change to the lake level can have a significant impact but in other circumstances, it can be

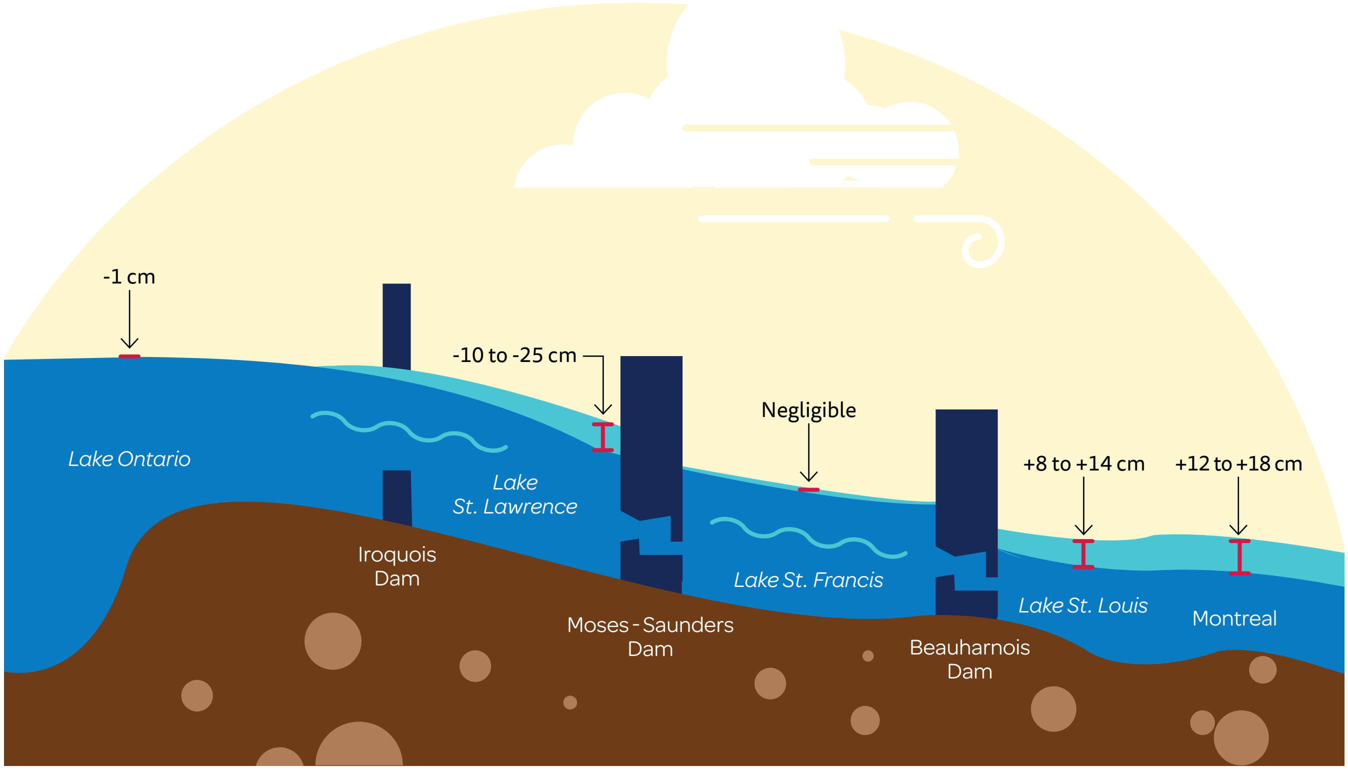


Figure 27:

OUTFLOW IMPACTS ON WATER LEVELS ACROSS THE LAKE ONTARIO – ST. LAWRENCE RIVER SYSTEM

(Source: International Lake Ontario – St. Lawrence River Board)

difficult to tell what effect it has had. Meanwhile, such deviations in outflow have a greater effect on water levels elsewhere in the system owing to the asymmetrical relationship between Lake Ontario and the St. Lawrence River. As noted previously, the vast Lake Ontario funnels into the relatively narrow St. Lawrence River; a change in outflow through the dam that causes a barely perceptible change in the lake level can cause a ten times greater change in water level at various points along the St. Lawrence River (Figure 27).

The social-economics of the Lake Ontario basin are complex: Some interests or geographic regions are more vulnerable than others to extreme high or low water. Some have every means and opportunity to make themselves more resilient, or to recover from the impact of extreme water, while others do not. The impact can be fleeting for some interests; it can last for weeks or months for others. Heavily populated urban areas are affected by high water much differently than small towns, rows of rural cottages, or tourist beaches and public parks.

Given the wide variety of uses and interests within the basin, it is inherently difficult to fully quantify and compare impacts: The cost of a temporary shutdown on commercial shipping, which is felt through supplies chains and by industries dependent on cargoes carried on the Seaway, are extensive but can be estimated. The repercussions of supply chain disruptions, job losses and impacts to local economies are also hard to assess. The impacts of extreme high water on shoreline residents, municipalities, tourism, small businesses, agriculture or recreational boaters are harder to quantify. Those impacts involve not just damage to property or loss of revenue, which can be calculated, but also loss of access and opportunity and a toll on physical and emotional health that can be profound and lasting but difficult to estimate. Likewise, environmental impacts may be quantifiable, but difficult to compare with more socio-economic impacts.

Impacts can be felt in different stages: Some impacts such as shoreline erosion, or degradation of Lake Ontario and the St. Lawrence River ecosystems, develop over a period of months or years and are not measurable in the short term. This again raises a comparison question: how would one weigh the impact of a water-level change when it hits some uses and interests immediately but others over a length of time?

The Board does not function in a vacuum: Board members are aware that countless cultural, social, political, legal, regulatory, financial and natural environments may be affected by their decisions, and members know that many people have strong opinions about Board actions. It is difficult for the Board to grasp the impacts on such a diffuse group of uses and interests, let alone address all the potentially competing objectives.

Insight

The board faces complex problems that impact their decisions, including climate change.

Heart Island, New York, USA

3.2.3

Information the Board wants and needs

Fresh from the 2017 and 2019-2020 extreme high-water events, GLAM Committee representatives conducted hour-long interviews in spring 2020 with each of the Board members (prior to the restructuring). Board members were asked about how they made their decisions and what gaps they saw in the knowledge they can draw upon when deliberating.

In their interviews, Board members made clear they wanted more detailed and comprehensive information about the real-world impacts of potential deviations as they said they often had little more than anecdotal information about impacts. Board members wanted to know with greater certainty what the risks to upstream and downstream interests are during extreme high water and how that risk would be shifted by their deviations. They wanted to know the true risk of seasonal storms, damage to shoreline infrastructure from very high current-velocities, the potential costs of a temporary halt to the shipping season due to higher flows and possible environmental damage should a ship grounding cause an oil spill. They wanted a fair and accurate way to compare impacts and they asked how they could identify deviations that would truly help one interest without unduly hurting others. They asked for **objective, normalized data to help them make comparison of impacts across interests and regions.**

The Board wanted **more information when it comes to deviating from the limits** — the elements in Plan 2014 that cap outflows to safeguard uses and interests on the St. Lawrence River. Some of the limit-related questions that face the Board were addressed in a study of the limits conducted by GLAM Committee members; that work is summarized in the subsequent section (see Section 3.3).

Winter storm on Lake Ontario, at Oakville, Ontario, Canada

Among specific issues regarding limits:

- **There was little** guidance available about deviating from the F Limit, which keys on the water level on Lake St. Louis to balance flood risk on Lake Ontario and lower St. Lawrence River. Board members asked if there was more information available about balancing the risk between upstream and downstream interests.
- **If the Board** is considering increasing the outflow beyond the L Limit, how can it weigh the benefit to shoreline interests on Lake Ontario against the potential impact on commercial shipping, recreational boating on the river and the river ecosystem?
- **How much can** be gained by deviating from the I Limit to remove more water from Lake Ontario in wintertime compared to the risks of damaging frazil ice, upstream or downstream ice jams, potential harm to the St. Lawrence River ecosystem and the possibility that the deviation will remove too much water from the lake?
- **Are there times** when the Board can and should deviate from the J Limit, which caps the change in outflow in any given week to protect interests on the St. Lawrence River?

KEY PERIODS OF RISK WHEN MAKING DEVIATIONS

During the spring freshet: Serious flooding on the lower St. Lawrence River can result from even a modest increase in outflow from Lake Ontario.

During and after ice formation: Ecological damage in Lake St. Lawrence can result from abnormally high winter outflows, as can weakening of the river ice cover and resultant local flooding damage.

During the Seaway navigation season: Shutdown of the Seaway with resulting damage to the shipping industry and its clients can result from deviations above the L Limit—but bring small, often difficult to measure improvements in terms of reduced levels on Lake Ontario.

The Board and GLAM Committee also identified what Board members consider the key periods of risk they face when making deviations. (see side box)

As well, discussion made clear that the Board often faces questions about how to balance impacts when those impacts can shift from one interest group to another due to changes to the water supply and other variables. When and to what degree should impacts be shifted from one interest group to another, and how does the Board weigh impacts like environmental damage or community-wide anxiety that are real but difficult or impossible to measure? How does the Board weigh the risk of long-term impacts that they cannot foresee, or weigh outcomes that have a high degree of certainty of occurring against others that are only speculative?

The Board also struggled with the uncertainty in forecasts of spring water supplies. Deviating to increase outflows above the limits to reduce the risk of high Lake Ontario levels months in advance may turn out to be unnecessary and damaging to many interests if spring weather is dry and runoff is low. Through numerous meetings between the GLAM Committee and Board, discussion of these questions and concerns informed the creation of the DST.

Insight

The Board needs more information on risks and uncertainties when deviating from plan limits.

3.3

The GLAM Committee examines Plan 2014's limits for deviation possibilities

Plan 2014 has three maximum outflow limits — the F, L and I limits — that often govern outflow to protect interests from excessive outflows during times of extreme high water. When criterion H14 "trigger levels" are reached as in 2017 and 2019-2020 (see Figure 3), and the Board has the authority to deviate, Board members must decide whether to override one of these limits despite a high degree of uncertainty about future conditions and without a great deal of information about potential outcomes of their decisions.

The GLAM Committee examined and documented deviations from the limits that have been made or considered in recent years. The committee also examined the origin and function of the limits and identified several possible options (Table 4) that are recommended for evaluation prior to future high or low water events. More details are provided below and in Sections 3.3.1, 3.3.2 and 3.3.3. These reviews and assessments will be considered in Phase 2 of the expedited review of Plan 2014 (GLAM, 2021a).

Limit	Area for Further Investigation
Maximum J Limit	• Assess modification or removal of J Limit under certain conditions
Maximum I Limit	• Assess reduction of minimum winter Lake St. Lawrence level of 71.8 m (235.6 ft) • Assess exceeding 9430 m^3/s (333,000 cfs) when conditions permit
Maximum L Limit	• Assess modification to minimum summer Lake St. Lawrence level of 72.6 m (238.2 ft) • Assess outflows above L Limit under certain conditions and with mitigation measures • Review the maximum outflow channel capacity • Review the flow limits of 10,200 m^3/s (360,200 cfs) and 10,700 m3 / s (377,900 cfs)
Maximum F Limit	• Review operations related to Lake St. Lawrence and Lake St. Francis • Assess alternative approaches to maximum F Limit informed by impact assessments f

Table 4:

LIMITS AND AREA FOR FURTHER INVESTIGATION (GLAM, 2021A)

Plan 2014-prescribed Rule or Limit	Weeks	Frequency
Rule Curve (R/R+)	32	15%
Limits	176	85%
I (ice) Limit	*34*	*16%*
F (flood) Limit	*30*	*14%*
L (navigation) Limit	*110*	*53%*
J (flow change) Limit	*2*	*1%*
M (minimum) Limit	*0*	*0%*
Total	**208**	**100%**

Table 5:

PLAN 2014 PRESCRIBED FLOWS, 2017 TO 2020.

(Number of weeks and frequency that each rule or limit was prescribed by Plan 2014 during the 208-week period from 7 January 2017 through 31 December 2020)

The prominence of the limits during periods of extreme high water was illustrated through an analysis by the GLAM Committee. It was found that from 2017 to 2020, if the Board had chosen not to deviate from Plan 2014, then Plan 2014's rule curve would have set the outflows for just 32 of the 208 weeks, or 15 percent of that four-year period (Table 5). Each of the three main maximum outflow limits would have applied for longer periods; the L Limit would have controlled outflows for 110 weeks, the I Limit for 34 weeks and the F Limit for 30 weeks. Combined, maximum outflow limits would have applied for a total of 85 percent of that four-year period.

However, the Board did choose to deviate from the rules and limits of Plan 2014 in 103 of those 208 weeks. Based on actual operations, including the weeks when the outflows were governed by deviations from the plan rules, the distribution of the applicable rule or deviation is as shown in Table 6.

The GLAM Committee found that while the purpose of each of the limits was well understood, there was little specific information available to the Board about the impact on St. Lawrence River and Lake Ontario interests of exceeding those limits. When the limits were examined in detail, additional information was described that may be helpful in future deliberations by the Board. Further discussion about specific research undertaken is found in Section 4.0.

Applicable Plan 2014 Rule, Limit or Deviation			Weeks*		Frequency	
Plan 2014 Flows	Rule Curve (R/R+)		17		8%	
	Max/Min Limits		88		42%	
	Type	*I (ice) Limit*		*30*		*14%*
		F (flood) Limit		*22*		*11%*
		L (navigation) Limit		*34*		*16%*
		J (flow change) Limit		*2*		*1%*
		M (minimum) Limit		*0*		*0%*
	Total Plan 2014		**105**		**50.5%**	
Deviations	Major Deviations (criterion H14)		65		31%	
	Type	*From Rule Curve*		*17*		*8%*
		L (navigation) Limit		*23*		*11%*
		Offsetting (payback) **		*25*		*12%*
	Condition J Deviations		8		4%	
	Type	Rule Curve		*1*		*<1%*
		L (navigation) Limit		*2*		*1%*
		F (flood) Limit		*5*		*2%*
	Minor Deviations		30		14%	
	Type	Lake St. Lawrence boat haulouts		*9*		*4%*
		Grounded ship		*1*		*<1%*
		Installation of safety booms		*5*		*2%*
		Hydropower maintenance		*1*		*<1%*
		Offsetting (paybacks)		*14*		*7%*
	Total Deviations		**103**		**49.5%**	
Total (all)			**208**		**100%**	

Table 6:

ACTUAL FLOWS, 2017 TO 2020.

(Number of weeks and frequency that each rule or limit of Plan 2014 was actually applied versus the number of weeks and frequency that deviations from Plan 2014 were conducted during the 208-week period from 7 January 2017 through 31 December 2020. *Determined based on majority of days during weeks where more than one rule, limit or deviation applied on different days, **Includes offsetting deviations (paybacks) of major deviations (criterion H14) and Condition J deviations as these were not possible to differentiate)

3.3.1

I Limit possibilities

The I Limit, which prescribes the maximum winter outflow, governed outflows approximately 14 percent of the time, or 30 weeks, between January 2017 and December 2020. The I Limit is designed to ensure water velocities on the St. Lawrence River are low enough to allow formation and maintenance of stable ice cover on the river and also low enough to maintain necessary minimum levels on Lake St. Lawrence after ice has formed. A higher rate of flow through the Moses-Saunders dam has the effect of lowering the dam's forebay, Lake St. Lawrence.

An examination of the I Limits yielded three possible changes to the limits, two of which also could be considered by the Board when it is making winter deviation decisions. The changes could permit greater winter outflows, either through alterations to the limits or by providing the Board additional latitude with winter deviations.

The I Limit requires that the level in Lake St. Lawrence be kept at 71.8 m (235.56 ft) or higher on a weekly mean basis, as measured at Long Sault Dam. That value was specified in the limit because it was believed to be the minimum level needed to allow municipal water-plant intakes to function properly.

The GLAM Committee research found this minimum level may no longer be appropriate because the Ingleside, Ontario water plant has been moved since its intake was compromised years ago when the level fell below 71.8 m (235.56 ft). This was the only such issue identified, and when water levels have fallen below 71.8 m (235.56 ft) again in recent years, no problems have been reported by water-system operators.

It is possible that the Board could deviate in winter and incrementally increase the outflow without compromising water intakes, though the GLAM Committee

Ice on Lake St. Pierre, Quebec, Canada

study noted that low water in Lake St. Lawrence can have impacts on aquatic life and power-plant operations. Any increase in outflow must weigh the potential benefits to Lake Ontario and lower St. Lawrence River shoreline interests against the potential impacts to Lake St. Lawrence interests.

A preliminary study by the St. Lawrence River Institute of Environmental Sciences (River Institute, 2020) concluded that substantial Lake St. Lawrence riverbed areas are exposed as water levels decline during the winter, but further lowering could expose significantly more areas, leaving isolated pools, resulting in significant impacts to aquatic organisms, especially amphibians, reptiles and small fish. Further studies were recommended (see Section 4.5 for more).

Higher flows through the Moses-Saunders hydropower plant may be prevented by the level of Lake St. Lawrence falling too low. Operating at very low head[6] (below 22.0 m (72.2 ft) at Moses generating station and 21.95 m (72 ft) at Saunders generating station) requires starting and operating units manually since plant rating tables do not extend to low-head conditions. Operating outside of the rating tables means that it is uncertain how much flow is actually being released. Efficiency of unit generation is also reduced at such low heads.

The GLAM Committee noted that the maximum wintertime outflow of 9,430 m^3/s (333,000 cfs) permitted under the I Limit when an ice cover exists is based on past experience. It may be possible for the Board to deviate to increase winter outflow beyond that point under some circumstances, though caution is needed as outflow capacity can be impacted for much of the winter if a poor or unstable ice cover collapses causing an ice jam to form. Further investigation of these matters is needed, and actual operations depend very much on the ice conditions existing in the Beauharnois Canal and Lake St. Lawrence at the time.

Insight

New information may allow different deviations from I Limit

3.3.2 L Limit possibilities

The L Limit, which relates to navigation by commercial vessels operating in the Seaway, governed outflows for approximately 16 percent of the time, or 34 weeks, between January 2017 and December 2020. In addition, deviations above the L Limit but constrained by safe navigation requirements occurred at least 23 weeks.

Broadly speaking, the L Limit caps the outflow through the Moses-Saunders dam at the maximum amount

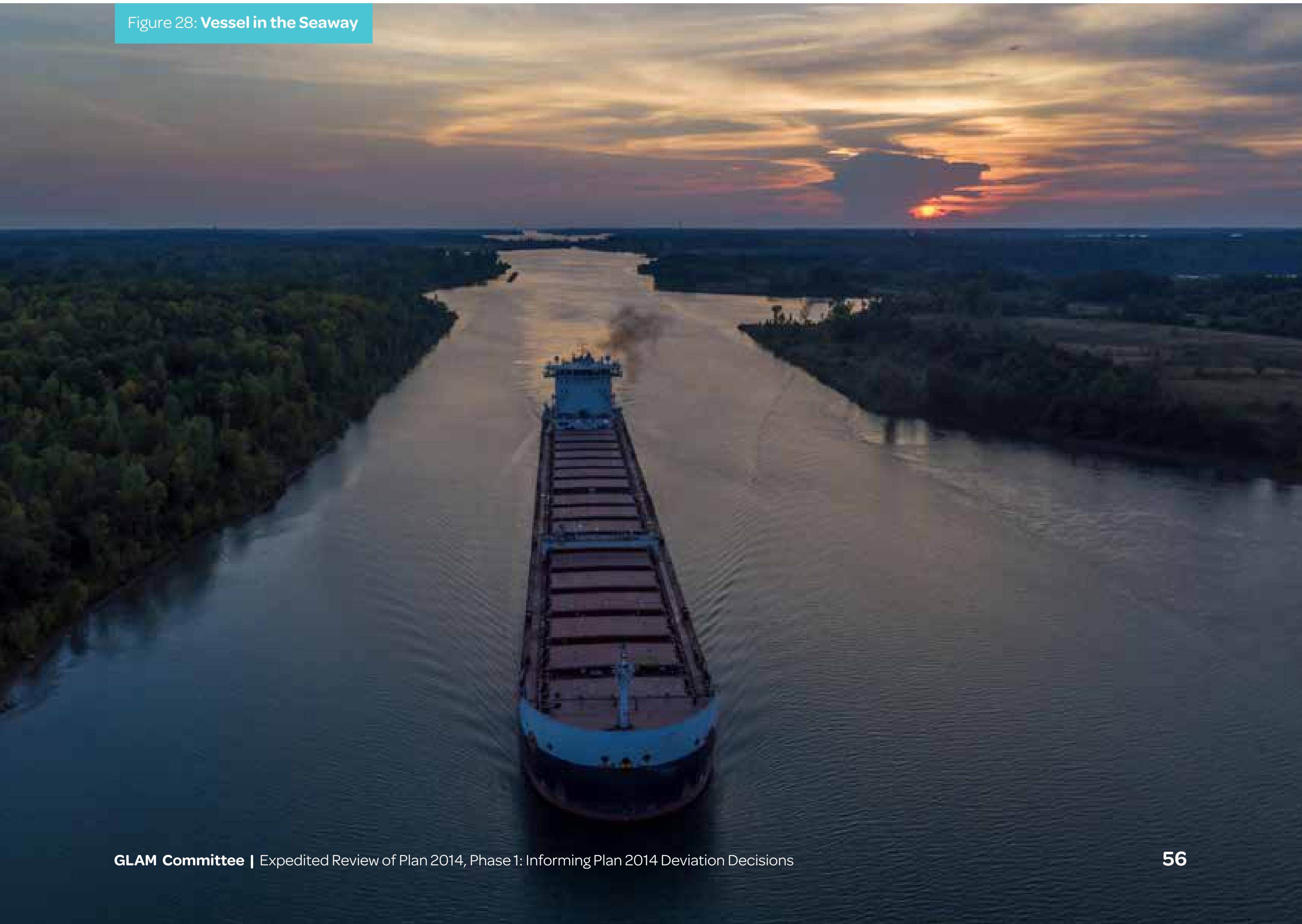
[6] "Head" = the water level on the upstream side of the dam minus the level on the downstream side. As the flow is increased through the dam, the upstream level drops and the downstream level rises causing a lower head.

that can be released without causing currents that are too strong to make navigation unsafe in certain sections of the river (refer to Figure 23 in Section 3.1.2 for a graphic representation of the L Limit). Another portion of the L Limit also ensures that levels of Lake St. Lawrence remain high enough for fully-loaded ships to transit through the channels. Like the other limits, there is a sliding scale under which higher outflows are allowed as the Lake Ontario level rises.

The second-highest outflow allowed under the limit, 10,200 m^3/s (360,000 cfs), permitted when the Lake Ontario reaches 75.5 m (248.36 ft), has been treated as the highest outflow during which normal navigation might be possible. The peak outflow allowed by the L Limit during the seaway navigation season, 10,700 m^3/s (378,000 cfs), applies when Lake Ontario reaches the extreme level of 76.0 m (249.34 ft) (see Figure 23). For periods of nearly two months in both 2017 and 2019, the Board chose to deviate from the L Limit by increasing the outflow to 10,400 m^3/s (367,000 cfs) until the Lake Ontario level fell below 75.50 m (248.36 ft).

The Seaway is jointly managed between Montréal and Lake Ontario by the Canadian non-profit corporation known as the St. Lawrence Seaway Management Corporation and a United States government agency known as the Great Lakes St. Lawrence Seaway Development Corporation (Figure 28). The Seaway corporations reported that vessels can safely navigate the St. Lawrence Seaway in the summertime during such an outflow with mitigation measures in place and Lake Ontario levels above 75.50 m (248.36 ft). They said commercial vessels had the most difficulty with outflows above the L Limit in the autumn, when currents were strong and the water level in the river was declining. The fall also brings more storms and gusty winds, which makes navigation in those conditions treacherous.

Figure 28: **Vessel in the Seaway**



The Seaway corporations have said that it is not possible to maintain safe navigation at 10,700 m^3/s (378,000 cfs). However, it may be possible that vessels could tolerate outflows above 10,400 m^3/s (367,000 cfs) in the early to mid-summer if Lake Ontario levels were higher and mitigation measures were in place. They also noted that flows of 10,400 m^3/s (367,000 cfs) or otherwise above the L Limit were found to be unsafe in late summer and fall. This suggests that at times, the Board might be able to deviate from the L Limit to a greater or lesser degree at times than it has to date. The Seaway corporations commissioned additional research and modeling following 2019 to provide real-time information to pilots regarding river conditions and to help them better navigate critical velocities and currents. This new information will be considered as part of future L Limit assessments.

The GLAM Committee also found that the basis for the two top outflows of 10,200 m^3/s (360,000 cfs) and 10,700 m^3/s (378,000 cfs) in Plan 2014's L Limit needs further assessment. The 10,200 m^3/s (360,000 cfs) tier outflows were derived from an experimental strategy employed during extreme high water in 1993, when the Board and Seaway operated with a pattern of intermittent outflows for a three-week span. That is, periods of very high outflow during which vessels did not try to navigate the seaway, alternated with periods of lowered outflow during which the vessels made way on the river. The 10,200 m^3/s (360,000 cfs) value used in Plan 2014's L Limit was based on the *average* outflow during the three weeks, not an *actual* constant outflow that was employed. The 10,700 m^3/s (378,000 cfs) value was derived from a *hypothetical* intermittent outflow scenario envisioned by the authors of Plan 2014.

The concept of intermittent flow was not employed during 2017 and 2019-2020. The Seaway industry has indicated that such a scenario today would no longer be feasible and would result in a complete mid-season shutdown. Rather, the seaway implemented mitigation measures to allow safe navigation at constant flows of 10,200 m^3/s (360,000 cfs) and as high as 10,400 m^3/s (367,000 cfs).

Another purpose of the L Limit is to cap the outflow during navigation season to prevent Lake St. Lawrence from falling below a minimum weekly mean threshold of 72.6 m (238.2 ft) at the Long Sault gauge that is required for full draft ships to safely transit. The GLAM Committee found that many shoreline residents, boaters and other recreational interests of Lake St. Lawrence prefer higher levels than 72.60 m (238.2 ft) and request minimum levels no lower than about 73.00 m (239.5 ft) in the summer season. During the summer of 2020, the Board agreed to offset earlier over-discharge deviations by reducing flows to maintain a higher minimum level of 73.00 m (239.50 ft) at the Long Sault gauge to provide some relief to these Lake St. Lawrence interests. In certain circumstances, the Board may be able to deviate from the L Limit in the summer to release less water to maintain higher Lake St. Lawrence levels for these interests. This would mean holding more water on Lake Ontario, though this increase in Lake Ontario levels would allow somewhat higher outflows in autumn and winter to make up for that.

Insight

Experience has shown that there is some flexibility to the L Limit possible in summer with mitigation measure in place, but less flexibility in the autumn when fall storms and gusty winds make navigation treacherous.

3.3.3 F Limit possibilities

The F Limit, which relates to balancing flooding on Lake St. Louis and Lake Ontario, governed outflows for approximately 11 percent of the time, or 22 weeks, between January 2017 and December 2020. In addition, deviations above the F Limit occurred in about 5 weeks.


Lake St. Louis, Quebec, Canada

The F Limit's fundamental purpose is to limit high water and possible flooding, including flooding caused or exacerbated by the Ottawa River freshet, or spring runoff (The "F" stands for "flood"). While it balances the impact of high water on Lake Ontario, the upper St. Lawrence River and the lower river downstream to Trois-Rivières, the F Limit is specifically tied to the water level of Lake Ontario and of Lake St. Louis, which is formed by the river at the upstream end of the Island of Montréal. As the water level in Lake Ontario steps toward extreme highs, the F Limit dictates repeated increases in the Lake St. Louis level (refer to Table 2 in Section 2.6) that may allow for higher outflows from Lake Ontario depending on conditions. Given Lake St. Louis is just a modest widening of the St. Lawrence River and behaves like a river, an outflow increase that has only minimal effect on Lake Ontario's level can cause a significant rise on Lake St. Louis (see Figure 29). As noted earlier, the F Limit plateaus with a maximum level for Lake St. Louis of 22.48 m (73.75 ft) when Lake Ontario reaches 75.60 m (248.03 ft).

However, the Board does have the ability to deviate from the F Limit when water levels rise. The highest of the criterion H14 "trigger levels" that authorize the Board to act, which apply in late May and early June when water levels often peak, are just 3 cm (1.1 in) above the highest F Limit tier.

The Board primarily chose to follow the F Limit in 2017 and 2019. Deviating under such circumstances was difficult because the Board members were aware that significant flooding was ongoing throughout the Lake Ontario – St. Lawrence River system, but had very little information about the incremental impact that any deviations would have both upstream and downstream.

This experience illustrates the Board's need for more data about the impacts both upstream and downstream of extreme high water that could allow the Board more confidence in developing a solid strategy for deviating from the F Limits in times of crises. The GLAM Committee analysis suggested the F Limits themselves could be amended as will be explored further in Phase 2.

The GLAM Committee analysis laid out several possible ways to adjust the F Limit or the Board's reaction to the limit that can be further developed and evaluated within Phase 2. These included extending the tiered target levels in increments for both Lake Ontario above the current thresholds of 75.60 m (248.03 ft) and Lake St. Louis above 22.48 m (73.75 ft), skipping the lower tiers of the target levels on Lake St. Louis if Lake Ontario is likely to rise above its corresponding tiers (the Board did this in the spring of 2020, see Section 3.1.2), varying the applicability of the targets with the timing of the freshet, tying those target levels to the inflow from the four upper Great Lakes or tying target levels to the inflow from the Ottawa River and adding a separate component to the F Limit to more directly consider Lake St. Pierre levels. All of these would require further exploration and evaluation before the Board may wish to consider these deviation options or as proposed modifications to the plan itself in Phase 2.

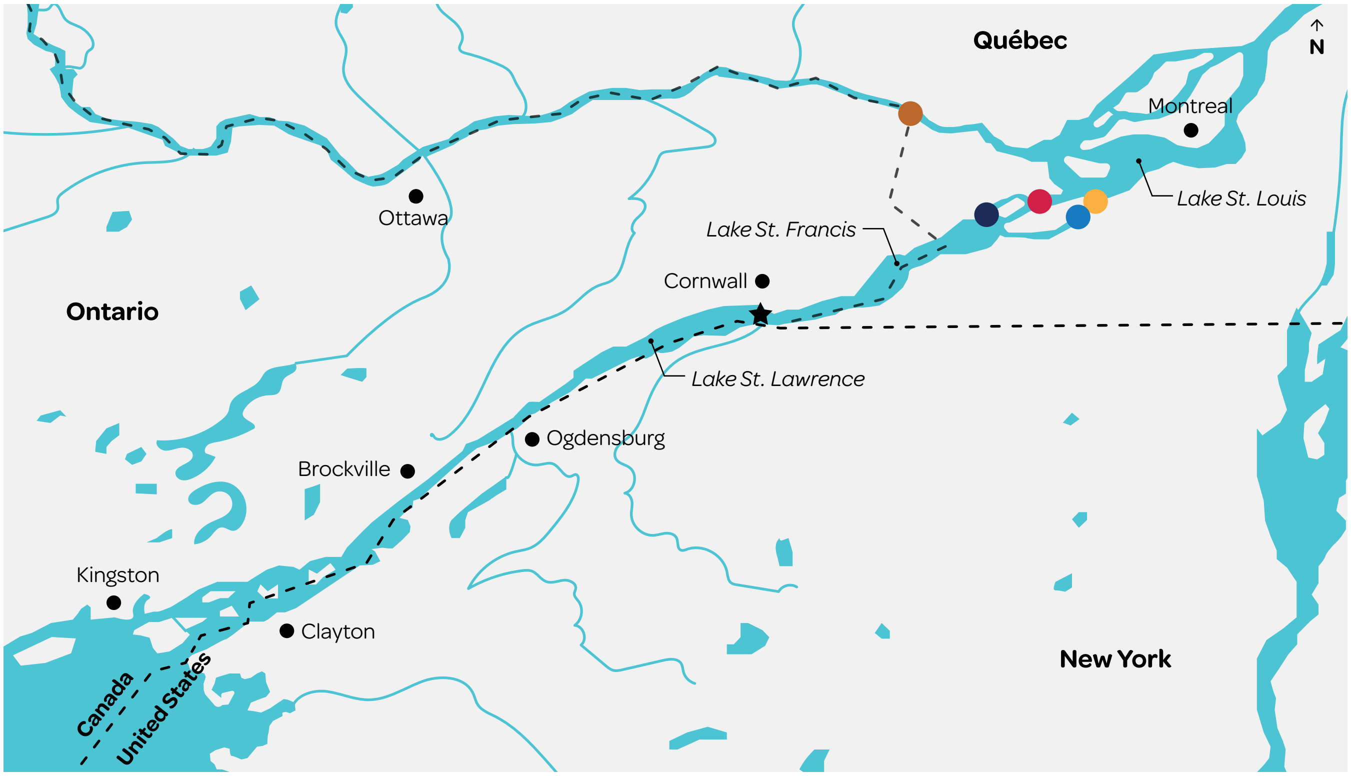


Figure 29:

MAP OF THE ST. LAWRENCE RIVER, LAKE ONTARIO TO MONTRÉAL, ALONG WITH HYDRO FACILITIES

Provincial border | International border | ★ Moses-Saunders Power Dam

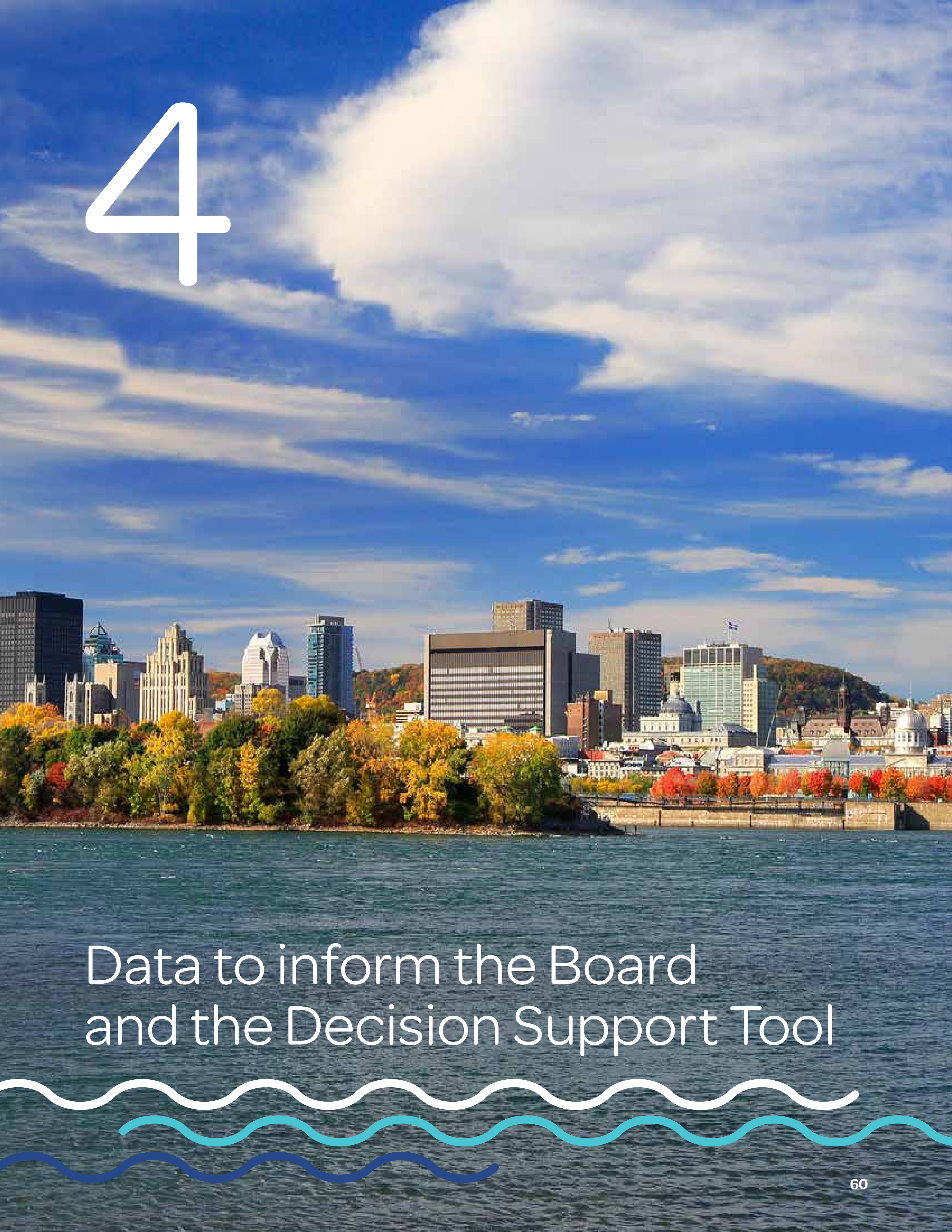
● Beauhamois ● Beauhamois ● Les Cedres ● Coteau ● Carillion

The GLAM Committee analysis also supported the notion that the Board should be provided with more information on the impact of extreme high water on Lake Ontario, the upper river, Lake St. Louis and downstream so that Board members could develop a deviation strategy during times of extreme high water. It was noted that impacts of large flow variations during F limit operations could have unintended impacts on Lake St. Lawrence and Lake St. Francis that need to be considered.

As well, the GLAM Committee indicated more information may be needed on the impact of high water and regulatory decisions on Lake St. Pierre. That section of the river below Montréal represents the eastern extreme of the area where levels are influenced by Plan 2014 or Board deviations. The Board attempted to consider the impact on Lake St. Pierre as it deviated in the spring of 2020 but found it did not have enough reliable real-time data and modeling of the numerous variables that affect water levels there.

Insight

There are a number of ways the F Limit could be adjusted that need further exploration in Phase 2



4

Data to inform the Board and the Decision Support Tool

4.0 Data to inform the Board and the Decision Support Tool

**Recognizing the International Lake Ontario – **St. Lawrence River Board (Board) needed more information about the comparative impacts of high and low water on the various uses and interests in the system to better make deviation decisions, the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee proceeded in Phase 1 to gather data on impacts and has made great strides towards satisfying that need. The information, which the GLAM Committee gathered from a wide variety of sources, provides a fuller picture of the nature and extent of those high-water impacts on many uses and interests on Lake Ontario and the St. Lawrence River.

Thousands of shoreline residents and business owners, municipal officials, Indigenous community representatives, marina operators, shipping company representatives and others provided information directly or indirectly to support this effort, and in the process the GLAM Committee and the IJC were able to forge or cement relationships with many of these people and groups. These relationships and the data that was collected not only contribute to Phase 1 but will also support future work, including Phase 2 of the expedited review of Plan 2014. The following sections highlight some of the work that was undertaken for each of the uses and interests previously outlined in Section 2.7 and 2.8.

4.1 Municipal and industrial water systems: Impacts to service

Municipal, industrial and private water and wastewater systems along Lake Ontario and the St. Lawrence River can be affected by both extremely high and extremely low water. The nature and extent of impacts is highly dependent on location and facility-specific characteristics making it challenging to undertake an overall assessment. High water impacts to municipal and industrial water systems were reported for locations along both the Lake Ontario and St. Lawrence River shoreline in 2017 (GLAM, 2018) and 2019. Low-water concerns in 2017 through 2020 have been most acute on Lake St. Lawrence where, as noted previously, high outflow through the Moses-Saunders dam can cause water levels just upstream in Lake St. Lawrence to decline steeply. Impacts can be experienced in other parts of the system during periods of extremely low levels, particularly along parts of the lower St. Lawrence River. However, those low-water impacts have not been a critical factor in high-water deviation decisions being considered in the Phase 1 effort.

The I Limit contains components meant to protect water intakes on Lake St. Lawrence by preventing water levels in that area from falling too low during winter months. The F Limit comes into play to protect shoreline buildings. Board deviations could affect water systems in numerous ways and the Phase 1 priority was to target specific data gathering to better understand high-water impacts across the Lake Ontario and St. Lawrence River system as well as specific low-water sensitivities on Lake St. Lawrence.

4.1.1 Surveys of Lake Ontario and St. Lawrence River municipal and industrial water use facilities

The GLAM Committee's summary report following the 2017 high-water event noted the need for more targeted data gathering from municipal and industrial water users (GLAM, 2018). The committee retained LURA Consulting to support that effort and their findings are available in their project report (LURA Consulting, 2019b).

LURA Consulting obtained information from 73 municipal and industrial water plant operators on Lake Ontario and the St. Lawrence River about impacts from the 2017 high water (Figure 30). These included facilities that draw water for drinking, industrial or power-plant cooling purposes or that treat wastewater.

Only 30 percent of respondents reported any impact from the 2017 high water conditions. Flooded manholes and pump stations and erosion of shore that affected pipes were the two most common, though small numbers of facilities reported more serious problems such as flooded buildings, spray from waves entering clear wells (where treated drinking water is held before distribution) or damaged pumps or pipes.

Fifteen facilities reported water-quality concerns and ten facilities — six on Lake Ontario and four on the St. Lawrence River — reported some loss of service. All were attributable to high water; there were no reports of problems caused by low water on Lake St. Lawrence in the LURA Consulting analysis of 2017 impacts.

Sixteen facilities on Lake Ontario and six on the St. Lawrence River supplied what they considered their critical high-water thresholds. Ten lake-based facilities and seven on the river provided critical low-water thresholds. The information provided through the LURA Consulting effort was based on feedback directly from facility operators.

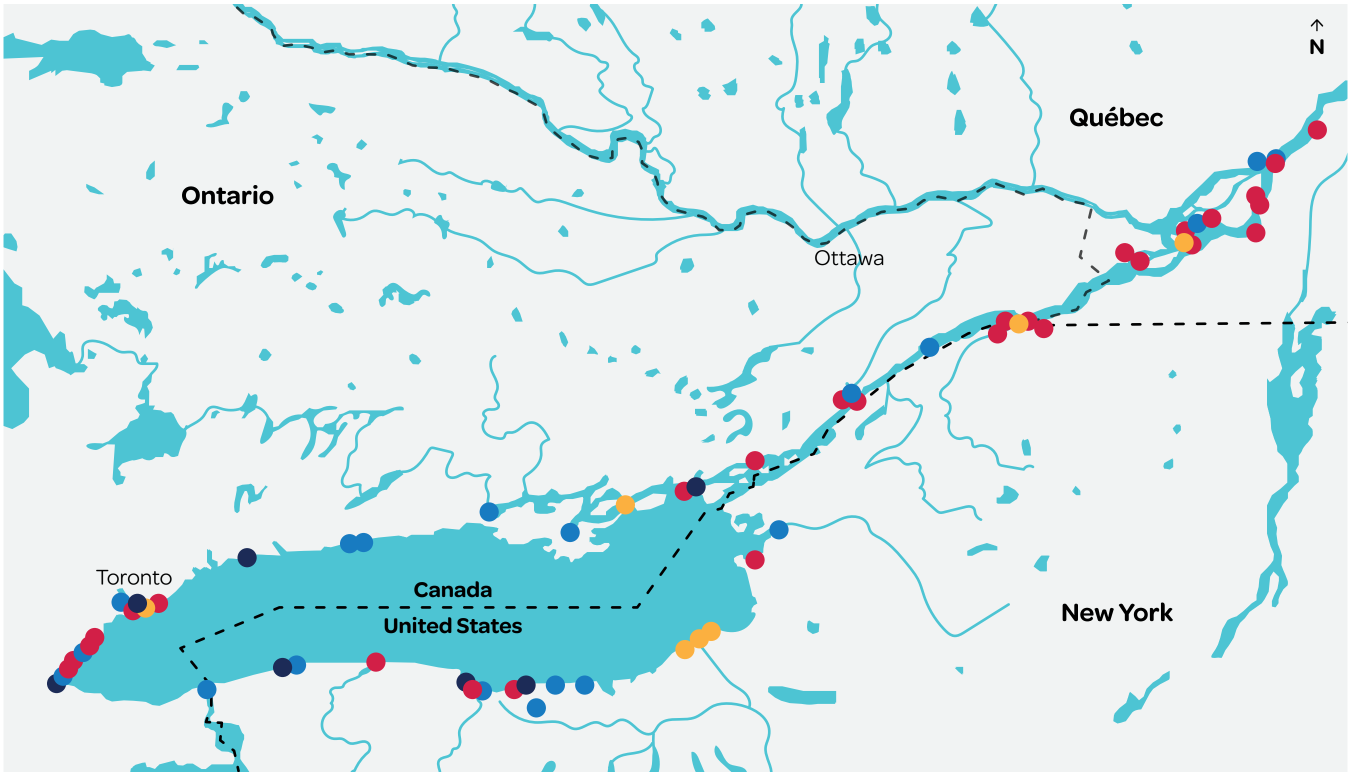


Figure 30:

FACILITIES PARTICIPATING IN LURA SURVEY (LURA Consulting, 2019b)

● Industrial Facility ● Municipal Wastewater Treatment Plant ● Municipal Water Treatment Plant
● Power Facility ▬ ▬ Provincial border ▬ ▬ International border

4.1.2

Assessment of water intake sensitivity on Lake St. Lawrence

The GLAM Committee engaged researchers from Polytechnique de Montréal to specifically review municipal water facility vulnerability to low water conditions on Lake St. Lawrence during winter operations and periods of ice cover, including specific system design specifications (Polytechnique de Montréal, 2020). The analysis found that none of the Lake St. Lawrence municipal and industrial water intakes and shore wells were vulnerable and the critical low water thresholds at each of the facilities are a meter or more lower than the minimum water levels observed on Lake St. Lawrence in recent years. The Cornwall drinking water intake was considered most likely to require additional investigation due to specific design conditions.

4.1.3 Other activities and next steps

Information from the two primary Phase 1 municipal and industrial water use data collection studies, along with input received directly from municipal operators as part of a municipal engagement effort, was summarized to support the creation of the Decision Support Tool (DST). While the information gathered to date provides a useful understanding of water level vulnerability at municipal and industrial facilities, it is important to recognize that each facility is unique and the GLAM Committee does not have site and design considerations for individual facilities outside of the Lake St. Lawrence review.

The GLAM Committee's focus for Phase 1 of the expedited review was high water deviations and data collection efforts were targeted to meet those needs. Given the more recent low water conditions in spring 2021, particularly on parts of the lower St. Lawrence River, further data collection may be required in Phase 2 of the expedited review to support deviations under low water "trigger levels" and/or when the M Limit applies.

Insight

Further data is needed on low water impacts on Lake St. Lawrence and the lower St. Lawrence River..

4.2 Commercial navigation: Financial and logistical impacts

Commercial shipping is a significant industry in the Great Lakes region, with 3,000 vessels carrying an average total of 38 million tons of cargo through the Seaway each year (Martin Associates, 2020). The stretch from Montréal to Lake Ontario — the portion of the Seaway considered in this study — typically is open from early spring through late December. The Seaway closes over the winter months due to ice conditions and to allow maintenance to occur. Water in the St. Lawrence River normally is maintained at levels that are deep enough for large freight carriers and with currents slow enough that they can safely maneuver.

The L Limit within Plan 2014 maintains outflows from Lake Ontario so that navigation can proceed safely.

The L Limit has been exceeded through Board deviation in times of extreme high water on Lake Ontario. In 2017 and 2019, a strategy was employed that allowed for releases by up to 5% above the L Limit while maintaining continuous navigation operations. The recent strategy allowed for an equivalent (or greater) amount of water released from what would have occurred with the 1993 intermittent flow strategy with fewer direct impacts to commercial navigation previously discussed in Section 3.3.2.

During periods of high water levels such as 2017 and 2019, very high outflows from Lake Ontario aimed at lowering its levels can cause currents in the St. Lawrence River that are strong enough to create unsafe conditions for ships navigating the river and increased risk of accidents. Outflows above the L Limit in 2017 and 2019 generated currents fast enough that large commercial vessels had to observe speed, meeting and passing restrictions in narrow sections of the St. Lawrence River and use tugboats for assistance in high-current areas (GLAM, 2018). Representatives from the shipping industry have indicated that mitigation measures put in place by the Seaway Corporations to manage the higher currents during such periods can increase operating costs for the Seaway corporations and their clients, especially if ship delays occur.

To support future Board deviation decisions under high water conditions, the GLAM Committee has been working to gather more information regarding the operational impacts associated with outflows above the L Limit based on the experiences in 2017 and 2019. In addition, the committee has undertaken an independent assessment of potential economic impacts to the navigation sector and the broader economy associated with ship delays at the beginning, middle, and end of the navigation season.

4.2.1 Study estimates industry losses from navigation halts

The US Army Corps of Engineers' Institute for Water Resources (IWR) was commissioned to estimate the cost to the commercial navigation industry of temporary Seaway closures. Three scenarios were considered: A delay in opening of the Seaway in late winter or early spring, a mid-season halt to navigation, and an early closure of the Seaway in late fall or early winter. For each of those three scenarios, IWR researchers sought to determine the impacts of closures of seven, 14, 21 and 30 days in length.

To help with this work, the GLAM Committee had asked the St. Lawrence Seaway Management Corporation and the Great Lakes St. Lawrence Seaway Development Corporation for details of daily vessel movements. The corporations did not provide this proprietary data. Instead they shared their own economic impact assessment, from John C. Martin Associates LLC (Martin Associates, 2020), of marine transportation interruptions that used the proprietary data from the shipping industry of daily vessel movements and a proprietary methodology for assessing costs of temporary closures.

As the GLAM Committee and IWR researchers did not have access to the daily vessel movement data, IWR examined the annual Seaway traffic reports, which break out monthly cargo tonnage for the Montréal-to-Lake

Ontario section of the Seaway. This is the most comprehensive data that is publicly available.

The researchers examined the three most recent available years of data in the annual traffic reports (2016-2018) to estimate the average daily tonnage in each month of the shipping season. The IWR researchers used the same data to obtain approximate breakdowns in the type of cargo being shipped in each portion of the shipping season and the direction of transport, upriver or down. (The cost of delay varied by cargo and destination; some could be held without substantial loss, while other cargo could not.) It should be noted that this analysis was not applied to the Port of Montréal or downstream of that city. This remains a gap to be filled.

USACE's established Regional Economic System (RECONS) model (USACE, 2019) and other analytical tools allowed researchers to estimate the financial impact of the delay in moving these cargoes under each closure scenario. They also estimated the number of jobs directly and indirectly affected.

A lengthy mid-season closure or an early end to the shipping season would be the most impactful because of the volume of traffic and the nature of cargo involved (Table 7) (USACE, 2020). While any closure was assessed as significant, a delayed opening beyond the preferred date was found to be the least impactful of the scenarios assessed, followed by a relatively brief mid-season shutdown.

1	7 - Day Delayed Opening
2	14 - Day Delayed Opening
3	7 - Day Mid - Season Stoppage
4	7 - Day Early Closure
5	21 - Day Delayed Opening
6	14 - Day Mid - Season Stoppage
7	14 - Day Early Closure
8	21 - Day Early Closure
9	1 - Month Delayed Opening
10	21 - Day Mid - Season Stoppage
11	1 - Month Early Closure
12	1 - Month Mid - Season Stoppage

Table 7:

RANKING OF TEMPORARY SEAWAY CLOSURE SCENARIOS, LEAST TO MOST COSTLY

(Source: USACE IWR, 2020)

The analysis verified that any stoppage of service would carry considerable cost; even the least impactful stoppage considered, a one-week delay in the start of the season, would cost the industry $13 million USD and affect 81 jobs (Table 8). In each delay scenario — season's opening, mid-season and season's end — cost grew exponentially as the period of stoppage grew from one week to longer periods. A 30-day delay in the start of the season would cost $370 million USD, the IWR estimated.

Vessel on the seaway near Montreal, Quebec, Canada

Delay	Cargo affected*	Direct economic loss**	Total economic loss**
Delayed opening			
7 Days	80,393	5	13
14 Days	379,260	22	62
21 Days	1,074,095	63	173
1 Month	2,313,971	135	370
Mid-season stoppage			
7 Days	445,317	25	69
14 Days	1,335,851	76	208
21 Days	2,671,902	151	416
1 Month	3,817,003	216	594
Early Closure			
7 Days	596,983	33	92
14 Days	1,591,954	89	245
21 Days	2,387,931	134	368
1 Month	3,411,330	191	526

*Short tons **Millions USD

Table 8:

IMPACTS RELATED TO COMMERCIAL NAVIGATION SCENARIOS
(Source: USACE IWR, 2020)

The IJC set up a peer review for the IWR report. That peer review found the IWR work provided sound analysis and insight on the economic impacts of Seaway closure given the data that was available for use. Comparisons between the IWR report and the separate Martin Associates study commissioned by the Seaway corporations were difficult given the proprietary nature of the corporations' report. Likewise, the Seaway corporations took issue with a number of items in the IWR report. Nevertheless, results were similar enough to give some confidence that the two methodologies were consistent. The peer review encouraged further collaboration with industry representatives to enable cross-checking of key assumptions and interpretations in the IWR analysis.

Insight

Progress was made on data gaps associated with commercial navigation impacts.

4.2.2

Industry views on navigation halts

Observations offered at a commercial navigation workshop convened by the GLAM Committee in November 2019 largely mirrored findings of the IWR study. Nearly 30 representatives of the commercial navigation industry shared their thoughts at the session, which was held in Montréal.

The representatives said any interruption in service was financially very costly and created the possibility that frustrated customers could temporarily or permanently shift to a different means of transport. They concurred with what IWR also later found, that a delayed opening or a single mid-season closure planned well in advance, while still troublesome, would have relatively less financial impact than an early closure of the Seaway. They said late-season volume is very heavy as customers stock up on commodities before the Seaway closes for the winter, making this approach particularly objectionable to the industry.

The representatives also said high financial costs and great disruption are associated with intermittent mid-season closures, an approach employed in 1993 and contemplated but not undertaken in 2019. Such a scenario was not considered in the IWR analysis as it was no longer considered a viable option.

Navigation industry representatives noted that Seaway closures not only harm shipping companies but disrupt entire supply chains, sending ripple effects through entire industries. Closures undercut the Seaway's image as a reliable, safe route, which encourages customers to consider shifting their cargo to a different means of transport that could affect their customer's competitive advantage. Once that happens, the representatives said it is very difficult to win back that business.

The industry representatives also discussed in detail their concerns about safe navigation during periods of extremely high flows in the St. Lawrence River. As noted above, the L Limit in Plan 2014 caps outflows so that commercial freighters can safely navigate the river. The limit changes depending on the water level in Lake Ontario. During the extreme high water events of 2017 and 2019, the Board ordered prolonged deviations that set the outflow at 10,400 m^3/s (367,000 cfs), or at least 200 m^3/s (7,100 cfs) above the applicable L Limit until Lake Ontario fell below 75.50 m (247.7 ft). Vessels continued to make way on the St. Lawrence River but under restrictions.

At the workshop, the shipping industry representatives said flows more than 200 m^3/s above the L Limit made navigation unsafe and that the Board should never permit outflows in excess of that. Asked why this was, some industry officials acknowledged it might be possible to navigate at flows that exceed the L Limit plus 200 m^3/s (7,100 cfs). But the consensus was the risk of a

Navigation industry representatives noted that Seaway closures not only harm shipping companies but disrupt entire supply chains, sending ripple effects through entire industries.

catastrophic accident such as a ship grounding or sinking or an oil spill far outweighed any possible benefit.

GLAM Committee officials asked why some known mitigation measures used in 2017 were not used in 2019 and if there were other measures that might allow higher flows. They also asked if some types of vessels might be able to navigate during higher flows. Industry officials did not respond in depth.

While the Seaway corporations did not provide any formal estimates of mitigation costs, at the 2019 workshop, one official of a shipping company said that speed restrictions during the 2019 season extended travel time through the upper river by two to three hours. The longer trip plus cargo weight limits that were imposed was costing his company $5 million in extra fuel and crew time in 2019. An official of another company put his firm's cost at $1.5 to $2.5 million. More recently, the Seaway corporations have provided an estimate to the GLAM Committee that their own direct mitigation costs were around $3 million.

Insight

Further data is needed on the value of and losses from commercial navigation mitigation measures

4.2.3 Other activities and next steps

In addition to work undertaken directly by the GLAM Committee, the Seaway corporations have continued to contribute to additional activities aimed at ensuring the safest operating conditions possible during periods of high currents in the St. Lawrence River. For example, additional hydraulic modeling commissioned by the Seaway corporations with support from the Canadian Hydrographic Service and ECCC provides near-real-time information on difficult currents in the system that can assist in safe navigation.

Going forward, the GLAM Committee is confident the new data and information gained through ongoing engagement with representatives of the commercial navigation industry will support future Board L Limit deviation decisions. The information has been incorporated into GLAM Committee's DST, where the potential impacts of navigation delays or stops for alternative scenarios could be examined. In addition, the GLAM Committee continues to engage with the Seaway corporations and look for opportunities to further improve the data and information within the DST in the future.

4.3 Hydropower production: Winter operations

Operation of the hydroelectric plants along the St. Lawrence River that rely on Lake Ontario outflow to generate power can be affected by extreme high or low water. The Moses and Saunders hydroelectric plants and the Long Sault Dam at the foot of Lake St. Lawrence (refer to Figure 10 in Section 2.7.3) control the outflow from Lake Ontario. The Moses-Saunders installation can be affected by extreme high flows, which lowers the net operating head (the difference in elevation between the upstream and downstream side of the dam) and affect operations negatively. The turbines in these plants require a minimum net head to operate, which can limit the outflow. If an ice jam or constriction forms upstream this can reduce the upstream level and the net head. This is something the Board may take into account in its deviation strategy and the GLAM Committee focused its Phase 1 efforts on gathering additional information to inform operations during periods governed by the I Limit.

The impacts of extreme flows are lesser known on the two downstream facilities, Beauharnois and Coteau-Les Cedres (refer to Figure 10 in Section 2.7.3).


Beauharnois dam

Hydro-Québec, which operates the plants, has noted past problems with ice affecting the capacities of the channels supplying these two plants and the properties along the Coteau channels. A GLAM Committee analysis of Plan 2014 has recommended more study of the effects of high flow on the operations of these two plants (GLAM, 2021a). Both of the Hydro-Québec facilities are run-of-river, meaning that they do not have the capacity to store water on Lake St. Francis above the dam, and must pass all water that is received from the Moses-Saunders and Long Sault dams upstream plus the flow from local rivers draining into Lake St. Francis.

4.3.1 More aggressive I Limit deviation potential

As winter sets in, ice cover usually forms on various sections of the St. Lawrence River, including in the Coteau channel, Beauharnois Canal and Lake St. Francis downstream of the Moses-Saunders dam and on Lake St. Lawrence upstream of it (Figure 31). Outflow is scaled back when ice is forming to encourage

Figure 31: **St. Lawrence River ice cover, January 2018**

a smooth, stable ice cover formation, and is ramped up again once the cover is solid. Persistent cold weather that allows a stable ice cover to form rapidly and persist until spring breakup allows a steady higher winter outflow from Lake Ontario. Fluctuating temperatures that prolong the time to form a solid ice cover or thaws that disrupt ice cover formation, can reduce overall winter outflows.

The hydropower companies and the Board's staff monitor ice conditions through on-site observation and remote sensing. Their goal is to manage the ice cover to prevent ice jams and resultant flooding of local shoreline development and maximize the winter outflow in periods of high water supplies.

The J Limit, which caps week-to-week changes in the flow, helps stabilize ice conditions in the river. The I Limit governs winter outflow with the intention of encouraging the formation of a stable ice cover on the river. During periods when the lake level is high enough to reach or exceed the Plan 2014 winter "trigger levels", the Board may consider deviating from the I Limit to maximize outflow.

Board members are conscious, though, of the need to prevent ice jams. A new study by researchers at Clarkson University, commissioned by the GLAM Committee, examined how much flow through the dam can be increased at any given time in the winter without disrupting ice cover on Lake St. Lawrence (Hung and Huang, 2020). The Clarkson University research provides the Board with additional insight into deviations from the I and J Limits during winter months.

The Clarkson study also examined the effect of wind speed on ice formation and advised that regulators be mindful of wind's impact. In addition, the researchers provided a means of estimating water levels in a portion of Lake St. Lawrence to help regulators maintain levels above the point where water intakes would be affected.

4.3.2 Other activities and next steps

The findings from the Clarkson University research are being examined by the Regulation Representatives that support the Board and the hydropower entities that operate the facilities. The work will contribute to further testing and evaluation of possible I Limit changes within Phase 2 of the expedited review. In addition, the GLAM Committee continues to work through the Board's Operations Advisory Group to understand critical operational issues related to high outflow conditions and ensure they are captured within the DST.

4.4 River and lake shoreline properties

Board deviations during times of extreme high water are intended to provide relief to the people, businesses and public facilities and lands along the shorelines of Lake Ontario and the St. Lawrence River. Plan 2014's limits and particularly the F Limit, which restrict outflow in varying ways, also have a direct impact on upstream or downstream shorelines. It was imperative, then, that the GLAM Committee collect additional detailed information about the impact of high water on shoreline interests so that Board members would have a better understanding of the effect of their deviations. In doing so, the GLAM Committee also had to take into account the fact that impacts can differ from one place to another under the same static water levels due to localized wind and wave conditions that drive up levels at some locations but not at others.

The Phase 1 effort obtained data on shoreline impacts in numerous ways including questionnaires for shoreline property owners, engagement with municipal staff and improved models to predict these water level impacts. The goal was to correlate the location and type of impacts from flooding and erosion with the water level to inform deviation decisions. This data also will be useful in Phase 2 of the expedited review, when it will be used to reassess the assumptions about high-water damage that were used in the creation of Plan 2014.

4.4.1 Residents provide detailed impact reports

One source of data was the 3,000-plus responses from shoreline property owner online questionnaires about the nature, location and timing of impacts from the extreme high water in 2017 and 2019. Most respondents in 2017 were New Yorkers (https://www.ijc.org/en/glam/questionnaires), while Ontario residents filled out the most 2019 questionnaires. Only a few dozen Quebec property owners took part in either questionnaire.

These were voluntary questionnaires administered by the GLAM Committee, open to all via the GLAM Committee website. It was not an attempt to sample shoreline impacts in a statistically representative manner but nevertheless, the questionnaires provided a great deal of useful information to the GLAM Committee on the nature of the impacts suffered. Questionnaire respondents were asked to supply the municipality and address where the high-water impact occurred allowing the committee to better identify where critical hot spots might exist. (This information, like other responses on individual questions, will be held as confidential and not revealed to others.)

About 90 percent of respondents said they experienced flooding in 2017 and 70 percent in 2019. In both years,

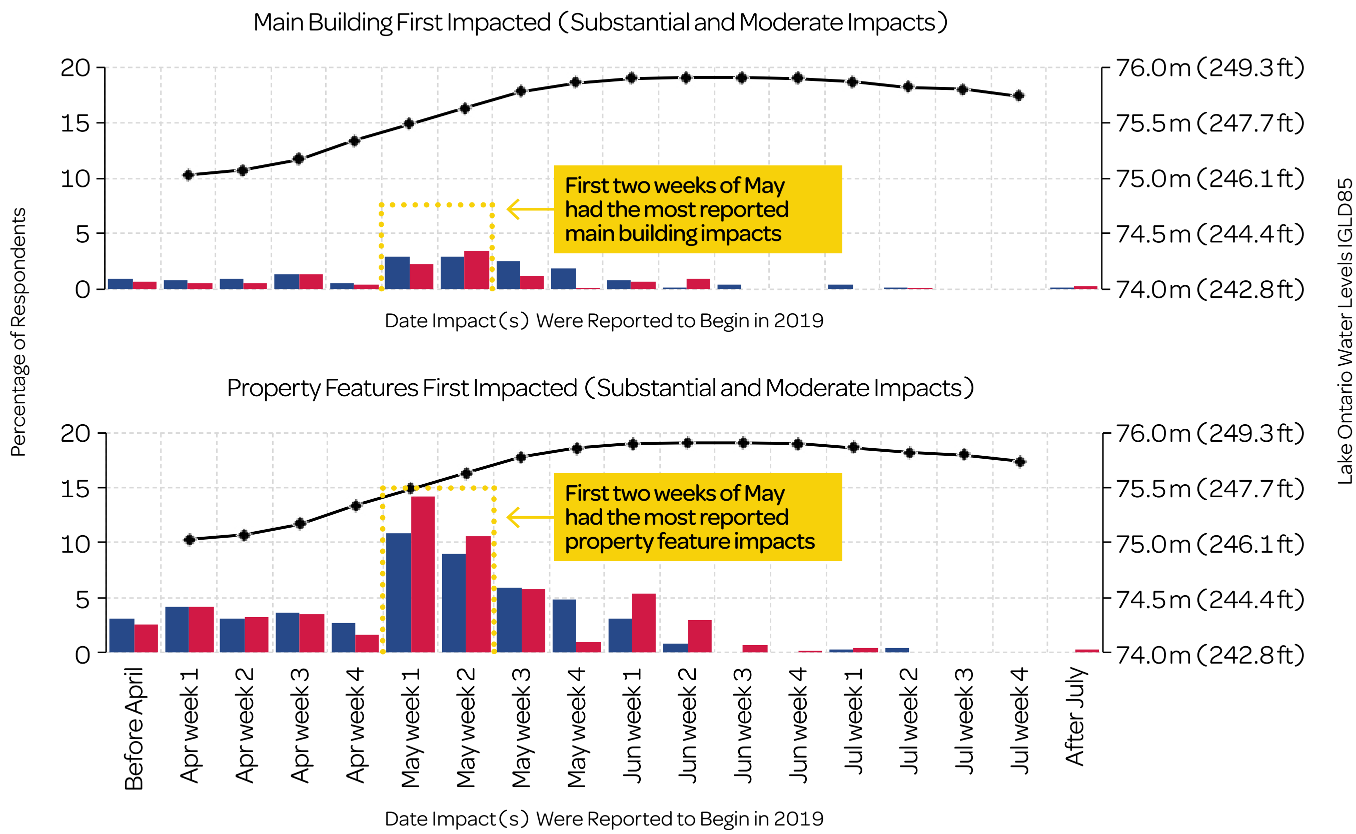


Figure 32:

2019 IMPACTS BY WEEK (Source: GLAM Committee)

New York (477 resp. reported flooding) Ontario (490 resp. reported flooding) Water Level

lawns and docks were reported the most as being impacted by flooding. Shoreline protective structures also were damaged, especially in 2017 according to questionnaire responses.

The GLAM Committee married that location data to the respondents' reports on high-water impacts to their property. Respondents often provided dates when certain impacts began, and the GLAM Committee was able to correlate those dates to the water level at that time (Figure 32). This factual collection was used to help create the DST impact zones.

Publicly reported findings from the 2017 and 2019 questionnaires, aggregated by state/province and by county (https://www.ijc.org/en/glam/questionnaires), can be used to improve the accuracy of the GLAM Committee's shoreline-impact models. Updated verifications of the impact models will be reported in the Phase 2 report of the expedited review.

Insight

Shoreline impact data allows DST creation; public assistance invaluable

4.4.2 Municipalities' impact data

Municipalities are on the front lines of response during high-water periods, supporting their residents and protecting public shoreline infrastructure. As part of Phase 1 efforts to gather additional shoreline impact information, the GLAM Committee engaged with staff from municipalities, conservation authorities and other local government entities in Quebec, Ontario and New York. Copticom Stratégies et Relations Publiques, Kennedy Consulting, and USACE-Buffalo were engaged to support the GLAM Committee in each jurisdiction, respectively.

Flooding in Toronto, Ontario, Canada

Some common themes emerged from all three jurisdictions. About 70 percent of those who responded said their municipalities incurred some physical impact from high water. Local roads, parks, trails and shoreline protective structures were the most commonly affected facilities. Erosion of public land was reported by many of the municipal entities. Many said constituents were severely harmed by high water and employees were overworked; officials in Quebec and Ontario noted that constituents and employees were emotionally fraught during the height of flooding due to exhaustion, stress and wariness about the future.

In terms of identifying the date or water level when impacts occurred on specific municipal facilities, results varied by location and municipality, an unsurprising result given the thousands of kilometers of shoreline. In Ontario, some local-government entities did provide location-specific dates when significant impacts began to their shorelines, providing valuable data for use in the DST. No such data were included in the Quebec or New York reports. This reflects the challenges of getting site specific information over such a large geographic area.

Insight

More details of impacts and critical water levels may be needed for municipal infrastructure.

4.4.3

Simulating building and agricultural land inundation

Building inundation, or flooding, is being used as an important impact metric that can be measured throughout the lake-river system. GLAM Committee members and associates have used technical studies and flood inundation modeling to estimate the number of buildings inundated under various conditions.

The work refined the range of potentially impacted shoreline buildings under a range of water levels and wave intrusions. This contributed to the identification of broad-based regional impacts upstream and downstream and critical water level thresholds. This data was important in the creation of the DST and will help the Board understand likely impacts in different parts of the system as they consider deviations.

To build a dynamic picture of buildings at risk of inundation, the GLAM Committee used GIS software to marry digital maps of ground elevations with digital resources that depicted the footprint of buildings on or near the shore. For properties on the Lake Ontario and upper St. Lawrence River shorelines, researchers defined a baseline condition by selecting all homes, garages, boathouses, sheds and other accessory buildings located on the immediate shoreline, along with properties set back from the shore but at low elevations relative to the waterline. For properties on the lower St. Lawrence River, the GLAM Committee began by selecting shoreline buildings in the same fashion. Researchers then ran a high-water flood simulation model and identified the inland buildings that would be inundated. The GLAM Committee has been building its own dataset of baseline building locations and elevations for use in the modeling. To date it has relied on publicly available data and engaged in some "data cleaning" (correcting errors and inconsistencies). It is continuing work in this area and improvements are likely to occur into Phase 2.

The initial construct for the flood inundation model development assumed static water levels, meaning waves and surge were not taken into account. To support the validation for this initial step, the GLAM Committee also has been reviewing oblique (angled) aerial images captured during the 2017 flooding on the Lake Ontario shoreline, and the 2017 and 2019 flooding on the lower St. Lawrence River (refer to Figure 20 in Section 3.1.2). It is working to develop interactive maps that will be available to the Board based on these images.

To build a dynamic picture of buildings at risk of inundation, the GLAM Committee used GIS software to marry digital maps of ground elevations with digital resources that depicted the footprint of buildings on or near the shore.

Two further modeling efforts were undertaken for the Lake Ontario shoreline to consider the effects of waves and storms on the initial static water level conditions, which can significantly add to the number of impacted

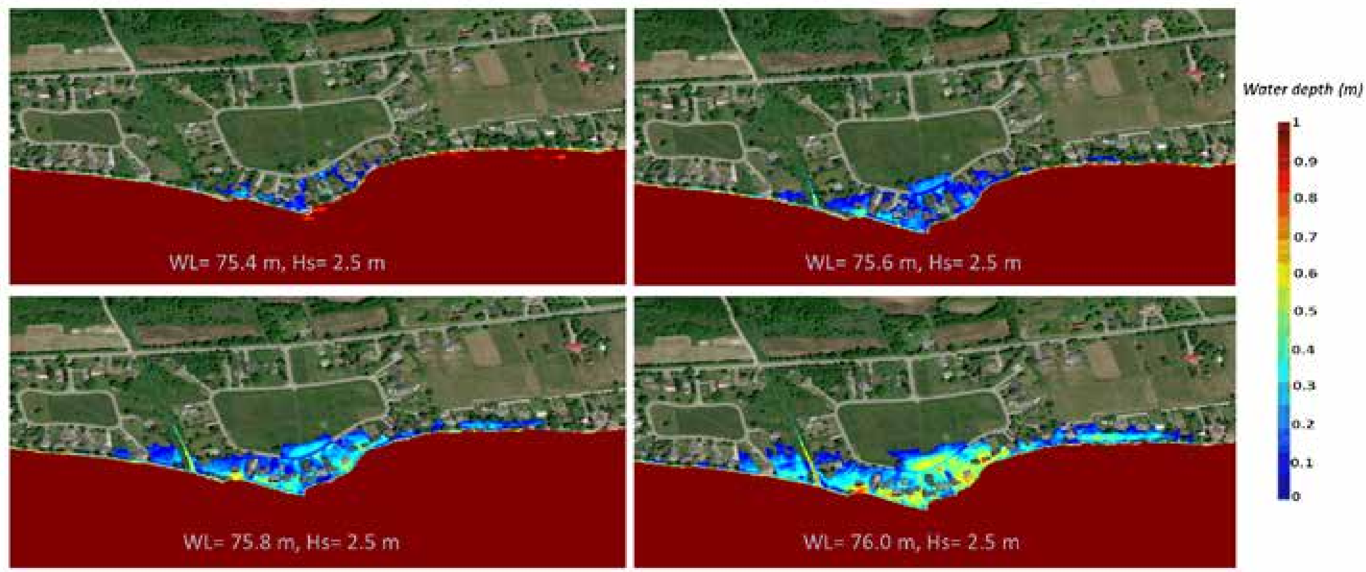


Figure 33:

ILLUSTRATION OF FLOOD INUNDATION UNDER DIFFERENT WATER LEVELS
(Source: Cornett, Ghodoosipour and Provan, 2021)

shore properties and the extent of damage. First, researchers at the National Research Council Canada (NRC) used a high resolution modeling package to simulate high-water and wave impacts along 1-2 km (0.6-1.2 mi) stretches of shoreline in three communities – the Municipality of Brighton, Port Darlington in the Municipality of Clarington and Stoney Creek in the City of Hamilton (Cornett, Ghodoosipour and Provan, 2021).

The NRC was able to estimate the land, buildings and roads inundated under various water level and wave scenarios at the three sites (Figure 33). The NRC modeling illustrated the increasing impacts on land as the water level rose and under varying storm conditions (Cornett, Ghodoosipour and Provan, 2021). However, even the detailed model used by the NRC researchers was not able to resolve the impact of small changes in levels from the combination of static water levels and storm surge. The results were still helpful in providing data that helped form the impact zones within the DST and also to illustrate challenges the Board faces when considering the potential benefits and impacts associated with deviation decisions that may only influence lake levels by a few centimeters (inches).

The second Lake Ontario modeling approach used to support GLAM Committee efforts in Phase 1 was applied by the USACE coastal engineering staff in Detroit who addressed waves and surge on the lake shore across broader sections of shoreline. Like the NRC researchers, the USACE team modeled how far water moves up the shoreline during storm events. The team used another coastal model featuring transects running perpendicular to the shoreline that incorporated near-shore buildings (Figure 34 and Figure 35)). The USACE team then applied 150 severe storm scenarios to simulate wave runup on each transect. The output indicates a statistical representation of the potential number of buildings that would be inundated under each of the scenarios given understanding of historical storm conditions, though the USACE team had to make assumptions about the type of shoreline protective structures in place, which introduces an added element of uncertainty.

On the lower St. Lawrence River, the GLAM Committee has continued to work with a water-level and flow model developed by ECCC for the Lake St. Louis to Lake St. Pierre stretch of the St. Lawrence River. Like the work

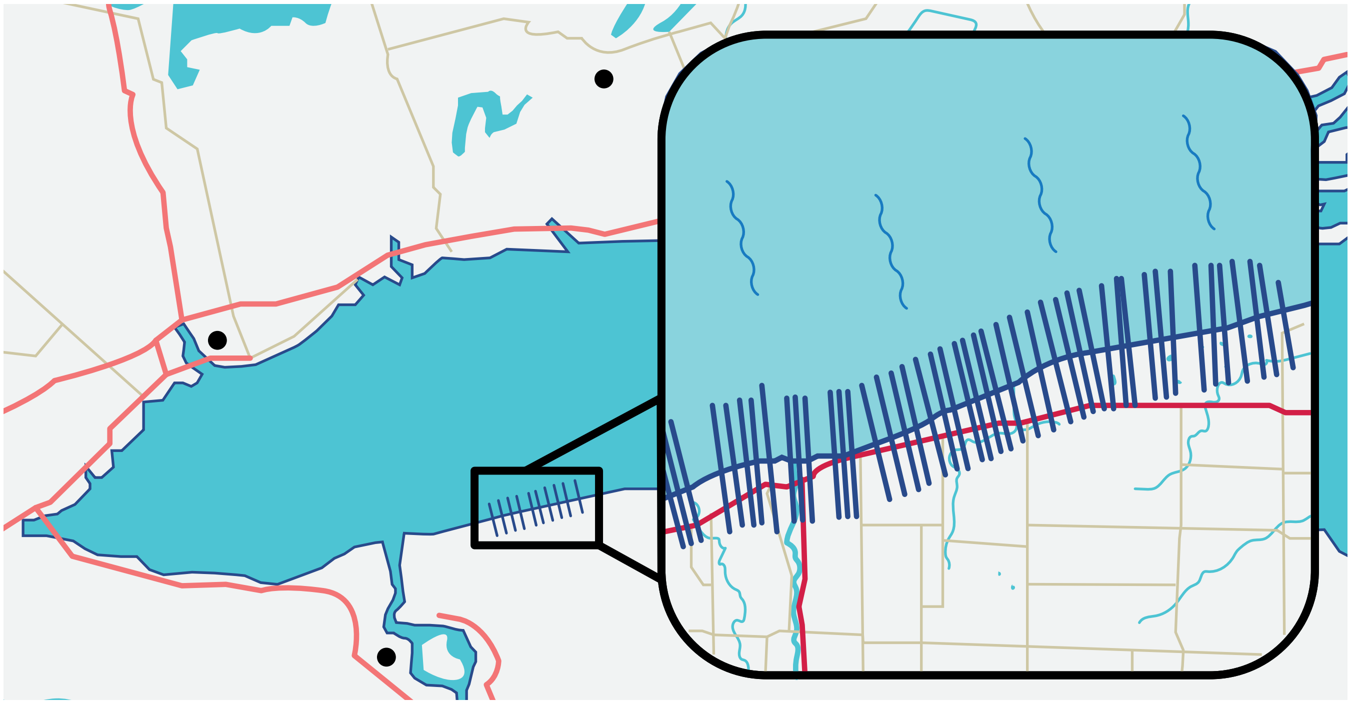


Figure 34:

ILLUSTRATION OF TRANSECTS GENERATED ON THE LAKE ONTARIO SHORELINE.
(Source: US Army Corps of Engineers)

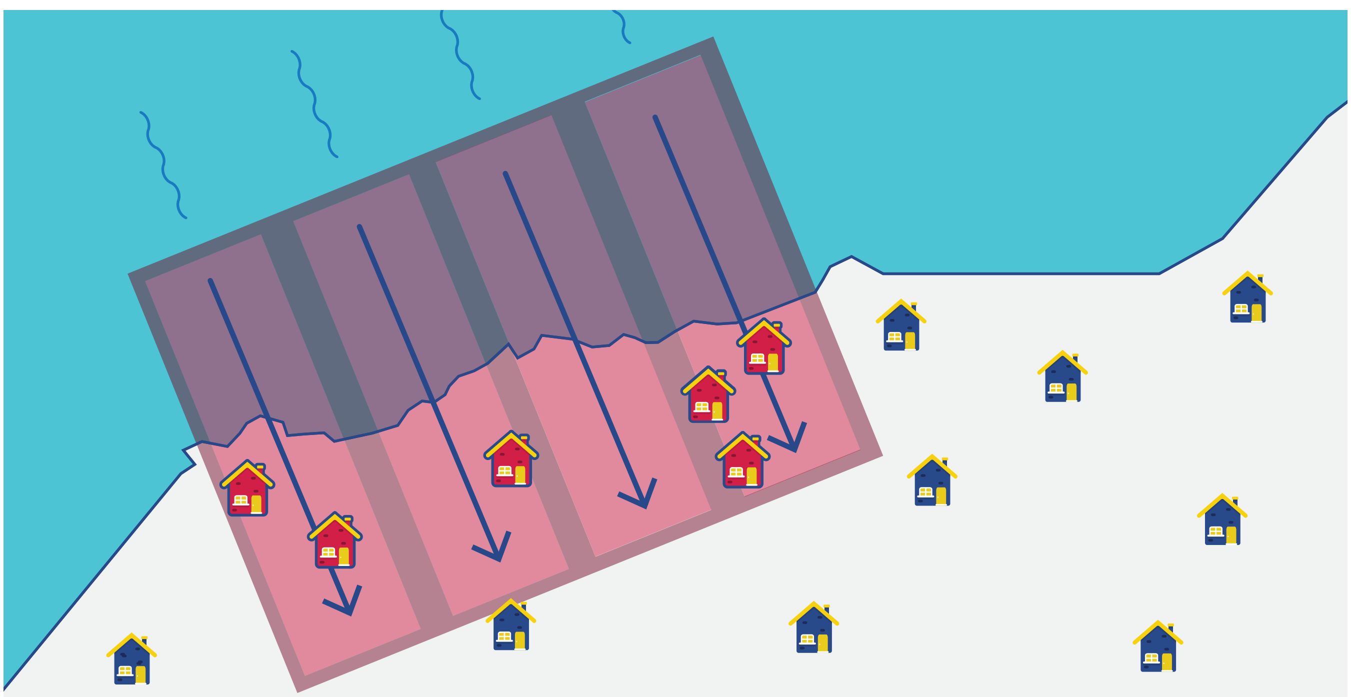


Figure 35:

TRANSECTS INCORPORATING HOMES AND OTHER BUILDINGS.
(Source: US Army Corps of Engineers)

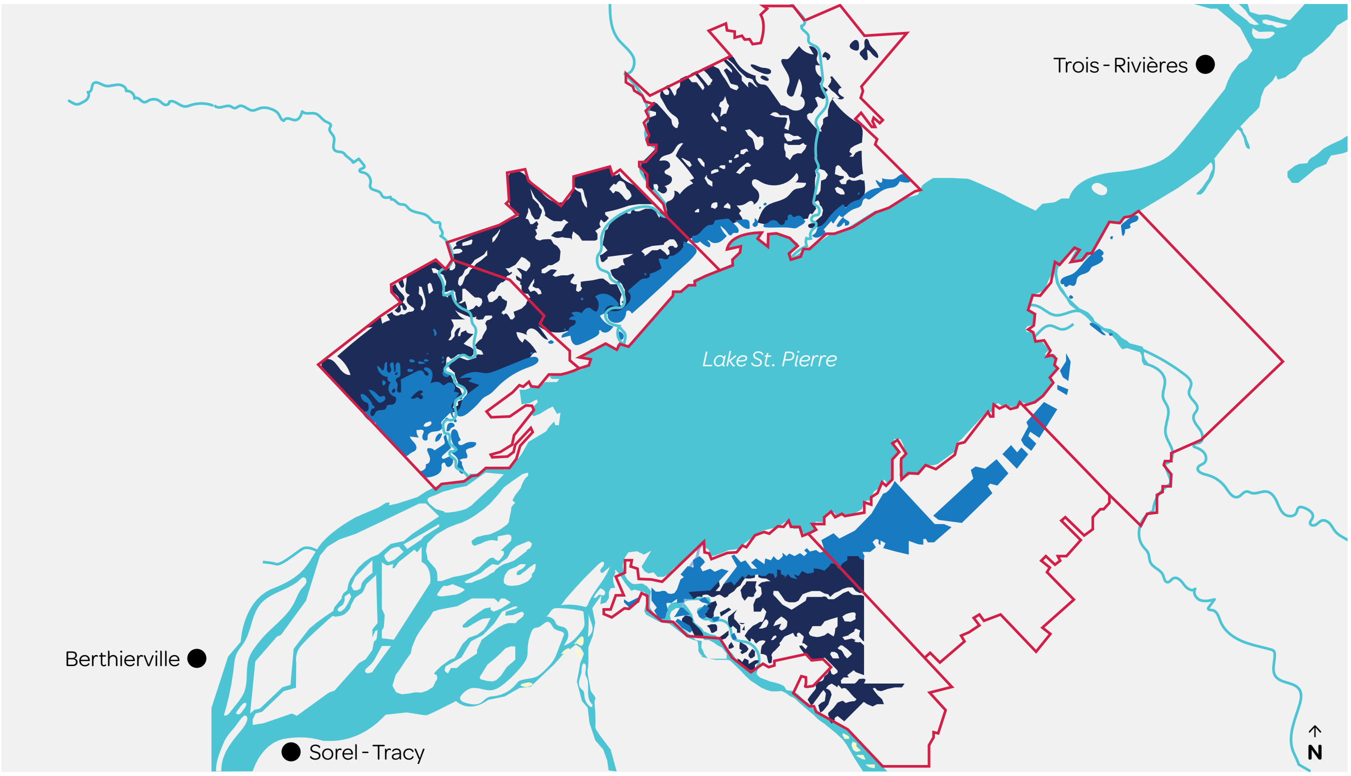


Figure 36:

SIMULATED FLOODING OF AGRICULTURAL LAND SURROUNDING LAKE ST. PIERRE BASED ON 2019 CONDITIONS

Municipalities associated to Lake St. Pierre | Flooded agriculture land | Agricultural lands

for the Lake Ontario shoreline, the GLAM Committee has been using recent aerial photographs and other materials to verify the locations of residential and commercial buildings, roadways and agricultural lands in 2017 and 2019. That same information has also been used to compare flood extent with the model output. This updated shoreline development data allows the model to generate more accurate simulation of impacts under various flow conditions.

Like the Lake Ontario modeling, the lower St. Lawrence River effort provides estimates of inundated buildings under different water level conditions for use in the DST. Waves and surge are smaller on the lower St. Lawrence River than on Lake Ontario. Nevertheless, the GLAM Committee added a component within the DST to statistically reflect the short-term (hourly) variability in levels due to winds and rapidly changing tributary inflows, etc. to better reflect the inundation data for that area.

In addition to building flooding, the lower St. Lawrence River modeling includes inundation of agricultural land. The area bordering Lake St. Pierre is home to about 500 farms. Based on model simulations of Lake St. Pierre water levels in 2017, approximately 3,300 hectares (8,150 acres) flooded, accounting for almost 11 percent of the agricultural land in the region. In 2019, about 3,600 hectares (8,900 acres), or 12 percent of the farmland, was flooded (Figure 36).

Brief spring flooding is not uncommon in this area and local growers know it takes about six weeks after a flood for the land to be dry enough to plant crops. It is the duration of the flooding, not the peak depth of flood waters, that is most critical to this analysis. In 2019 flood waters persisted for seven weeks, causing a considerable delay in planting that year and a loss in productivity.

Flooding of agricultural land was included in the impact zones categorization for the lower St. Lawrence River. While the Board should be mindful that long-duration floods can disrupt planting and greatly delay harvest there may be little the Board can do to shorten the length of the flood through deviation decisions.

Insight

Modeling provides valuable data on shoreline impacts for the DST.

4.4.4 Other activities and next steps

High water impacts to shoreline interests are a critical factor when the Board is considering deviation decisions. The information collected and modeling undertaken during the Phase 1 effort provides the Board with additional understanding of how their decisions may influence those impacts. Efforts to consolidate impact reports from both 2017 and 2019, as well as new modeling to improve estimates of flood impacts under varying water level conditions have been a crucial aspect of the GLAM Committee's work in Phase 1 of the expedited review. This information became key components of the DST, which informs the Board how impacts increase along the shoreline as water levels rise. This data also will be useful in Phase 2 of the expedited review, when it will be used to reassess the assumptions about high-water damage that were used in the creation of Plan 2014. The GLAM Committee recognizes the importance of assessing shoreline impacts and will be working to continually improve its datasets in this area.

4.5 Ecosystem response to deviation decisions

In recent years, the IJC has concluded, with govern-ments concurrence, that the ecosystems of the St. Lawrence River and Lake Ontario should be taken into account by outflow regulations (IJC, 2014). As noted previously, it has been found that the previous regulation plan, which sought to suppress the natural range in water levels, had degraded diversity of species in shoreline wetlands and caused the wetlands to be dominated by cattails (IJC, 2014).

Plan 2014 was written in such a way as to allow more natural variations of water levels of Lake Ontario and the St. Lawrence River to reverse some of the harm to ecosystems while minimizing possible increased shoreline damages. While none of the limits or deviation guidance in Plan 2014 were specifically written to protect the lakes or river ecosystems, the Board must consider potential impacts when making deviation decisions.

Since its inception, the GLAM Committee has placed particular focus on tracking wetland vegetation in response to water level fluctuations. Wetlands are valuable features on Lake Ontario and the St. Lawrence River; they provide habitat for numerous animal and plant species, play an important role in nutrient and sediment dynamics and in some cases can influence shoreline flooding as vegetation serves to dissipate wave energy. However, the wetlands indicator developed in previous IJC studies (Wilcox et al, 2005; ILOSLRSB, 2006) is less suited to support comparison of short-term Board deviation decisions during periods of extreme high water levels. Instead, the GLAM Committee focused its Phase 1 ecosystem work in the Lake St. Lawrence area where deviation decisions, particularly in the winter months, can have a more substantial influence on water level conditions and potential ecosystem response as described in 4.5.1 below.

4.5.1 Winter operation impacts on Lake St. Lawrence biota

The GLAM Committee supported a targeted effort by the St. Lawrence River Institute to examine potential impacts to flora aquatic life in Lake St. Lawrence during extreme water level declines in the winter (Figure 37). Lake St. Lawrence water levels decline naturally as ice forms. Further water level declines can occur when outflow through the dam, at the foot of Lake St. Lawrence, is very high. Such high flows likely would be the consequence of a Board deviation from rule curve or the I Limit, which normally prevents very high outflows in wintertime to protect ice cover.

As the River Institute study notes, Lake St. Lawrence was formed when the river was dammed as part of the

Figure 37: **Low Lake St. Lawrence levels at Whalen Park Boat Launch, January 2020**

Seaway construction. Villages and farm fields were submerged by the damming, and significant portions of the bottom remains flat or gently sloping. When outflows ramp up, these areas can be exposed (River Institute, 2020).

The River Institute examined six winter scenarios with increasing high outflows. The most extreme scenario resulted in Lake St. Lawrence water levels rapidly declining by 2.33 m (7.6 ft) compared to a typical navigation season level and left 27 percent of the lakebed exposed. The researchers then examined the likely impact of each scenario on mammals, fish, herpetofauna (frogs, toads, turtles and salamanders) and benthic invertebrates (e.g. crayfish, clams).

The researchers found that since the Seaway was created, it is likely there have been many instances where parts of the riverbed have been exposed during periods of low water levels. The most vulnerable areas to this have been bays on the north shore near Ingleside, Ontario and along the south shore west of Massena, New York. However, the more extreme and expeditious scenarios the River Institute considered could lead to creation of hundreds of small unconnected pools of water in which aquatic creatures would be stranded. Most such pools would be within 20 km (12.4 mi) of the power dam.

The report prepared by the River Institute notes that some aquatic life can survive being stranded for short periods of time, but not for extended periods (River Institute, 2020). The researchers said populations of at least 47 fish species, turtle species, three frog species, one salamander species and four aquatic mammal species could be vulnerable under the more extreme outflow scenarios because their winter habitats are concentrated in areas that could become exposed. Benthic invertebrates also might decline in numbers and diversity.

To fully protect all species, the River Institute recommended that Lake St. Lawrence water levels in the winter be maintained above the lowest levels observed in the autumn, since many species choose their winter habitat in the autumn. If that proved impossible, they said the level should be lowered slowly and be of as short a duration as possible. While the River Institute work is considered preliminary, the findings have been incorporated into the DST to help inform outflow deviation decisions. The GLAM Committee is looking at future options for monitoring ecosystem response in Lake St. Lawrence during ice operation periods.

4.5.2
Other activities and next steps

The GLAM Committee is tracking external research such as that being conducted by the State University of New York on the effects of muskrat herbivory and structure building on plant biodiversity in wetlands along the upper St. Lawrence River as it relates to water regulation and non-native cattail invasion (Kua et al., 2020). The committee will also be looking at additional work on the critical timing, duration and magnitude of flow and water level changes on the reproductive stages of birds, fish and turtle species on the lower St. Lawrence River.

Going forward into Phase 2 of the expedited review, the GLAM Committee will be reassessing its suite of ecosystem indicators for both short-term Board deviation decisions as well as longer-term plan evaluation. The committee will continue to focus on coastal wetland monitoring and modeling along the Lake Ontario and upper St. Lawrence River shoreline but will also be looking at what additional ecosystem metrics can be readily tracked and modeled to support Board deviation decisions and also the comparison of regulation plan alternatives.

Insight

More research into ecosystem impacts from deviations is needed.

Wetland along the St. Lawrence River

4.6 Recreational boating: Data gathered from marinas

Recreational boating and shoreline tourism can be negatively impacted by extreme high water in several ways. It is valuable, therefore, to understand more about how and when those impacts come about. The GLAM Committee focused on two key tasks during Phase 1 of the expedited review, 1) integrating findings from a survey of marina and yacht clubs following the 2017 high water event, and 2) undertaking a general review of reported recreational boating and tourism impacts to guide future performance indicator development.

4.6.1 Marina and yacht club survey

LURA Consulting undertook a study to look at the impact of the 2017 high water event on recreational boating along the Lake Ontario and St. Lawrence River shoreline (LURA Consulting, 2019a). LURA Consulting drew responses from 106 marinas and yacht clubs, 71 percent of which were located on Lake Ontario and the balance on the St. Lawrence River.

Eighty-two percent of these facilities reported negative impacts from high water in 2017, with shoreline erosion, submerged boat-launch ramps and flooding of fixed docks (Figure 38) the most common. Operators were asked to identify the water level at which they felt they could no longer do business, with an average response from Lake Ontario marinas and yacht clubs of 75.62 m (248.1 ft). Information from the LURA Consulting effort was used in the development of the DST.

Figure 38: **Brockport (N.Y.) Yacht Club, April 2017**

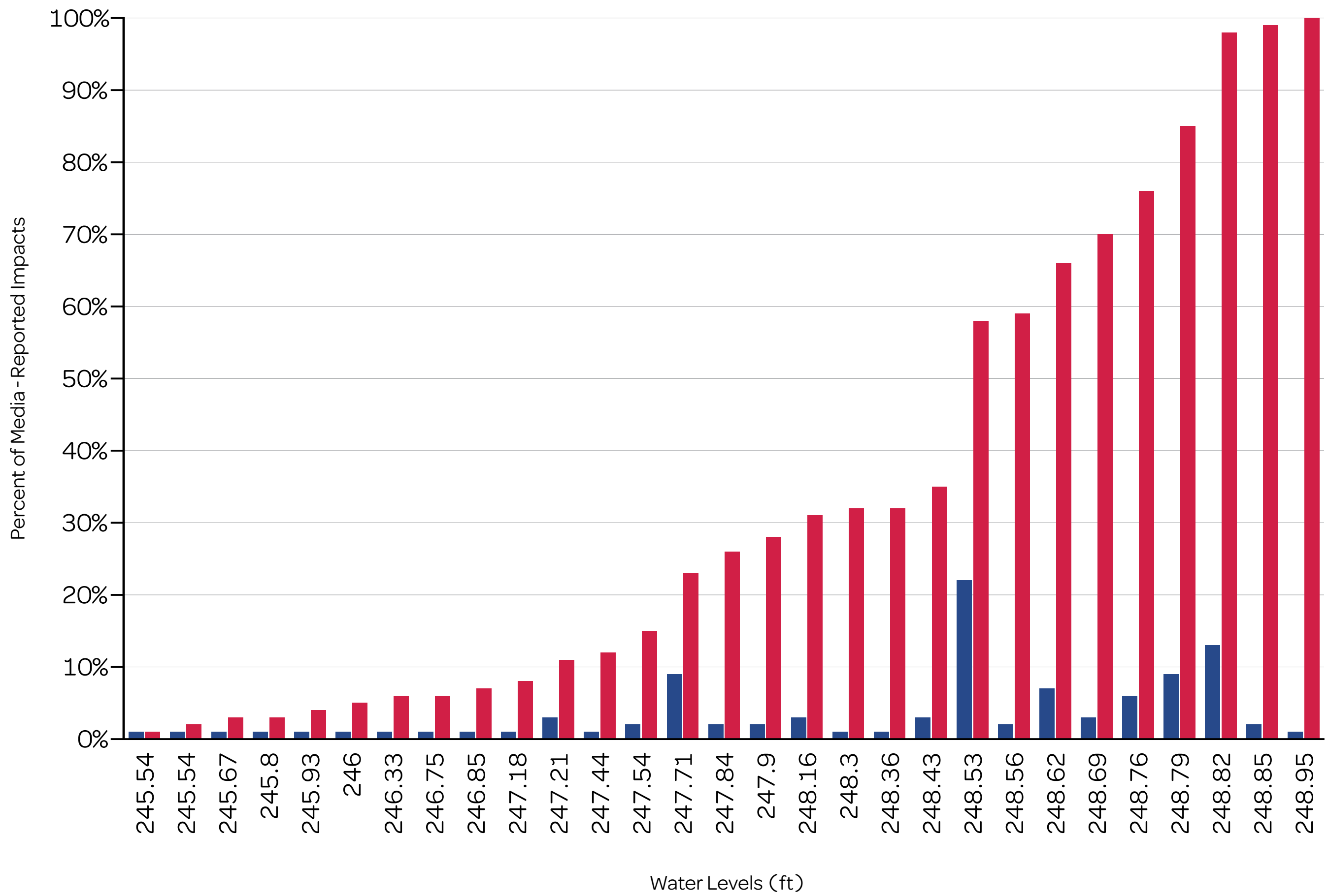


Figure 39:

NEW YORK BOATING AND TOURISM IMPACTS BY WATER LEVEL (Source: USACE, 2021b)

■ % of impacts at water level ■ % of impacts below water level

4.6.2 Identifying potential tourism impact metrics

A **study by the USACE focused on media reports** and other public materials that documented about 370 impacts on marinas, yacht clubs and shoreline parks and tourism venues on Lake Ontario in Ontario and New York (USACE, 2021b). By scouring these reports, USACE was able to determine the dates and water levels when the effects of high water were first felt in 2017 and 2019 (Figure 39). Data from the studies made clear there were specific water levels where the number of impacts jumped appreciably. The New York report provided the location of many of the impacted marinas, yacht clubs and recreation venues; coupled with the water level when the impact occurred, this provided data points for the DST that will aid the Board in deviation decisions.

4.6.3 Other activities and next steps

The studies done for the Phase 1 report documented numerous impacts of high water during the 2017 and 2019-20 events, including an inability of boat owners to get their craft in the water, submerged docks, and marinas that suffered flood damage and were unable to provide full services to boaters. There also were numerous instances of beaches and shoreline parks being closed or damaged by high water.

It should be noted that a wholly separate concern exists for boaters and marinas on Lake St. Lawrence, which is susceptible to large declines in water levels when outflows are high. This made docks unusable and made access to boats difficult at times. Further study is needed to quantify the low water impacts on Lake St. Lawrence.

The GLAM Committee has integrated the information from the recreational boating and tourism work into the DST. While the new information will provide additional information for the Board when they consider deviation options, the GLAM Committee recognizes that further work will be required in Phase 2 to supplement what has been learned so far.

Insight

Recreational boating and tourism data fills some gaps, but further data gaps remain.

4.7 Indigenous Nations

The construction of the St. Lawrence Seaway and the Moses-Saunders dam caused great disruption to the people of Akwesasne and their way of life and its operations continue to affect both the land and people of the Akwesasne Mohawk Territory as well as other Indigenous Nations. During the IJC's International Lake Ontario-St. Lawrence River Study (ILOSLRSB, 2006), the Akwesasne Task Force on the Environment prepared a report highlighting specific aspects of outflow management that impact their community (Akwesasne Task Force on the Environment, 2004). Some of the issues highlighted increased impacts to fish species and mammals that require low velocity and/or stable water levels. Increased inundation of areas where traditional medicines grow were also flagged especially because these medicines are criti-

[7] Members of the Mohawk Nation at Akwesasne

cal to the maintenance of Mohawk culture and of the relationships the Akwesasronon[7] have with the entire ecosystem. Outside of this report from 2004, there was little documentation through the International Lake Ontario – St. Lawrence River Study on impacts to First Nations, Tribal Nations or the Métis Nation further upstream on the Lake Ontario shoreline or downstream of the Beauharnois Dam on the St. Lawrence River.

4.7.1 Reaching out to Indigenous Nations

Following the high water event of 2017, the GLAM Committee led efforts to gather obtain more information and understanding on shoreline impacts associated with high water levels on Lake Ontario and the St. Lawrence River for the development of the GLAM Committee report on 2017 high water conditions (GLAM, 2018). Through this process, the GLAM Committee identified a critical gap regarding impacts to First Nations, Tribal Nations and the Métis Nation along the Lake Ontario and St. Lawrence River shoreline (downstream to Trois Rivières in Quebec). The GLAM Committee respects and recognizes First Nations, Tribal Nations and the Métis Nation's experiences and knowledge regarding fluctuating Lake Ontario and St. Lawrence River water levels and therefore initiated a process to plant a relationship and learn towards action with Indigenous Nations.

Through a competitive process, the GLAM Committee (through the IJC) retained the Ontario consultancy, People Plan Community, to engage First Nations, Tribal Nations and the Métis Nation that may be impacted by fluctuating Lake Ontario and St. Lawrence River water levels and listen to impacts, experiences and knowledge. The GLAM Committee is seeking to open a dialogue to learn more and document critical aspects that could be considered within the expedited review of Plan 2014 going forward. In particular, the GLAM Committee is interested in discussing how fluctuating Lake Ontario and St. Lawrence River water levels and particularly the extreme levels in 2017 and 2019

NOTES FROM THE EIGHT LISTENING SESSIONS THUS FAR

- There is a willingness and interest from Indigenous Nations to collaborate and share Indigenous knowledge with the IJC and the GLAM Committee as shown through high response rates, the number of sessions hosted to date, the anticipation of future sessions, as well as the request for additional and follow-up sessions and ongoing correspondence.
- There are identified impacts and concerns for land and water from fluctuating water levels, pollution, habitat loss and species decline.
- There are associated impacts to traditional activities, including restricted access to the shoreline, impacts to fishing from fluctuating water levels and medicinal harvesting from habitat loss and pollution
- Capacity issues limit participation and the ability to appropriately share traditional knowledge; nonetheless, there is an interest in exercising traditional rights through "boots on the ground" funding and resources.

directly affected Indigenous Peoples including their cultural and traditional uses of the shoreline.

People Plan Community started their work in May 2021 and will carry that work through the end of March, 2022 after the completion of the Phase 1 report. As of October 2021, initial outreach has taken place to representatives of all First Nations, Tribal Nations and the Métis Nation that reside directly along the Lake Ontario and St. Lawrence River shoreline as well as those Indigenous Nations that maintain Treaty and Indigenous rights along the shoreline. To date eight meetings have been held, with up to five others planned (as previously listed in Section 2.8).

Insight

Indigenous Nations have valuable insights into water and water-level issues, and are directly impacted by outflow management.

4.7.2 Other activities and next steps

The GLAM Committee views these Indigenous engagement sessions as a first step in a long-term effort to review Lake Ontario outflow management. As such, the committee did not want to be constrained by the time limits of Phase 1 of the expedited review. While information gathered through the process can support Phase 1 reporting and contribute to the initial prototype DST for deviation decisions, the First Nations, Tribal Nations and the Métis Nation engagement effort is meant to inform the broader Phase 2 plan review.

The GLAM Committee will continue following up with First Nations, Tribal Nations and the Métis Nation to coordinate initial listening sessions based on interest and availability of each community. The GLAM Committee will remain flexible and extend their availability in order to build trust, plant a relationship to meet the needs and timing requests of individual communities to support a long-term effort to ensure Indigenous voices in the regulation plan review and on-going adaptive management process.

Insight

Outreach to Indigenous Nations created connections, and provided some impact information. More outreach is needed in Phase 2.

5

GLAM Committee's Decision Support Tool

5.0

GLAM Committee's Decision Support Tool

Phase 1 of the expedited review of Plan 2014 centered on supporting International Lake Ontario – St. Lawrence River Board (Board) deviations by addressing gaps in knowledge. As Board members themselves told the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee, they need more information about the potential outcome when they choose a deviation strategy or decide against it. Previously, the Regulation Representatives were able to give the Board the outlines of changes to water levels that each proposed deviation would bring but the associated impact information was largely anecdotal and based on past operational experience.

Board members have said that what they want is a factual understanding of the trade-offs that accompany deviations — the benefit of changing the outflow to aid one interest or region versus the harm that outflow change might bring to another interest or region. Board members need insight into the uncertainties about the impacts that near-term and longer-term weather will have on the water levels and flows they are altering when they deviate.

The Decision Support Tool (DST) addresses these needs by making the Board's work better-informed, more systematic and based on objective, vetted information.

The DST is not a panacea. It cannot eliminate uncertainty about future water supply. There are gaps in knowledge and capability that

DECISION SUPPORT TOOL BENEFITS

Based on the forecasted water levels, the tool will display the broad-based impacts of each deviation option being considered. It will, for instance, allow the Board to judge how many properties along the St. Lawrence River and Lake Ontario shorelines would be inundated if a particular deviation is pursued and how much harm, if any, that deviation would do to commercial navigation.

The tool offers Board members close-up views of a variety of impacts on specific communities on the Quebec, Ontario and New York shorelines, as well as on Lake St. Lawrence. Members can drill down to better understand what might happen in a community they know – how many properties might flood, how many roads might be under water, how recreational uses might be unusable. A feature known as "impact zones" will help Board members compare the impacts from one community to the next.

For the specific communities, rich descriptive information and local context is provided in a supplementary interactive map product. Currently, a single example is available with the expectation of developing ones for additional locations in the future.

These metrics track how impacts would change over time, as waters rise or recede. This function is enabled by a DST feature that addresses the uncertainty of not knowing what the weather will bring: Board members can see how deviation options would play out under a variety of future water supply scenarios.

make it impossible for the GLAM Committee's DST or any other tool to provide complete assurance that a deviation will bring the result the Board intended. (See Section 5.5 for more on risk and uncertainty).

The Board still will have only incremental influence on water levels. But the tool still represents a valuable step forward because it allows the Board to act with much more knowledge than before and a new ability to understand impacts among the many competing uses and interests. The DST now offers insight into the impacts of extreme high water; during Phase 2 of the expedited review, the GLAM Committee will add data about low-water impacts as well.

Decision support tools are increasingly used in a variety of settings, including water resource management. The Lake Ontario-St. Lawrence River DST was modeled after a tool that scientists created for the IJC's International Upper Great Lakes Study (http://www.iugls.org/) which led to a new water-level regulation plan for Lake Superior in 2014.

The GLAM Committee assembled the DST with the support of US Army Corps of Engineer's (USACE) Institute for Water Resources. The Committee relied on a great deal of help from the Board, the PAG and others. Board members have already begun making practice decisions using the DST through a series of GLAM Committee-led workshops to review, evaluate and provide feedback in the real-time development of the DST. These practice runs are expected to continue as the DST transitions to a tool available to support Board deviation decisions.

As helpful as it should prove to be, the DST neither recommends deviations to the Board nor makes deviation decisions for it. Those decisions remain the sole responsibility of the six Board members themselves.

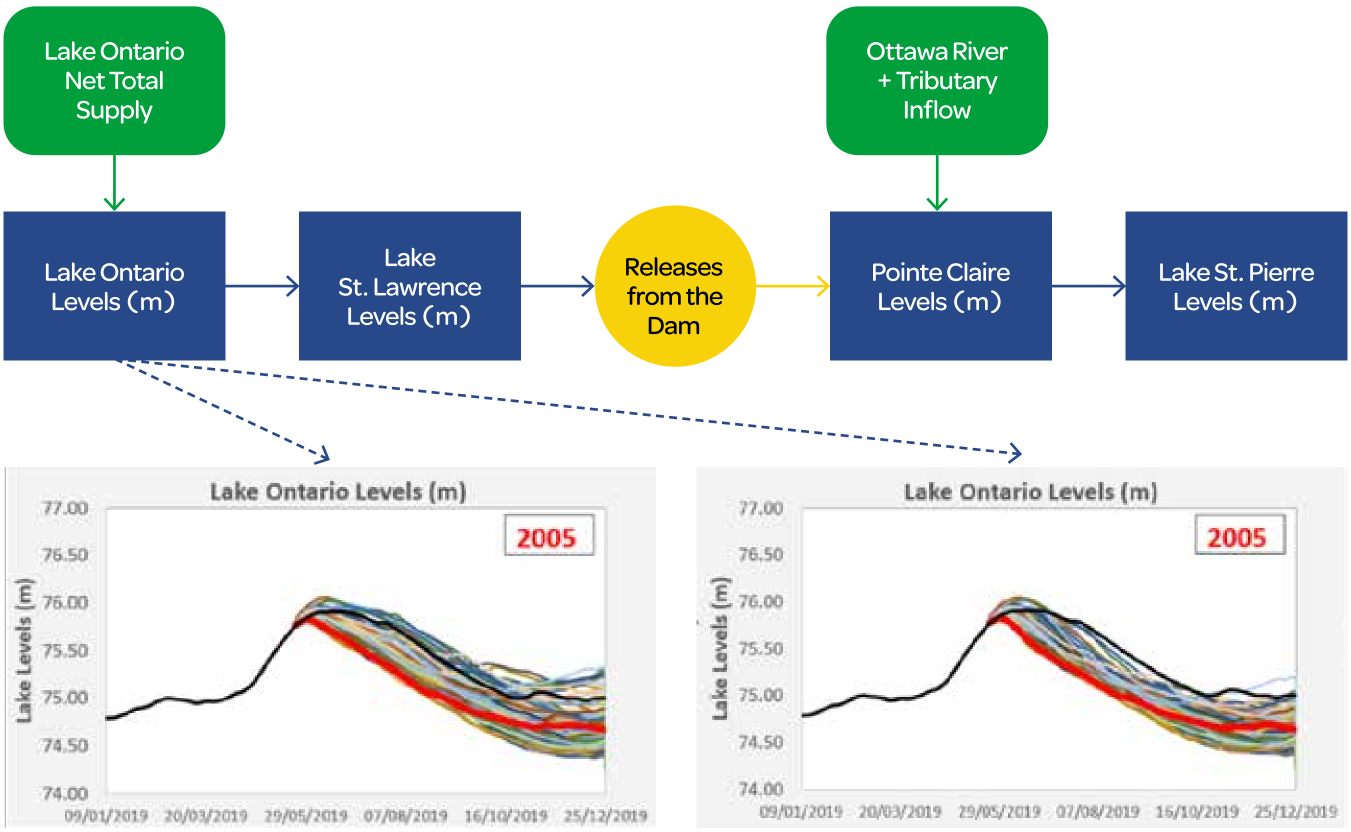
5.1 Decision Support Tool water-supply forecasts

It is useful to know the impact of an outflow change the first week that change is in effect. But Board members have to be concerned that an unexpected change in the Lake Ontario water supply farther into the future could eliminate the benefit of a deviation or worse, cause a benefit to suddenly become a detriment.

For some years, the Board has been given weekly forecasts of the water supply in the coming six months that are binationally coordinated. These forecasts are based on actual supplies in the years from 1900 to 2007 plus near-term precipitation outlooks. The "most likely" water supply in the coming months are modeled as well as possible high and low extremes.

These products are by nature imprecise. There is no way to really know Lake Ontario's future water supply — no way to accurately foresee a rainy summer or a dry one, a fall with unusually high evaporation rates, a winter heavy with snow or a spring freshet that comes weeks earlier or later than normal. Any of those factors can cause relatively sudden rises or dips in Lake Ontario's net basin supply and significantly alter the flow in the St. Lawrence River.

The DST speaks to that problem of uncertain hydrological conditions by giving the Board a chance to see how a deviation option would play out in a variety of water-supply scenarios. The Board can continue to consult the forecasts it has been receiving. But they



Range of possible water levels from Deviation Strategy 1

Range of possible water levels from Deviation Strategy 2

Figure 40:

ILLUSTRATION OF FORECAST INPUTS (GREEN) AND OUTPUTS (BLUE AND YELLOW) ALONG WITH ILLUSTRATION OF COMPARISON FORECAST GRAPHS FOR LAKE ONTARIO LEVELS (WATER SUPPLIES SIMILAR TO 2005 HIGHLIGHTED IN RED)

also can select six-month forecasts based on the actual water supply in any year between 1900 and 2007, or the average supply in any sequence of those years. If the Board wants to see conditions that mirror the supply in 1976, or the average supply in the years from 2000 onward, they can do so with the click of a computer mouse.

The Board also can consider "more extreme" scenarios within the DST, such as a six-month period in which basin-wide precipitation breaks the record set in 2017 and inflow from Lake Erie and the Ottawa River is greater than the records set in 2019, or a 1-in-500-year water-supply sequence generated through a statistical analysis. These options were generated by the GLAM Committee's Hydroclimate Working Group in a study done to support the expedited review (GLAM, 2021b).

There is no certainty that any of these six-month scenarios will come to pass. But their availability will give Board members at least some sense of a deviation's potential impact under a wide range of possible future meteorological conditions.

Once one or more water supply sequences have been selected within the DST, the Board can view in graphical form how deviation strategies would change water levels and flows in the coming six months. As many as three possible deviation plans, each with a different way of adjusting outflow, can be compared side by side. For comparison, the tool also will show what the water levels would be if no deviation were put in place and what the levels would be if the Seaway project had never been built. (This comparison is needed because the IJC's 1956 Order of Approval includes conditions that the operation of the project works provide no less protection for navigation and downstream interests than would have occurred without the project.)

To illustrate how water supply conditions can be compared, Figure 40 shows the Lake Ontario and Ottawa River/St. Lawrence River tributary water supply conditions used to generate water level and outflow forecasts at some of the key locations throughout the system. The two related graphs illustrate the Lake Ontario water level forecast for the same water supply sequences but using two outflow strategies. Observed conditions are shown as the single black line, and the various colored lines are possible water level forecasts for a range of water supply sequences. The red line in the two water level graphs represents the forecast using water supply conditions similar to those observed in 2005. In other words, if water supplies would be similar to those observed in 2005, the two graphs show the possible differences in Lake Ontario water levels given the two deviation strategies.

Board members can compare different water supply scenarios and possible deviation strategies, gleaning insight into potential outcomes throughout the lake-river system in a more objective, comparable and systematic way. Board members get a sense of how impacts might change over a range of hydrologic conditions and different deviation decisions. This is made possible by an array of metrics at their fingertips that impart information about high-water impacts on Lake Ontario and the St. Lawrence River that has never before been assembled and presented in this way.

Insight

The DST addresses uncertainty caused by a lack of skilled forecasts and a changing climate through scenario testing.

5.2 Metrics: Impact zones and broad-based views

The DST gives Board members a dynamic way to estimate the type and scope of impacts from extreme high water, to see how impacts might change over time or to see in graphic terms how a proposed deviation might ease some of those impacts — or make them worse. The tool will show how a proposed deviation would change impacts compared to the no-deviation option.

The tool does not observe actual impacts on the fly. Instead, it draws on a database of known impacts during the 2017 and 2019-2020 events and projects which of those impacts are likely to recur at any given water level. The DST provides this information on several levels. First, the tool offers broad-based metrics that shows the total number of buildings on and near the shoreline that would be inundated by flood waters at a particular water

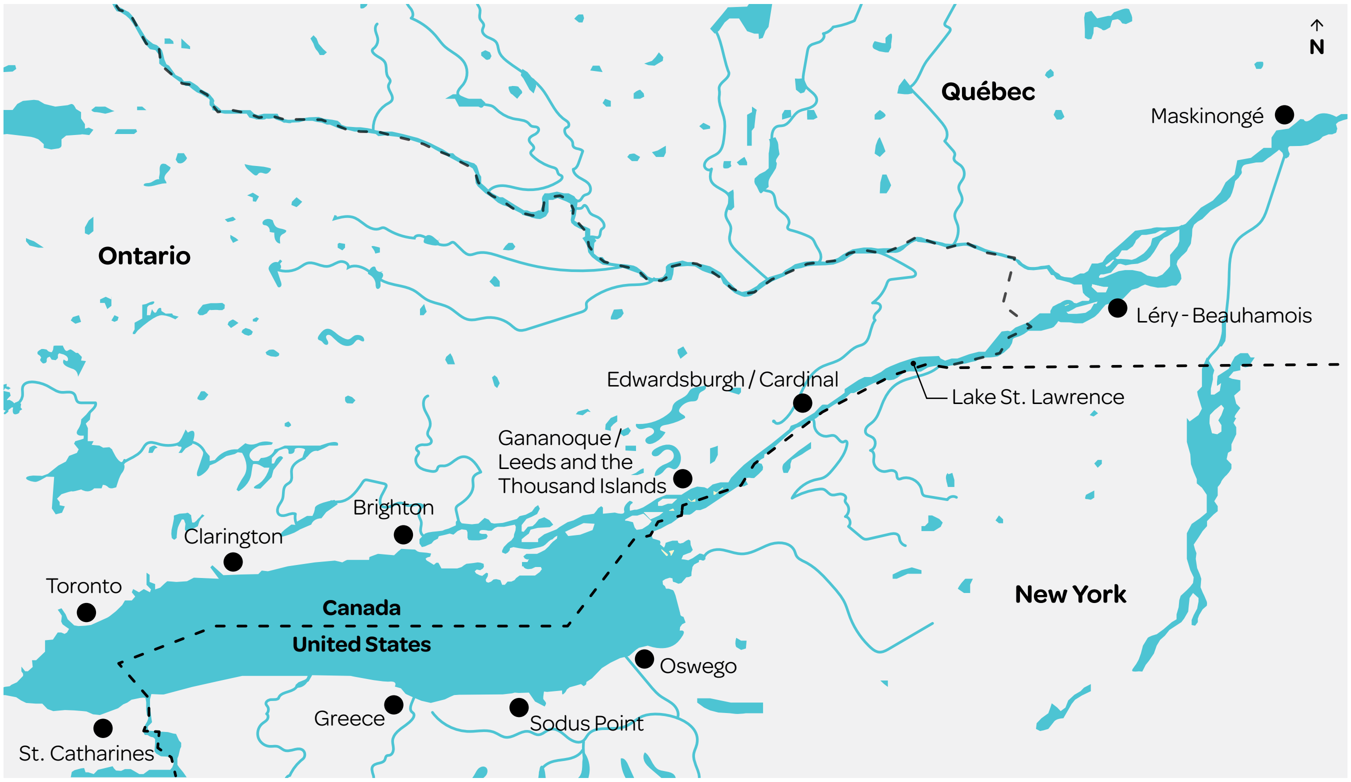


Figure 41:

LOCATIONS WITH IMPACT ZONES (Source: GLAM Committee)

Provincial border   International border

level in Lake Ontario or rate of flow in the St. Lawrence River. This information was derived from innovative modeling work by the USACE team in Detroit as well as ECCC in Québec City and Burlington. In response to suggestions from the PAG, the DST can display these broad-based building estimates as a rough approximation of the number of people potentially impacted based on census information on average household size.

Another view is more close up. It was created because Board members asked for a sense of on-the-ground impacts, a request that was strongly reinforced by the PAG. The Board was also interested in the breadth of impacts, beyond just building impacts. In response, the GLAM Committee selected 12 distinct locations for which to chart localized impacts (Figure 41).

- **Seven communities on Lake Ontario:** Oswego, Sodus Point and Greece in New York state, and St. Catharines, Toronto, Clarington and Brighton in Ontario.
- **Two communities on the upper St. Lawrence River:** Gananoque/Leeds and the Thousand Isand, Ontario in the Thousand Islands section and Edwardsburg-Cardinal, Ontario near the head of Lake St. Lawrence.
- **Lake St. Lawrence as a whole.**
- **Two communities on the lower St. Lawrence River:** Lery-Beauharnois on Lake St. Louis, and Maskinongé on Lake St. Pierre in Quebec.

The initial 12 locations were chosen because they are known to be sensitive to extreme water or are considered representative of larger stretches of the shoreline; some of the selected communities are small waterfront villages, others are subdivisions with rows of shoreline homes, others are more urban and some are mostly rural. The list is not meant to be final; more areas that are sensitive to water-level fluctuations will be added over time.

Drawing on extensive research of the extreme high water in 2017 and 2019, conducted for Phase 1 of the

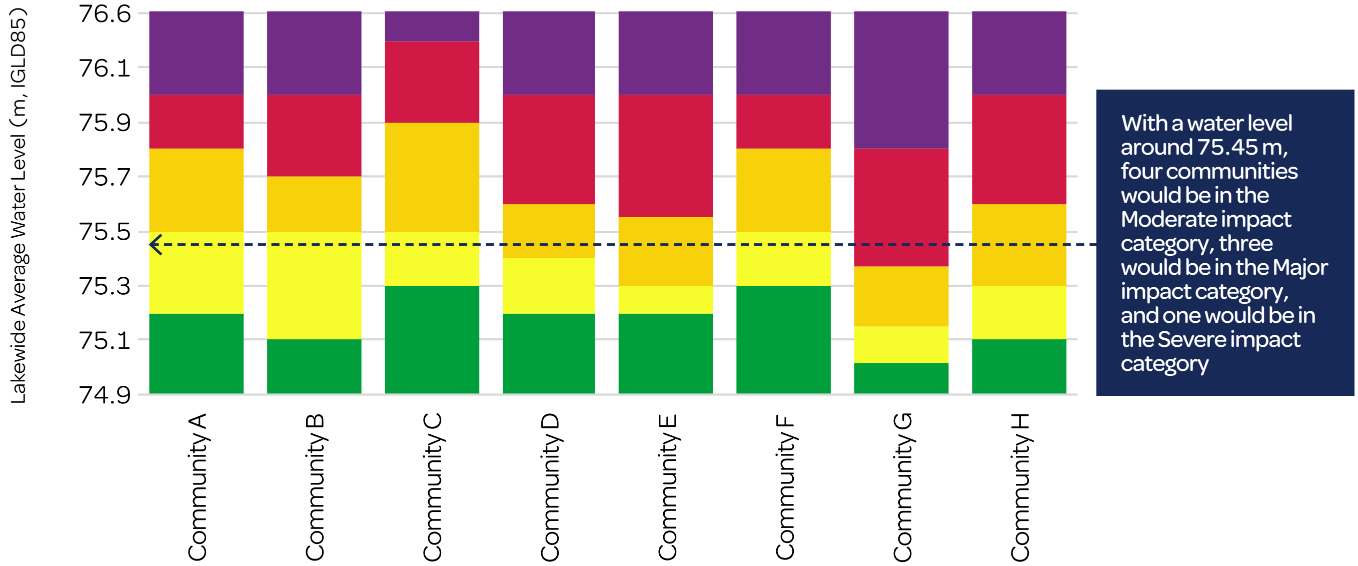


Figure 42:

CONCEPTUAL ILLUSTRATION OF DIFFERENCES IN COMMUNITY IMPACT ZONES. EXAMPLE IMPACT ZONES FOR A NUMBER OF DIFFERENT COMMUNITIES AROUND LAKE ONTARIO.

Low Moderate Major Severe Extreme

expedited review and described in Section 4.0, the GLAM Committee cataloged the type of impacts that occurred in the 11 shoreline communities — water washing over a lawn, disabling a private septic system, flooding a marina parking lot or forcing the closure of roads or parks, for example. Then the committee compiled the reported water levels associated with each of these impacts at the 11 locations. This became the framework of a DST feature that shows the Board in detail what impacts are expected at each of these locations as water levels rise and fall.

To improve the ability to readily compare the impacts at the 11 communities, the GLAM Committee divided the observed impacts into five color-coded categories of increasing severity using common criteria. Annoyances and relatively minor problems such as flooded lawns were lumped in a "low concern" category, for instance. The most damaging impacts, such as large swaths of shoreline residences with flooded foundations, were placed in an "extreme concern" category. The GLAM Committee then noted the water levels at which each category of impact occurred to shoreline residences at all 11 locations.

There was considerable variation. Some low-lying communities will suffer flooded streets and sewers at water levels that pose few problems elsewhere. The homes in other communities sit well above flood waters on bluffs, but those same bluffs are subject to significant erosion when levels are high. Still other communities lie downwind of prevailing winds and tend to suffer the worst impacts from storm-driven waves and surge. The variability in impacts is evident in the different water level ranges for each location (Figure 42). For the same water level (75.45 m IGLD85 in the example), some communities would be in the moderate impact category, some in the major, and one would already be experiencing extreme impacts.

The GLAM Committee used this information to create impact zones for each of the 11 communities. These

Brighton - Impact Zones			
			Shorline Property
Context			The Municipality of Brighton, ON has a population of 11,844 (2016) and is located on the north shore of Lake Ontario just west of the Bay of Quinte. The shoreline of Brighton has considerable residential / private property. It is estimated there are about 1,600 buildings directly along the shoreline or near the shoreline and below 78m elevation. There are around 620 buildings below 77 m and around 430 of those are estimated to be main residential buildings. There are approximately 67 km of shoreline in Brighton, including considerable amount of wetland shoreline and the Presqu'ile peninsula.
Lake Conditions	**Thresholds (m IGLD85)**	**Thresholds (ft. IGLD85)**	
Extreme	> 76.0	>249.4	Many home foundations flooded at static water levels; A high number of shoreline homes at risk of foundation flooding with expected reports of first floor inundation to many primary structures. Flooding along Harbour Street, and flooding of only access road to Gosport Peninsula (a residential area). High risk of wave damage to structures during even small storms. Around 250 main buildings with foundation elevations below 76.5 m. Up to 620 buildings with elevations below 77 m and at greater risk of impact during big storms.
Severe	> 75.8 and ≤76.0	>248.7 to ≤249.4	Some home foundations flooded at static water levels; Many primary structures at risk of water at the foundation with storms and / or some with first floor inundation reported to primary structures and / or inability to use septic systems at many locations. Widespread risk of storm – event flooding on open areas of Brighton shoreline. Approximately 100 homes affected at these levels in 2017 and 2019 according to municipality – sandbagging required.
Major	> 75.5 and ≤75.8	>247.7 to ≤248.7	A few home foundations flooded at static water levels. Critical low lying areas at widespread risk of storm - event flooding on open areas of Brighton shoreline. Foundation / crawlspace, outbuildings, decks, septic systems, shorewells, utility, road access, and signficant dock and lawn flooding commonly reported from questionnaire responses. Risk of water at foundations to some homes – sandbagging necessary
Moderate	>75.3 and ≤75.5	>247.1 to ≤247.7	Residential and property flooding occurs during the most extreme storm events. Elevated risk of storm event flooding for open areas of shoreline. Flooding of lawns and impacts to shoreline docks / boathouses and / or inability to access property reported through questionnaire responses at some locations. A few shoreline homes (<5%) at risk of water at foundation with storms. A few reports of septic issues within questionnaire responses.
Low Concern	≤75.3	≤247.1	Common summer peak water levels - some risk during spring or fall with higher portential of larger storms and erosion. First impacts reported starting at ~75.0 m (246.0 ft) from questionnaire responses. Almost no home foundations flooded at static water levels; few to no homes at risk of water at foundation with storms. Almost no reports of septic issues in questionnaire responses.

Table 9:

EXCERPT FROM OUTPUT FOR BRIGHTON, ONTARIO IMPACT ZONE

Note, this is a preliminary version that will continue to be modified through the adaptive management process

(Source: GLAM Committee)


Lake Ontario near Brighton, Ontario, Canada

impact zones are sets of water levels, or zones, that cause low to extreme impacts to residential properties at each of the sites. Table 9 provides an example, with the understanding that all the impact zones will be refined and improved as new information is gathered through the adaptive management process.

Within these impact zones, the GLAM Committee also identified water level-and-impact data pertaining to other uses and interests at each of those 11 communities — marinas and yacht clubs; recreational boaters; parks, roads and other municipal infrastructure; public and private water systems and, for Maskinongé on Lake St. Pierre, agricultural land.

The result of this laborious and admittedly complicated work, which was done on a very tight timetable, was a dynamic feature of the DST that shows which impact zones are in place at each of the 11 communities when the water is at a given level.

On the DST's map displays, the impact zones are color-coded. At a glance, Board members can see an accurate reflection of which communities are likely to suffer "major" impacts from that water level, for example, and which can expect impacts to be "severe." They can see how the degree of impact might change as a deviation strategy begins or ends, or as time passes. The Board can look more closely at any community they choose to see in detail what the impacts would be there. The tool allows the Board to judge the duration of flooding in various locations, including those where agriculture is a dominant land use.

The DST also offers a text description, based on the data collected about the 2017 and 2019 high-water events, of the kind of impacts expected at that site for each impact zone. The narratives cover not just shoreline buildings but local marinas, parks, water systems and municipal infrastructure.

Impact zones have similarly been created for a twelfth location, Lake St. Lawrence, which is hydrologically unique from the rest of the system because it serves as the forebay to the Moses-Saunders dam. Lake St. Lawrence's levels drop quickly when flows through the dam are increased and conversely Lake St. Lawrence's levels rise rapidly when outflows are decreased. Lake St. Lawrence's water levels have impacts on hydropower generation, commercial navigation, recreational boating, the local ecosystem and water systems located there, and those elements are included in the Lake St. Lawrence impact zones.

To provide additional information about each community where impact zones were developed, the GLAM Committee developed a prototype interactive map product, or story map, for one of the communities. A story map, in this context, is a visual asset built on an ArcGIS framework; it is a technique IJC has used in other watersheds to provide easily accessible information about locales.

The Brighton story map displays the inundated-building data for the shoreline but incorporates many other elements: a detailed description and photographs of the community during high water periods and the location of local resources such as docks, parks and water-treatment plants. The GLAM Committee tapped census data to provide information about the population such as age and income that speaks to the community's ability to cope with extreme high water based on recommendations from the PAG. The GLAM Committee is working on at least two more story maps in the near term, for a community in Quebec and another in New York. The goal is to eventually develop story maps for each location highlighted by an impact zone if the Board determines they would be helpful.

The GLAM Committee has begun to meet with community representatives to discuss and validate existing data and will continue to do so. It is possible some of the impact zones or the data underlying them will be altered over time as part of an adaptive management process. The GLAM Committee also plans to add impact zones focused on Indigenous communities and on aspects of the Lake Ontario and St. Lawrence River ecosystems. The impact zones, then, are a work in progress, but the GLAM Committee is confident these first iterations represent a good starting point in defining water level sensitivity.

Insight

More data is needed to improve and refine the DST.

5.3

Summarizing and visualizing the data in the Decision Support Tool

The DST offers Board members a rich cache of data that offers many different views of metrics described above. The data are presented graphically so that it can be grasped quickly.

Some of the graphs (Figure 43) allow the Board to compare how deviation strategies might perform for specific water supply sequences in a selected year. In the figure, observed conditions are shown in black. The forecast water level with no deviation is shown in white, while deviation strategy 1 and 2 are in brown dashes and solid brown respectively. In all cases, water levels would be high enough to reach into the severe impact category given the selected water supply sequence. Deviation strategy 1 would be very similar to the baseline for Lake Ontario levels while deviation strategy 2 slightly increases the rate of lake level reduction.

The DST also lays out the impact of proposed deviations on commercial vessels in the St. Lawrence River. At present, the output is expressed both as the tons of cargo delayed or disrupted and as the sum of money lost under deviation scenarios that force stoppages on commercial navigation. This metric makes use of the Institute for Water Resources study that estimates the tons of cargo delayed and financial cost by navigational stoppages. Board members have never had access to this material previously.

At present, this is the only DST metric that estimates impacts in dollar terms, making it difficult to compare those values with other metrics such as the number of buildings inundated. But the economic data do provide the Board with context about the regional implications

DECISION SUPPORT TOOL GRAPHIC EXAMPLES

- An estimate of the number of buildings across the full system that might be impacted under both calm and transitory wind-driven conditions
- The number of days the water level at each of the 12 locations will be in the major, severe or extreme impact zones
- The highest level the water would reach under a given deviation and future water supply or a plot of changes in water levels over the coming six months
- The number of buildings at each of the 12 locations that would be inundated by high water

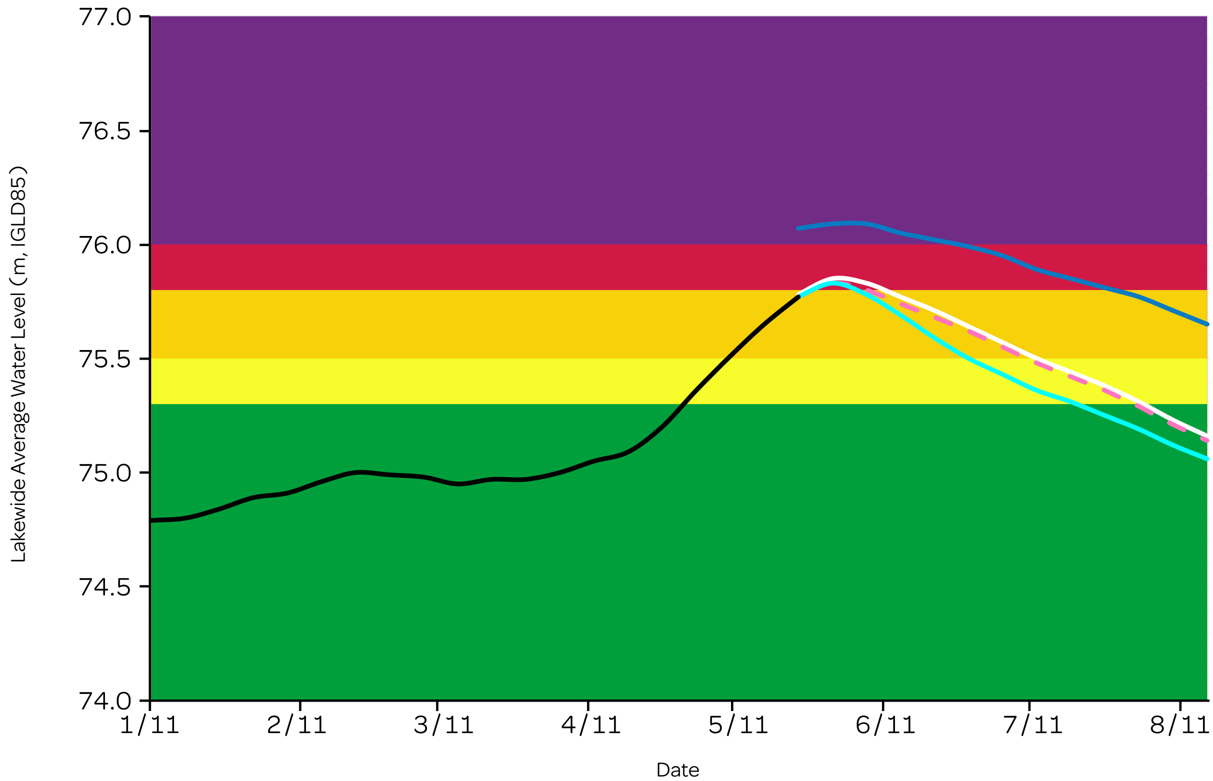


Figure 43:

GRAPHICAL ILLUSTRATION COMPARING FORECASTS FOR A SINGLE WATER SUPPLY SEQUENCE USING DIFFERENT DEVIATION STRATEGIES RELATIVE TO EXAMPLE IMPACT ZONES.

Low Moderate Major Severe Extreme

Observed Pre-Project Deviation Strategy 1 Deviation Strategy 2 Baseline

of an interruption of commercial navigation and an objective examination of costs that can be used to verify any impact information the Board receives directly from the commercial navigation sector. Going forward, the GLAM Committee will be looking to integrate economic information for other sectors as well.

Insight

The DST, based on the GLAM Committee's research, responds to the Board's need for more information.

5.4

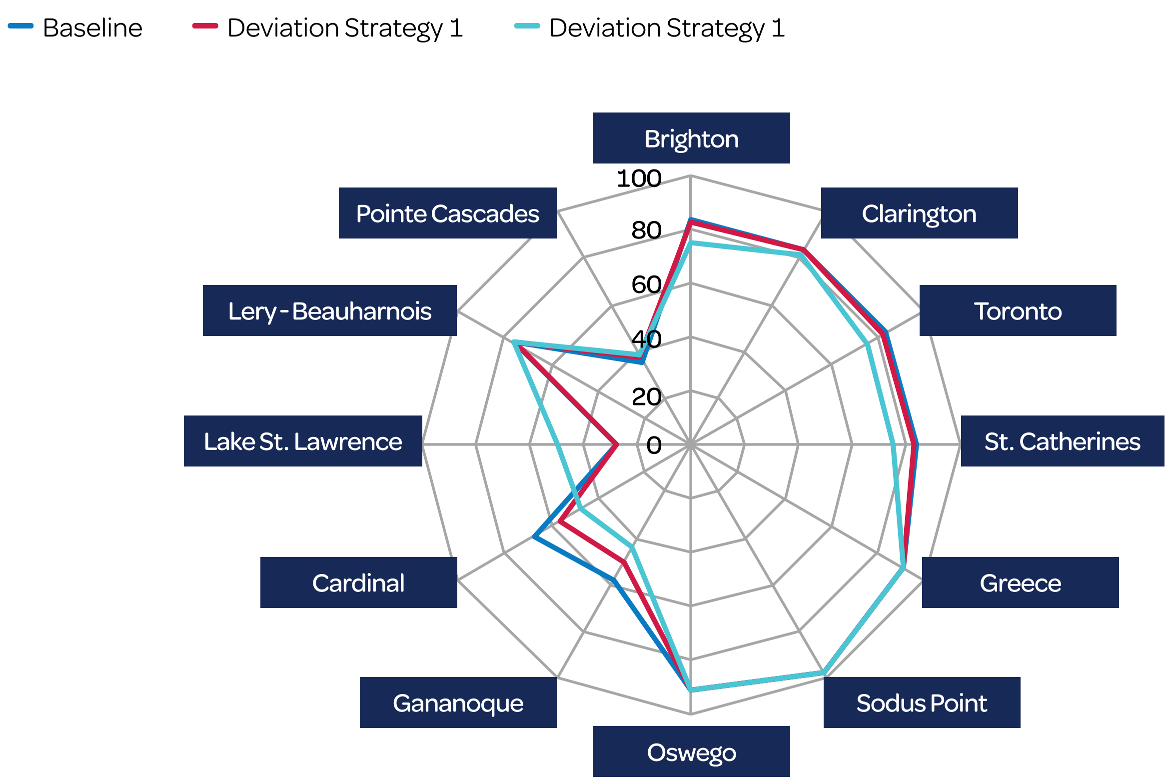
Tradeoffs displayed in the Decision Support Tool

Rarely does a decision improve outcomes for every interest in every category. When a potential deviation decision will produce a mix of outcomes — some better and some worse than those that would be produced by Plan 2014, the Board must weigh the merit of moving ahead with that deviation. This is among the most difficult, and at times controversial, aspect of their job.

The DST will aid in tradeoff decision-making. A section of the tool offers direct comparison of impacts on the uses and interests that most often are involved in a proposed deviation's positive-negative equation. A prime example: Properties on the shorelines of Lake Ontario, the upper St. Lawrence River and the lower St. Lawrence River (Figure 44 and Figure 45). As noted previously, a reduction in water levels that might ease flooding for Lake Ontario riparians can worsen conditions for both riparians on the St. Lawrence River.

Figure 44:

ILLUSTRATION OF TRADEOFFS BETWEEN IMPACT ZONE COMMUNITIES BASED ON THE EXPECTED NUMBER OF DAYS AT OR EXCEEDING THE MAJOR WATER LEVEL CATEGORY USING THE 80TH PERCENTILE OF FORECAST SCENARIOS



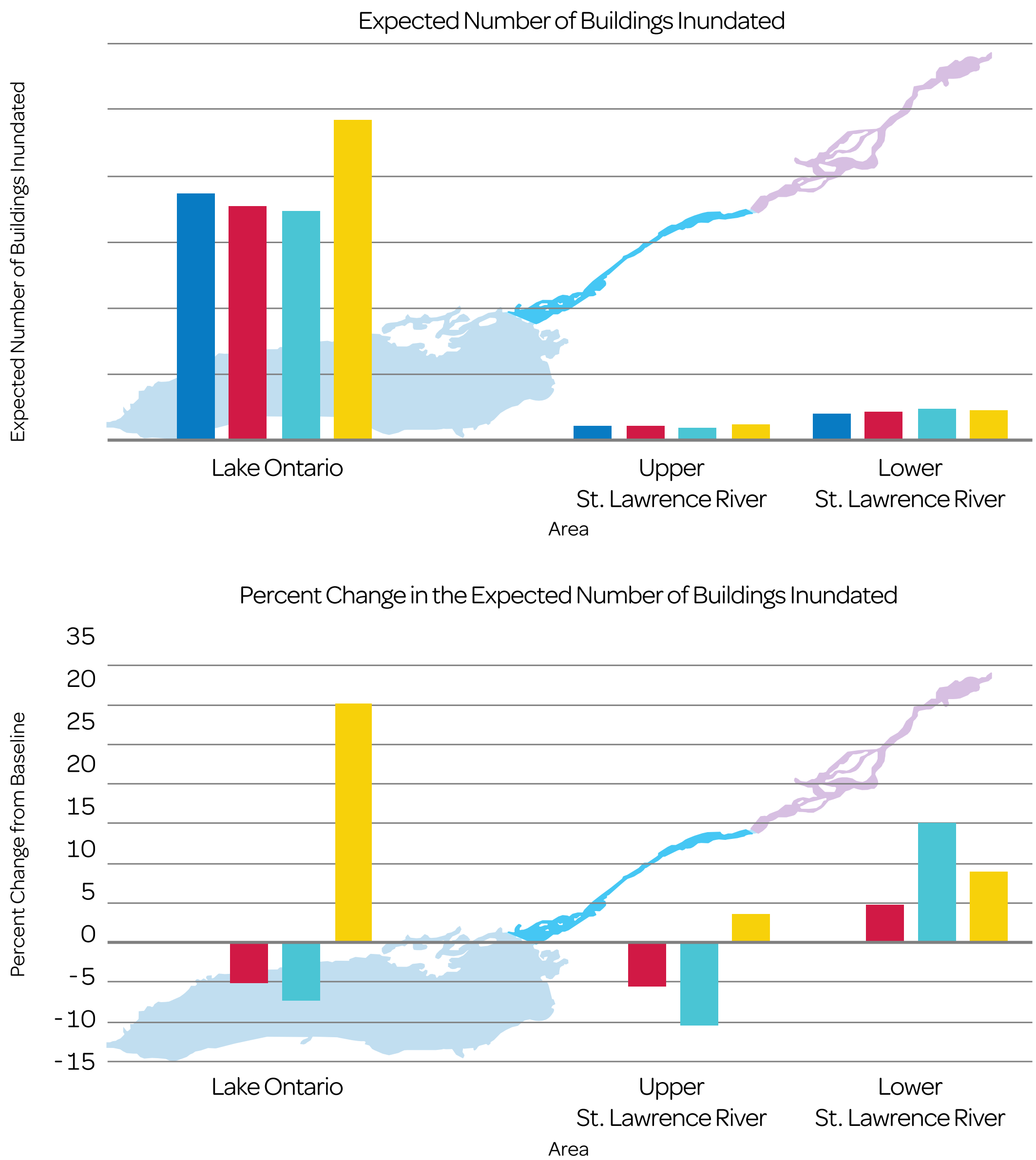


Figure 45:

ILLUSTRATION OF THE NUMBER OF BUILDINGS IMPACTED UPSTREAM AND DOWNSTREAM (includes the expected number of buildings impacted and associated percent change in the expected number of buildings inundated as could be illustrated in the DST under different outflow scenarios for different parts of the system)

— Baseline — Deviation Strategy 1 — Deviation Strategy 2 — Pre-Project

Using the inundated-buildings metric, the tool shows how a proposed deviation would impact shoreline properties, aggregating the numbers for the shoreline regions of Lake Ontario and the upper and lower St. Lawrence River. The tool also includes a snapshot of impacts by sector — buildings inundated on the Lake Ontario and St. Lawrence River shorelines, tons of commercial cargo delayed.

In a number of ways, the tool highlights the choice the Board faces when it considers a proposed deviation from the F (flood) Limit: how to fairly apportion high-water impact among upstream and downstream riparians. It also informs L (shipping) Limit deviations that may impact the commercial navigation industry, and it will also help with I (ice-formation) Limit decisions with a focus on ecosystem impacts on Lake St. Lawrence.

The DST gives the Board improved data to help it understand the tradeoffs of risks that might be required by proposed deviations, and as it ponders questions that rise from such deviations: Could a deviation help now but cause problems later? If so, how bad could those problems be? Where do impacts linger the longest and where are they short-lived? Do a large number of people in one part of the system benefit slightly while a much smaller number elsewhere are hurt badly? Is there a risk that the benefits of a regulation decision could be negated by other complicating factors, such as high wind and waves or a sharp change in weather conditions?

While the data and information will never be perfect, the tool allows the Board to better compare the impacts of different deviation strategies across the system and glean answers to those questions and others. This is only possible if the Board has trust in the information and data being presented. It is imperative therefore that the tool be continually updated and verified and the tool maintained by expert support staff trusted by the Board.

Insight

The DST helps the Board to better understand tradeoffs and compare deviation strategies, and will require continual maintenance and improvements to stay relevant for the Board's use.

5.5

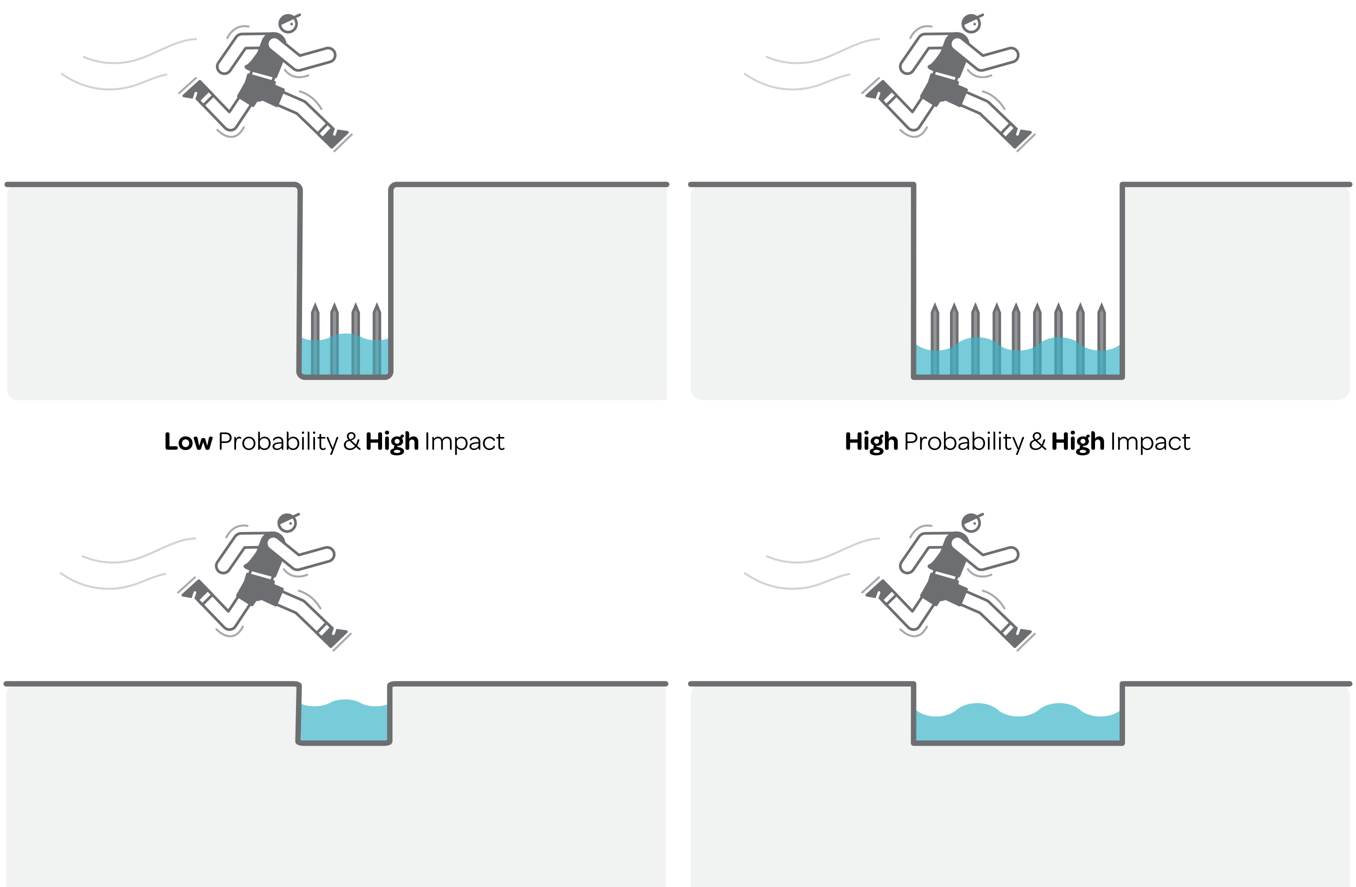
Risk and uncertainty and the Decision Support Tool

Risk and uncertainty surround Board deviation decision-making. Risk is a measure of the probability and consequence of uncertain future events. It is the chance of an undesirable outcome (Yoe, 2017).

As simplified in Figure 46, risk is a measure of how bad an impact will be and the probability or likelihood of it happening.

Figure 46:

ASSESSMENT OF RISK EXPOSURE.
RISK = SEVERITY OF IMPACT TIMES THE PROBABILITY OF OCCURRENCE
(modified based on original graphic from TheProjectManagementBlueprint.com, used with permission, copyright Mark Warner, TheProjectManagementBlueprint.com)



Low Probability & **High** Impact

High Probability & **High** Impact

Low Probability & **Low** Impact

High Probability & **Low** Impact

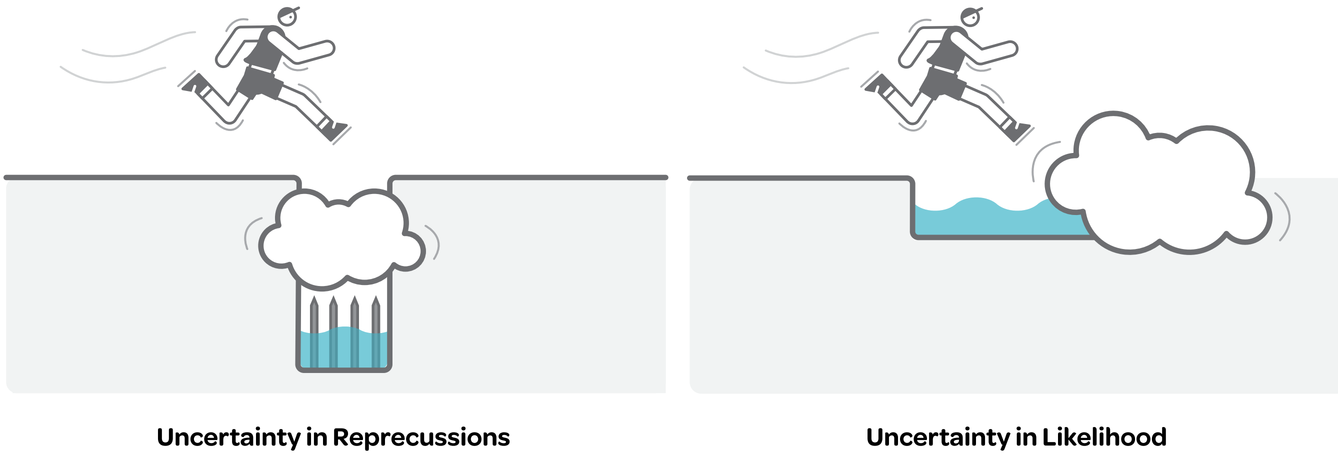


Figure 47:

IMPLICATIONS OF UNCERTAINTY ON REPERCUSSIONS AND LIKELIHOOD OF OUTCOMES
(modified based on original graphic from TheProjectManagementBlueprint.com, used with permission, copyright Mark Warner, TheProjectManagementBlueprint.com)

In assessing risk, the Board must weigh the likelihood of known outcomes based on their probabilities of occurrence. For example, they must assess the probability that buildings will be flooded in the spring. The Board is now much better able to assess this probability of occurrence by using the DST and the range of water-supply forecasts it provides. Uncertainty adds complexity to the assessment of risk because either the severity of the consequence and/or the probability of occurrence are unknown (Figure 47).

Under extreme conditions when the Board has the authority to deviate from Plan 2014, they must decide, in real-time and while various interests and regions are experiencing a range of impacts, whether or not to override plan limits. The Board understands that these decisions could shift the balance of impacts to other interests and regions. These are not easy decisions to make, especially when faced with a high degree of uncertainty around both future conditions and the actual outcomes of a deviation decision. For example, in 2017 as water levels were rising, as has been noted in earlier discussions, the Board had little information on what the outcomes would be if the F Limit was exceeded on the lower river. At the same time, the Board was unable to assess the added risk that storms could have on Lake Ontario shoreline properties when the water levels were so high.

The GLAM Committee has been attempting to help the Board better understand the risk or probability of a bad outcome of a deviation decision. The Committee also has been trying to reduce the amount of uncertainty around the expected outcomes and the probability of occurrence. This has not been easy given the large size of the basin, the difficulty in gathering information during extreme conditions, and because of the level of detail required to inform a deviation decision whose outcome is measured in centimeters and inches, not feet and meters. However, the GLAM Committee has made considerable progress in characterizing impacts upstream on Lake Ontario, on the upper St. Lawrence River, including Lake St. Lawrence, and downstream on the lower St. Lawrence River. The DST allows the Board to explore the differences in outcomes from deviation strategies across these geographic regions.

The GLAM Committee has also characterized impacts across a number of interests, so the Board can get a better sense of who is being impacted by extremes, the severity of those impacts and whether their deviation strategy can improve conditions. This can help the Board assess the risk of taking, or not taking actions and the risk of transferring impacts from one interest or region to another.

While uncertainty in forecasted conditions will continue to be an issue faced by the Board, the GLAM Committee continues to seek out the best science and will work with its partners in looking for ways to improve mid to long-term forecasts. Climate change adds even more uncertainty. The recent Intergovernmental Panel on Climate Change (IPCC) (https://www.ipcc.ch/) report notes that widespread and rapid changes in the atmosphere, ocean, glacial and arctic regions, and biosphere have occurred, that the scale of changes are unprecedented and that these changes are already affecting many weather and climate extremes (IPCC, 2021).

The Great Lakes have always been and will continue to be a dynamic system, and this will only be exacerbated by climate changes. The GLAM Committee will be incorporating an assessment of projected climate changes into its Phase 2 analysis. In the meantime, the GLAM Committee has developed some more extreme-case scenarios for the Board to take into consideration as it assesses risk of forecasted water supplies (GLAM, 2021b). This helps the Board assess the risk under a range of future conditions to try to minimize the chance of surprises.

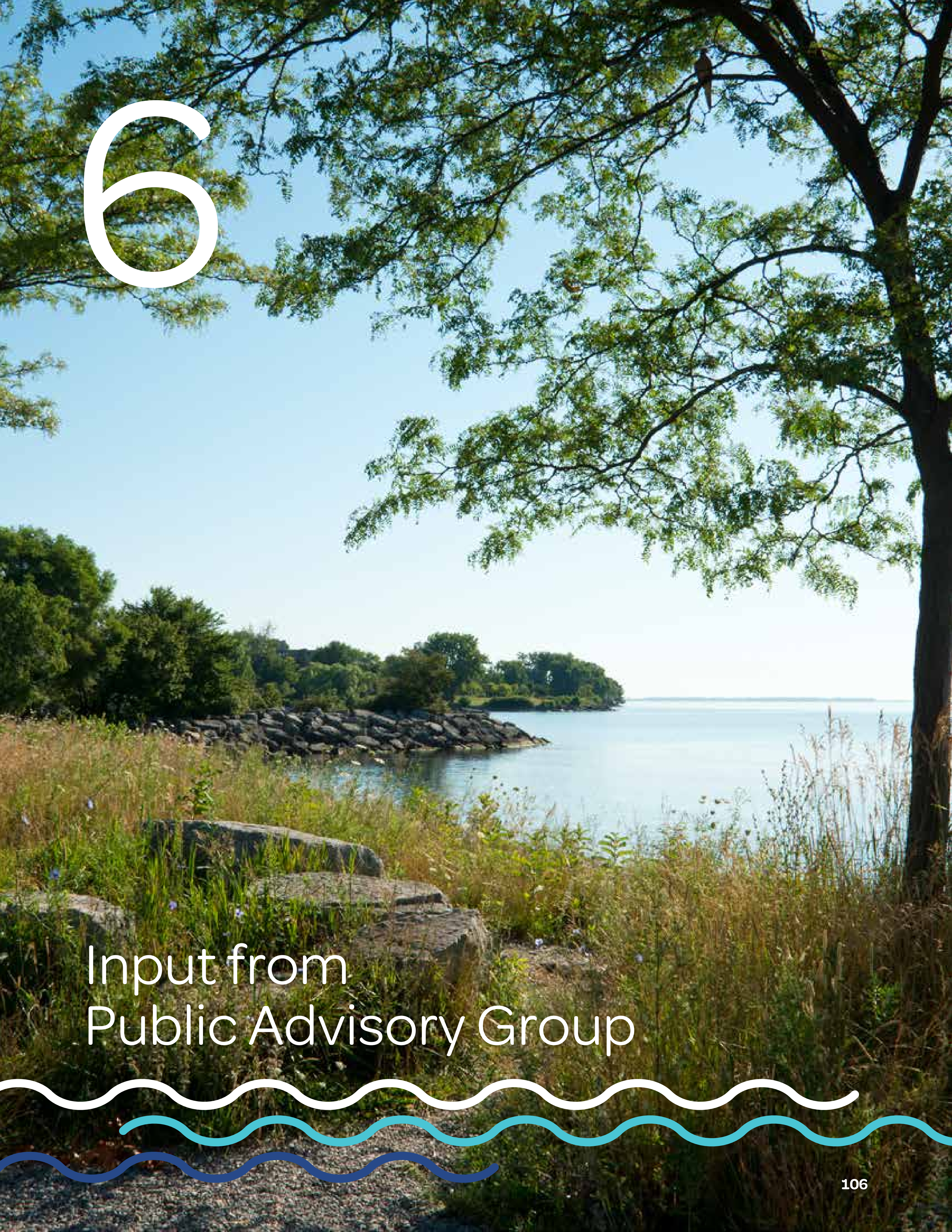
In addition, the GLAM Committee has tried within the DST to isolate the added risk of complicating factors such as wind, waves, surge and incoming tributary flows. Outcomes are presented both in terms of still water (the part the Board can influence), but also in terms of the likelihood for major storm events and how that may or may not impact a deviation decision.

This is an on-going requirement as conditions, interests and science are always changing. The GLAM Committee will continue to identify the key areas for risk that surround deviation decisions and the uncertainties that can impact that risk. The GLAM Committee will also look for opportunities to reduce that uncertainty through more monitoring, assessment and verification, and identify which uncertainties will remain unresolved for the foreseeable future. The GLAM Committee will continue to work on how risk and uncertainty are displayed in the DST and what areas of research for reducing uncertainty will be carried forward into Phase 2 and beyond.

Risk and uncertainty are key drivers for on-going adaptive management so that decisions can be adjusted as more is learned or conditions change. A Board decision will never be made without some degree of risk and uncertainty. What adaptive management can do is identify the risks and reduce the level of uncertainty as much as possible through on-going monitoring, modeling and verification and present this information to the Board to inform its deviation decision-making.

Insight

Risk and uncertainty surround Board deviation decision-making. The GLAM Committee can help by working to reduce uncertainty where possible. This is an on-going requirement of adaptive management.



6

Input from Public Advisory Group

6.0 Input from Public Advisory Group

The 18-member Public Advisory Group (PAG), unpaid volunteers who met on a continuing basis between June 2020 and October 2021, were appointed by the IJC to promote public input and transparency.

The PAG was created so that representatives of groups that are directly affected by Board deviations could bring their insights into the impacts of extreme high water to the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee. The GLAM Committee and the PAG worked together to understand and assess data about system impacts, a process that helped build trust in the IJC. It was also hoped that PAG members would communicate back their insights to their constituents, colleagues and neighbors, a goal that PAG members fulfilled as best they could.

The advisory group's assigned role was to provide input on how extreme high-water impacts should be assessed and help the GLAM Committee consider what criteria should inform International Lake Ontario – St. Lawrence River Board (Board) decision-making on deviations. The PAG also was to help formulate a means of presenting this information to the Board, and to come up with ways to communicate with their constituents about what is being done to better inform the deviation decisions.

Many of the PAG's sessions in 2020 were devoted to the nuts and bolts of Lake Ontario outflow regulation, which gave GLAM Committee officials a chance to explain how and why decisions are made and PAG members a chance to present perspectives on their priorities and interests and express concerns about the impact of those decisions. Through the intensive exchange, the advisory group built a deeper, shared understanding of the difficulties in managing this complex system, which involves accounting for differing costs, pain, protection, and benefits across geographies and interests and a set of difficult trade-offs within a risk-based management approach that is technically intensive, full of uncertainty, and difficult to communicate to stakeholders.

The PAG concluded its 2020 work by outlining what it had learned and identifying additional key issues concerning resilience and emergency response, which are outside the IJC's mandate but are deemed critical to managing flooding along shorelines. The PAG also sought further clarity and transparency in regard to the IJC's governance.

6.1 Public Advisory Group Work on the Decision Support Tool

In 2021, much of the advisory group's time was spent working on the Decision Support Tool (DST). The PAG assisted the GLAM Committee with laying out key objectives for the tool such as ensuring that all uses and interests are accounted for, and that the analysis of impacts is multi-dimensional and evidence based. The PAG recognized that tradeoff decisions should be based on monitoring and model results but that the presentation of these tradeoffs would not always make the decision any clearer for the Board members' especially where the countervailing factors do not point in a clear direction. But there was a general sense among the PAG that with the DST, the issues and concerns of each of the interests and regions are being recognized and assessed.

It was agreed the DST needed to be flexible, in the sense that it can be readily updated with new data and new strategies, and that it should include a broad range of plausible future water supply scenarios, both high and low water. The risks of taking a given deviation action — or not taking it — should be equally apparent.

The PAG also offered suggestions about creating impact zones and crafting the descriptions of impacts that accompany each zone. They made numerous suggestions about ways to make the tool's output more user-friendly, comprehensive and transparent.

The PAG engaged with the GLAM Committee on these matters and others despite an on-going conversation as to whether it is ever really possible for deviation decisions to balance interests and regions, some PAG members felt the answer was no. This was due to the complex nature of the system (Lake Ontario and the St. Lawrence River), the uncertainty inherent in weather projections, the varied ways in which impacts translate into costs borne by various interests (e.g. commercial navigation that serves a broader supply chain versus individual property owners versus ecosystem responses), and the limits inherent in water regulation compared to natural phenomena such as extreme wet and dry conditions.

As the GLAM Committee worked on the tool, PAG members pushed the GLAM Committee not to populate it just with numerical measures but to also incorporate what their report termed "a more nuanced and people-centered view of how various options may affect various parts of the system when deviation decisions are made."

The PAG members said building inundation metrics did not capture shoreline impacts fully. They wanted the disruption of people's lives and livelihoods taken into account, and metrics that were local as well as system-wide. The PAG emphasized that the DST should include impacts on local infrastructure — roads, docks, sewer systems, parks and the like — and find a way to use the DST to communicate subtler but significant impacts of extreme high water on shoreline residents such as the disruption of everyday life and the physical and emotional stress which PAG members recognized were difficult to measure.

PAG members argued that the public would have more confidence in the Board's decisions if the public knew that local concerns and impacts were built into the tool. To show how this might be accomplished, the GLAM Committee created a prototype story map for a shoreline community in the Municipality of Brighton, Ontario, as previously discussed in Section 5.2. The prototype story map for Brighton received positive feedback from the PAG.

Soldiers of the New york army national guards 105th military police company construct a sandbag barrier to protect property at Sodus Point, NY, USA

6.2

Public Advisory Group's assessment of the Phase 1 public engagement process

In 2021, the PAG spent most of their time focused on reviewing the DST, but they were also tasked with commenting on lessons learned and contributing their thoughts on a longer-term public engagement process.

In these discussions, PAG identified several benefits of the process. (see side box)

At the same time, the PAG encountered some difficulties, particularly related to the time commitment necessary to fully participate and the enormity of the challenge to understand the complex natural and human systems that interact in the watershed.

Members also struggled to fulfill the function of reaching out to their networks, partly because information developed by the GLAM Committee was in developmental stages and not ready for public distribution and partly because PAG members lacked the capacity for information sharing across such a large and diverse region. Some PAG members concluded that it is unrealistic to expect a relatively small group of volunteers to manage constituency engagement on subjects of significant controversy in the current atmosphere of polarized public discourse.

Looking ahead to any future public advisory bodies, PAG members said they would highly welcome the continuation of such a group to build on the social relationships and knowledge gained over the course of more than a year. However, time would need to be better managed, with sub-working groups and more concise and accessible educational materials available for communicating with the public. PAG members suggested

PAG IDENTIFIED BENEFITS OF THE PROCESS

- The process provided an opportunity for exchanging information and educating other PAG members and members of the GLAM Committee. PAG members shared insights from their own experiences on Lake Ontario and the St. Lawrence River and their own travails dealing with extreme high water. Opportunities for more dialogue came after PAG members expressed their readiness to move beyond structured educational based presentations.
- PAG members formed good relationships with others, especially across a diverse group of fellow advisory group members and addressed disagreements in an atmosphere of mutual respect, despite being unable to interact in person due to the COVID-19 pandemic
- Trust-building through the open sharing of information: PAG members were kept up to speed on current conditions and Board deviation strategies by Board staff.
- The advisory committee helped shape public engagement efforts by the GLAM Committee or the Board, offering advice on questionnaires and the design of public meetings.

that if the PAG continues into Phase 2, current members should be invited to stay with new members phased in. The PAG recommended that new committee members reflect greater diversity in socio-economic status, race, gender identity and ethnicity to provide a great range of experience and knowledge. The group provided some specific suggestions for protecting and potentially compensating the volunteers in a way that would allow them to retain their independence.

Finally, the PAG appreciated the stepped-up communications efforts and urged the IJC, Board and GLAM Committee to continue to improve its communications to the public and suggested more plain-language public communications and the establishment of public liaisons to act as two-way conduits for information in communities around the St. Lawrence River and Lake Ontario.

In a December 2020 communiqué, PAG offered recommendations on topics that were outside the immediate scope of their assigned duties but that they felt were imperative to work towards flood management. The PAG said the IJC should urge government agencies to create and fund robust emergency response plans that can be activated when extreme high water threatens, and to encourage government shoreline resilience planning, regulations and grants to help property owners, municipalities and other stakeholders.

Insight

PAG recommends changes to process for Phase 2 to make it more effective and palatable to new members.

6.3

GLAM Committee appreciates Public Advisory Group's work

From the GLAM Committee's perspective, the PAG was a welcomed and important addition in the Phase 1 expedited review process. Despite the pandemic, the GLAM Committee was able to get acquainted with all of the PAG members and learn about their issues, seek their feedback and establish relationships, albeit virtual.

The GLAM Committee was very pleased with the level of engagement from PAG members, and with their dedication and willingness to learn and hear each other's points of view. The GLAM Committee also appreciated the thoughtful feedback received regarding the DST and guidance on how to address concerns. The GLAM

Committee appreciated the coordination role of the Consensus Building Institute (CBI) who were expert facilitators and provided neutral moderation and a safe space for discussion and debate.

The GLAM Committee recognizes the burden placed on PAG members, both in terms of the time commitment necessary for a meaningful process and for trying to reach out to their respective networks. The committee agrees with the PAG's assessment that more materials need to be available to help the PAG with this. This was difficult during the Phase 1 expedited review due to the tight timelines and involvement of the PAG in the real-time development of the DST which meant communication materials were not yet available. Nevertheless, the GLAM Committee deeply appreciates that PAG did reach out to their constituents at times and provided knowledgeable information via traditional media and social media which helped inform broader communities of the GLAM Committee process and helped correct misinformation.

The GLAM Committee sometimes found it difficult to maintain the pace required to keep the PAG informed and updated, but at the same time the semi-monthly schedule for meetings kept the process moving forward. The GLAM Committee did, at times, find it difficult to manage the high expectations of the PAG, especially when special requests were made for specific information and in regard to their assigned role as an advisory committee to the GLAM Committee and not the Board.

The GLAM Committee recognizes and appreciates the recommendations provided by the PAG for robust emergency response plans and resiliency planning and acknowledges the importance of these aspects in potentially reducing the risks of and improving the response to high water impacts. While largely outside the GLAM Committee's scope, these recommendations have been forwarded to the IJC and the GLAM Committee will support the IJC as they consider how best to share these with responsible agencies.

Overall, the PAG provided great support to the GLAM Committee and was a critical voice in the development of the DST. The GLAM Committee is hopeful the IJC will renew the PAG for Phase 2 of the Expedited Review.

Insight

The PAG was extremely helpful during Phase 1 of the expedited review of Plan 2014.

7

Findings and Recommendations from Phase 1 and transitioning to Phase 2: What comes next?

Sailing on Lake Ontario at Toronto, Ontario, Canada

7.0 Findings and Recommendations from Phase 1 and transitioning to Phase 2: What comes next?

The expedited review of Plan 2014 is a good example of adaptive management in action. It is part of an iterative process to reduce uncertainty via system monitoring and modeling as well as learning through doing. This first Phase of the expedited review was geared towards filling some immediate data and information gaps needed to support International Lake Ontario – St. Lawrence River Board (Board) discretionary deviation decisions. This included gathering information from those directly impacted by the recent high-water conditions and undertaking technical studies to assess impacts across the different interests and regions. This first phase was focused in part on the flow limits in Plan 2014 and how these limits should be considered when the Board has authority to deviate from Plan 2014 flows. The following identifies the key findings from this Phase 1 effort based on a consolidation of the insights and observations identified in earlier sections of this report.

7.1

Summary of Key Findings

Key Finding 1

Inclusion of Indigenous peoples' perspectives and traditional ways of knowing are important to the adaptive management process and the on-going review of the regulation plans. (Sections 2.8 and 4.7)

The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee noted that little information has been gathered from Indigenous communities about the impacts of the recent high-water events. The GLAM Committee respects and recognizes the rights of Indigenous communities along the lake-river region and seeks to close this gap within the adaptive management effort including cultural perspectives and traditional practices. To achieve this, in 2021 the GLAM Committee began a process to hear more about perspectives of First Nations, Tribal Nations and the Métis Nation along the Lake Ontario and St. Lawrence River shoreline and/or with rights along the shoreline.

Key Finding 2

PAG proves helpful and recommends changes to process for Phase 2 to make it more effective and palatable to new members. (Sections 3.2..4 and 6.0)

The GLAM Committee found the Public Advisory Group (PAG) to be a welcome and important addition in the Phase 1 expedited review process. The level of engagement from PAG members was excellent and members were dedicated and willing to learn and hear each other's points of view. The GLAM Committee received thoughtful feedback regarding the Decision Support Tool (DST) and was provided guidance on how to address concerns that were raised.

The GLAM Committee sometimes found it difficult to maintain the pace required to keep the PAG informed and updated, but at the same time the frequent meetings kept the process on a steady track forward. The GLAM Committee at times, found it difficult to manage the high expectations of the PAG, especially when special requests were made for specific information and in regard to their assigned role as an advisory committee to the GLAM Committee and not the Board.

The GLAM Committee found that the third-party contractor was essential to engaging the PAG and provided expert facilitation and coordination, neutral moderation and a safe space for discussion and debate.

Both the PAG and GLAM Committee agreed that a similar group to the PAG is needed moving into Phase 2, however, the PAG suggested that time would need to be better managed, with sub-working groups and more concise and accessible educational materials available for communicating with the public. The GLAM Committee and PAG also agreed that any changes to the current membership should be phased in.

Key Finding 3

The Board faces complex problems, including climate change. Scenario testing is a helpful approach to better understand uncertainties. (Section 3.2.2 and 5.1)

The GLAM Committee and Board identified a number of factors that complicate deviation decisions, not the least of which is the uncertainty about what future water supplies will be. Reliable precipitation forecasts beyond a few days in the future are not yet available and yet a period of heavy rain or a drought can easily erase a deviation's benefit. Climate change only exacerbates that uncertainty and increases the likelihood of even greater variability in water supplies in the future.

While uncertainty in forecasted conditions will remain an issue for the Board, the GLAM Committee will continue to seek out the best science and will work with its partners for ways to improve mid- to long-term forecasts. In the meantime, the GLAM Committee has developed some extreme water-supply scenarios that go beyond the historical record that the Board can take into consideration as it assesses risk of forecasted water supplies.

Key Finding 4

Board needed more information on the incremental impacts of deviating from the regulation plan. The GLAM Committee's research will help the Board better understand the shift in risks across interests and geographies. (Sections 3.2.3 and 5.5)

The Board wanted to know the certainty of the risks to interests and regions that are presented by extreme high water and how that risk would be shifted by their deviations. They identified some serious risks related to deviation decisions:

- **During the spring freshet:**
  Serious flooding on the lower St. Lawrence River can result from even a modest increase in outflow from Lake Ontario.

- **During and after ice formation:**
  Ecological damage in Lake St. Lawrence can result from abnormally high winter outflows, as can weakening of the river ice cover and resultant local flooding damage.

- **During the navigation season:**
  Shutdown of the Seaway with resulting damage to the shipping industry and its clients can result from deviations above the L Limit.

The GLAM Committee has characterized impacts across a number of interests, so the Board can get a better sense of who is being impacted by extremes, the severity of those impacts and whether their deviation strategy can improve conditions. This can help the Board assess the risk of taking, or not taking actions and the risk of transferring impacts from one interest or region to another.

Key Finding 5

New information may allow limits and deviations from them to be changed. The research provides some possible options for deviations in the future as well possible plan alternatives to explore in Phase 2.
(Sections 3.3 and 4.0)

I Limit

The I Limit requires that the level in Lake St. Lawrence be kept at 71.8 m (235.56 ft) or higher, as measured at Long Sault Dam. That value was specified in the limit because it was believed to be the minimum level needed to allow water-plant intakes to function properly. GLAM Committee research found this minimum may not be a limiting factor. Rather, new research conducted in support of the GLAM Committee found that low water levels on Lake St. Lawrence could lead to the stranding of aquatic creatures and concluded more research is required. The GLAM Committee also identified that another limiting factor may be loss of hydropower efficiency when operating at very low head caused by low levels on Lake St. Lawrence.

GLAM Committee research also found that it may be possible that the Board could deviate to increase winter outflow beyond the current I Limit when ice cover exists of 9,430 m^3/s (333,000 cfs) under some circumstances and recommended further study.

L Limit

Broadly speaking, the L Limit provides a maximum outflow limit through the Moses-Saunders dam to maintain safe velocities and currents for commercial navigation to transit the Seaway. Another portion of the L Limit also ensures that levels of Lake St. Lawrence remain high enough for ships to transit through the channels.

Research and stakeholder engagement conducted by the GLAM Committee found that there may be some room for flexibility to the limit, especially in the summertime, if mitigation measures are in place. (There is less flexibility in the in the autumn, when currents are strong and the water level in the river was declining.) The GLAM Committee developed an independent, objective and non-proprietary assessment of the duration, timing and magnitude of the potential impacts to the commercial navigation sector of extremely high flow velocity scenarios. This research found that any temporary closure of the Seaway would have marked and measurable impacts and the most impactful would be a lengthy mid-season closure or an early end to the shipping season due to the volume of traffic and nature of cargo involved. In addition, the GLAM Committee also found there was no empirical basis for the two top outflows in Plan 2014's L Limit and the assumptions in selecting 10,200 m^3/s (360,000 cfs), and 10,700 m^3/s (378,000 cfs) need revisiting.

As well, the GLAM Committee focused several studies on Lake St. Lawrence, which can be negatively impacted by efforts to reduce Lake Ontario flooding and is therefore critical to Board decision-making. Low-level thresholds on Lake St. Lawrence have been questioned and additional data gathering efforts for Lake St. Lawrence are required. The Board has expressed the importance of having all of this more detailed information to help them decide whether it is safe to exceed the flow limits, and the risk of taking, or not taking actions and the risk of transferring impacts from one interest or region to another.

F Limit

The F Limit's fundamental purpose is to limit springtime high water and possible flooding, including flooding caused or exacerbated by the Ottawa River freshet, or spring runoff and to "balance" upstream and downstream impacts. During the high water events of 2017 and 2019 the Board found they lacked information to confidently develop a deviation strategy from the F Limit.

The GLAM Committee found several possible ways to adjust the F Limit or the Board's reaction to the limit that can be further developed and evaluated within Phase 2. This included extending the target levels in increments and/or skipping the lower tiers of the target levels on Lake St. Louis. It also included varying the applicability of the targets with the timing of the freshet, tying those target levels to the inflow from Lake Erie or tying target levels to the inflow from the Ottawa River and adding a separate component to the F Limit to more directly consider Lake St. Pierre levels. All of these require further exploration and evaluation before being seriously considered for application by the Board as deviation options or as proposed modifications to the plan itself in Phase 2.

Building inundation, or flooding, is being used as an important impact metric that can be measured throughout the lake-river system. This contributed to the identification of broad-based regional impacts upstream and downstream and critical water level thresholds that can help inform F Limit deviation decisions.

Through various studies, the GLAM Committee was able to better define the scale and breadth of impacts to shoreline interests under different conditions and locations and assign critical water level thresholds (impact zones) to help inform the Board of the implications of deviation decisions across different geographies.

Key Finding 6

Risk and uncertainty surround Board deviation decision-making. GLAM can help by working to reduce uncertainty where possible. This is an on-going requirement of adaptive management. (Section 5.5)

A Board decision will never be made without some degree of risk and uncertainty. What adaptive management tries to do is identify the risks and reduce the level of uncertainty as much as possible through on-going monitoring, modeling and verification. The GLAM Committee has tried within the DST to identify risks and uncertainties for the Board. For example, to isolate the added risk of complicating factors such as wind, waves, surge and incoming tributary flows, outcomes are presented both in terms of still water and in terms of the likelihood by season for major storm events and how that may or may not impact a deviation decision. The GLAM Committee cannot eliminate uncertainty, but it can continue to work toward improving science and data and filling data gaps in an effort to provide the best science available to the Board.

Key Finding 7

The DST, based on GLAM research, responds to Board need for more information but it cannot eliminate impacts or assure an objective will be met. The board must still make decisions consistent with the 2016 Order and IJC Directives. (Section 5.0)

Board members have said they want a factual understanding of the trade-offs that accompany deviations — the benefit of changing the outflow to aid one interest or region versus the harm that outflow change might bring to another interest or region. Board members need insight into the uncertainties about the impacts that near-term and longer-term weather will have on the water levels and flows they are altering when they deviate.

The DST addresses these needs by making the Board's work better-informed, more systematic and based on objective, vetted information.

While the DST cannot eliminate uncertainty about future water supply or provide complete assurance that a deviation will bring the result the Board intended, the tool still represents a valuable step forward because it allows the Board to act with much more knowledge than before and with a new ability to understand impacts among the many competing uses and interests. It is important that the Board trust the information within the DST, which means that updating and maintenance is critical to its use and effectiveness in information Board decisions.

As helpful as it should prove to be, the responsibility for the discretionary deviation decision remains with the six Board members consistent with the 2016 Supplementary Order of Approval and associated IJC Directives. The DST is not a decision-making tool.

HOW THE DST ADDRESS BOARD NEEDS

- The DST will allow the Board to judge how many properties along the St. Lawrence River and Lake Ontario shorelines might be inundated by a particular deviation and what impact, if any, that deviation would have on commercial navigation.
- The tool will help the Board compare the impacts from one community to the next by offering Board members close-up views of a variety of impacts on specific communities on the Quebec, Ontario and New York shorelines, as well as on Lake St. Lawrence, through a feature known as "impact zones"
- For the specific communities, rich descriptive information and local context is provided in a supplementary interactive story map product. Currently, a single example is available with the possibility of developing ones for additional locations in the future.
- The DST addresses the uncertainty of not knowing what the weather will bring by allowing Board members to see how deviation options would play out under a variety of future water supply scenarios.

Key Finding 8

More data are needed for DST: extreme low-water impacts on all interests; ecosystem impacts; additional impact zones, including for Indigenous communities; additional story maps; possible generation of financial impacts on interests other than commercial navigation. (Section 5.4)

Phase 1 of the expedited review was initiated due to concern over extremely high water levels. In spring 2021, the concern shifted to low water levels. This demonstrates the need for adaptive management as conditions are always changing. A key data gap that must be addressed is the lack of low-water metrics in the DST.

Additional ecosystem indicators, particularly for the upper St. Lawrence River and downstream areas that can be impacted by short-term Board deviations, should also be added to the DST. Further study of ecosystem impacts from low water levels during the winter on Lake St. Lawrence also is needed. Longer-term implications to ecosystems that may not be apparent in the short-term should be explored in Phase 2.

Shoreline erosion on the lower river needs to be added as a metric and was something identified in the Quebec municipal meetings due to the high sustained outflows in 2017 and 2019-2020. Shoreline erosion is also an important impact on Lake Ontario, though it may not be possible to differentiate erosion impacts on the lake shore that are associated with short-term deviation decisions and incremental water level differences of a few centimeters or inches.

While the Institute for Water Resources study that estimates the tons of cargo delayed and financial cost by navigational stoppages provides information the Board members have never had access to previously, it does not currently cover the Port of Montréal or downstream. Given the importance of this port to container ship traffic coming from the rest of the world, this is still a gap that needs to be filled. The GLAM Committee should continue to work with the Seaway corporations towards the development of a common metric and consider the development of a full Great Lakes/St. Lawrence River commercial navigation model.

Recreational boating and tourism were greatly affected by the high-water events of 2017 and 2019 and clearly are impacted by low water extremes. While some work was initiated in Phase 1, more study is needed to better understand the sensitivity of both direct and indirect impacts of deviation decisions on this sector. This will be given a greater emphasis in Phase 2 of the expedited review.

While targeted studies were completed for Lake St. Lawrence in Phase 1, given the immediate and sometimes significant affects deviation decisions can have directly on the forebay of the dam, a full and detailed investigation of all impacts categories (ecosystem, recreational boating and tourism, municipal water uses, First Nations, shoreline property, commercial navigation and hydropower infrastructure) should be completed for the entire Lake St. Lawrence region.

Some other locations within the system may require more site-specific study of indicators that are particularly relevant to their region such as tourism in the Thousand Islands area, traditional ecological knowledge and traditional ways of knowing in the Bay of Quinte and Lake St. Francis areas, and agriculture near Lake St. Pierre.

The PAG has strongly encouraged the GLAM Committee to include a wider range of metrics in the DST to reflect that personal nature of certain shoreline impacts for the Board. While preliminary efforts were made to incorporate that advice, the GLAM Committee will need to continually look at the suite of metrics in the DST and consider whether these metrics adequately reflect the range of impacts experienced by the different uses and interests. As well, the GLAM Committee will continue to work towards common and measurable metrics across all interests, including financial costs, to the degree possible.

7.2 Recommendations from Phase 1

SUMMARY OF RECOMMENDATIONS

- **A.** Indigenous Relations Building continue into Phase 2 and beyond
- **B.** Public Outreach and Engagement continue in Phase 2 and for the longer-term Adaptive Management process
- **C.** The Decision Support Tool should be considered a dynamic tool that needs continual updates and improvements
- **D.** The Board should use the DST to prepare for the next crisis situation
- **E.** Data gaps should continue to be filled and new technologies explored
- **F.** Phase 2 of the Expedited Review should provide for a fulsome review of Plan 2014 (see Section 7.3)

Recommendation A

Indigenous Relations Building continue into Phase 2 and beyond

As of July 2021, initial outreach had taken place to representatives of all First Nations, Tribal Nations and Métis Nations that directly reside along the Lake Ontario and St. Lawrence River shoreline along with those Indigenous Nations with rights related to the shoreline (as listed in Section 2.8) and a number of individual virtual meeting sessions had been arranged. The GLAM Committee continued to follow up with various First Nations, Tribal Nations and Métis Nations throughout the late summer and fall of 2021 as a starting point from which to begin a dialogue and build relationships to improve learning and the integration of Indigenous perspectives and knowledge and it is expected this will continue through Phase 2. The GLAM Committee is committed to exploring opportunities to include traditional ecological knowledge, cultural perspectives, and traditional ways of knowing into the plan evaluation effort and on-going adaptive management process for informing both the on-going review of Plan 2014 and efforts on the upper Great Lakes related to Plan 2012 for the outflows from Lake Superior.

Recommendation B

Public Outreach and Engagement continue in Phase 2 and for the longer-term Adaptive Management process

The GLAM Committee has found the PAG to be dedicated contributors to the Phase 1 process and have appreciated the thoughtful feedback received. The GLAM Committee wholly supports and recommends the continued involvement of the PAG in Phase 2. The Committee will consider the recommendations for on-going public engagement from the PAG and work with the IJC on next steps. This includes the pags recommendations that a new committee reflect greater diversity in socio-economic status, race, gender identify and ethnicity to provide a greater range of experience and knowledge. The PAG urged the IJC, Board and GLAM Committee to continue to improve its communications to the public and recommended the establishment of public liaisons to act as two-way conduits for information in communities around the St. Lawrence River and Lake Ontario.

The GLAM Committee further recommends that an independent facilitator continue to be engaged to help ensure an effective and efficient public engagement process.

Recommendation C

The Decision Support Tool should be considered a dynamic tool that needs continual updates and improvements

Information from various sources was used by the GLAM Committee to develop the DST to assist the Board in assessing impacts and tradeoffs associated with high water levels throughout the Lake Ontario and St. Lawrence River system. While the Board views the information provided by the tool as a considerable improvement, it is also recognized that the tool is only effective if the Board has full confidence in the information it provides. It is therefore critically important for the DST to be continually updated and improved over time as an on-going component of adaptive management.

The DST currently is a Microsoft Excel-based tool. The GLAM Committee should explore alternative platforms in consideration of the long-term use, accessibility and performance of the DST. A strategy for the on-going maintenance and updating of the DST should be developed and implemented including identified resources and agency support within the GLAM Committee and Board.

The DST has been identified as having potential benefits both for communicating with the public and for informing practitioners interested in water level/resiliency issues. The GLAM Committee should continue discussions with the Board of potential public and practitioner uses of some version of the tool. At the very least the Board and GLAM Committee should explore opportunities for using the outcomes from the DST as a means of communicating with the public on how and why a deviation decision was made.

Recommendation D

The Board should use the DST to prepare for the next crisis conditions

Even with the additional information provided by the DST, deviation decisions will not be easy. There is good evidence from hydroclimate science that higher levels are possible upstream and downstream than experienced in 2017 and 2019-2020. While Phase 1 was focused on high water extremes, it is recognized — especially given the experience in the spring and summer of 2021 — that low-water extremes also must be considered and will be added to the DST in the future. This again is an example of why adaptive management is needed to address a system that is always changing.

Given all of this variability and the dynamic nature of the system and that new information will continue to be included into the DST, it is highly recommended by the GLAM Committee that the Board continue to practice with the DST so members become accustomed to using the tool in an operational mode. It is further recommended that the Board use the DST to explore different extreme scenarios and to learn how Board members can use the tool to assess risk and uncertainty of various deviation options prior to an extreme event (high or low). While the Board members themselves will likely not be the ones manipulating the tool, that support will come from GLAM Committee and Board staff, it is important for the Board and its IAG members to have a solid understanding of the tool itself and the data that drives it. In doing so, the Board can be better prepared to address extreme conditions when they do occur, and they can work with the GLAM Committee to identify improvements that could be made to improve the DST.

Recommendation E

Data gaps should continue to be filled and new technologies explored

Adaptive management tries to identify the risks and reduce the level of uncertainty as much as possible through on-going monitoring, modeling and verification and this must continue to inform the Board's deviation decision-making. The GLAM Committee has an on-going mandate to review and assess the performance of the regulation plans and this requires continual data gathering and verification. The GLAM Committee should prioritize the data gaps identified in the findings above and systematically address these gaps. The GLAM Committee should be looking to build common metrics where possible and should be examining and making use of new and evolving technologies such as machine learning for gathering data more efficiently.

Data sharing procedures and protocols, and where necessary data sharing memorandums of understanding, should be established with potential partner agencies to allow accessibility to data, information and tools generated for the GLAM Committee.

Recommendation F

Phase 2 of the Expedited Review should provide for a fulsome review of Plan 2014 (see section 7.3)

Phase 1	Phase 2
Focused on better informing deviation decisions	Review of Plan 2014 — can it be improved, especially during extremes (high and low)
Short-term horizon (weeks/months)	Long-term time horizon (years/decades)
Considers six month forecast and some more extreme scenarios	Considers a full range of possible water supply conditions including climate changes
Greater emphasis on those directly impacted by deviation decisions	Considers all interests and regions including longer-term ecosystem impacts and Indigenous perspectives and knowledge
Established a Decision Support Tool to inform Board deviation decisions (operational tool)	Develop Shared Vision Model to compare and rank alternatives to the regulation plan
Includes input and advice from Public Advisory Group	Includes input and advice from public (TBD based on Public Advisory Group feedback)
Board is decision-maker	Board recommends — IJC decides with government concurrence
Complete in 20 months	Complete in 3 years (pending funding)

Table 10:

DIFFERENCES BETWEEN PHASE 1 AND PHASE 2 OF THE EXPEDITED REVIEW EFFORT

7.3 Transitioning to Phase 2 of the Expedited Review and a fulsome review of Plan 2014

Phase 2 will include analysis of possible modifications to Plan 2014's rules, limits and "trigger levels". A study done in Phase 1 by the GLAM Committee identified a number of possible changes to the I, J, L and F limits that will be explored in Phase 2 (see Section 3.3), and others may be added.

The next phase will build upon the data and modeling tools developed during Phase 1 (see Table 10) and will include acquisition and analysis of data about impacts of extreme high and low water, building upon the data gaps noted above. Phase 2 analyses will directly include Indigenous Nations and will have a greater emphasis on ecosystem impacts on Lake Ontario and the St. Lawrence River than were included in Phase 1. This is because some of these impacts are only measurable after a number of years and Phase 2 will consider a long-term time horizon.

Analyses will be conducted under a full range of possible future water supply conditions, including climate change projections. It is important to note, that while Phase 1 focused primarily on providing information to inform Board deviation decisions and did not recommend specific options for the Board, Phase 2 will take a different and more fulsome approach to evaluating alternatives to Plan 2014 rules, limits and "trigger levels" for leading to improved outcomes and will include the evaluation of options to allow for the ranking of alternatives.

References

Akwesasne Task Force on the Environment, 2004. An Assessment of the Environment, Shoreline Erosion, and Recreational Boating within the Mohawk Territory of Akwesasne: A Review of Literature Supplemented by Empirical Data from Mohawk Elders, Gatherers, and Key Informants. Prepared for the International Joint Commission in its Study of Lake Ontario and the St. Lawrence River and its Review of Plan 1958-D on the Regulation of Water Level and Flow in the St. Lawrence River.

Auburn Citizen, 2020. Roger Misso, candidate for Congress, asks IJC to address high Lake Ontario levels. Auburnpub.com. https://auburnpub.com/news/local/govt-and-politics/roger-misso-candidate-for-congress-asks-ijc-to-address-high/article_3ac44227-8bad-5058-a1a2-0a070f35a996.html.

Benke, Arthur C., Cushing, Colbert E., 2005. Rivers of North America. Academic Press. pp. 989–990. ISBN 978-0-12-088253-3.

Bryce, J.B. 1982. A Hydraulic Engineering History of the St. Lawrence Power Project with Special Reference to Regulation of Water Levels and Flows. Prepared for Ontario Hydro, January 1982.

CCGLBHHD [Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data], 1977. Coordinated Great Lakes Physical Data. https://www.lre.usace.army.mil/Portals/69/docs/GreatLakesInfo/docs/CoordinatedGreatLakesPhysicalData/CoordinatedGreatLakesPhysicalData-May1977-MediumRes.pdf

Cornett, A, B., Ghodoosipour, B, and M. Provan, 2021. High-Resolution Numerical Investigation of Wave-Driven Flooding on Lake Ontario. Technical Report NRC-OCRE-2021-TR-030. Prepared for the International Joint Commission by the Ocean, Coastal and River Engineering Research Centre of the National Research Council of Canada.

Copticom, 2021. Report on consultations carried out form November 2020 to February 2021 with municipalities, towns and cities along the St. Lawrence River Shoreline. Presented to the International Joint Commission and the Great Lakes-St. Lawrence River Adaptive Management Committee by Copticom Stratégies/Relations Publiques. April 28, 2021.

ECCC [Environment and Climate Change Canada], 2020. LEVELnews: Great Lakes and St. Lawrence River water levels, February 2020 - Canada.ca, Volume 28, number 2. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/great-lakes-levels-related-data/levelnews-great-lakes-st-lawrence/febuary-2020.html.

ECCC [Environment and Climate Change Canada], 2021. LEVELnews: Great Lakes and St. Lawrence River water levels, October 2021 - Canada.ca, Volume 29, number 10. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/great-lakes-levels-related-data/levelnews-great-lakes-st-lawrence.html.

GAO-20-529, [Government Accountability Office], 2020. Lake Ontario-St. Lawrence River Plan - Improved Communication and Adaptive Management Strategy. United States Government Accountability Office Report to Congressional Requesters, GAO-20-529 (Washington, DC: July 23, 2020). https//www.gao.gov/products/gao-20-529

GLAM [Great Lakes-St. Lawrence River Adaptive Management] Committee, 2018. Summary of 2017 Great Lakes Basin Conditions and Water Level Impacts to Support Ongoing Regulation Plan Evaluation; Prepared for the International Joint Commission, November 13, 2018. https://ijc.org/en/glam/report-summary-2017-great-lakes-basin-conditions-and-water-level-impacts-support-ongoing.

GLAM [Great Lakes-St. Lawrence River Adaptive Management] Committee, 2020a. International Lake Ontario-St. Lawrence River Board Responses to GLAM Committee Interview, August, 2020 (Internal Document).

GLAM [Great Lakes-St. Lawrence River Adaptive Management] Committee, 2020b. Short-Term and Long-Term Strategy For Evaluating and Improving the Rules for Management Releases from Lakes Ontario and Superior, Great Lakes St. Lawrence River Adaptive Management Committee. September 1, 2020. https://ijc.org/sites/default/files/2020-10/GLAMShortAndLongTermStrategy-20200901-EN.pdf.

GLAM [Great Lakes-St. Lawrence River Adaptive Management] Committee, 2021a. Maximum Flow Limits of Plan 2014: Background and Purpose, Application during Recent High Water Events, and Potential for Modifications. A report by the Plan Review Team in support of the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee's expedited review of Lake Ontario Regulation Plan 2014.

GLAM [Great Lakes-St. Lawrence River Adaptive Management] Committee, 2021b. Expedited Review – Phase 1 - Plausible Scenarios. A report by the Hydroclimate Working Group in support of the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee's expedited review of Lake Ontario Regulation Plan 2014. June 30, 2021.

Global News, 2020. Communities pleading for action to prevent further damage from Lake Ontario flooding. February 19, 2020. Globalnews.ca. https://globalnews.ca/news/6566715/lake-ontario-flooding/.

Hung, T.S. and F. Huang, 2020. Assessment of Winter Operations Associated with Ice-Covered Period for Lake St. Lawrence. Submitted to: Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee and International Lake Ontario-St. Lawrence River Board (ILOSLRB). May 31, 2020. Department of Civil and Environmental Engineering, Clarkson University. 93 p.

IJC [International Joint Commission], 1952. Order of Approval: in the Matter of the Applications of the Government of Canada and the Government of the United States of America for an Order of Approval of the Construction of Certain Works for Development of Power in the International Rapids Section of the St. Lawrence River. https://ijc.org/sites/default/files/Docket%2068%20St.%20Lawrence%20Power%20Order%201952-10-29.pdf

IJC [International Joint Commission], 2014. Lake Ontario – St. Lawrence River Plan 2014: Protecting against extreme water levels, restoring wetlands and preparing for climate change. A Report to the Governments of Canada and the United States by the International Joint Commission June 2014. https://www.ijc.org/sites/default/files/2019-04/Plan2014.pdf.

IJC [International Joint Commission]. 2015. Great Lakes-St. Lawrence River Adaptive Management Committee of the Great Lakes Boards of Control Directive. https://ijc.org/en/media/724.

IJC [International Joint Commission], 2016. Directive to the International Lake Ontario – St. Lawrence River Board on Operational Adjustments, Deviations and Extreme Conditions. https://ijc.org/sites/default/files/2019-04/LOSLRB-Directive_on_deviations-2016.pdf

IJC [International Joint Commission], 2016. Supplementary Order of Approval, International Joint Commission in the matter of the regulation of Lake Ontario outflows and levels. https://ijc.org/sites/default/files/Docket_68_Order_Sup-RegulationOfLakeOntarioOutlfows-2016-12-08.pdf

IJC [International Joint Commission], 2020a. Letter to Great Lakes-St. Lawrence River Adaptive Management Committee of the Great Lakes Boards of Control requesting Expedited Review of Plan 2014, February 3, 2020.

IJC [International Joint Commission], 2020b. Terms of Reference for a Public Advisory Group in support of Phase 1 of the Expedited Review of Plan 2014 by the Great Lakes-St Lawrence River Adaptive Management

(GLAM) Committee. https://ijc.org/en/glam/expedited-review/terms.

ILOBE [International Lake Ontario Board of Engineers], 1957. Regulation of Lake Ontario. Volume 1, Text. Report to the International Joint Commission (Under the Reference of 25 June 1952). March 1957. https://www.ijc.org/sites/default/files/K32.pdf .

ILOSLRB [International Lake Ontario – St. Lawrence River Board], 2018. Observed Conditions & Regulated Outflows in 2017. Report to the International Joint Commission. https://ijc.org/en/loslrb/observed-conditions-regulated-outflows-2017.

ILOSLRSB [International Lake Ontario – St. Lawrence River Study Board], 2006. Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows: Final Report by the International

Lake Ontario - St. Lawrence River Study Board to the International Joint Commission. https://ijc.org/sites/default/files/L40.pdf.

INBC [International Niagara Board of Control], 2021. Mandate | International Niagara Board of Control (IJC.org) https://ijc.org/en/nbc/who/mandate.

IPCC, 2021. Climate Change 2021 – The Physical Science Basis Summary for Policymakers. Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. August 7, 2021. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.

IWR [Institute for Water Resources], 2021. Economic Impact Assessment of Halting Commercial Navigation on the Montreal-to-Lake Ontario Section of the St. Lawrence Seaway. Prepared by the Institute for Water Resources, US Army Corps of Engineers for the International Joint Commission's Great Lakes-St. Lawrence River Adaptive Management Committee. May 2020.

Kennedy Consulting, Dillon Consulting and People Plan Community, 2021. Impacts of High Lake Ontario and St. Lawrence River Water Levels on Ontario Municipalities and Conservation Authorities: An Engagement Summary Report to Support the Great Lakes-St. Lawrence River Adaptive Management Committee's Expedited Review of Plan 2014. Prepared for the International Joint Commission's Great Lakes-St. Lawrence River Adaptive Management Committee. March 5, 2021.

Kua, Zi Hun, Stella, J.C., Farrell, J., 2020. Local disturbance by muskrat, an ecosystem engineer, enhances plant diversity in regionally altered wetlands. Ecosphere, Volume 11, Issue 10. October 2020. https://doi.org/10.1002/ecs2.3256.

LURA Consulting, 2019a. High Water Impacts Research on Lake Ontario and St. Lawrence River – Marinas and Yacht Clubs Final Results. Prepared for the International Joint Commission and the Great Lakes-St. Lawrence River Adaptive Management Committee. June 2019.

LURA Consulting, 2019b. High Water Impacts Research on Lake Ontario and St. Lawrence River – Municipal and Industrial Water Users Final Results. Prepared for the International Joint Commission and the Great Lakes-St. Lawrence River Adaptive Management Committee. June 2019. 54 p.

Macfarlane, Daniel, 2014. Negotiating a River: Canada, the U.S. and the Creation of the St. Lawrence Seaway. Vancouver: UBC Press.

Martin Associates, 2020. Economic, Environmental, and Societal Impacts of Restrictions to Commercial Navigation on the St. Lawrence Seaway. Prepared for the U.S. Saint Lawrence Seaway Development Corporation and the Canadian St. Lawrence Seaway Management Corporation. November 2020. 32 p.

Polytechnique Montréal, 2020. Assessment of critical low water thresholds for Lake St. Lawrence during winter operations and periods of ice cover. Submitted to: International Joint Commission – International Lake Ontario-St. Lawrence River Board and the Great Lakes-St. Lawrence River Adaptive Management Committee. March 2020. 52 p.

Ministère de la Sécurité publique, 2017. Daily summary reports of flooding impacts, by municipality.

River Institute, 2020. Review of potential ecological impacts from winter drawdown scenarios in Lake St. Lawrence. Prepared for the International Joint Commission, Lake Ontario-St. Lawrence River Board and Great Lakes-St. Lawrence River Adaptive Management Committee. April 24, 2020. 56 p.

Talbot, A (ed.). 2006. Water Availability Issues for the St. Lawrence River: An Environmental Synthesis. Environment Canada, Montéal. 204 p.

United States and Great Britain, 1909. Boundary Waters Treaty (Treaty between the United States and Great Britain Related to Boundary Waters and Questions Arising Between the United States and Canada). https://www.ijc.org/en/who/mission/bwt

USACE [U.S. Army Corps of Engineers] Institute for Water Resources, 2019. Regional Economic System (RECONS) 2.0 Methods Manual.

USACE [US Army Corps of Engineers] Institute for Water Resources, 2020. Economic Impact Assessment of Halting Commercial Navigation on the Montreal-to-Lake Ontario Section of the St. Lawrence Seaway. A report completed for the Great Lakes-St. Lawrence River Adaptive Management Committee, a sub-committee of the International Joint Commission's (IJC) International Lake Ontario-St. Lawrence River Board, under a support agreement with the IJC. 2020-R-03, May 2020.

USACE [US Army Corps of Engineers], 2021a. Engaging South Shore Lake Ontario Municipalities in Document High Water Impacts. Completed by the US Army Corps of Engineers - Buffalo District for the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee on behalf of the International Joint Commission. February 2021. 93 p.

USACE [US Army Corps of Engineers], 2021b. Lake Ontario Baseline Recreation Assessment. Completed by the US Army Corps of Engineers - Buffalo District for the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee on behalf of the International Joint Commission. February 2021. 22 p.

Wilcox, D. A., J.W. Ingram, K.P. Kowalski, J.E. Meeker, M.C. Mazur, Y. Xie, G.P. Grabas, K. Holmes, N.J. Patterson, 2005. Evaluation of Water-level-regulation Influences on Lake Ontario and Upper St. Lawrence River Coastal Wetland Plant Communities. Final project report. International Joint Commission, Washington, DC and Ottawa, Ontario. 67 p. https://www.researchgate.net/publication/228477533_Evaluation_of_water_level_regulation_influences_on_Lake_Ontario_and_Upper_St_Lawrence_River_coastal_wetland_plant_communities_Final_Project_Report.

Appendix 1: List of Contributors

Phase 1 Report Preparation

Primary Author	
Steve Orr	Science writer
GLAM Committee Writing Team	
Wendy Leger	CDN GLAM Committee Co-Chair
Mike Shantz	CDN GLAM Committee secretary
David Fay	Associate
Jamie Ferguson	Associate
Chris Warren	Associate
John Allis	US GLAM Committee Co-Chair
Melissa Kropfreiter	US GLAM Committee secretary

GLAM Committee Members/Secretaries
(listed alphabetically – refer to detailed list on page ii of report)

US Members/Secretaries	Canadian Members/Secretaries
Dena Abou	Jacob Bruxer, Plan Review co-lead
John Allis, GLAM US Co-chair	Patricia Clavet
Mary Austerman	Chief Linda Debassige
Lauren Fry, Hydroclimate co-lead	Susan Doka
Keith Koralewski	Wendy Leger, GLAM CDN Co-Chair
Melissa Kropfreiter, GLAM US secretary	Jean Morin
Scudder Mackey	Frank Seglenieks, Hydroclimate co-lead
Bill Werick, Impact Assessment co-lead	Mike Shantz, Impact Assessment co-lead
	Jonathan Staples

GLAM Associates and Working Team Affiliations

USACE	ECCC
Deanna Apps, Hydroclimate	Olivier Champoux, Coastal
Bryce Carmichael, Decision Support	Yin Fan, Decision Support co-lead
Michael Deegan, Decision Support	Joe Fiorino, Ecosystem
Lynn Greer, Communications	Daniel Ferreira, Coastal
Sung Lee, Project management support	Patrice Fortin, Coastal
Rachel Malburg, Coastal	Jamie Ferguson, Plan Review co-lead
Guillermo Mendoza, Decision Support	Natalie Gervasi, Plan Review
Jenny Olszewski, Decision Support	Greg Grabas, Ecosystem
Lauren Schifferle, Plan Review	Nicole O'Brien, Hydroclimate
James Selegean, Coastal	Elyse Parent, Coastal
Jonathan Waddell, Coastal	Caroline Sevigny, Decision Support
Chris Warren, Decision Support co-lead	Zach Simard, Plan Review
Laura Witherow, Project management support	Ian Smith, Ecosystem
	Yuki Yeung, Coastal
	OMNRF
	David Copplestone – Coastal
IJC - US	**IJC - Canada**
Mark Colosimo – IJC advisor	David Fay – IJC advisor
Adam Greeley – IJC Advisor	Erika Klyszejko – IJC Advisor
Ed Virden – Communications	Sarah Lobrichon – Communications
	Catherine Lee-Johnston – Contracting

Public Advisory Group (listed alphabetically)

US Members	Canadian Members
John Boyce St. Lawrence Seaway Pilots Association	Jean-François Belzile Montréal Port Authority / RUSL
Robert Cantwell Jefferson County Legislator	Gilbert Cabana Université du Québec à Trois-Rivières Sciences de l'Environnement
Pat Davis New York Power Authority	Ghalia Chahine Union des producteurs agricoles
Corey Fram Thousand Islands International Tourism Council	Sarah Delicate United Shorelines Ontario
Bernie Gigas Rochester, NY	Abraham Francis Mohawk Council of Akwesasne
James Howe The Nature Conservancy	Rick Layzell Boating Ontario Association
John Peach Save The River Upper St. Lawrence Riverkeeper	Nicolas Milot Communauté métropolitaine de Montréal
David Scudder Save Our Sodus	David Speak Beaconsfield Yacht
Jonathan Schultz Niagara County	Cliff Steinburg Ault Island, ON

Contractors and Agency Support (listed alphabetically)

US	Canada
Consensus Building Institute	ECCC - Canadian Wildlife Service - Ontario
Clarkson University	Copticom Stratégies et Relations Publiques
Limnotech	Kennedy Consulting Ltd.
Steven Orr	National Research Council of Canada
New York Sea Grant	ECCC - National Hydrological Service
USACE – Buffalo District	People Plan Community
USACE – Detroit District	Polytechique Montréal
USACE – Institute for Water Resources	River Institute

Appendix 2: Letter from the IJC to the GLAM Committee Initiating the Expedited Review of Plan 2014

International Joint Commission
Canada and United States

Commission mixte internationale
Canada et États-Unis

February 3, 2020

Ms. Wendy Leger
Canadian Chair
867 Lakeshore Rd.
Burlington, Ontario L7S 1A1

Mr. John Allis
U.S. Chair
477 Michigan Ave.
Detroit, MI 48226

Dear Ms. Leger and Mr. Allis,

We are following up on our participation in your Great Lakes – St Lawrence River Adaptive Management (GLAM) Committee teleconference call on January 29, 2020. Thank you for giving us an opportunity to address the Committee at the beginning of the call.

The Commission thanks the GLAM Committee for all its efforts in carrying out its work and for supporting the Commission's need for information, sometime with short deadlines and limited resources. For example, we appreciate your quick response last summer to the Commission's request to work with the International Lake Ontario – St Lawrence River Board (Board) to identify priority work activities and costs for conducting an expedited review of Plan 2014.

As we indicated during your January 29, 2020, call, the U.S Section obtained 1.5 million dollars in its U.S. FY 2020 budget to conduct phase 1 of the expedited review of Plan 2014. The Commission is taking the steps necessary to request release of funds held by the Treasury Board of Canada that were allocated in the Government of Canada's Budget 2016 for the implementation of Great Lakes adaptive management, pending matching US funds. We confirm at this time that Canadian funding is available until April 2021. Hence, the Commission formally requests the GLAM Committee collaborate with the Board to complete phase 1 of the expedited review of Plan 2014 with the combined 3 million dollars available from both countries. As noted in your work plan, phase 1 focuses on flow releases from Lake Ontario under board deviation authority, recognizing current conditions and high lake levels and high inflows in the foreseeable future.

The Commission encourages the GLAM Committee to explore all possible ways of modifying operations, within and outside of the confines of the existing plan and order. The GLAM Committee may also recommend the need for future study of possible structural changes within the system that could allow the Board to provide further relief to riparian interests in times of extreme water levels and extraordinary circumstances.

We were pleased to note during the January 29 call that the Commission approved the GLAM Committee's FY 2020 work plan dated December 31, 2019. The Commission was pleased to see the work plan contain the phase 1 activities to conduct the expedited review of Plan 2014. We ask that you work with the Commission's liaisons to update this document to reflect funding conditions to date (rather than as of December 31, 2019), so that the updated version can be posted on the IJC website.

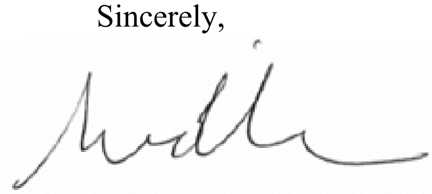
Although the Commission is hopeful that the expedited review will shed new light on innovative ways of regulating outflow during extreme events, we agree that it is essential to properly set public and stakeholder expectations of what can be achieved through the adaptive management process. As such, an effective communication strategy will be an essential part of the expedited review.

As we indicated on January 29, 2020, the Commission has approved the formation of an Advisory Group to the GLAM Committee to provide input and information from basin stakeholders and interests into the expedited review. This Advisory Group will also serve to take information and study findings from the expedited review back to their networks. At least one municipal member from each country shall be included in the list of nominations to be considered by the Commission. We ask that you work with the Commission's liaisons to GLAM to develop the Terms of Reference (TOR) for the Advisory Group, including a definition of its roles and responsibilities, as well as its operating procedures and requirements. We understand the GLAM Committee is very busy, but we ask that the Committee provide the potential nominee list and draft TOR to the Commission for consideration by February 18, 2020. Due to time and resource limitations associated with conducting phase 1, the Commission's initial view is limiting the size of GLAM's Advisory Group to 12 members (6 from each country).

Within the context of properly setting public and stakeholder expectation of what can be achieved through conducting phase 1 of the expedited review, the Committee should work with the Commission's communications staff and the Board to formulate a press release formally announcing receipt of the 3 million dollars in funding and launch of the expedited review, as well as formation of the Advisory Group to the GLAM Committee.

Again, the Commission wishes to thank the GLAM Committee for their high quality and timely work, especially during these times of extraordinary circumstances. If you have any questions on this matter, please don't hesitate to contact us or Erika Klyszejko in our Ottawa Section Office (613 995 0113) or Mark Colosimo in our Washington D.C office (202 736 9021).

Sincerely,



Pierre Béland
Chair, Canadian Section

Jane Corwin
Chair, U.S. Section

CC: Bryce Carmichael, U.S Secretary, GLAM
Mike Shantz, Canadian Secretary, GLAM

List of Acronyms

CBI
Consensus Building Institute (contractor)

ECCC
Environment and Climate Change Canada

GIS
Geographic Information System

GLAM
Great Lakes-St. Lawrence River Adaptive Management

IAG
Interim Advisory Group (to the International Lake Ontario-St. Lawrence River Board)

IGLD
International Great Lakes Datum

IJC
International Joint Commission

ILOSLRB
International Lake Ontario-St. Lawrence River Board

INBC
International Niagara Board of Control

IPCC
Intergovernmental Panel on Climate Change

IUGLS
International Upper Great Lakes Study

IWR
Institute for Water Resources (USACE)

LOSLRSB
Lake Ontario - St. Lawrence River Study Board

NRC
National Research Council of Canada

PAG
Public Advisory Group

RUSL
Regroupement des usagers du Saint-Laurent (Quebec-St. Lawrence River Users Group)

USACE
United States Army Corps of Engineers

USGS
United States Geological Survey

US
United States of America

Unit of Measurement Abbreviations

cm	Centimeter	in.	Inch
m	Meter	ft	Foot
km	Kilometer	mi	Mile
m^3/s	Cubic meters per second	cfs	Cubic feet per second

Glossary of Terms

ADAPTIVE MANAGEMENT
A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modeling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

AKWESASRONON
Members of the Mohawk Nation at Akwesasne.

ArcGIS
A family of client software, server software, and online geographic information system (GIS) services developed and maintained by Esri. ArcGIS was first released in 1999 and originally was released as ARC/INFO, a command line based GIS system for manipulating data.

AUTHORITY
The right to enforce laws and regulations or to create policy.

AVERAGE WATER LEVEL
An arithmetic average of past observations of water levels for a given time period (e.g. monthly) and a certain period of record (e.g. 1918 through 2020).

BASIN; WATERSHED
The region or area of which the surface waters and groundwater ultimately drain into a particular course or body of water.

BASIN (GREAT LAKES-ST. LAWRENCE RIVER)
The surface area contributing runoff to the Great Lakes and the St. Lawrence River downstream to Trois Rivières, QC.

BENTHIC INVERTEBRATES
Benthic (meaning "bottom-dwelling") macroinvertebrates are small aquatic animals and the aquatic larval stages of insects. Examples in the Great Lakes include dragonfly and stonefly larvae, snails, worms, beetles, crayfish and freshwater mussels.

BLUFF
A steep bank or cliff or variable heights, composed of glacial tills and lacustrine deposits consisting of clay, silt, gravel and boulders.

BOUNDARY WATERS TREATY OF 1909
The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

CHART DATUM
The water level used to calculate the water depths that are shown on "navigation charts" and are a reference point for harbor and channel dredging. Also known as Low Water Datum.

CLIMATE
The prevalent weather conditions of a given region (temperature, precipitation, wind speed, atmospheric pressure, etc.) observed throughout the year and averaged over at least 30 years.

CLIMATE CHANGE
A non-random change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

COAST
The land or zone adjoining a large body of water.

COMPUTER MODELLING; COMPUTER MODEL
The use of computers to develop a series of equations and mathematical terms based on physical laws and statistical theories that simulate complex natural systems or processes.

CONSERVATION AUTHORITY

Local watershed management agencies within the Province of Ontario that deliver services and programs to protect and manage impacts on water and other natural resources in partnership with all levels of government, landowners and many other organizations.

DECISION SUPPORT TOOL

Refers to a wide range of computer-based tools (simulation models, and/or techniques and methods) developed to support decision analysis and participatory processes. A DST consists of a database, different coupled hydrodynamic and socio-economic models and is provided with a dedicated interface in order to be directly and more easily accessible by non-specialists (e.g. policy and decision makers).

DEVIATIONS; OUTFLOW DEVIATIONS

Temporary changes in outflows (from Lake Ontario) that differ from those prescribed by a regulation plan that are intended to provide beneficial effects or relief from adverse effects to an interest, without causing appreciable adverse effects to any of the other interests.

DIRECTIVE

An IJC instruction to a new or existing Board or Committee specifying their terms of reference, including tasks and responsibilities.

ECOSYSTEM

A biological community in interaction with its physical environment, and including the transfer and circulation of matter and energy.

ENVIRONMENT

Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

EROSION; COASTAL EROSION; SHORELINE EROSION

The wearing away of land surfaces through the action of rainfall, running water, wind, waves and water current. Erosion results naturally from weather or runoff, but human activity such as the clearing of land for farming, logging, construction or road building can intensify the process. Coastal or shoreline erosion refers to the wearing away of a shoreline as a result of the action of water current, wind and waves.

FLOODING

The inundation of low-lying areas by water.

FLOODPLAIN

The lowlands surrounding a watercourse (river or stream) or a standing body of water (lake), which are subject to flooding.

FOREBAY

A forebay is an artificial pool of water in front of another body of water. For the purposes of this report, forebay refers to Lake St. Lawrence, a widening and deepening of the St. Lawrence River directly upstream of the Moses-Saunders and Long Sault dams created during the construction of the dams by permanently flooding a large portion of land (see https://ijc.org/en/loslrb/lake-st-lawrence).

FRAZIL ICE

Ice with the consistency of slush, formed when small ice crystals develop in supercooled water as air temperatures drop below freezing. These ice crystals join and are pressed together by newer crystals as they form.

FRESHET

The sudden overflow or rise in water level as a result of heavy rains or snowmelt.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

A conceptualized framework that provides the ability to capture and analyze spatial and geographic data. GIS applications are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as maps.

GREAT LAKES-ST. LAWRENCE RIVER ADAPTIVE MANAGEMENT (GLAM) COMMITTEE

A Committee of the International Joint Commission applying an adaptive management approach to the review of the outflow regulation plans for Lake Superior and Lake Ontario. The committee reports to the International Lake Ontario-St. Lawrence River Board, the International Lake Superior Board of Control and the International Niagara Board of Control.

HABITAT
The particular environment or place where a plant or an animal naturally lives and grows.

HAZARD ZONES
An area of land that is susceptible to flooding, erosion, or wave impact.

HERPETOFAUNA
The reptiles (e.g. turtles) and amphibians (e.g. frogs) of a particular region, habitat, or geological period

HYDRAULICS
The study of the mechanical properties of liquids, including energy transmission and effects of the flow of water.

HYDRAULIC MODELING
The use of mathematical or physical techniques to simulate water systems and make projections relating to water levels, flows and velocities.

HYDROCLIMATE
The study of the influence of climate upon the waters of the land including the energy and moisture exchanges between the atmosphere and the Earth's surface and energy and moisture transport by the atmosphere.

HYDROELECTRIC POWER
Electrical energy produced by the action of moving water.

HYDROLOGIC CYCLE; WATER CYCLE
The natural circulation of water, from the evaporation of water into the atmosphere, the transfer of water to the air from plants (transpiration), precipitation in the form of rain or snow, and runoff and storage in rivers, lakes and oceans.

HYDROLOGIC MODELING
The use of physical or mathematical techniques to simulate the hydrologic cycle and its effects on a watershed.

HYDROLOGY
The study of the properties of water, its distribution and circulation on and below the earth's surface and in the atmosphere.

ICE JAM
An accumulation of river ice, in any form which obstructs the normal river flow.

INDIGENOUS
originating or occurring naturally in a particular place; native. In this report Indigenous refers to the First Nations, Tribal Nations and Métis Nations of North America.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)
The United Nations body for assessing the science related to climate change.

INTERNATIONAL GREAT LAKES DATUM (IGLD)
The elevation reference system used to define water levels within the Great Lakes-St. Lawrence River basin. Due to the movement of the earth's crust, the "datum" must be adjusted every 30-40 years.

INTERNATIONAL JOINT COMMISSION (IJC)
International independent agency formed in 1909 by the United States and Canada under the Boundary Waters Treaty to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects. It also has a permanent reference under the Great Lakes Water Quality Agreement to help the two national governments restore and maintain the chemical, physical, and biological integrity of those waters.

INTERNATIONAL REACH
The portion of the St. Lawrence River that is between Lake Ontario and the Moses-Saunders Dam.

INTERNATIONAL LAKE ONTARIO - ST. LAWRENCE RIVER BOARD
Board established by the International Joint

Commission originally in its 1952 Order of Approval and renamed from the "International St. Lawrence River Board of Control" in 2017 with the implementation of Plan 2014 and the revised Order of Approval. Its main duty is to ensure that outflows from Lake Ontario meet the requirements of the Commission's Order.

IMPACT ZONE
Water level or flow ranges where impacts to an interest or use can be low, moderate, major, severe or extreme. Impact zones are based on a series of data and information sources and are meant to show the type and breadth of impacts at different water level ranges.

LAKE ONTARIO - ST. LAWRENCE RIVER STUDY (LOSLRS)
A study, sponsored by the IJC and completed in 2006, to examine the effects of water level and flow variations on all Lake Ontario-St. Lawrence River uses and interest groups and to determine if better management of Lake Ontario's outflows is possible.

LIGHT LOAD
A load less than a ship's capacity. Ships transiting the St. Lawrence Seaway are required to "light load" or carry less than their maximum capacity when a fully loaded ship would otherwise be too close to the channel bottom because of low water levels.

LIMITS
Special rules within a regulation plan that are meant to "limit" (e.g. restrict or increase) the outflow from Lake Ontario under certain conditions to address specific uses and interests on the St. Lawrence River that can be affected by water levels and/or flows there.

LOWER ST. LAWRENCE RIVER
The portion of the St. Lawrence River downstream of the Moses-Saunders Dam is called the lower St. Lawrence. It includes Lake St. Francis, Lake Saint-Louis, Montreal Harbour, Lake Saint-Pierre and the portions of the River connecting these lakes as far downstream as Trois-Rivieres, QC.

MARINA
A private or publicly-owned facility allowing recreational watercraft access to water and offering mooring and related services.

MARSH
An area of low, wet land, characterized by shallow, stagnant water and plant life dominated by grasses and cattails.

NET BASIN SUPPLY (NBS); WATER SUPPLY
The net amount of water entering one of the Great Lakes (e.g. Lake Ontario), comprised as the precipitation onto the lake minus evaporation from the lake, plus runoff from its local basin. The net basin supply does not include inflow from the upstream lake through the connecting channel.

NET TOTAL SUPPLY (NTS)
The Net Basin Supply plus the inflow through the connecting channel from the upstream lake (e.g. the Net Basin Supply to Lake Ontario plus the inflow from Lake Erie through the Niagara River and Welland Canal make up the Net Total Supply to Lake Ontario).

OBLIQUE IMAGERY
Aerial photography that is captured at approximately a 45 degree angle with the ground.

ORDERS OF APPROVAL
In ruling upon applications for approval of projects affecting boundary or transboundary waters, such as dams and hydroelectric power stations, the IJC can regulate the terms and conditions of such projects through Orders of Approval to maintain specific targets with respect to water levels and flows in the lakes and connecting channels.

PERFORMANCE INDICATOR
A measure of economic, social or environmental health. In the context of this report, performance indicators relate to impacts of different water levels in Lake Ontario and the St. Lawrence River.

PRE-PROJECT CONDITIONS; PREPROJECT RELATIONSHIPS
The outflow conditions that would occur without the St. Lawrence Seaway/Moses-Saunders Dam project

can be simulated using a stage-discharge relationship between the observed Lake Ontario water levels and outflows that occurred prior to the construction of the project. These conditions and this relationship are known as "preproject".

PUBLIC ADVISORY GROUP (PAG)

The group of 18 unpaid volunteers from the United States and Canada that worked as representatives of groups that are directly affected by outflow management (including deviations from the regulation plan) to bring their insights of the impacts of extreme high water to the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee and ensure effective communication, to help formulate a means of presenting this information to the Board, and to come up with ways to communicate with their constituents about progress of the Phase 1 expedited review of Regulation Plan 2014.

REFERENCE

A request from government for the IJC to study and recommend solutions to transboundary issue. The word is derived from Article IX of 1909 *Boundary Waters Treaty*, which stipulates that such issues "shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred."

REGULATION PLANS

In the context of the report, the management of water outflows (from Lake Superior and Lake Ontario) through regulatory structures (on the St. Marys River and St. Lawrence River) following a set of rules and objectives that are intended to meet the needs of various water-using interests in a basin. These plans have incorporated the specific objectives established in the IJC's Orders of Approval, establish monthly or weekly outflows, and allocate flows to various water-use interests.

REGULATORY STRUCTURES

Adjustable structures, such as a gated dam that can be operated to adjust outflows and influence water levels. In the Great Lakes-St. Lawrence River basin, there are regulatory structures on the St. Marys River at the outlet of Lake Superior and on the St. Lawrence River at the outlet of Lake Ontario.

REVETMENT

A natural (e.g., grass, aquatic plants) or artificial (e.g., concrete, stone, asphalt, earth, sand bag) covering to protect an embankment or other structure from erosion.

RIPARIAN; RIPARIANS

Of, relating to or found along a shoreline. Persons residing on the banks of a body of water. Typically associated with private owners of shoreline property.

RUNOFF

The portion of precipitation on the land that ultimately reaches streams and lakes.

RULE CURVE

Outflows set by Regulation Plan 2014 begin with a sliding "rule curve" based on a pre-project stage-discharge relationship such that as Lake Ontario levels and water supplies increase, outflows increase and as water levels and supplies decrease, outflows decrease.

ST. LAWRENCE SEAWAY

A system of locks, canals, and channels providing an inland waterway capable of accommodating seagoing ships travel from the Atlantic Ocean to the Great Lakes as far inland as Duluth, Minnesota at the western end of Lake Superior.

SHORE WELL

A well close to a lake in which the well water levels are directly influenced by lake levels.

SHORELINE

Intersection of a specified plane of water with the shore.

STAKEHOLDER

An individual, group, or institution with an interest or concern, either economic, societal or environmental, that is affected by fluctuating water levels or by measures proposed to respond to fluctuating water levels within the Lake Ontario–St. Lawrence River basin.

STOCHASTIC SUPPLIES
Statistically generated simulated sequences of water supply conditions based on historical climate variability.

STORY MAP
A web based product that has been thoughtfully created, given context, and provided with supporting information so it becomes a stand-alone resource. It integrates maps, legends, text, photos, and video and provides functionality, such as swipe, pop-ups, and time sliders, that helps users explore the content.

SURGE
A movement of water that happens when a storm (low pressure center) moves across the lake and causes the water to be "pushed" in the same direction the storm is moving. This results in water levels rising at one end of the lake and falling at the other end.

UPPER ST. LAWRENCE RIVER
The portion of the St. Lawrence River upstream of the Moses-Saunders Dam is called the upper St. Lawrence River. It includes the entire river from Kingston/Cape Vincent to the Moses-Saunders Dam and locks at Cornwall-Massena, including Lake St. Lawrence.

USES AND INTERESTS
In the context of the report, the groups or sectors served by the waters of Lake Ontario and the St. Lawrence River, including municipal and industrial water uses, commercial navigation, hydroelectric power generation, coastal development, ecosystems, and recreational boating. Under the *Boundary Waters Treaty* of 1909, the interests of domestic and sanitary water uses, navigation and hydroelectric generation and irrigation are given order of precedence in water uses in the development and operation of regulation plans.

WATER LEVEL
The elevation of the surface of the water of a lake or at a particular site on the river. The elevation is measured with respect to a certain datum (e.g. International Great Lakes Datum) or average sea level.

WATER LEVEL PROJECTION; WATER LEVEL FORECAST
The projected range of water levels that may be expected to occur under potentially wet, average and dry conditions. Actual water levels will depend primarily on weather and water supplies, and during periods of extreme conditions, may fall outside of the projected range.

WAVE
An oscillatory movement in a body of water which results in an alternate rise and fall of the surfaces.

WETLANDS
An area characterized by wet soil and high biologically productivity, providing an important habitat for waterfowl, amphibians, reptiles and mammals.

Photo Credits

Cover: Cavan Images / Alamy Stock Photo
Page III: Cindy Hopkins / Alamy Stock Photo
Page IV: iStock
Page 1: iStock
Page 8: RLS PHOTO / Alamy Stock Photo
Page12: Aerial Archives / Alamy Stock Photo
Page13: Clair Milanovich / Alamy Stock Photo
Page 21: P.Spiro / Alamy Stock Photo
Page 28: Cindy Hopkins / Alamy Stock Photo
Page 32: iStock
Page 34: Emiliano Joanes / Alamy Stock Photo
Page 38: Christian Ouellet / Alamy Stock Photo
Page 48: Madeleine Jettre / Alamy Stock Photo
Page 49: Elena Korchenko / Alamy Stock Photo
Page 54: Adrien Le Toux / Alamy Stock Photo
Page 58: Sean O'Neill / Alamy Stock Photo
Page 60: Vlad Ghiea / Alamy Stock Photo
Page 66: RLS PHOTO / Alamy Stock Photo
Page 70: iStock
Page 74: Puffin's Pictures / Alamy Stock Photo
Page 82: Megapress / Alamy Stock Photo
Page 88: Cindy Hopkins / Alamy Stock Photo
Page 96: Gaertner / Alamy Stock Photo
Page 98: Cindy Hopkins / Alamy Stock Photo
Page 106: iStock
Page 108: public domain sourced / access rights from Ted Small / Alamy Stock Photo
Page 112: iStock
Page 113: Torontonian / Alamy Stock Photo
Page 120: Matt Strauss / Alamy Stock Photo

GLAM GREAT LAKES – ST. LAWRENCE RIVER ADAPTIVE MANAGEMENT COMMITTEE

ijc.org/glam