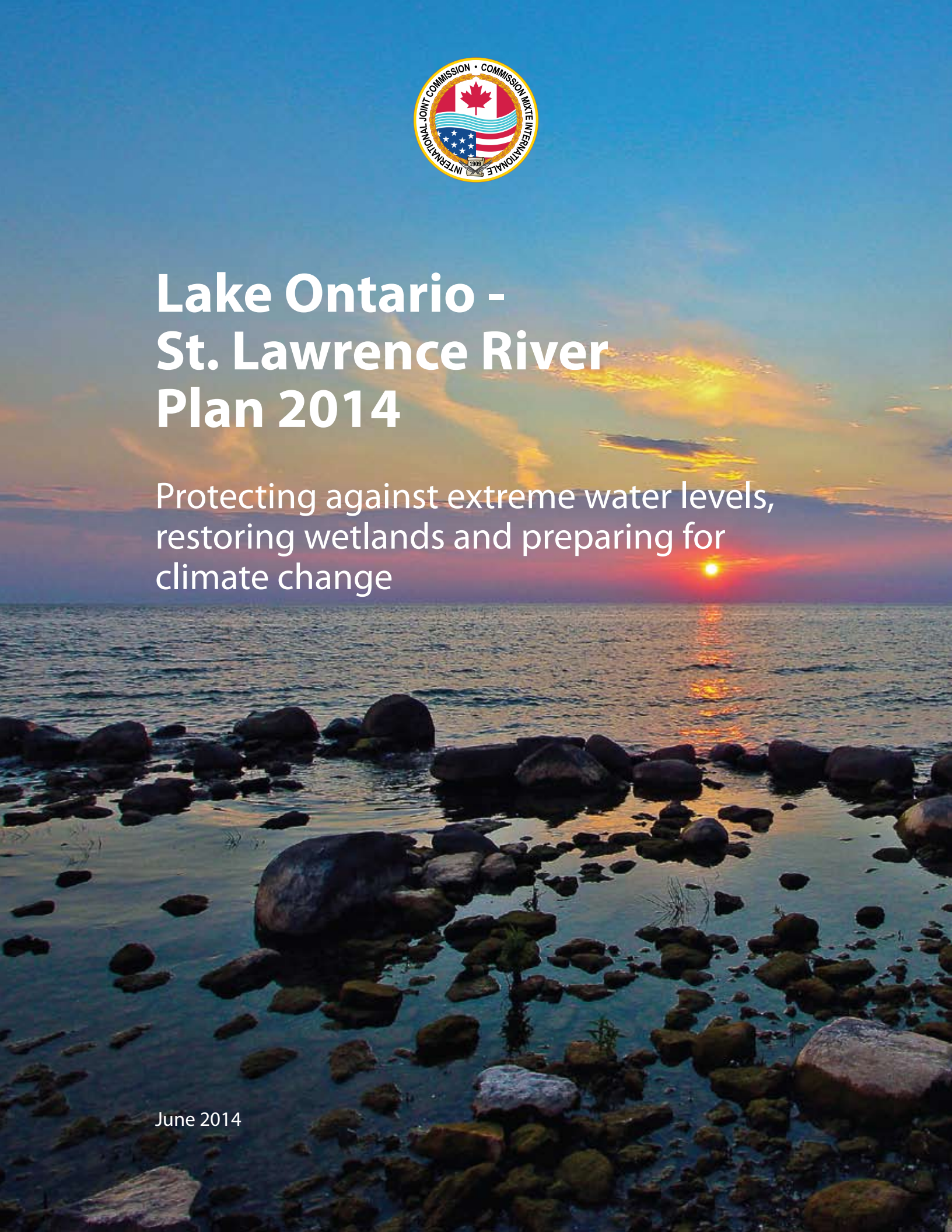

Lake Ontario - St. Lawrence River Plan 2014

Protecting against extreme water levels, restoring wetlands and preparing for climate change

June 2014

A Report to the Governments of Canada and the United States by the International Joint Commission

For more information on regulation of Lake Ontario and St Lawrence River water levels or the International Joint Commission (IJC), please visit the IJC's website: www.ijc.org. Information also can be obtained by contacting any of the following IJC offices:

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Front Cover shows sunset over Lake Ontario at Three Mile Bay, New York.
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Preface

The Akwesasne people have lived in the territory that currently straddles the borders of Ontario, Quebec and New York for centuries. Although divided by an international border today, the Akwesasne live as one community, with some people in this nation residing just two miles downstream of the Moses-Saunders dam on Kawhno:ke, also known as Cornwall Island.

The Akwesasne live within sight of the Moses-Saunders Dam and in the 1950s they watched the dam be built across their western view. Perhaps they, more than any, appreciate the change to nature that was made, and they continue to press their concerns for the well-being and long-term health of the Lake Ontario and St. Lawrence River basins.

On July 19, 2013 during the International Joint Commission's Public Hearings on Plan 2014 that were held throughout communities within the basins, Henry Lickers, Environmental Science Officer and former member of the International Lake Ontario – St Lawrence River Study Board, honored Commissioners with an invocation that traditionally opens and closes his nation's meetings with governments and contains the teachings of how one is to conduct one's self in harmony with the natural world.

> *These words that come before all else are the ones that open everything, and we heard a little bit about the good mind and bringing your mind together to think about the problems. These are all of our problems. These are our issues and we feel responsible for them, whether it's my boating friends or my little minnow, we have a responsibility to them.*
>
> *And we say whenever we are gathered, one of us is chosen to do a greetings and thanks giving and I'd like you to think about the people of this world. There are many people that aren't as well off as we are and they live across this world and across this River. And I would say to you that my sons and daughters and your sons and daughters live in that water as well. So I ask you to bring together your minds and think about the peoples of this world, and can we agree that they are important to us?*
>
> *I ask you to think about the Mother Earth, for she continues to carry out her responsibility to us, never ceasing in her responsibility. We say that if you look at the colors of the soils of that world, in those colors of those soils you see the colors of every one of our skins and we know that she is our mother and that she will continue in her responsibility. So I ask you to bring together your minds and think about the Mother Earth, and can we agree that she is important to us?*
>
> *Today we have concentrated on the waters and the fishes of this world; they have been most important to our discussions and we know that they will continue to carry out their responsibilities. And they don't need anyone to teach them what their responsibilities to us are, but they continue to do this. So I ask you to bring together your minds and think about the waters and the aquatic life like our fishes, and can we agree that they are important to us?*
>
> *I know that we have spent a little time talking about the plants of this world, and the Haudenosaunee looked at the plants and we have a special relationship with them. We have three, called the Three Sisters: corn, beans and squash that have helped sustain our populations. But we also know that in those waters have been many medicine plants that can help us and it seems that the waters and the marshes and the wetlands seem to be those places where those medicine plants are. And then we talk about the trees. The trees that give so much to us and all of the things we see around us that are beneficial to make our lives a better place to live upon this world. So I ask you to bring together your minds and think about the plants of this world, and can we agree that they are important to us?*
>
> *We don't live here alone. We live here with many other species and this morning I rose and heard the crows crying in my backyard, waking me as usual. But we also have other animals; the four legged type. Some of them living in our own homes and we call them our pets but we treat them like they're our brothers and sisters. And so I would say to you that all of the animals and birds of this world deserve the same respect and deserve the same as our brothers and sisters. And so I ask you to bring together your minds and think about the animals and birds of this world, and can we agree that they are important to us?*

Today as we look outside we see the Four Great Winds getting ready to blow us a blustering night I think, and during that time we will hear the voices of our grandfathers. We call those the Thunderers, and they speak to us. But what they tell us is to be ever vigilant as we live upon this land for the land is changing and we must be ready for it. We must be the ones that help fulfill our responsibilities to the world around us. And so I ask you to bring together your minds and think about the Four Great Winds and those Thunderers, and can we agree that they are important to us?

This morning our elder brother the sun rose as he has done millennium after millennium, never ceasing in his responsibility to us and to all of creation. That we could carry out our responsibilities as such, this would truly be a wonderful thing. So I ask you to bring together your minds and think about our elder brother the sun, and can we agree that he is important to us?

This evening we'll see our grandmother moon as she turns her face to us every 28 days, and that 28-day cycle is the cycle of all female things in this world. And without that 28-day cycle it would truly be a lonely place. But she's also very powerful and she has the ability to move all of the waters of this world, even the waters of the first environment: the womb. And so I ask you to bring together your minds and think about grandmother moon and through her all female things upon this world, and can we agree that she is important to us?

In the evening we see the stars as they shine down upon us, and the Haudenosaunee say these are our aunties and uncles and they are still here with us looking down upon us. They guide us across the surface of this Earth and foretell of great events that will occur in our communities, but they too are carrying out their responsibilities to us. And so I ask you to bring together your minds and think about those stars, and can we agree that they are important to us?

Again we know that we don't exist here alone but we know that there's a spiritual world that surrounds us and that there are many spirits out there that can help us in our deliberations. The Haudenosaunee say that whenever our deliberations are so tough and that we really need to think about our answers and questions, that if we look deep into our souls those answers will come to us and lead us to peace and harmony upon this world. And so I ask you to bring together your minds and think about the spiritual world that surrounds us, and can we agree that they are important to us?

We know that there are many other teachers in this world and we sit here today and listen to our problems that we have, but we know that we have the knowledge that come to us down the corridors of time from elders and ancestors that have preceded us and each of us have those trusted elders that we have listened to in the past and hear their knowledge today and we will build on that knowledge that this will be a better place. And so I ask you to bring together your minds and think about those teachers of the world, and can we agree that they are important to us?

It has come that at this time we will cover our Council fire and as the Haudenosaunee would say "unbind that stout cord that bound us all in this place that we could talk about our responsibilities to the world. And I'll cut that cord now that we may each go our own separate way." But before we do that, the Haudenosaunee say we must never ask anything of the Creator, but on your behalf today I'll ask two things of the Creator: I'll ask that as you proceed from this place to your homes, your lodgings and your communities, that no impediment is placed in your way and that you arrive there safely. And the second thing I'll ask on your behalf is that when you arrive at your homes, your lodgings and your communities, that you see the happy smiling faces of your people and that no misfortune has befallen them while you've been here.

And so now those words have been said and our Council fire is closed but I call on you my friends one last time to bring together your finest thoughts and your finest thanksgiving and we'll pile them in a huge pile before us to send to the Creator of all things for the beauty that surrounds us. Ne onkwa'nikònra

International Joint Commission
Canada and United States

Commission mixte internationale
Canada et États-Unis

The United States of America and Canada are the applicants on the St. Lawrence Power Project as well as the Parties to the Boundary Waters Treaty. The International Joint Commission (the Commission) seeks the views and concurrence of the United States and Canada on the matter of amending the Order of Approval for the St. Lawrence Power Project (Docket No. 67 and 68). The Commission submits its conclusions on the matter of regulating Lake Ontario and St. Lawrence River levels and flows in a spirit consistent with the Boundary Waters Treaty.

The International Joint Commission, after 14 years of scientific study and public engagement, advances Plan 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows. Scientific studies reveal that the Commission's 1956 Orders of Approval and regulation of the flows through the power project following Plan 1958D with deviations, have harmed ecosystem health primarily by substantially degrading 26,000 hectares (64,000 acres) of shoreline wetlands. After exhaustive consideration of alternative plans, the Commission concludes that Plan 2014 offers the best opportunity to reverse some of the harm while balancing upstream and downstream uses and minimizing possible increased damage to shoreline protection structures.

The Commission was created by a century-old treaty between the United States and Canada to help the two countries address challenging issues arising from managing their shared waters. The Commission has respectfully considered the diverse and often competing uses and interests affected by any regulation plan in reaching its conclusion that the current method of regulating the levels and flows of Lake Ontario and the St. Lawrence River needs to be modified. The Commission seeks the concurrence of the Parties on revising the Order to consider ecosystem health with respect to all other interests and uses of the Lake Ontario-St. Lawrence River system.

Plan 2014 is designed to provide for more natural variations of water levels of Lake Ontario and the St. Lawrence River that are needed to restore ecosystem health. It will continue to moderate extreme high and low levels, better maintain system-wide levels for navigation, frequently extend the recreational boating season and slightly increase hydropower production. More year-to-year variation in water levels improves coastal health. Thriving wetland habitats support highly valued recreational opportunities, filter polluted run-off, and provide nurseries for fisheries and wildlife. Ecosystem health was not considered in the 1950s when decisions were made to artificially compress the natural variability of levels of Lake Ontario.

Plan 2014 incorporates insights from more than 50 years of operational experience, significantly increased knowledge gained through the Commission's five-year landmark study, and additional analysis by U.S. and Canadian experts and important contributions from Quebec, Ontario and New York State, as well as from municipal governments, indigenous governments, and shipping, fishing, recreational, riparian, cultural, environmental and other interests that depend upon the St. Lawrence River and Lake Ontario.

The Commission acknowledges that erosion and storm damage are realities along the Lake Ontario shoreline. Varying degrees of erosion and damage to structures built close to the shoreline were present before the dam was built, are present under Plan 1958D with deviations (Plan 1958DD) and will exist under Plan 2014 or any other regulation plan. Due to local geology, as well as land use and development patterns, some south shore areas of Lake Ontario are uniquely vulnerable to occasional higher waters. In comparing Plan 2014 to Plan 1958DD, the Commission recognizes that costs to maintain hardened shoreline protection structures, such as shorewalls and revetments, may increase by a relatively small amount under Plan 2014.

However, before selecting Plan 2014, the Commission considered an exhaustive list of options in order to select the best possible plan to provide significant environmental restoration with overall economic benefits and the smallest increase in damage to any property, infrastructure, shipping or recreational interests.

Based on the science and consultations that guided the development of Plan 2014 – as well as on the principles and objectives of the recently reaffirmed Great Lakes Water Quality Agreement – the Commission recommends that governments and the Commission's Lake Ontario-St. Lawrence Board adopt an adaptive management strategy to foster a binational technical network, and support performance evaluation. The Board will provide regular public engagement opportunities through annual and special meetings, regular electronic updates, and timely responses to questions and comments received through its website or via social media.

Recognizing that modifications to Plan 1958DD have been the subject of discussion for several decades, the Commission believes Plan 2014 should be implemented soon after a timely review and concurrence by the Parties on the question of amending the Order of Approval. Once adopted, no significant changes would occur to Plan 2014 without a convenient opportunity for all interested parties to be heard and consultation with the governments. The accompanying report provides a brief historical overview, description of Plan 2014, responses to common concerns, alternatives considered and information on its public engagement process. Annexes provide further technical aspects of Plan 2014 regulation rules, governance, and an adaptive management program.

Plan 2014 represents the culmination of considerable work undertaken by all interests in the basin. Plan 2014 found widespread but not unanimous support throughout the basin. The Commission appreciates the more than $20 million financial investment by the Governments of Canada and the United States, which made possible the extensive scientific studies and public engagement that provide the foundation for Plan 2014. The Commission thanks the scores of Study Board and Public Advisory Group participants, hundreds of involved scientists and technical experts, its own staff and the thousands of people who have commented on the impacts of regulating levels and flows in Lake Ontario and the St. Lawrence River. On whole, the IJC is confident that Plan 2014 is the best management path for the human, plant, and animal communities and for the commercial interests that depend on Lake Ontario and the St. Lawrence River system in both Canada and the United States.

Lana Pollack
United States Chair

Gordon Walker
Interim Canadian Chair

Richard Moy
Commissioner

Benoît Bouchard
Commissioner

Dereth Glance
Commissioner

Executive Summary

This report to the Governments of Canada and the United States presents the conclusions of the International Joint Commission (IJC) investigation regarding needed changes to the 1952 and 1956 Orders of Approval for the St. Lawrence River Power Project.

After years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible. A summary description of Plan 2014 is included in the main body of this report, with further technical details provided in the annexes.

The IJC finds that the regulation of water levels and flows in the St. Lawrence River in accordance with the 1952 and 1956 Orders of Approval has damaged ecosystems along the coast of Lake Ontario and upper St. Lawrence River over the last 50 years or more. The effects of the regulation of water flows and lake levels on ecosystems were not fully understood or considered when the existing Order of Approval and regulation plan were developed. However, robust coastal ecosystems are now recognized as essential in both countries, and the IJC finds that the effects on ecosystems should now be considered along with effects to other interestsand uses.

The IJC has reached these conclusions in consideration of the results from 14 years of study and extensive open public consultations with all interested parties. In 2000, the U.S. and Canadian governments agreed to provide about $20 million over five years for the IJC to conduct a thorough and comprehensive study to evaluate and recommend improvements to the regulation of Lake Ontario levels and outflows, including, among other issues, environmental concerns. This investment enabled the IJC to undertake scientific studies to understand and measure the effects of water levels and conduct extensive engagement with people from all interests in the formulation and evaluation of hundreds of potential alternative regulation plans.

Among the conclusions of its 2006 final report (IJC, 2006), the IJC's Lake Ontario-St. Lawrence River Study Board found that the compression of the range of water levels on Lake Ontario and the upper river has degraded coastal wetlands. It found that environmental conditions could be improved by changing the regulation plan, but not without tradeoffs that will reduce some existing economic benefits.

The IJC invited public comment and undertook a thorough review of the 2006 report and public comments. In 2008, the IJC invited comment on a proposed new Order of Approval and regulation plan, known as Plan 2007, based on one of the three options recommended by the Study Board. The IJC heard widespread opposition to Plan 2007 throughout the Lake Ontario–St. Lawrence River basin. In 2008, the IJC concluded that Plan 2007 was not viable, and sought the advice of governments on how to proceed.

In 2009, a new group was established with officials appointed by the two federal governments and the governments of New York, Ontario and Quebec to advise the IJC on the potential for a new regulation plan. Of the many regulation plans developed to date, the group determined that a plan that resulted in more natural flows and lake levels was preferable. It then worked to refine a regulation plan that the IJC developed into Plan 2014.

The IJC finds that Plan 2014 provides the best response to the range of issues that must be considered in regulating the water levels and flows of the Lake Ontario-St. Lawrence River system. Plan 2014 will mitigate much of the harm done by the existing regulation regime to the shoreline environment, while striving to maintain the benefits to other interests and users throughout the system. Plan 2014 will respect the order of precedence of uses specified in the *Boundary Waters Treaty of 1909*, while protecting interests that may be harmed by regulation.

Plan 2014 returns Lake Ontario levels to more natural variability, while continuing to moderate extreme low and high water levels

Figures Ex-1, Ex-2 and Ex-3 are examples of what are known as a "spaghetti graph". In these graphs, each year's water levels are shown as a separate line running from January to December. These three simulations of Lake Ontario levels were run using the historical water supply data for 1900-2000. The thick black dashed lines in each graph follow the minimum and maximum levels of Plan 1958DD for any year.

Under Plan 1958DD, the range of water levels is more compressed, particularly at the beginning of the year, when lower levels mean less productive wetlands.

By contrast, Plan 2014 represents a return to more natural level variability for Lake Ontario. It would relax the compressed Lake Ontario levels of Plan 1958-DD, but with the upper levels still substantially controlled to protect Lake Ontario riparians. The maximum level simulated under Plan 2014 is only 6 cm (a little more than 2 in) higher than the maximum level under Plan 1958DD.

The Natural Plan (referred to as Plan E in study documents) represents the release of Lake Ontario water through the existing flow control structures equivalent to what would occur with the unregulated river as it was circa 1953-1955 after removal of Gut Dam, but before any of the structures or channels approved in the 1952 and 1956 Orders were built, with minimal adjustments to reflect necessary ice management with the structures in place.

The reduction in high levels from Plan E to either Plan 2014 or Plan 1958DD represents the benefit provided to riparians along the Lake Ontario shoreline in terms of reduced damages to coastal shoreline protection structures and fewer flooded houses. In water supply conditions more extreme than historical conditions, Plan 2014 would operate under the same premise as Plan 1958DD: protecting riparians both upstream and downstream of the control structures.

Figure Ex-1

Lake Ontario Levels, Simulated for Plan 1958DD

(1 line for each of 101 years historical record)

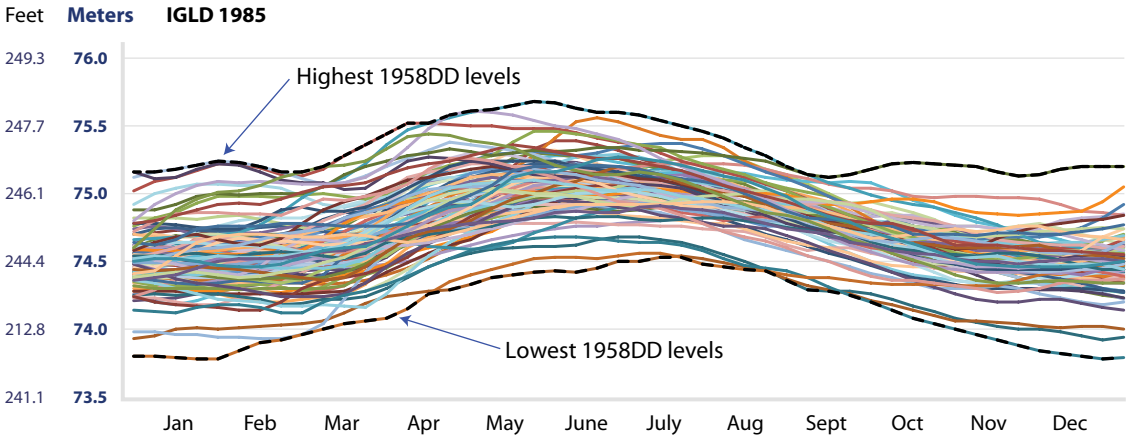


Figure Ex-2

Lake Ontario Levels, Simulated for Plan 2014

(1 line for each of 101 years historical record)

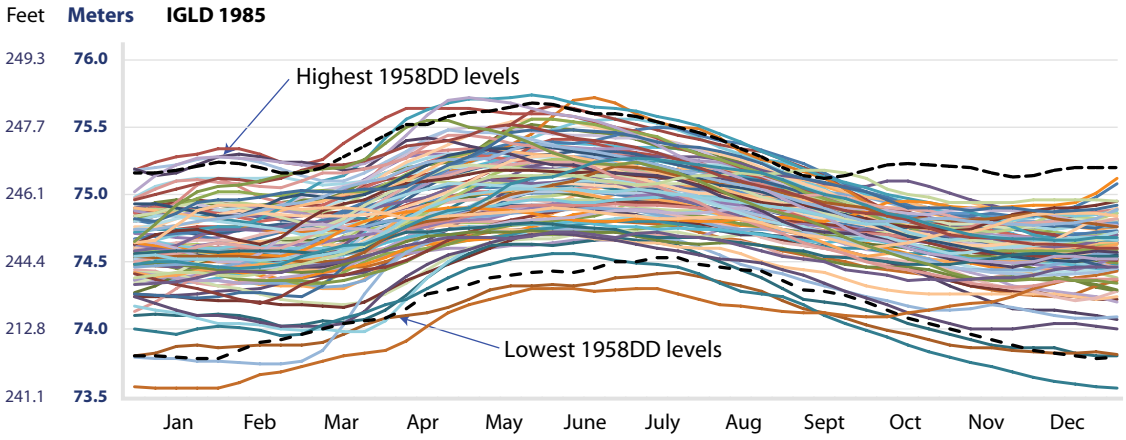
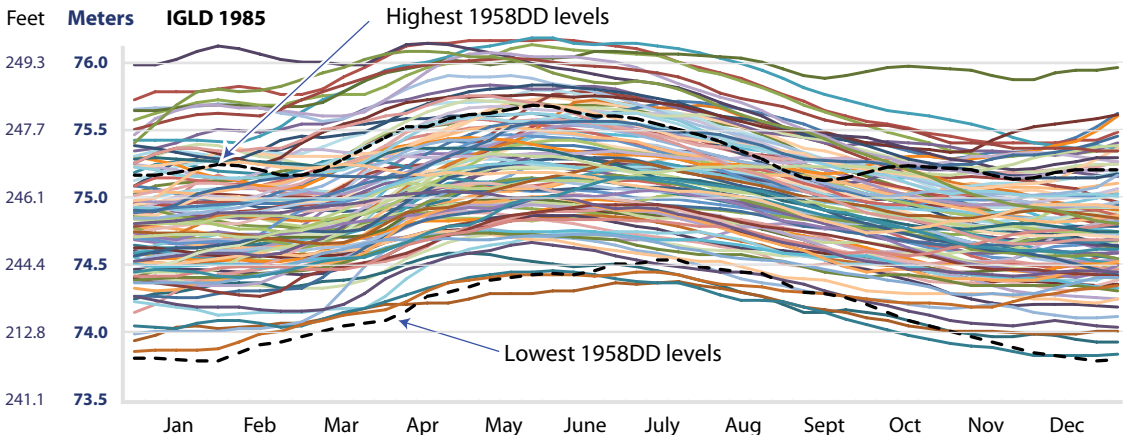


Figure Ex-3

Lake Ontario Levels, Simulated for No Regulation (Plan E)

(1 line for each of 101 years historical record)



Compared to the existing regulation plan for Lake Ontario and the St. Lawrence River, Plan 2014 will:

- provide essentially the same level of benefits to **domestic water uses**;
- provide essentially the same level of benefits for **navigation**;
- increase by a small amount the generation of **hydropower** at the Moses-Saunders dam and the Hydro-Quebec facilities on the St. Lawrence River;
- provide **riparians** (owners of shoreline property) on the upper and lower river essentially the same level of protection;
- result in a small reduction of benefits to **riparians** on Lake Ontario, in the form of increased costs of maintaining shoreline protection structures;
- work to restore the natural **environment** of Lake Ontario and the upper St. Lawrence River that support wetlands, birds, amphibians, fish, and mammals;
- have a mixed effect on **recreational boaters**; and,
- provide essentially the same benefits **downstream** of the dam as does the current regulation regime.

Some of the benefits now enjoyed by domestic water users, commercial navigation, hydropower producers and riparians on the St. Lawrence River are the result of ad hoc, discretionary decisions by the International St. Lawrence River Board of Control. Plan 2014 will make these benefits more assured and predictable, by removing the discretionary aspect of many of these decisions and formally making them part of the Plan's regulation rules.

Regulation of Lake Ontario outflows since 1960 has substantially compressed the range of Lake Ontario water levels compared to what would have occurred without regulation. Figures Ex-1 to Ex-3 illustrate this compression using what have come to be known as "spaghetti" graphs. These three graphs show 101 years of Lake Ontario water levels, with each year's level shown as a separate line running from January to December. These simulations were run using the historical water supply data for 1900-2000:

- Figure Ex-1 shows the compression of the range of lake levels resulting from the application of the current regulation regime (called Plan 1958-D with deviations, or Plan 1958DD);
- Figure Ex-2 shows the lake levels with Plan 2014 applied; and
- Figure Ex-3 shows what levels would be with no regulation except that minor amount necessary to control ice jam flooding.

The compression of lake levels shown in Ex-1 has benefitted property development along the Lake Ontario shore, but caused substantial harm to coastal ecosystems. To address that harm, Plan 2014 produces more natural water level cycles, while continuing to moderate extreme high and low water levels. The benefit provided to Lake Ontario shoreline property interests under either Plan 2014 or Plan 1958DD is clear when comparing Figure Ex-3 to either of the other two figures. The IJC's analysis found that without lake level regulation, property damage along the Lake Ontario shoreline would average more than $45 million[1] per year (IJC, 2006).

Plan 2014 is projected to have little effect on buildings compared to the current plan but likely will increase the costs of shore protection structures, such as sea walls and revetments. Plan 2014 will continue to provide significant benefits for riparians relative to what they would experience if there were no lake level regulation.

Plan 2014 will have little impact on buildings compared to the current plan, but is likely to increase the cost of shore protection.

[1] All economic values are expressed in $US 2005.

Despite a 10-year open and vigorous competition to design the ideal regulation plan, no plan has ever been developed that can help restore coastal ecosystems, maintain all the benefits to other interests and gain unanimous public support. After examining many alternative regulation plans, the IJC concludes that no regulation plan can meaningfully reduce the current risk of damage to some shoreline protection structures and some properties along the south shore of Lake Ontario. However, it may be possible to significantly reduce that risk through better coastal zone and floodplain management. The IJC acknowledges the domestic efforts to address coastal hazard risks and offers its support to these efforts as requested.

Plan 2014 should be implemented as soon as possible. In the near term, Plan 2014 will provide benefits to coastal ecosystems around Lake Ontario. Its more natural variation in levels and generally higher fall-through-spring water elevations will benefit wetlands, birds, fish, mammals, and amphibians. In most years, Plan 2014 will extend the boating season on Lake Ontario. Plan 2014 will slightly increase the production of hydropower. Overall, navigation will be held whole. Shippers will benefit from more consistent available drafts at different sections on the route from Montreal to Lake Ontario that will occur with Plan 2014, though tonnage transported per ship between Lake Ontario ports will be reduced in the driest years. Important opportunities to restore coastal wetlands arise with low and high water supply conditions that historically have occurred every few decades. If such an opportunity to expand meadow marsh is lost due to delayed implementation of Plan 2014, then the next opportunity may not arise for decades.

Since the IJC began regulating flows and water levels in the St. Lawrence River, much information and knowledge have been gained. Realizing that there is always more to learn, Plan 2014 performance will be tracked and evaluated. Applying an adaptive management framework, which includes ongoing monitoring and evaluation of plan performance, as well as continued public involvement, will allow for additional scientific knowledge to suggest opportunities to further improve and refine the plan over time. In this approach, both countries will continue to benefit from the investments made by the governments to develop an evaluation system for the regulation plans. Research over the last two decades has identified key areas, such as long-term weather forecasting, where improvements to information could further strengthen performance of the plan.

Adaptive management will provide insights and prompt recommendations, but once a new to the Order of Approval is approved and Plan 2014 is implemented, changes to the Order and regulation plan will occur only after considerable public consultation and the concurrence of the Governments of the United States and Canada.

The IJC concludes that Plan 2014 will provide the best possible balance between the multiple – and sometimes conflicting – uses and interests, including domestic and sanitary use, navigation, hydropower, and coastal development, while addressing environmental harm caused by past regulation and enhancing recreational boating opportunities in most years. The IJC has found widespread support for Plan 2014 with people around the basin, as well as strong opposition concentrated in Lake Ontario south shoreline property owners in New York. After thoroughly reviewing and considering thousands of comments from people throughout the Lake Ontario and St. Lawrence River watershed, the IJC believes that Plan 2014 is the best plan to maintain and improve Lake Ontario-St. Lawrence River water levels and flows for all uses and interests.

Despite an open and vigorous design competition to produce the ideal regulation plan, no plan has ever been developed that gained the support of all interests.

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1. Introduction

1.1 Purpose of the Report

This report to the Governments of Canada and the United States presents the conclusions of the International Joint Commission (IJC) investigation regarding needed changes to the 1952 and 1956 Orders of Approval regulating water levels and flows in Lake Ontario and the St. Lawrence River.

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible.

The report presents:

- an overview of the Lake Ontario-St. Lawrence River setting;
- a review of the history of the regulation of Lake Ontario and the St. Lawrence River since the 1950s;
- a review of the IJC's efforts to develop a new regulation plan and the role of public participation in this effort;
- a description of the rationale and key features of Plan 2014;
- a review of the expected effects of Plan 2014 on the uses and interests in the Lake Ontario-St. Lawrence River basin, including ecosystems; and,
- a discussion of the role that adaptive management can play in improving the outcomes of Lake Ontario-St. Lawrence River water level regulation.

The Annex provides technical details on the operations of Plan 2014, information on an adaptive management strategy, references, and a glossary.

1.2 Setting

Figure 1 shows a map of the Lake Ontario-St. Lawrence River system drainage basin. Lake Ontario has a water surface area of about 18,960 km^2 (7,340 mi^2). The lake's watershed is about 64,030 km^2 (24,720 mi^2) in size, though it receives water draining from the entire Great Lakes watershed, which covers more than 765,000 km^2 (more than 295,000 mi^2).

The St. Lawrence River at the northeast end of Lake Ontario is the natural outlet for the Great Lakes. Numerous rocky islands and reefs dominate the broad channel of the river for the first 80 km (about 50 mi) forming the section known as the Thousand Islands. The river then flows through the Galops channels, and into Lake St. Lawrence. Approximately 160 km (100 mi) downstream from Lake Ontario are the structures that are used to control the flow from Lake Ontario. The Moses-Saunders powerhouses use most of the flow and the roughly 24.5 m (80 ft) drop from Lake St. Lawrence into Lake St. Francis for hydroelectric generation. Additional water may be released through the gates of the nearby Long Sault Dam. From Lake St. Francis, the river flows through the Beauharnois Power and Navigation Canal and down the adjacent Coteau Rapids to Lake St. Louis, and then down the Lachine Rapids at Montreal. At Montreal, the St. Lawrence River is joined by its largest tributary, the Ottawa River, which drains a basin of about 146,300 km^2 (56,500 mi^2). From Montreal, the river flows through the St. Lawrence lowlands to Lake St. Pierre and finally to the Gulf of St. Lawrence.

The St. Lawrence River and Seaway connects the Great Lakes to the Atlantic Ocean and provides navigation for lake and ocean-going vessels with drafts to up to 8.08 m (26.5 ft). Typically, the Seaway from Montreal to Lake Ontario is open from mid or late March until late December, depending in part on ice conditions in the river. The Montreal and downstream ports of the St. Lawrence River are open year-round and can accommodate larger, deeper-draft ships.

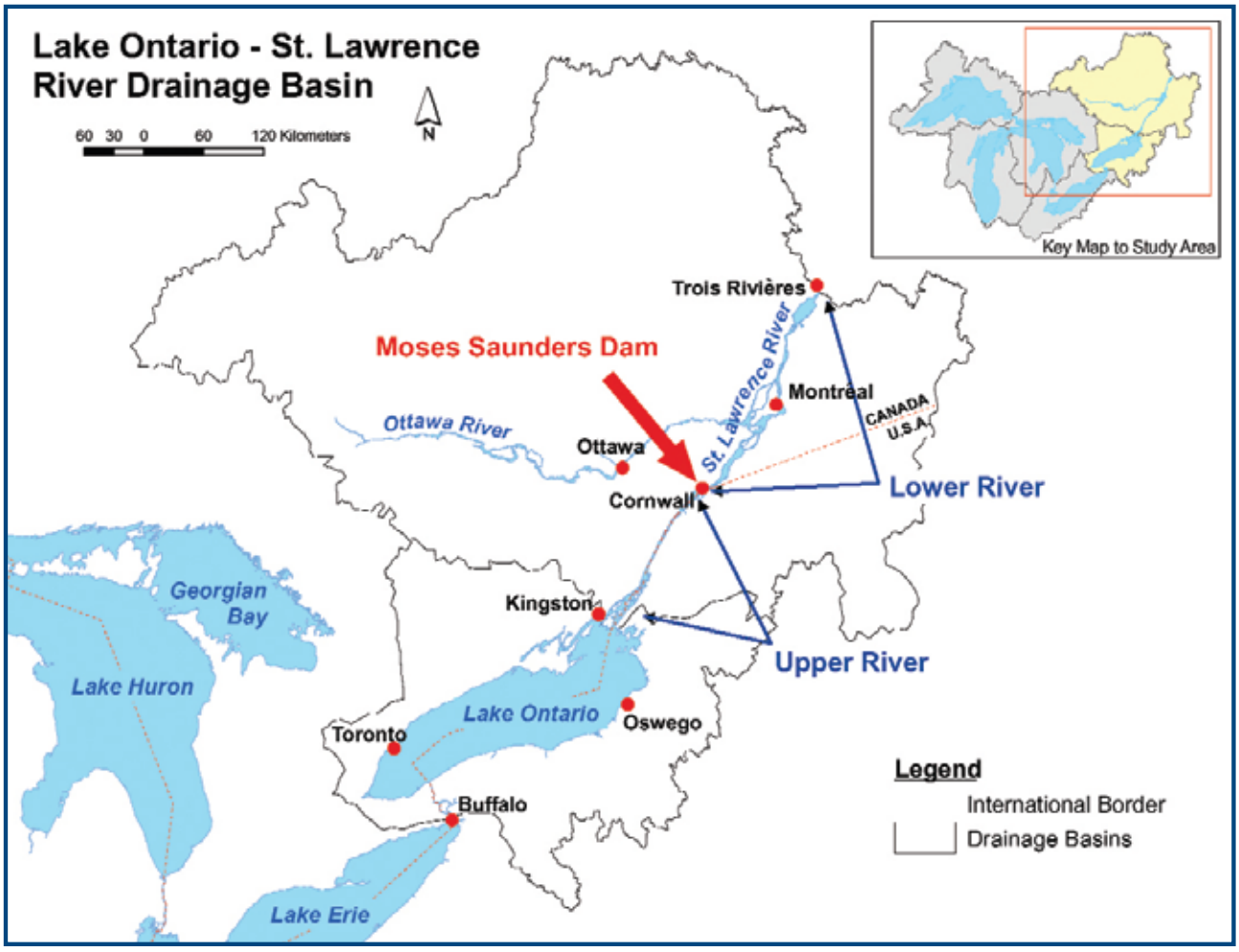
The net water supplies to Lake Ontario and the upper St. Lawrence River are made up primarily of inflow from Lake Erie (about 80% of the total), precipitation onto the lake's surface and runoff to the lake from streams that drain its watershed, minus evaporation from the lake's surface. Each of these components varies on timescales that range from seconds to seasons to decades (Figure 2). Within each year from 1860 to 2013, there re wet

and dry periods. But decades-long trends are also visible – for example, the long decline to the 1940s, the high supplies of the 1950s before the dam was built, a relatively quick return to the very dry 1960s, followed by three decades of high levels. Scientists have tried to understand the driving factors behind these long-term cycles, but for now they are unpredictable.

The water level of Lake Ontario changes in response to the difference between the supply it receives and its outflow. The supply is uncontrolled, while the Moses-Saunders and Long Sault Dam on the St. Lawrence control the outflow. A change in outflow of 323 cubic meters per second (m^3/s) for a period of one week will cause a change of 1 centimeter (cm) in the Lake Ontario level, while a change in flow of this amount will cause a change in the level of Lake St. Lawrence of 16 cm and of Lake St. Louis of 10 cm.[2] The use of the dam to change the amount of water that would naturally flow from Lake Ontario into the St. Lawrence River provides some control over the impacts of water levels, but that control is very limited. There are physical limits to the amount of water that can be released. Larger releases may reduce Lake Ontario flooding but increase river flooding. Smaller releases can deepen water at Lake Ontario ports but reduce Seaway depths. A release that makes sense based on current supply conditions may or may not seem right in retrospect, but the ability to foresee water supply conditions even two months away is limited.

Figure 1

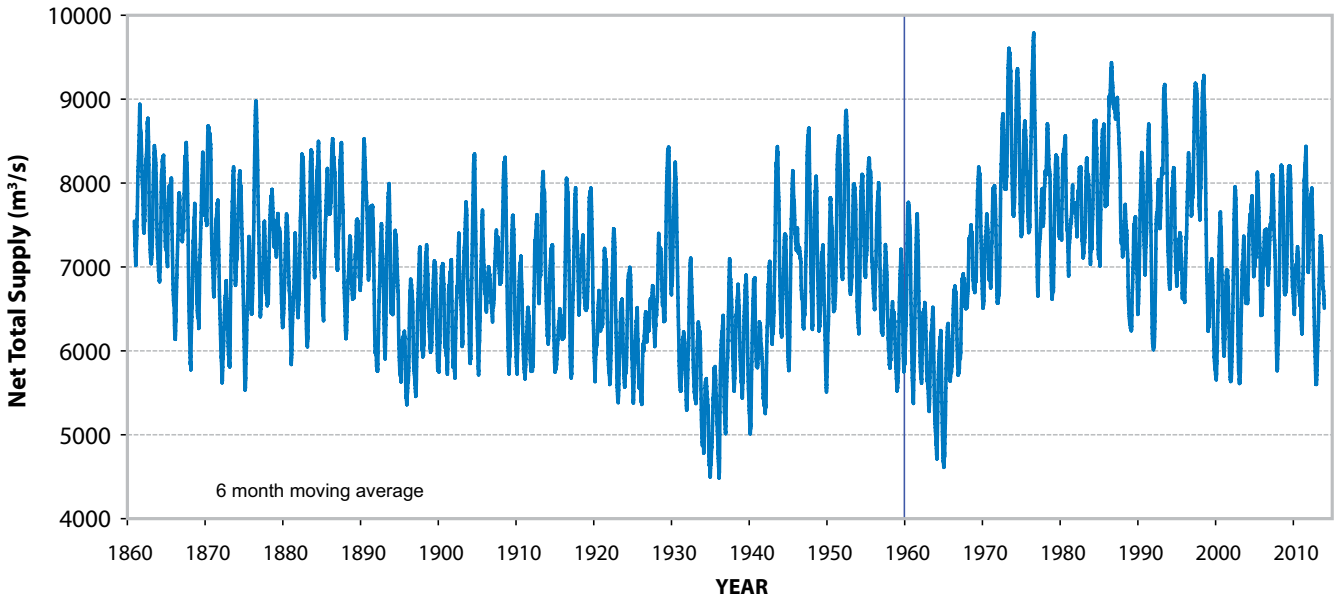
Lake Ontario-St. Lawrence River Drainage Basin



[2] In US customary units, about 29,000 cubic feet per second (cfs) for 1 week equates to a 1 inch change in the Lake Ontario level, while this change in flow of 29,000 cfs would change the level of Lake St. Lawrence by 16.5 inches and of Lake St. Louis by 10 inches.

Figure 2

Recorded Lake Ontario Net Total Supplies 1860-2013



Measurement Units Used in the Report

Metric units are presented first in this report, given that most of the collection, modeling and analysis of data undertaken in this study and previous studies used the metric system. The equivalent United States customary system units are provided, as well.

All water surface elevations are referenced to the International Great Lakes Datum, 1985 (IGLD 1985).

2. Regulating Water Levels and Flows of the Lake Ontario-St. Lawrence River System

This section presents a review of the history of the regulation of Lake Ontario and the St. Lawrence River since the 1950s. It describes the efforts of the IJC to develop a new regulation plan and provide interested parties with opportunities to comment on various proposed plans. Figure 3 presents a timeline of significant events in the history of Lake Ontario-St. Lawrence River regulation.[3]

2.1 History of the Project and Current Regulation Plan

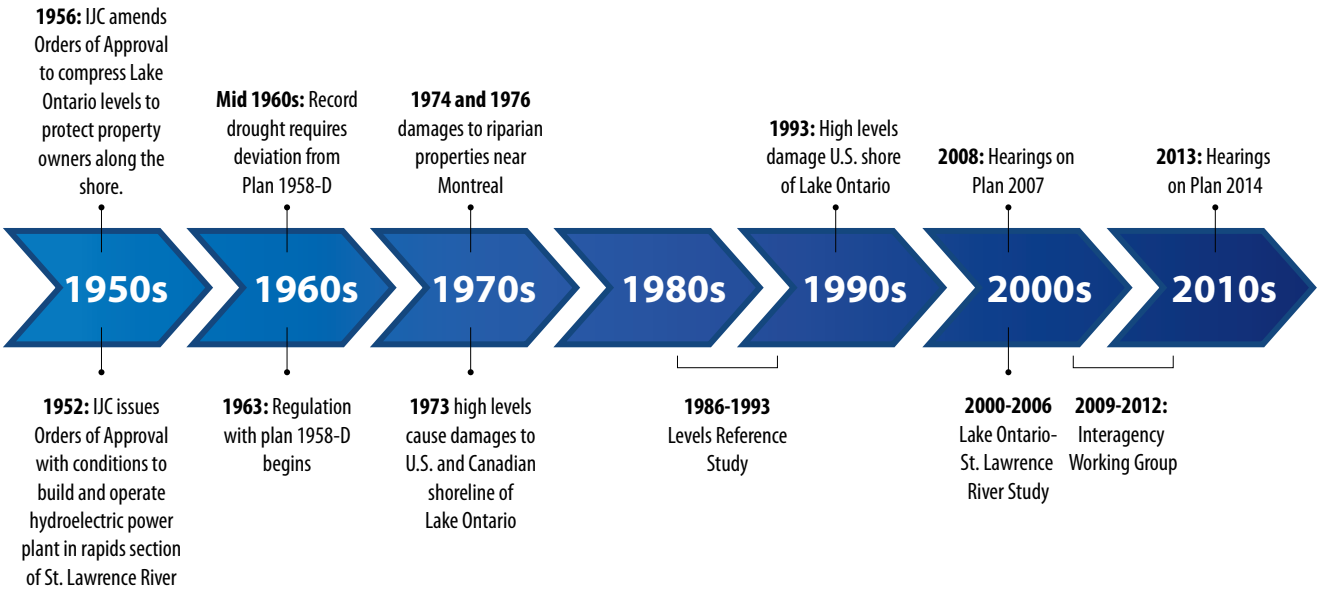
2.1.1 The 1952 Order of Approval

In accordance with the *Boundary Waters Treaty of 1909*, the Governments of Canada and the United States submitted an application to the IJC in June 1952 for approval to develop a hydroelectric power project in the International Rapids section of the St. Lawrence River (Figure 4). Operation of this project would determine the outflow from Lake Ontario and thus affect the water levels of the lake as well as the flows and levels of the St. Lawrence River from Lake Ontario downstream as far as Trois Rivières, QC. The design and operation of the hydropower dam would affect the design and operation of the St. Lawrence Seaway, then under construction. Under the terms of the Treaty, the hydropower use could not materially conflict with or restrain the navigation use.

The IJC considered the information received from the governments and from public hearings in 1952 on the application. On October 29, 1952, the IJC issued an Order of Approval adopting conditions for the construction and operation of the project presented by the governments. The Order established the International St. Lawrence River Board of Control (the Board of Control) to carry out the IJC's instructions and ensure that the provisions in the Order related to flows in the river were met.

Figure 3

Timeline of Significant Events, Lake Ontario-St. Lawrence River Regulation

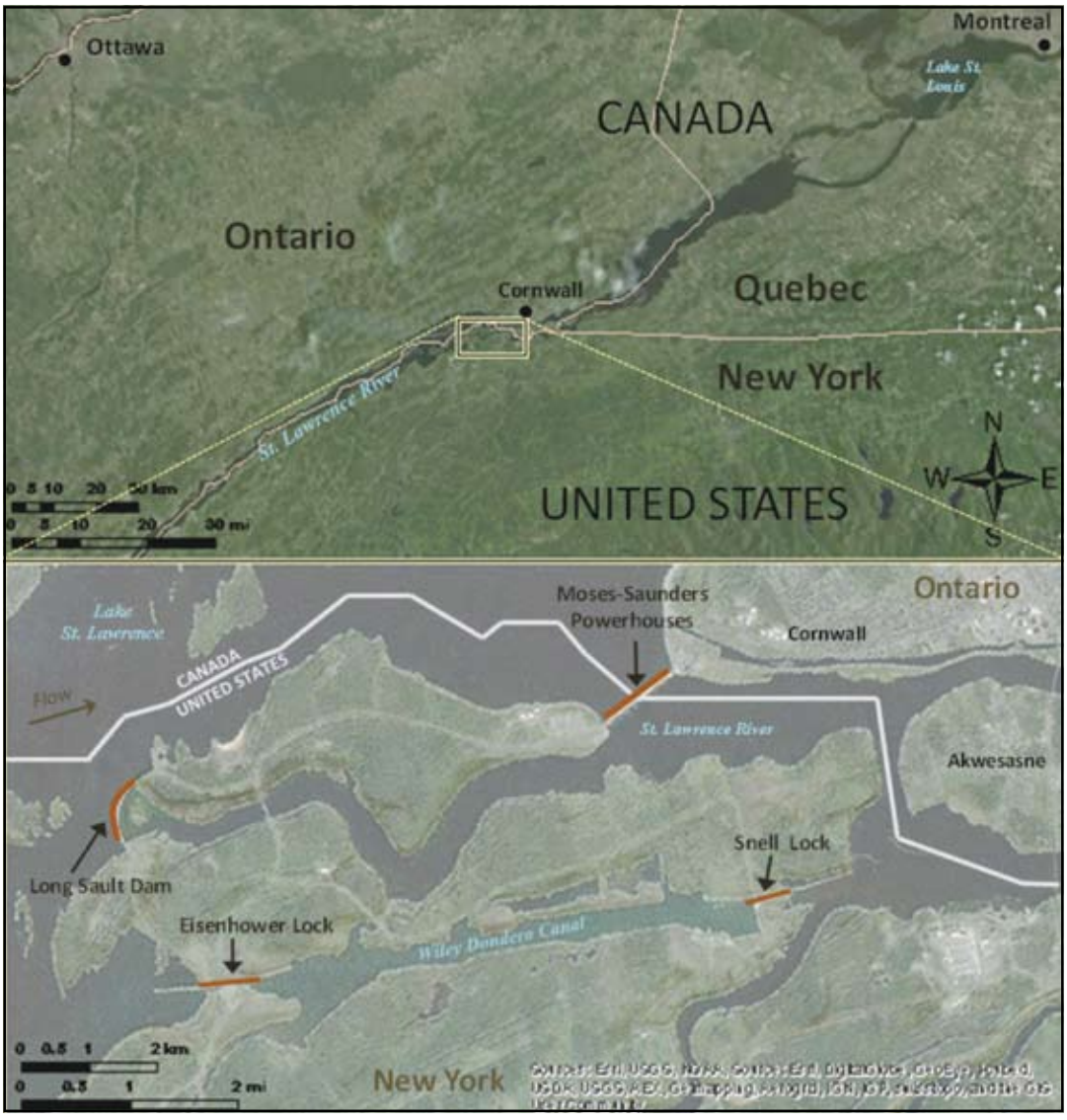


[3] This report focuses on the regulation of water levels and flows of Lake Ontario and the upper St. Lawrence River since the 1950s. However, the natural regime of the outlet from Lake Ontario into the St. Lawrence River was first changed in 1825 to facilitate navigation. By 1850, works in the St. Lawrence River provided a minimum channel depth of 2.7 m (9 ft) from the Atlantic Ocean to Lake Ontario. Between 1884 and 1905, a canal-building program undertaken by the Canadian government enabled ships with a 4.3 m (14 ft) draft to navigate from Montreal to Lake Superior. (Source: IJC, 1976)

In 1952, following record floods in the early 1950s, the 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 of the lake, "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" (IJC, 1952). The historical record up to that time showed that the range of Lake Ontario monthly average levels had been more than 1.8 m (6 ft). The IJC advised the governments that the project could be operated so that Lake Ontario could be regulated within a narrower 1.2 m (4 ft) target range of elevations from April through November for the benefit of shoreline property owners, provided that natural water supplies were no more extreme than those experienced in the past. As was the norm at the time, environmental interests were not considered in the analysis.. The IJC recommended 11 criteria for regulating Lake Ontario outflows and a regulation plan for setting the outflows in a manner that would meet the criteria. It also listed the benefits that the project and Order would provide to shoreline owners on Lake Ontario, to navigation on Lake Ontario and in the International Rapids section, and to power development in the International Rapids section.

Figure 4

Control Structures at Cornwall, ON and Massena, NY



2.1.2 The 1956 Order of Approval

In December 1955, the governments approved the provisions recommended by the IJC. After additional public hearings, the IJC amended its Order of Approval on July 2, 1956 to incorporate the design range of elevations for Lake Ontario, the 11 criteria, and a regulation plan. The project was to provide no less protection for navigation and riparian interests (shoreline property owners) downstream than with unregulated flows. The criteria addressed:

- regulated outflows from Lake Ontario and their effect on the minimum level of Montreal Harbour;
- winter outflows to permit power generation;
- outflows during the annual spring break-up in Montreal Harbour and during the annual flood discharge from the Ottawa River;
- minimum regulated outflows to secure the maximum dependable flow for power;
- limiting the maximum outflow to reduce the required channel excavation;
- reduction in the frequency of high Lake Ontario levels to benefit riparians; and,
- both maximum and minimum lake levels intended to benefit shoreline owners on Lake Ontario and navigation and other interests.

Several of these criteria are contingent on the water supplies to Lake Ontario being within the range of supplies experienced during the period of record (1860-1954), adjusted to account for the diversions into and out of the Great Lakes basin. The IJC recognized that not all of the criteria could be met when water supplies to Lake Ontario were more extreme than those experienced in the past. The 11th criterion, criterion k, specifies how Lake Ontario outflows should be regulated when water supplies are higher or lower than those experienced in the past.

The project includes many components. The principal structure used to regulate Lake Ontario outflows is the Moses-Saunders Power Dam that crosses the St. Lawrence River between Cornwall, Ontario, and Massena, New York (Figure 5). The nearby Long Sault Dam acts as a spillway when specified outflows from Lake Ontario exceed the capacity of the power dam. In addition, the river channel was enlarged in several locations to carry the higher flows needed to reduce maximum Lake Ontario levels and to facilitate navigation.

Initially, an evolving set of rules was used to determine how much water to release from Lake Ontario on a weekly basis, with each ruleset named Plan 1958 and a dashed letter suffix to denote the version. The IJC put Plan 1958-A into operation in April 1960. The IJC approved revised versions of

Figure 5

Moses-Saunders Dam

that plan that were made operational in January 1962 (Plan 1958-C) and October 1963 (Plan 1958-D). These refined plans were developed to better meet the criteria specified in the 1956 Order of Approval (IJC, 1963).

Plan 1958-D has remained in effect since 1963. Its rules use recent water supplies to the lake, lake levels, the time of year, Ottawa River flows, and various flow limits to determine the flow to be released for the coming week. These rules have been programmed to produce the specific weekly release for any given set of conditions.

2.1.3 Deviations from Plan 1958-D

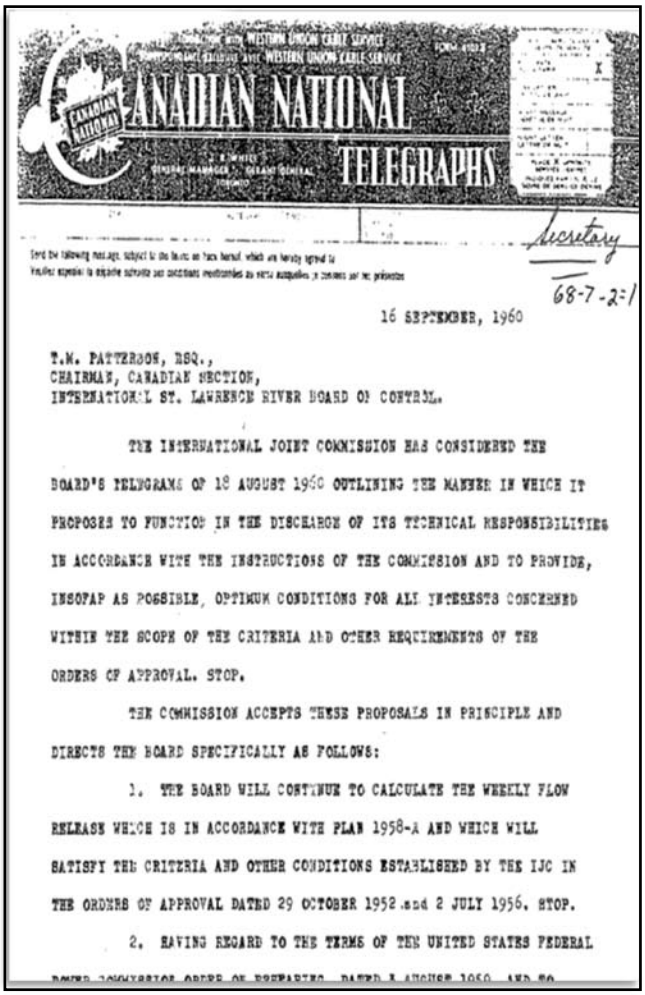
The regulation criteria, Plan 1958-D, and the project were designed for the hydrological conditions experienced from 1860 to 1954. For that reason, Plan 1958-D without deviations would not have performed well for riparians under the more extreme high water supply conditions experienced since that time. Without the deviations required by criterion k of the 1956 Order to deal with supplies more extreme than those experienced from 1860 to 1954, Plan 1958-D would have raised Lake Ontario levels to about 77.0 m (about 253 ft.). In spite of the major deviations from Plan 1958-D made in accordance with criterion k during these periods of extreme supplies, Lake Ontario levels have been outside the 1.2 m (4 ft.) target range specified in the 1956 Order for a total of 78 weeks since regulation began, with actual levels ranging about 0.3 m (1 ft) above and below the target range.

In a 1960 telegram to the Board of Control, the IJC granted authority to temporarily deviate from the regulation plan flow under emergency conditions and when ice formed and broke up during winter operations (Figure 6) (IJC, 1960).

In 1961, at the Board's request, the IJC granted "discretionary authority" for the Board to deviate temporarily from the plan to provide beneficial effects or relief from adverse effects to an interest, without causing appreciable adverse effects to any of the other interests. Given that the Lake Ontario outflow is quite often different from the Plan 1958-D outflow because of deviations, the current approach to regulation now is called "Plan 1958-D with deviations" or 1958DD.

Figure 6

Portion of 1960 IJC Telegram to the Board of Control



CANADIAN NATIONAL TELEGRAPHS

Secretary

68-7-2:1

16 SEPTEMBER, 1960

T.M. PATTERSON, ESQ.,
CHAIRMAN, CANADIAN SECTION,
INTERNATIONAL ST. LAWRENCE RIVER BOARD OF CONTROL.

THE INTERNATIONAL JOINT COMMISSION HAS CONSIDERED THE BOARD'S TELEGRAMS OF 18 AUGUST 1960 OUTLINING THE MANNER IN WHICH IT PROPOSES TO FUNCTION IN THE DISCHARGE OF ITS TECHNICAL RESPONSIBILITIES IN ACCORDANCE WITH THE INSTRUCTIONS OF THE COMMISSION AND TO PROVIDE, INSOFAR AS POSSIBLE, OPTIMUM CONDITIONS FOR ALL INTERESTS CONCERNED WITHIN THE SCOPE OF THE CRITERIA AND OTHER REQUIREMENTS OF THE ORDERS OF APPROVAL. STOP.

THE COMMISSION ACCEPTS THESE PROPOSALS IN PRINCIPLE AND DIRECTS THE BOARD SPECIFICALLY AS FOLLOWS:

1. THE BOARD WILL CONTINUE TO CALCULATE THE WEEKLY FLOW RELEASE WHICH IS IN ACCORDANCE WITH PLAN 1958-A AND WHICH WILL SATISFY THE CRITERIA AND OTHER CONDITIONS ESTABLISHED BY THE IJC IN THE ORDERS OF APPROVAL DATED 29 OCTOBER 1952 and 2 JULY 1956. STOP.

2. HAVING REGARD TO THE TERMS OF THE UNITED STATES FEDERAL

2.2 Review of the Regulation Plan

2.2.1 Levels Reference Study

During the record high water levels of 1986 on the upper Great Lakes, the governments issued a reference[4] to the IJC to examine and report on methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes–St. Lawrence River basin (the Levels Reference Study). One of the specific requests in the reference was for

[4] A reference is a request from the governments for the IJC to study and recommend solutions to a transboundary issue. The word is derived from Article IX of the *Boundary Waters Treaty of 1909*, 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."

the IJC to review and revise its earlier studies on lake level regulation.

The IJC 's Levels Reference Study Board report (IJC, 1993) recommended that the "Orders of Approval for the regulation of Lake Ontario be revised to better reflect the current needs of the users and interests of the system." Among other recommendations, the Board suggested that criteria should be added that consider the environmental interests on Lake Ontario and the St. Lawrence River.

2.2.2 Lake Ontario-St. Lawrence River Study

In April 1999, the IJC informed the Governments of Canada and the United States that it was becoming increasingly urgent to review the regulation of Lake Ontario levels and outflows in view of dissatisfaction on the part of some riparians and boaters, in light of environmental concerns, and because of the potential for climate change to affect lake levels (Figure 7). In response, the governments appropriated approximately $20 million for the IJC to undertake the five-year Lake Ontario-St. Lawrence River study (IJC, 2006).

The IJC appointed a binational Study Board to conduct the study (Figure 8). The Board was to assess the impacts of fluctuating water levels on the affected uses and interests and present the IJC with options for regulating the lake. Approximately 200 researchers and more than 20 organizations participated directly in the study.

The IJC also created an independent Public Interest Advisory Group (PIAG) as part of the Study (see section 2.3, below). The Study Board and PIAG interacted from the beginning to create a rigorous, thorough and transparent study. The U.S. and Canadian PIAG co-chairs were also Study Board members.

The analysis was carried out by technical work groups. Six of the groups were formed around the interest areas of navigation, municipal and industrial water use, hydropower, recreation, coastal impacts and the environment. Other groups managed climatological and hydrological research, common data needs such as Geographic Information System (GIS) of nearshore topography and bathymetry, data archiving and storage, and the formulation

Figure 7

Portion of IJC 1999 Letter to Governments

International Joint Commission

April 15, 1999

Honourable Lloyd Axworthy
Minister of Foreign Affairs
Department of Foreign Affairs and International Trade
125 Sussex Drive
Ottawa, ON K1A 0G2

Honorable Madeleine Albright
Secretary of State
Department of State
2201 C Street, NW
Washington, D.C. 20520

Dear Minister Axworthy and Secretary Albright:

It is becoming increasingly urgent to review the regulation of Lake Ontario in view of dissatisfaction, on the part of some interests, with the working of that system and in the light of environmental concerns and climate change issues. We would like to take this opportunity to provide some background information on this subject, inform you of recent

Figure 8

A Meeting of the Lake Ontario- St. Lawrence River Study Board

and evaluation of regulation plans. Each group was composed of experts and stakeholders[5].

In planning its work, the Study Board recognized that there are many possible effects that changes to the regulation of Lake Ontario outflows could have on the interests and uses. As not every possible effect could be studied and evaluated in detail, the Study Board chose to limit the extent of impact studies in all water sectors to those that best fit the study's purpose (that is, determining whether improvements can be made in flow regulation), budget, and timeline. The measures

[5] For a full list of participants in the Lake Ontario-St. Lawrence River Study, see IJC, 2006.

used to characterize the effects on each interest were consistent with widely-accepted planning and evaluation principles.

Economic performance indicators (for example, the value of additional hydropower energy produced) were approved by a separate advisory panel of four economic experts and based on scopes of work approved by the Study Board.

An binational team of environmental scientists worked with the Study Board to select the quantitative environmental "performance indicators" used in its evaluation (for example, an index of reproductive success for the Black Tern). Their selection was based on the sensitivity of the indicator to changes in water levels and flows, the significance and representativeness of the indicator, and the certainty in the research results.

Experts and members of the public worked with the Study Board to create a sound and transparent review and decision-making process. Together, they defined regulation plan objectives and then collaborated to create a computer evaluation model that measured how well alternative regulation plans met those objectives. The Study Board conducted six "practice" decisions using this collaboratively-built model starting in the second year of the five-year study to refine the decision framework and make sure that the research being done was sufficient for the decision. After each practice decision, the results were disseminated through the PIAG to the larger public and adjustments made to the research and models based on the feedback.

This collaborative framework supported a wide-ranging plan formulation and evaluation effort. Four plan formulation teams worked in friendly competition, each taking a different design approach. One team tried to improve the parameters in Plan 1958-D; another added rules to modify the pre-project or "natural" releases in order to moderate extreme levels; a third used "interest-satisfaction" curves; and a fourth used optimization models. The teams collaborated electronically, and then worked together in workshops to compare results and share lessons learned. Their intensive use of the evaluation model also provided an effective peer review of that model.

The design of the evaluation model allowed each plan formulator to evaluate new plan rules quickly, and that in turn permitted a much more thorough exploration of alternative regulation plans than would have been possible in traditional water resources studies. The legacy of the Study's comprehensive and collaborative approach is a framework that has been used since 2006 to formulate and evaluate hundreds of alternative regulation plans, including Plans 2007, Bv7 and 2014. In addition, the approach will be used in the future to support adaptive management.

Consideration of Climate Change and Variability

To ensure that the regulation plans developed in the study could perform under a wide range of water supply conditions, plans were tested with stochastically-generated water supplies[6] as well as the historical water supplies. The plans also were tested with four climate chan ge scenarios.

The historical supplies covered the period 1900-2000. The stochastic data provided the equivalent of another 495 water supply datasets, each set 101 years long. Some sequences had much wetter and some much drier periods than any experienced in the 20th century. All the economic evaluations shown in Table 2, in section 4, are based on the stochastic water supplies.

The four climate change supply sequences were based on the range of predictions from scenarios from the latest available two Global Circulation Models (Mortsch *et al*, 2005). The changes from base temperature, precipitation, humidity, wind speed and solar radiation for each of these four scenarios were used to adjust the historical recorded series of these climate properties.

To quantify the impact climate change might have for Lake Ontario interests, the evaluation model was run for each of these four different climate change scenarios using Plan 1958DD in all four evaluations. The warmest and driest of four scenarios was the most damaging. With this scenario, Lake

[6] Stochastic generation is a statistical method used in water resources studies for nearly 50 years to develop simulated water supply data that include conditions both wetter and drier than the historical data. The stochastic supplies are considered plausible because they have the same statistical properties as the historical supplies (e.g., the same average, standard deviation). The rules in Plan 1958-D (without deviations) were flawed because they were based on an analysis using recorded data from 1860-1954. Actual water supplies in the 1960s were lower than any in the 1860-1954 record, and supplies in the 1970s, 1980s and 1990s were wetter, requiring deviations from 1958-D.

Ontario levels and flows were generally lower than experienced with historical supplies, reducing hydropower benefits by more than $68 million a year, and recreational boating opportunities were reduced by almost $50 million a year (IJC, 2006). On the plus side, Lake Ontario shore protection damage was reduced slightly by about $1 million per year.

Alternative plans were also tested to determine their suitability under climate change and other extreme climate scenarios. These analyses showed that changes in climate could overcome the influence of regulation plans to protect stakeholders. For example, when tested using the driest portion of the stochastic water supplies, Lake Ontario levels dropped to 73.04 m (239.63 ft) under Plan 1958DD. This is 74 cm (2.5 ft) lower than the historical 1958DD minimum. By comparison, using the same water supplies but replacing Plan 1958DD with Plan 2014, the minimum Lake Ontario level simulated was 73.20 m (240.15 ft). This is clearly higher than the comparable 1958DD minimum, but still about .6 m (2 ft) below the historical levels. Similarly, when water supplies were extremely high, Plan 2014 and Plan 1958DD produce very high but very similar levels (76.62 m/251.4 ft for Plan 2014; 76.56 m/251.2 ft for Plan 1958DD).

Key Study Board Findings

The Study Board used the evaluation model to determine the limits of lake level regulation to address stakeholder concerns. The Study Board found that regulation has provided significant economic benefits to basin interests, particularly to riparians on Lake Ontario. The assessment of benefits to riparians included substantial information on the minimum level of risks under any regulation plan. The Board found that even if Lake Ontario were regulated solely for the benefit of Lake Ontario shoreline property owners, disregarding the interests of shoreline owners on the lower river, navigation and all other uses and interests, then Lake Ontario shoreline damages would be reduced by only about 5% from the levels produced by Plan 1958DD. Lake Ontario shoreline protection structures in particular were vulnerable, with many too low to avoid destruction no matter how the lake was regulated. In addition, erosion of the unprotected shoreline could not be slowed appreciably by regulation.

The Study Board also found that the compression of the range of Lake Ontario levels had resulted "… in a more narrowly defined transition zone within wetlands from submerged to upland plants, thus reducing the diversity of plant types along the shore and populations of animal species who feed on and live in the environments affected by the reduced water level ranges." Regulation also has caused dewatering drawdowns in the fall through early spring, to the detriment of some habitat. The Study Board noted that these degraded environmental conditions could be improved by changing the regulation plan, but not without tradeoffs that would reduce some existing economic benefits.

The evaluation of alternative plans showed that Lake Ontario shoreline protection structures in particular were vulnerable, with many too low to avoid destruction no matter how the lake was regulated.

The Study Board proposed three regulation plans (Plan A+, Plan B+, and Plan D+) that provided net economic and environmental improvements when compared to Plan 1958DD, but with varying trade-offs among the uses and interests on the lake and river. The Study Board found that, compared to the case without regulation, Plan 1958DD reduced the damages due to fluctuating water levels on Lake Ontario shoreline properties by about 60%, that "coastal damages occur regardless of the regulation plan", and that "the current Regulation Plan 1958-D with Deviations comes close to minimizing damages for Lake Ontario shoreline property owners."

2.2.3 Development of Plan 2007

Following the release of the Study Board's final report, the IJC invited public comment and subsequently undertook a thorough review of the report and public comments. The IJC then asked experts who had been associated with the Study to explore whether any of the three plans recommended by the Study Board could be refined to restore more of the environmental benefits while maintaining as much as possible the level of protection and benefits that other interests and uses enjoy under Plan 1958DD. This new work by

the IJC resulted in additional candidate plans being developed.

In March 2008, the IJC invited comment on a proposed new Order of Approval and regulation plan, known as Plan 2007. The proposed new Order of Approval, among other things, made provision for the environment and recreational boating. The simulation models developed in the Lake Ontario–St. Lawrence River Study showed that the proposed regulation plan would have provided net economic improvements compared to Plan 1958DD and benefits to shoreline property owners comparable to those currently received under Plan 1958DD. The models also showed that Plan 2007 would have provided more environmental improvements than the existing Plan 1958DD. Nonetheless, at the public hearings held on the proposal in the summer of 2008, the IJC heard widespread opposition to Plan 2007 throughout the Lake Ontario-St. Lawrence River basin.

In September 2008, the IJC wrote the U.S. Department of State and the Canadian Department of Foreign Affairs and International Trade to inform them that the testimony at the hearings and the approximately 1,200 comments submitted outside the hearings showed serious divisions by political unit and little support for Plan 2007, but broad, strong interest in returning to more natural levels and flows.

The IJC informed the governments that "the Commission has determined that Plan 2007 is not a practical option for implementation and concludes that the regulation of water levels and flows should be based on a revised set of goals and objectives and criteria, specifically moving towards more natural flows to benefit the environment, while respecting other interests."

2.2.4 Development of Plan 2014

In October 2009, the IJC wrote to the governments of the United States, Canada, Quebec, New York and Ontario asking each government to nominate two senior officials to a Working Group to advise the IJC on its proposals on how to:

- manage water levels and flows in the Lake Ontario-St. Lawrence River system; and,
- better define and adequately protect all interests – economic, social and environmental– both upstream and downstream of the Moses-Saunders Dam, in compliance with the *Boundary Waters Treaty of 1909*.

After reviewing the range of regulation plans that had been developed to date, the Working Group agreed to investigate and further refine a set of release rules based on Plan B+, known as Bv7 (that is, the seventh version of the candidate B plan). The Working Group also considered a more detailed adaptive management strategy to respond to climate change, modifications to the plan's management oversight structure and policies on deviations from the plan.

All of the design and analysis done leading up to Plan 2007 and to Plan Bv7 used the same evaluation model and, with several minor improvements, the same performance indicators that the Lake Ontario-St. Lawrence River Study Board had developed with stakeholders. Using that system, the Working Group was able to evaluate about 60 variations on Plan Bv7 before recommending a version to the IJC.

In 2012, the IJC conducted public information sessions and invited comment on Plan Bv7. After further consultation with stakeholders, deliberation and refinement to the proposed regulation plan and the other components, the IJC then developed a formal proposal, known as Plan 2014. Plan 2014 included modifications to the rules of Bv7 to better balance Lake Ontario and river levels during low supply periods. Also, set of high and low lake levels were added to trigger special actions to better protect water intakes, navigation, boating and riparian interests.

Tables 1 and 2, presented in section 4, summarize a comparison of the environmental and economic performance of Plan 2014 and other regulation plans as measured using the performance indicators developed in the Lake Ontario-St. Lawrence River Study.

2.3 Public Participation in Plan Development

Throughout the studies into regulating Lake Ontario and the St. Lawrence River, the IJC has made extensive efforts to involve all interested parties in the formulation and evaluation of new regulation

plans. These efforts have allowed the people whose lives would be affected by lake level regulation to help define the problem and the measures of success, help design new plans and communicate the results (Figure 9). The efforts during and after the Lake Ontario-St. Lawrence River Study were preceded by public outreach and involvement activities of the Board of Control.

Public Interest Advisory Group Role in the Lake Ontario-St. Lawrence River Study

Figure 10 shows the locations where the IJC hosted hearings, technical sessions and other public meetings during and after the Lake Ontario-St. Lawrence River Study.

During the work that led up to the 2006 report, the 20 members of PIAG worked with organizations and interests throughout the study area and conducted public participation activities on key issues to assist the Study Board in its deliberations. PIAG members acted as liaisons to each of the study science teams, suggesting performance metrics that were used in the coastal, environment and recreational boating technical work groups. PIAG members also reviewed the candidate plans and provided feedback into the Study Board's decision-making process.

In the executive summary of its final report, the PIAG reported that it could not find a consensus on a regulation plan (see text box). The inability of the PIAG as a group to endorse any of the candidate plans (regulation plans presented as options from the Study Board for the IJC) was the first, but not the last indication that no regulation plan can satisfy all interests.

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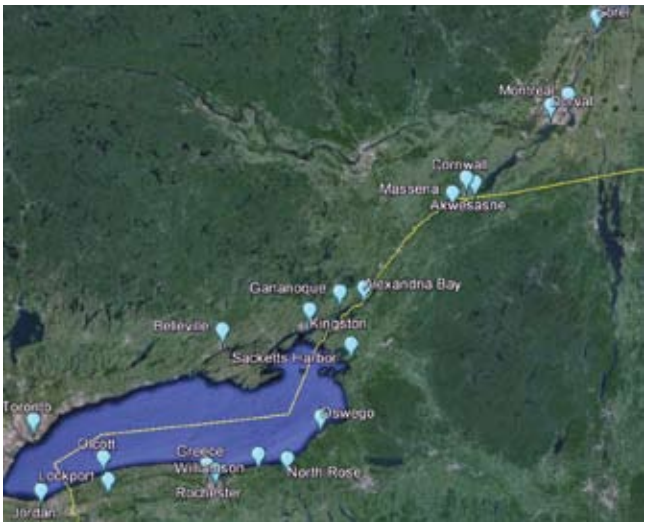
The inability of the Public Interest Advisory Group to endorse any of the candidate plans was the first, but not the last, indication that no regulation plan can satisfy all interests.

Figure 9

PIAG Members Participating in a Review of Performance Metrics during the Lake Ontario-St. Lawrence River Study

Figure 10

Location of Public Meetings on Lake Ontario Regulation, 2005-2013



In the summer of 2013, the IJC held hearings or technical sessions on Plan 2014 in Alexandria Bay, Cornwall, Jordan, Lockport, Montreal, Rochester, Williamson, and Oswego. There was widespread strong opposition to the plan in south shore communities, with a minority expressing support. Shipping industry representatives in Montreal supported the ecosystem goals so long as the order of precedence was maintained. There was strong, widespread support for Plan 2014 elsewhere around the lake and in communities along the river.

Executive Summary from Public Interest Advisory Group Final Report November 30, 2005

The International Lake Ontario - St. Lawrence River Study has been a trailblazer. The International Joint Commission (IJC) decided prior to the initiation of this Study to have the public represented at the "table" right from the start. The Public Interest Advisory Group (PIAG) had a separate mandate from the IJC, allowing it to act independently. We were an internal "peer review" group for the Study. To develop this "peer review" group, the IJC selected members of the public, in many cases, who were the toughest and most active critics of the International St. Lawrence River Board of Control's operations prior to the Study. Through this process, PIAG members met and learned from each other, gaining a better understanding of the system geographically and technically and of the various concerns of the regions. Consequently, the Study has now developed a cadre of lay-experts available to the International Joint Commission in the public interest.

Another facet of our mandate was to ensure effective communication between the public, which we represented, and the Study and its technical work groups. We provided input to Study decisions and communication and education to the public. We were there at the table for all Study Board discussions. The PIAG assisted the decision process, ensuring that the public input was considered and that the process remained transparent.

The Study Board kept an arms-length approach to our activities. We tested several innovative instruments of public outreach; the results of what worked and what did not work will be provided to the International St. Lawrence River Board of Control.

The two main lessons learned from the Study are:

We have to realize that the Study cannot satisfy the needs of all of the interests all of the time. This is indeed the case as the PIAG as a group does not favor any one candidate plan over another.

Communications cannot be an ad hoc procedure. The IJC must commit funds to ensure proper communications of the Board of Control by means of dedicated communication person(s) and budget to allow publication of meetings and other important communications, using techniques developed by PIAG during this Study and other valid methods of ensuring two-way communication.

(From: Lake Ontario-St. Lawrence River Study Public Interest Advisory Group, 2005)

Public Hearings on Plan 2014

In the summer of 2013, the IJC invited public comment and convened public hearings on the proposed Plan 2014. More than 5,500 comments were received, in total. This included 206 oral testimonies at the 12 hearings and public teleconferences, over 3,500 signatures on four different petitions, more than 700 post cards and form letters, and nearly 1,000 written website, email and unique letter responses. This latter group of responses ranged from short endorsements or rejections of Plan 2014 to formal responses from local governments, governmental departments and non-governmental organizations.

The response was polarized. Most south shore property owners in New York State who participated in the hearings and their local governments strongly opposed Plan 2014, though a few respondents from that area either supported Plan 2014 or supported the environmental objective but not Plan 2014 itself. *Save our Sodus*, a non-profit group, presented a petition with more than 400 comments that either opposed Plan 2014 or documented past flooding and erosion problems that had occurred under the current regulation rules. The concerns of these citizens were that the higher high water levels of Plan 2014 would cause more shoreline damage, and that the lower low levels would make boating more difficult.

The U.S. Department of Transportation raised concerns that the priority given to environmental objectives in Plan 2014 violated the Treaty, reflecting similar statements by several other respondents involved with commercial navigation on the seaway, including the St. Lawrence Seaway Management Corporation, the Canadian Shipowners Association and the Shipping Federation of Canada. The concern from commercial navigation was that Plan 2014 would create significantly lower levels on Lake Ontario in a few years out of a hundred, thus forcing ships to carry reduced loads.

Other than these groups, there was general, and often strong, support for Plan 2014. For example, the U.S. Environmental Protection Agency (USEPA) supported Plan 2014, writing that Plan 1958DD has significantly degraded Lake Ontario wetlands and vital fish and wildlife populations, and that Plan 2014 would increase the diversity and functioning of 26,000 ha (64,000 acres) of coastal wetlands. Conservation Ontario wrote to explain the significant economic value of wetlands and asserted that Plan 2014 would contribute to the economic, ecological and social well-being of the Lake Ontario and St. Lawrence River. The U.S. Department of the Interior wrote that Plan 2014 would best meet the stated goals and that it represented the most logical approach to bringing water level regulation into the 21st century. The City of Montreal supported Plan 2014, as well. The Nature Conservancy noted that selecting Plan 2014 would reverse decades of environmental harm, while rejecting it would not solve the coastal impact problems that would have to be confronted no matter the regulation plan. Audubon New York wrote to advise that Plan 2014 was central to the long-term success of the Great Lakes Restoration Initiative and the overall restoration of this important ecosystem. Ducks Unlimited commented that the IJC and other principal interests had done an outstanding job of balancing the needs and requirements of all the major parties, and encouraged the IJC to implement Plan 2014.

> ***"Selecting Plan 2014 will reverse decades of environmental harm; rejecting Plan 2014 will not solve coastal damage problems."***
>
> - The Nature Conservancy

3. Regulation Plan 2014

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible.

Section 3 presents:

- the rationale for Plan 2014;
- a description of the key features of the plan; and,
- an overview of the role of the International Lake Ontario–St. Lawrence River Board in overseeing implementation of the plan.

3.1 Rationale

Based on the comprehensive Lake Ontario-St. Lawrence River Study, extensive consultations with governments and the public on two revised regulation plan proposals, and subsequent analysis and refinements, the IJC finds that Plan 2014 provides the best response to the range of issues that must be considered in regulating the flows through the Moses-Saunders Dam. These issues include the requirement of Article VIII of the Treaty to follow the order of precedence of water uses while providing "suitable and adequate protection" for interests that may be harmed by operation of the project.

Plan 2014 maintains the order of precedence while addressing the harm done by the 1956 Order and existing regulation rules to Lake Ontario coastal ecosystems. The IJC finds that the coastal and riverine ecosystems are an interest that existed but was not considered when the 1956 Order was developed. The design of Plan 2014 takes into consideration the more extreme water supplies experienced since 1954, the even more extreme supplies that may be experienced in the future, and other improvements in knowledge and analytical techniques.

Plan 2014 has been designed to satisfy the conditions and criteria specified in a revised Order of Approval for Lake Ontario-St. Lawrence River regulation. These conditions and criteria are listed in Annex A of this report.

Highlights of the Proposed Conditions and Criteria of an Order of Approval

Lake Ontario regulation plans must be consistent with the IJC Order of Approval governing the operation of the control structures. The IJC has concluded that some of the conditions and criteria in the 1952 and 1956 Orders of Approval for the St. Lawrence Power Project must be updated. Annex A lists the conditions and criteria to be included in a new Order of Approval that would govern Plan 2014 and subsequent plans.

The new conditions provide formal recognition of an established practice, which is that the IJC may issue directives to guide regulation of the discharge in addition to the criteria listed in this condition. The requirement that no less protection be provided for interests downstream than would have occurred under pre-project conditions carries over from the 1956 Order. The period of supplies used to evaluate plans is updated to 1900-2008, which encompasses more extreme high and low supply events than the 1860-1954 supply sequence upon which the criteria of the 1956 Order were based.

The criteria establish objectives and performance standards that Plan 2014 and any future regulation plans must meet when tested with the 1900-2008 supply sequence. The updated criteria recognize that:

- low levels at any time of year affect Port of Montreal navigation (the Port operates all year) as well as water intakes and other uses and interests, and that the frequency of low levels is of concern in addition to the minimum level;
- low levels affect water intakes as well as navigation and other uses and interests on Lake St. Louis;
- adequate levels for navigation in the Montreal to Lake Ontario section of the river need to be considered together for Seaway uses;
- releases above certain thresholds can cause currents that threaten safe navigation or reduce hydropower production if they are above the capacities of the hydropower plants;
- maintaining minimum flows as high as possible maintains a dependable amount of electricity generation;
- high levels can damage shoreline property and other uses and interests affected by flooding on Lake St. Louis and Lake St. Lawrence throughout the year;
- high levels can damage shoreline property and other uses and interests affected by flooding and erosion on Lake Ontario throughout the year, and that the seasonality of supplies to the lake, ice restrictions on winter flows and the fall storm season warrant maximum levels that vary through the year;
- when tested with the more extreme 1900-2008 supplies, no plan can maintain Lake Ontario levels within the range set in 1956;
- low levels can impact water intakes, shipping, boating and other uses and interests on Lake Ontario throughout the year, and that the seasonality of supplies to the lake warrant minimum levels that vary through the year;
- when Lake Ontario water levels reach or exceed extremely high levels, management of releases should provide all possible relief to the riparian owners upstream and downstream;
- when Lake Ontario levels reach or fall below extremely low levels, management of releases should provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream;
- deviations from the approved plan to provide all possible relief to interests are more clearly triggered by specific Lake Ontario levels, rather than "supplies outside the range of the past," which is more ambiguous;
- releases must be adjusted to avoid ice jam flooding whenever ice forms, to protect uses and interests upstream and downstream;
- water levels affect ecosystems and that releases must be managed to enhance wetland health whenever possible; and,
- releases must be managed to benefit recreational boating whenever possible.

In addition, current practices authorized in various letters are formally recognized in the Order for the first time. A new condition states that the IJC will issue directives to guide peaking and ponding operations and for deviations from the plan of regulation to address such matters as winter operations, emergencies and other special short-term situations. The installation of ice booms in the St. Lawrence River is also authorized subject to established conditions.

3.2 Key Features

This section summarizes the features of Plan 2014. For more technical information on the plan, see Annexes B and C.

3.2.1 A More Natural Hydrological Regime

The objective of Plan 2014 is to maintain beneficial uses for the key water-using interests while returning the Lake Ontario-St. Lawrence River system to a more natural hydrological regime, thereby helping to restore coastal and riverine ecosystems. This approach was first used during the Lake Ontario-St. Lawrence River Study to create Plans B and B+, and in 2012 to create Plan Bv7 (see Annex B for more details). Plan Bv7 included revisions made to Plan B+ by the IJC based on advice from the working group, public and stakeholder input. These revisions included additional rules to maintain navigation and flood reduction benefits on the St. Lawrence River below the control dam, rules to maintain navigation and boating benefits on Lake St. Lawrence, and adjustments to better balance Lake Ontario and St. Lawrence River levels below the dam.

Plan 2014 will use the releases prescribed by Plan Bv7 rules until Lake Ontario levels reach specified high or low trigger elevations. If levels reach the high trigger levels, then the Board will "provide all possible relief to the riparian owners upstream and downstream." If the levels reach the low triggers, then the Board will "provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream." This is the same logic the Board applies when it operates under criterion k of the existing 1956 Order.

Unlike the current plan, which is not based on the natural release, Plan 2014 rules start with the natural release, adjust it for supply conditions and then modify it when necessary to protect the various interests and the uses in the order of precedence of Article VIII of the Treaty.

In its natural state, without a dam regulating the release, the outflow from Lake Ontario is mainly a function of the lake level and, to a lesser degree, the resistance to flow in the river. Heavy vegetation or ice in the river channel can reduce the flow. If the lake rises, then the natural release increases. As lake levels change gradually, natural releases change gradually, as well.

Unlike the current plan, which is not based on the natural release, Plan 2014 rules start with the natural release and then modify it to protect the various interests and the uses in the order of precedence of Article VIII of the Treaty.

3.2.2 Adjusting for Changing Supplies

The eventual outcome of a water release decision cannot be fully known at the time it is made, because the outcome depends in part on future water supply conditions. Adjusting the release based on trends in the long-term supply and using supply forecasts, even though uncertain, improves release decisions. The release rules in Plan 2014 use an index of the long-term trend in supplies and a short-term statistical supply forecast to adjust the natural release. Although the releases in Plan 2014 tend to change less from week to week than with Plan 1958-D, this adjustment to the natural flow makes Plan 2014 respond to changing supplies more quickly than nature would to reduce the risk of coastal damage, unsafe navigation conditions, or other undesirable outcomes.

As in Plan 1958-D, flow limits are used in Plan 2014 to satisfy some of the criteria set out in the Order of Approval. This includes preventing river levels from falling too low or rising too high, facilitating stable river ice formation and providing acceptable navigation conditions and safe operating conditions for control structures. However, the Plan 2014 flow limits improve upon those in Plan 1958-D that were developed in the 1950s before the project started operation. The Plan 2014 limits incorporate the knowledge gained from more than 50 years of operational experience, including during times of extreme supplies outside the design range of Plan 1958-D.

3.2.3 Short-Term "River" Deviations

From time to time, the Board of Control has used the authority granted to it by the IJC to deviate from the releases specified by Plan 1958-D, first to avoid a temporary problem and then later to restore Lake Ontario levels to what they would have been without the deviation from the Plan specified flow. For example, ships entering the St. Lawrence River may encounter shallower conditions than expected based on forecasts of river levels used to load the ships in overseas ports.

The Board of Control occasionally has discharged more than the plan release for a day or two to increase river depths by up to several centimeters (a few inches) near Montreal, thus avoiding the need to re-direct the ship to another port or transfer cargo to lighten the ship. The larger releases lowered Lake Ontario by a fraction of a centimeter below the plan intent, so the Board then ordered a discharge less than the plan release to bring Lake Ontario back to its plan intended level. This practice was not foreseen in the 1956 Order but has developed under a policy approved by the IJC in 1961 to grant the Board of Control the authority to make discretionary deviations from the Plan specified release to provide benefits or relief to interests when they can be made without adverse impacts to others.

Under the proposed new order, these deviations for shipping and similar short-term "river" deviations would be specifically directed by the IJC and would continue in an identical manner under Plan 2014, except that the cumulative effect of these minor deviations would be limited to the equivalent of plus-or-minus 2 cm (nearly 1 inch) of water on Lake Ontario, unless there is a special approval by the IJC.

3.2.4 Less Frequent Need for Major Deviations from the Plan

Both Plans 1958-DD and 2014 include major deviations to moderate Lake Ontario levels from what they otherwise would be if the plan rules were followed as written. However, under Plan 2014, these major deviations would be less frequent and more clearly exercised. Criterion k of the 1956 Order requires that the release "provide all possible relief to the riparian owners upstream and downstream" when supplies exceed those experienced from 1860 to 1954, and to provide all possible relief to navigation and power interests when supplies are less than 1860-1954 supplies. The Board of Control advises the IJC when supplies are outside the 1860-1954 range, but it is the IJC that makes the determination that releases should be made according to this criterion, not the Board of Control.

Under criterion H14 of the proposed new Order, the same relief would be provided to riparian owners upstream and downstream when Lake Ontario levels hit high trigger levels. All possible relief to municipal water intakes, navigation and power purposes, upstream and downstream, would be provided when Lake Ontario reaches low trigger levels. Weekly Lake Ontario levels are expected to be at or above the higher trigger levels 2% of the time, and at or below the low trigger levels 5% of the time. The IJC directive to the Board on deviations from Plan 2014 is provided in Annex C.

Some future water supplies likely will be greater and some likely smaller than any on record. The supplies of the 1960s dipped lower and the supplies of the 1970s, 1980s and 1990s peaked higher than the 1860-1954 supplies that were used to design Plan 1958-D. The magnitude and frequency of these extreme supplies were estimated by hydrologists by using stochastic modeling. The high trigger levels are nearly as high as recorded highs on Lake Ontario, so they do not diminish coastal damages significantly based on 20th century supplies. However, in more extreme supply conditions, the sustained application of criteria k and H14 tends to make Plan 2014 and Plan 1958DD releases, levels and projected damages more similar.

The more natural, but still compressed, Lake Ontario levels of Plan 2014 are shown in comparison to those of Plan 1958DD and the Natural plan in Figures Ex-1 through Ex-3 of the Executive Summary.

3.3 International Lake Ontario–St. Lawrence River Board

The IJC establishes boards to ensure compliance with its Orders of Approval and to put its approved regulation plans into operation. Typically, the IJC appoints to its boards experienced water managers

from government agencies on both sides of the border and other people with expertise on the water uses and an understanding of how local interests are affected by water regulation. These boards: direct the dam owners as to the amount of water they must release to comply with the regulation Orders; oversee the day-to-day regulation operations; maintain a liaison with stakeholders and the public; and report to the IJC on conditions and regulation actions.

The IJC will transform the existing International St. Lawrence River Board of Control into the International Lake Ontario–St. Lawrence River Board to implement the Plan 2014 regulation plan and the directives stemming from the Order of Approval. This new Board would be responsible for making release decisions in accordance with the rules of the regulation plan (Annex B) and the directive on deviations (Annex C), and other duties assigned by IJC directives. The new Board will have at least 10 members, with an equal number from each country, including at least one Board member from each of the five federal, provincial and state jurisdictions. In addition, the IJC would appoint members to obtain a balance of expertise on the Board from across the Lake Ontario–St. Lawrence River basin, including First Nations and Tribes.

The IJC would appoint one member from each country to serve as co-chairs of the Board. Each of the co-chairs of the Board would appoint a Regulation Representative who would maintain a database of hydrological information for the Board, conduct the regulation plan calculations, make needed within-the-week flow adjustments, coordinate and keep account of flow deviations, and advise the Board on regulation operations.

The new Board would also: oversee the normal hourly and daily flow variations carried out by the hydropower entities according to the directive on peaking and ponding issued by the IJC; guide the development and implementation of an adaptive management plan; and promote outreach and engagement with the public and industry so that everyone interested in the regulation of the Lake Ontario-St. Lawrence River system can access the Board's information and has opportunities to express views regarding regulation. The Board will report at least semi-annually to the IJC.

Annex D addresses the governance of Plan 2014 in more detail.

4. Effects of Plan 2014 on the Uses and Interests

The *Boundary Waters Treaty of 1909* lists an order of precedence for the uses of boundary waters. It gives precedence to water uses for domestic and sanitary water purposes, uses for navigation, and for hydroelectric generation and irrigation. The Treaty also requires that the IJC ensure, as part of its approval of a project, that "suitable and adequate provision be made for the protection and indemnity of all interests" on either side of the boundary. The IJC respects the order of precedence of the listed uses while ensuring that all legitimate interests are protected.

Section 4 presents an overview of the projected effects of Plan 2014 on the uses and key interests served by the waters of Lake Ontario and the St. Lawrence River, compared to the effects under the existing Plan 1958DD. The uses and interests are:

- municipal and industrial water use;
- commercial navigation;
- hydropower generation;
- coastal development;
- ecosystems; and,
- recreational boating.

Tables 1 and 2 summarize the expected environmental and economic performance, respectively, of Plan 2014 relative to five other regulation plans, including the existing plan, Plan 1958DD. Performance estimates used in this section of the report are drawn from these tables.[7]

[7] Economic effects in Table 2 are expressed in U.S. dollars using the Canadian exchange rate of 0.833 of September 2005, reflecting the study timeframe. Updating costs and benefits to current dollars would entail consideration of changes in the exchange rate, energy and real estate prices, changes in the costs of operating ships, and more. However, updated costs would not change the conclusions of the analysis summarized in this section.

Table 1

Environmental Performance Indicators for Six Regulation Plans

Environmental Performance, Ratio to 1958DD, Historical water supplies	Regulation plans					
	Natural	1958DD	2007	B+	Bv7	2014
Lake Ontario						
Meadow marsh	1.56	1.00	1.22	1.44	1.46	1.41
Spawning habitat supply (Low Veg 18C)	0.88	1.00	0.93	0.95	0.96	0.96
Spawning habitat supply (High Veg 24C)	1.08	1.00	1.01	1.00	0.98	0.99
Spawning habitat supply (Low Veg 24C)	1.11	1.00	1.01	1.02	1.05	1.04
Northern Pike - YoY recruitment	1.03	1.00	1.02	1.00	0.98	0.99
Largemouth Bass - YoY recruitment	0.96	1.00	0.98	0.98	0.98	0.98
Least Bittern - reproductive index	1.13	1.00	0.93	1.04	1.12	1.11
Virginia Rail reproductive index	1.15	1.00	0.96	1.11	1.16	1.15
Black Tern reproductive index	1.16	1.00	0.97	1.12	1.19	1.16
Yellow Rail preferred breeding habitat	1.01	1.00	0.99	1.01	1.04	1.02
King Rail preferred breeding habitat	1.27	1.00	1.04	1.10	1.19	1.16
Upper River						
Spawning habitat supply - Low Veg 18C	1.04	1.00	1.01	1.01	1.02	1.01
Spawning habitat supply - High Veg 24C	1.02	1.00	1.02	1.01	1.00	1.01
Spawning habitat supply - Low Veg 24C	1.04	1.00	1.01	1.01	1.02	1.01
Northern Pike - YOY recruitment	1.06	1.00	1.00	1.03	1.03	1.03
Largemouth Bass - YOY recruitment	1.00	1.00	1.00	1.00	1.00	1.00
Northern Pike - YOY net productivity	2.07	1.00	1.01	1.46	1.39	1.39
Virginia Rail (RALI) - reproductive index	1.33	1.00	1.31	1.27	1.17	1.17
Muskrat house density,drowned river mouth wetlands	14.29	1.00	1.35	2.99	2.59	2.56
Lower River						
Golden Shiner - suitable feeding habitat area	1.01	1.00	1.02	1.00		1.00
Wetlands fish - abundance index	0.97	1.00	0.81	0.90		1.00
Migratory wildfowl - habitat area	0.94	1.00	1.00	0.97		0.98
Least Bittern reproductive index	1.06	1.00	1.03	1.03		1.02
Virginia Rail reproductive index	1.04	1.00	0.96	1.05		1.03
Migratory wildfowl productivity	1.02	1.00	1.00	1.01	See note	1.01
Black Tern reproductive index	1.01	1.00	0.95	0.97		1.01
Northern Pike reproductive area	1.01	1.00	0.97	1.03		1.01
Eastern Sand Darter reproductive area	1.00	1.00	1.03	0.99		1.00
Spiny Softshell Turtle reproductive habitat area	1.01	1.00	1.01	1.01		0.99
Bridle Shiner reproductive habitat area	0.97	1.00	1.06	0.92		0.95
Muskrat surviving houses	1.05	1.00	1.14	0.99		0.96
Shading indicates species at risk						

Note: Scores above 1.1 and below 0.9 are considered significantly different from Plan 1958DD results. Lower river results for Bv7 are not available; scores for a similar plan ranged from 0.94 (Muskrat) to 1.03 (Virginia Rail and Wetland fish abundance index)

Table 2

Average Annual Net Economic Benefits for Six Regulation Plans

(in $US million 2005)

Economic Benefits (Net Average Annual, using stochastic water supplies)	Natural	1958DD	2007	B+	Bv7	2014
Total	**-$20.80**	**$0.00**	**$3.55**	**$1.31**	**$1.61**	**$3.12**
Municipal and industrial water use	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
St. Lawrence River one time infrastructure costs	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Lake St. Louis water quality investments	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Commercial Navigation	**-$0.05**	**$0.00**	**-$0.29**	**-$1.24**	**-$0.02**	**$0.00**
Ontario	-$0.02	$0.00	$0.00	-$0.01	-$0.01	-$0.01
Seaway	-$0.02	$0.00	-$0.31	-$1.19	-$0.01	$0.00
Montreal	-$0.01	$0.00	$0.02	-$0.04	$0.00	$0.01
Hydropower	**$12.59**	**$0.00**	**$2.37**	**$6.08**	**$5.40**	**$5.26**
NYPA-OPG	$8.77	$0.00	$0.77	$3.85	$3.45	$3.41
Hydro-Quebec	$3.82	$0.00	$1.60	$2.22	$1.95	$1.85
Coastal	**-$29.88**	**$0.00**	**$0.16**	**-$2.78**	**-$3.17**	**-$2.23**
Ontario total	-$27.38	$0.00	$0.06	-$2.53	-$3.11	-$2.22
Shore protection maintenace	-$19.85	$0.00	$0.03	-$2.16	-$2.62	-$1.94
Erosion to unprotected developed parcels	-$0.58	$0.00	$0.01	-$0.17	-$0.17	-$0.16
Flooding	-$6.94	$0.00	$0.02	-$0.20	-$0.32	-$0.11
Upper St. Lawrence River flooding	-$2.00	$0.00	$0.01	-$0.04	-$0.07	-$0.01
Lower St. Lawrence River flooding	-$0.49	$0.00	$0.08	-$0.22	$0.00	$0.00
Recreational Boating	**-$3.46**	**$0.00**	**$1.32**	**-$0.74**	**-$0.60**	**$0.10**
Above dam	-$5.31	$0.00	-$0.15	-$1.42	-$1.33	-$0.68
Ontario	-$4.93	$0.00	-$0.27	-$1.18	-$1.11	-$0.57
Alexandria Bay	-$0.36	$0.00	$0.06	-$0.29	-$0.25	-$0.14
Ogdensburg	-$0.07	$0.00	$0.01	$0.00	-$0.02	-$0.01
Lake St. Lawrence	$0.05	$0.00	$0.05	$0.05	$0.04	$0.05
Below the dam	**$1.85**	**$0.00**	**$1.47**	**$0.68**	**$0.72**	**$0.78**
Lake St. Louis	$1.03	$0.00	$0.74	$0.49	$0.45	$0.48
Montreal	$0.64	$0.00	$0.55	$0.19	$0.20	$0.22
Lake St. Pierre	$0.18	$0.00	$0.18	$0.00	$0.07	$0.08

4.1 Municipal and Industrial Water Use

4.1.1 Overview of the Use[8]

Municipal and industrial water uses include public and private sector organizations using water for domestic, municipal and industrial purposes. This group includes owners/operators of municipal water and wastewater treatment facilities and large self-supplied industrial plants.

4.1.2 Effects of Plan 2014

The analysis concludes that there would be no change in the economic impacts on municipal and industrial water and wastewater use under Plan 2014. Regulation under Plan 2014 would continue to provide benefits to domestic water uses in the Lake Ontario-St. Lawrence River region. In its 2006 report, the Lake Ontario-St. Lawrence River Study Board concluded that domestic use on the St. Lawrence River would be affected by water levels regardless of the regulation plan. However, additional analysis undertaken for this study concludes that there would be no difference in those effects between Plans 2014 and 1958DD.

The Study Board's municipal and industrial water use studies[9] were based on the responses to questionnaires sent to 43 water treatment plants and 79 wastewater treatment plants in the basin. Shore well[10] and industrial users were also studied. Researchers and utility managers considered how low and high critical lake and river level elevations would affect domestic water uses.
The questionnaire responses were supplemented by telephone conversations and on-site visits in Quebec, New York and Ontario. Other issues, such as the impact of frazil ice at lower water surface elevations, were investigated, as well.

The Study Board identified two potential low water issues: whether water supply plants could draw water through the intake; and whether the quality of water drawn in at those levels would require additional treatment to avoid taste and odor problems. In general, evaluation of the ability to withdraw water was based on the minimum amount of water or "cover" that an operator would prefer to have above an intake structure. On Lake Ontario, water intakes are at least 3.6 m (12 ft) below chart datum (also known as low water datum), with large system intakes 12 to 18 m (40 to 60 ft) deep. St. Lawrence River water treatment plant operators reported taste and odor problems had occurred at low river stages, and researchers developed cost estimates for treatment based on operator experience.

The Study Board concluded that during long droughts, St. Lawrence River municipal water suppliers would need to undertake additional treatment because of taste and odor issues caused by the tendency for increased algal blooms at lower water elevations. However, the frequency and magnitude of this effect would be the same under Plan 2014 as under Plan 1958DD.

The Study Board also identified potential high water effects on water supply operations and wastewater treatment discharges. Flood damages to plant and shore protection structures were measured under the coastal sector in the Lake Ontario-St. Lawrence River Study. Wastewater treatment plant operators identified the high and low water elevations that would begin to affect or even interrupt the services they provided.

During and after the 2000-2006 Study, concerns were raised about the flooding of water supply and wastewater infrastructure on the Lake Ontario south shore. In all these cases, the facilities reported experiencing problems with the lake levels in recent decades under the current regulation plan. Following additional interviews and analysis, the Study Board concluded that, "municipal, industrial and domestic water-use facilities are generally not vulnerable to water level changes." For example, the Study Board reported that the Ginna Nuclear Generating Station planned to address design issues relating to the intake of water at low water levels that could occur with any regulation plan. However, the Monroe County potable water treatment plant in Greece on the south shore of Lake Ontario would

[8] Based on Lake Ontario-St. Lawrence River Study Municipal, Industrial and Domestic Water Uses Technical Work Group Report (IJC, 2006a).
[9] IJC, 2004
[10] A shore well is a well close to a lake in which the well water levels are directly influenced by lake levels.

experience problems even within the historical high water level range.

The Study Board also found that the Montreal water supply system could be at risk in the future if river levels fell below historical lows in conditions similar to those modeled with the driest climate change scenario.

During the IJC's 2013 public hearings on Plan 2014, representatives from the Village of Sodus Point, NY, reported that the main municipal sewer lift station was "at an elevation of 248 feet above sea level" and that higher Plan 2014 water levels would create a health and environmental hazard from some low-lying Wayne County septic systems (Figure 11). As noted earlier in this report, the IJC acknowledges that Lake Ontario levels would exceed this level slightly more often under Plan 2014 than under Plan 1958DD. However, Lake Ontario has risen above 75.59 m (248.0 ft) under Plan 1958DD in the 1970s and 1990s and will under any regulation plan with high water supplies to the lake. Parts of Wayne County, including septic tanks on Crescent Beach, will continue to be vulnerable to flooding and erosion under any regulation plan.

Regulation of Lake Ontario levels under either Plan 2014 or Plan 1958DD greatly reduces the frequency and depth of flooding in Sodus Point that would occur without regulation. The IJC recognizes that Lake Ontario's shoreline, particularly the south shore, is vulnerable to damage that can occur with any regulation plan due to extremely high supplies that have occurred a few times in the 20th century. The IJC supports collaborative attempts to reduce this vulnerability. Moreover, the IJC's extensive work with communities along the Lake Ontario-St. Lawrence River shoreline in Canada and the United States provides a unique opportunity to promote greater public and private collaboration to address this challenge.

4.2 Commercial Navigation

4.2.1 Overview of the Use[11]

Commercial navigation uses include domestic and international commercial ships transporting goods in the St. Lawrence and Lake Ontario system, including the St. Lawrence Seaway and the Port of Montreal. Ship traffic at the Port of Montreal includes ship transiting the Seaway and larger, deeper-draft ocean-going ships.

An estimated 70,000 jobs and nearly $4 billion in income and expenditures have been attributed to St. Lawrence River-Great Lakes commerce that transited the New York State waters (Martin Associates, 2011). The Port of Montreal handles more than 30 million tonnes of cargo annually and over 1 million TEUs (twenty-foot equivalent unit containers) (Port of Montreal, 2012).

The St. Lawrence River hydropower project was designed and built separately from the Seaway locks and channels but was to "be adaptable to the improvement of the International Rapids Section of the St. Lawrence River for navigation purposes" (IJC, 1952). The regulation of water levels and flows affects the water depths available on Lake Ontario and the St. Lawrence Seaway, which runs from Lake Ontario to Montreal. Lake Ontario outflow regulation also affects the levels at the Port of Montreal and those in the St. Lawrence ship channel as far downstream as Trois Rivières, QC.

4.2.2 Effects of Plan 2014

The IJC finds that, overall, Plan 2014 would provide about the same benefits as Plan 1958DD for commercial navigation in the Lake Ontario-St. Lawrence Seaway, as well as for ships using the Port of Montreal and lower St. Lawrence River.

Plan 2014 was developed and refined in collaboration with representatives of the navigation industry, including officials from the Canadian and U.S. St. Lawrence Seaway agencies and the Port of Montreal. The plan includes rules to support adequate levels for full-draft ships on the Seaway at all points in the navigation channel from Lake Ontario to Lake St. Louis. Formalized rules built into the plan mean that the Seaway would no longer have to rely on discretionary deviations by the Board of Control to provide adequate levels on Lake St. Lawrence and Lake St. Louis for shipping.

To address situations when water supplies are extremely low and threaten the plan's ability to maintain full depths throughout the system, the revised Orders would give authority to the

[11] Based on Lake Ontario-St. Lawrence River Study Commercial Navigation Technical Work Group Report (IJC, 2006b).

Board to deviate from the Bv7 release rules when Lake Ontario levels are at low trigger levels to provide relief to water intakes, navigation and hydropower in the system, consistent with the order of precedence of uses specified in the Treaty. In response to comments received during public consultations on Plan 2014, the IJC modified the draft directive to grant the Board the authority to deviate without first needing approval from the IJC (see Annex C).

The revised Order would establish the International Lake Ontario-St. Lawrence River Board, reporting to the IJC, to oversee daily operations and oversight of Lake Ontario-St. Lawrence River water levels and flows. In recognition that safe navigation depends on adequate water levels throughout the system, navigation expertise will be included on this Board.

Shipping Costs

The IJC's Lake Ontario-St. Lawrence River Study of the effects of regulation on commercial navigation was designed by experts from the Great Lakes-St. Lawrence Seaway Navigation community[12]. The Study measured the impact of available water depths and water velocities on shipping costs in the different reaches of the Lake Ontario and St. Lawrence River system. Table 2 lists the results using the Study's commercial navigation performance indicators.

The Commission finds that, overall, Plan 2014 will provide about the same benefits as Plan 1958DD for commercial navigation in the Lake Ontario-St. Lawrence Seaway as well as for ships using the Port of Montreal and lower St. Lawrence River.

Review of the navigation performance indicators after the Study found that the cost of light-loading[13] ships due to limited available depths downstream of Montreal had been underestimated, as only the effect on the ship travel cost on the St. Lawrence River had been included rather than the effect on travel costs on the entire ocean route. (A post-study analysis showed that correcting this error would not change plan rankings). Later, Seaway entities also questioned several of the assumptions in the Study's economic analysis of navigation, particularly those regarding costly ship stoppages due to unsafe velocities in the international section of the St. Lawrence River (St. Lawrence Seaway Management Corporation. 2008). They suggested that instead of an economic analysis, an analysis of water levels and flows resulting from the regulation plans would be more appropriate.

A full suite of water level and flow statistics defined by the Study Board's navigation work group is available for all regulation plans, including Plan 2014. This analysis indicates the frequency and magnitude of levels that require light-loading by ships on different routes and the frequency of flows greater than that considered safe by the Seaway. Although such statistics do not reveal the economic impact on navigation, the IJC did consider these statistics in its evaluation. This analysis shows that:

- the frequency of low levels on the St. Lawrence River at Montreal would be about the same under Plan 2014 as Plan 1958DD;
- Plan 2014 would increase the frequency of rare low levels Lake Ontario[14] that cause some ships that operate only on Lake Ontario to light-load; and,
- overall, there would be slightly fewer draft restrictions due to low levels for ships transiting the route from Lake Ontario to Montreal with Plan 2014 than with Plan 1958DD, which is the result of the rules built into Plan 2014 that better coordinate levels on the river with those on the lake.

[12] The Navigation Technical Working Group was led by representatives from the Canadian St. Lawrence Seaway Management Corporation, the U.S. Army Corps of Engineers, and the Shipping Federation of Canada. It also included members from the Port of Montreal, the Montreal Port Authority, Transport Quebec, the Canadian Coast Guard, and the U.S. St. Lawrence Seaway Development Corporation (IJC 2006).

[13] To light-load means to take on a load less than the ship capacity or less than a complete cargo, as the fully loaded ship would be too close to the channel bottom because of low water levels

[14] Analyses using the stochastic 50,000-year water supply set indicated that the frequency of quarter-month mean Lake Ontario levels below 74.27 m (the lake level required for full Seaway draft ships to transit without restrictions) during the nominal seaway season would increase from 1.8% to 3.3% of the time. The frequency of Lake Ontario levels below 74.00 m during the nominal seaway season would increase from 0.3% to 0.8% of the time.

Some navigation interests are concerned that lower Plan 2014 Lake Ontario levels, while very infrequent, could significantly impact commercial operations. Ships that do not leave Lake Ontario would have to carry reduced loads in those periods. However, most ships that traverse Lake Ontario are on their way to the St. Lawrence River or upper Great Lakes, and are loaded based on the minimum depth available along their entire route. The loading depths of ships that transit Lake Ontario and the upper Great Lakes may not be affected by lower Lake Ontario levels due to even shallower conditions on the upper lakes. The Lake Ontario-St. Lawrence River Study navigation analysis models did not consider the effect that water levels on the upper Great Lakes may have on shipping, but historical data demonstrate that Lakes Superior, Michigan and Huron are far more likely to determine ship loading than Lake Ontario levels under Plan 2014. Depths of water shown on Great Lakes navigation charts are referenced to one low water elevation called chart datum on each lake. Based on simulations using historical water supplies, Lake Ontario would be below chart datum during the seaway season 4% of the time under Plan 2014, while Lake Superior would be below chart datum 19% of the time and Lakes Michigan and Huron, 21% of the time. Thus, though Plan 2014 does not affect levels of any of the Great Lakes except Lake Ontario, water levels on the upper lakes should be taken into consideration when evaluating the effects of Lake Ontario regulation plans.

Other Benefits to Navigation Interests

The IJC concludes that Plan 2014 would offer benefits for navigation beyond providing adequate shipping depths. These additional benefits include the following:

- *Certainty of benefits that have previously been obtained through deviations at the discretion of the Board of Control*. Criterion H1 of the conditions to be included in a new Order of Approval (Annex A) would mandate limits on the occurrence of low levels at the Port of Montreal to rates similar to what has been achieved through past discretionary deviations from Plan 1958-D by the Board of Control. Criterion H2 would provide similar protection of levels on the Seaway at Lake St. Louis.
- *Clearer definition of the conditions required for long-term major deviations that help commercial navigation*. Criterion H14 would provide protection for navigation similar to criterion k of the current orders. The IJC changed the Directive on Deviations based on comments received during the 2013 Hearings on Plan 2014 so that the Board would no longer need to seek IJC approval to make these deviations. Under the current orders, the IJC has to approve criterion k deviations.
- *Greater ability to improve operations*. With an adaptive management framework in place, the performance of Plan 2014 for navigation would be monitored and suggested improvements tested.
- *Safer velocities*. More natural changes in flow from week to week and better maximum outflow rules would provide safer velocities for navigation in some circumstances.

In addition, minor deviations authorized now as part of Plan 1958DD to provide short-term assistance to commercial navigation would continue under Plan 2014. Deviations from the new regulation plan are expected to be much less frequent, because procedures to provide adequate river levels in the Seaway have been built into the new plan that were not in Plan 1958-D.

4.3 Hydropower

4.3.1 Overview of the Use[15]

Hydropower uses include: the two hydroelectric generating stations on the international section of the St. Lawrence River (the Robert-Moses station owned by the New York Power Authority and the Robert H Saunders station of Ontario Power Generation, which together form the Moses Saunders Dam); and the Beauharnois and Les Cedres stations of Hydro Quebec at the outlet of Lake St. Francis.

Combined, these power plants have an annual hydropower production of approximately

[15] Based on Lake Ontario-St. Lawrence River Study Hydroelectric Power Generation Technical Work Group Report (IJC, 2006c).

25 million MWh (13 million MWh at Moses-Saunders and 12 million MWh at Beauharnois-Les Cedres). The market value of this energy is approximately $1.5 billion U.S. a year at current market rates.[16] These hydroelectric plants produce enough energy to meet the needs of about two million homes.

4.3.2 Effects of Plan 2014

Under Plan 2014, the slightly higher and more natural fall through spring Lake Ontario levels that benefit coastal ecosystems also would slightly increase the head[17] and thus, energy production at the Moses-Saunders power plants. Plan 2014 also would slightly increase the amount and value of hydropower produced at the Hydro-Quebec plants. Although the higher Lake Ontario levels also would slightly reduce the head at the Niagara power plants, the net effect would be to increase the production of hydropower at all these plants by about 0.4%, or enough to supply the needs of about 8,000 homes.

In the Lake Ontario-St. Lawrence River Study, the economic experts panel advised the Study Board that the best metric to reflect societal impact in the energy sector was the increase in the value of hydropower energy caused by different regulation plans. Other societal metrics, such as the reduction in carbon emissions, were acknowledged but not evaluated in economic terms.

The Hydropower Technical Work Group of the Lake Ontario-St. Lawrence River Study helped design other metrics that were important to hydropower producers, termed the *stability* and *predictability* of flows. More stable releases change less from week to week, while more predictable releases change less from month to month. When possible, hydropower producers will take turbines out of production for maintenance only when the water release can be routed through other turbines that remain in service. A large, unexpected release increase may require spilling part of the release (that is, releasing the water but not running it through a turbine to create electricity). Plan 2014 would provide slightly more stable and predictable releases, thereby reducing the chance of energy losses during turbine maintenance.[18]

4.4 Coastal Development

4.4.1 Overview of the Interest[19]

Coastal development interests include individuals and organizations with a direct interest in the property along the shorelines of Lake Ontario and the St. Lawrence River (riparian property), particularly private property owners.

Approximately 60% of the Lake Ontario and St. Lawrence River shoreline is devoted to residential land use. In some of the developed counties, such as Monroe County, in New York on the southeast shore, the percentage of developed property is much higher, at almost 90% (Figures 11 and 12). The Lake Ontario-St. Lawrence River Study concluded that an estimated 25,000 privately owned riparian properties are located on Lake Ontario and the St. Lawrence River upstream of the Moses-Saunders Dam. More than 3,000 shoreline property parcels are located below elevation 76.2 m (250 ft) and could be at risk of flooding on Lake Ontario and the upper St. Lawrence River.

On the St. Lawrence River downstream of the Moses-Saunders dam, there are an estimated 5,770 single-family dwellings within the 100-year floodplain, with an estimated value of $380 million.

Shoreline protection structures are already present for a large percentage of riparian properties exposed to flooding and erosion hazards around the shores of Lake Ontario (Figure 13). Analysis undertaken as part of the Lake Ontario-St. Lawrence River Study found that approximately half of the developed shoreline length has been armoured with some sort of shorewall or revetment. In addition, shore protection measures have been added to about half of the total frontage on both the Canadian and American shores of the lower St. Lawrence River.

[16] Estimated price of $60 per MWh.

[17] The change in elevation between the water level upstream and downstream of the hydropower dam. Head, flow and turbine efficiency determine how much power is generated. All else being equal, greater head means more power generation.

[18] Flow into a turbine can be redirected to other turbines when it is necessary to perform maintenance or repair tasks, but only if the total flow is small enough to fit the capacity of the remaining turbines. When possible, turbine maintenance is scheduled for periods when releases are expected to be low. Plan 2014 releases do not change as much as 1958DD releases from week to week or even month to month.

[19] Based on Lake Ontario-St. Lawrence River Study Coastal Processes Technical Work Group Report (IJC, 2006d).

Figure 11

Crescent Beach, Wayne County, NY

Figure 12

Monroe County, NY

These photographs, taken in March 2012, show two locations on the south shore of Lake Ontario when water levels are at 74.98 m (246.00 ft) IGLD 1985. This level is slightly above average for that time of the year, more typical of mid-summer levels, though 0.78 m (2.6 ft) below the maximum recorded level. Almost all the damage estimated by Lake Ontario coastal computer models is related to shore protection structures (either damage to existing structures or erosion that requires a new structure to protect a building). But there are some buildings that are vulnerable to flooding and storm damage, no matter the regulation plan.

Figure 13

Examples of Shore Protection, Lake Ontario

(source: U.S. Army Corps of Engineers)

4.4.2 Effects of Plan 2014

Over the past several decades, many property owners and their municipal and state elected representatives on the south shore on Lake Ontario in New York have expressed concern about coastal property damage from high lake levels. During public hearings on Plans 2007 and 2014, property owners spoke to the IJC about damage that has occurred in the past and additional damage that could result with a change in the regulation plan.

The damages, as identified in Table 3, suggest that Lake Ontario coastal development will be vulnerable, no matter the regulation plan. Both the gross and net damages in Table 3 show that these damages are mainly to shore protection structures, not homes. The vulnerable shore protection structures typically are revetments made of large rocks piled in a sloping cross-section on the graded bank of the shore, or vertical shore walls made of concrete or steel sheet-piles capped by a concrete or stone pad, or a combination of these structures.

The structures are meant to stop erosion of the bank by absorbing or reflecting the energy of coastal waves. The size of the rock, the steepness of the side slope and especially the elevation of the top of the structure are all important factors in the design of a revetment. A single major storm event with waves that rush over the top of such structures can cause significant erosion damage to the structure.

Computer simulations show that average annual damages to the Lake Ontario coastal development are expected to be somewhat larger under Plan 2014 than under Plan 1958DD. These long-term simulations are based on estimates of the damages under 1958DD and each alternative plan. For

example, the average net increase in damage to all Lake Ontario shore protection structures for Plan 2014 is estimated at $1.94 million per year (the difference between estimated average annual damages of $15.48 million for Plan 1958DD and $17.43 million for Plan 2014).

The fact that Plan 2014 would cause more damage on average does not mean that continued regulation under Plan 1958DD would guarantee lower coastal damages. In some future circumstances, Plan 2014 could reduce damages compared to those under Plan 1958DD. The damages summarized in Table 3 are based on thousands of simulations of different water supply scenarios, each representing a different, possible sequence of water flowing into Lake Ontario. Of these, there are more scenarios in which Plan 2014 damages are greater than Plan 1958DD damages, but many in which Plan 1958DD is more damaging. The near-term future could include either type of water supply sequence.

Coastal damage will occur no matter the regulation plan

Most of the damage is to shore protection structures, not homes

More often than not, Plan 2014 would increase damages compared to Plan 1958DD

Table 3

Gross and Net Damage to Lake Ontario Coastal Development

(in $US millions 2005)

Expected Average Annual Lake Ontario Coastal Damages	1958DD	2014	Bv7	Natural
Damages	$18.15	$20.37	$21.26	$45.53
Shore Protection Maintenance	$15.48	$17.43	$18.11	$35.33
Erosion to Unprotected Developed Parcels	$2.50	$2.66	$2.67	$3.08
Flooding	$0.17	$0.28	$0.49	$7.11
% total damage attributed to shore protection structures	85%	86%	85%	78%
Net change from 1958DD damages	**$0.00**	**$2.22**	**$3.11**	**$27.38**
Net damages to shore protection structures		$1.94	$2.62	$19.85
% of changes attributes to shore protection structures		88%	84%	73%

Under either Plan 1958DD or Plan 2014, only about 1% of expected coastal damage is due to flooding of buildings; the rest is due to damage to existing shore protection (85-86%) and the costs of new shore protection because of erosion of unprotected developed parcels (13-14%). Five percent of the increase in coastal damages along Lake Ontario under Plan 2014 is due to increased flooding.

The Natural Plan (referred to as Plan E in Study documents) represents the release of Lake Ontario water through the existing flow control structures equivalent to what would occur with the river as it was circa 1953-1955 after removal of Gut Dam, but before any of the structures or channels approved in the 1952 and 1956 Orders were built, with minimal adjustments to reflect necessary ice management with the structures in place. Plan 2014 combines the release rules of Bv7 with deviations described in Annex C.

Tradeoffs in Managing the Natural and Developed Shore

There are challenges to balancing healthy coastal wetlands and property damage along the Lake Ontario shoreline. In its 2006 report, the Lake Ontario-St. Lawrence River Study Board found that Plan 1958DD came close to minimizing damages for Lake Ontario shoreline property owners but had reduced the diversity of plant types along the shore and populations of animal species that feed on and live in the environments affected by the reduced water level ranges.

The Study Board and Working Group produced a range of regulation plans that met the Treaty's requirements but that produced different levels of benefits among interests. No plan, however, could completely overcome this inherent conflict. Plans that restored a significant measure of coastal ecosystem health did so with more natural lake levels. More natural levels, by contrast, increased damages to vulnerable shoreline development. An alternative such as Plan 2007, which relaxed the compressed summer levels Lake Ontario while keeping autumn and winter levels unnaturally low, resulted in a slight reduction in coastal damages on average, but did little to reverse the harm to the environment.

In selecting a new regulation plan, the IJC chose to strike a balance between the two objectives. Plan 2014 produces a large improvement in coastal ecosystems in return for a small reduction in the benefits provided in the 1956 Order for those shoreline property owners who need to maintain shore protection to limit erosion and flooding.

Most south shore residents who testified in the 2013 hearings opposed Plan 2014. They argued that Plan 2014:

- would cause significant coastal damage;
- is based on past studies that underestimated impacts to south shore residents;
- is unfair because only the south shore would be hurt by Plan 2014;
- changed the rules for regulating Lake Ontario water levels after decades of long-term development decisions were made based on the previous regulation rules;
- damages should be mitigated if the plan were implemented; and,
- is based on flawed wetland science.

The IJC considered each of these concerns carefully before making its findings in support of Plan 2014.

Concern 1: Coastal Damage

Some south shore residents expressed concern that the new regulation plan would destroy coastal development and with it, the associated tax revenue, property values and tourism opportunities upon which shoreline counties depend.

This risk exists no matter the regulation plan. While models demonstrate that Plan 2014 is likely to increase coastal damage to shore protection structures on Lake Ontario by a relatively small margin, the same models also demonstrate that coastal damage could occur under either plan in the near future.

About 87% of the increase in expected damages to Lake Ontario coastal development under Plan 2014 would be to shore protection structures (Figure 14). This incremental damage could be avoided by designing such structures a few inches higher. Another 7% of the increase in cost would be due to new shore protection structures for currently unprotected developed properties. These structures would be built with either Plan 2014 or Plan 1958DD. But it is expected that they would be needed sooner with the higher frequency of higher levels under Plan 2014.

Figure 14

Increases in Lake Ontario Coastal Damage under Plan 2014, by Type

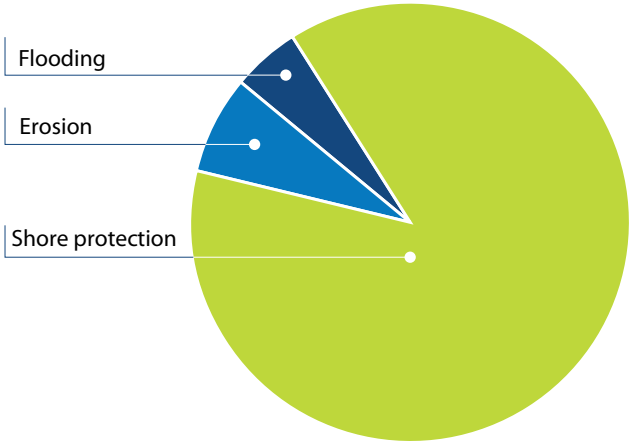
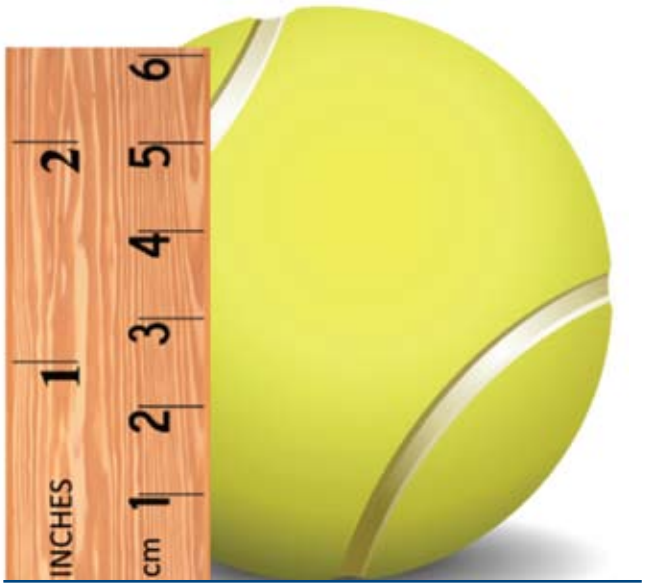


Figure 15

Comparing Maximum Triggering Levels of the Two Plans



Based on historical supplies, Plan 2014's projected maximum level would be 6 cm (2.4 in) higher than the maximum level under 1958DD. By way of comparison, a tennis ball is about 6.7 cm in diameter

The incremental increase from Plan 1958DD to Plan 2014 flooding damage to homes and other buildings is about 5%. Based on the best estimates available to the IJC, Plan 2014 would not change the floodplain delineation. Rather, the 5% increase in damages is based on the use of standard "depth damage" relationships that show the typical increase in damages with each additional centimeter (or inch) of flooding. The Plan 2014 maximum Lake Ontario level in the historical simulation, for example, is 6 cm (less than 3 inches) higher than the Plan 1958DD maximum level (Figure 15).

Water levels could be both higher and lower than any on record, regardless of the plan. With Plan 2014, if Lake Ontario water levels reach the high trigger levels, then releases from the dam would need to provide all possible relief to the riparian owners upstream and downstream. This is the same release requirement provided by criterion k of the 1956 Order. The proposed new Order would define a clear threshold for the relief to riparians, thus eliminating the need for IJC authorization.

The potential for record-breaking water supplies to cause serious damage to shoreline property was noted in testimony before the IJC. The risks of this level of damage are about the same under Plan 1958DD and Plan 2014. Because of the triggers, the more extreme the water supplies, the more Plan 2014 levels and releases would resemble Plan 1958DD levels and releases. At Lake Ontario levels of 76.0 m (249.34 ft) and higher, Plan 1958DD levels are higher than Plan 2014 levels 50% of the time.

Concern 2: Measurement of Effects

As noted, the Lake Ontario-St. Lawrence River Study Board had to limit studies in all categories, including coastal property damage, to those effects that were significant and useful in discerning differences between alternative regulation plans. An expert panel of economists advised the Study Board that measurement of secondary effects would have been practically impossible and, more importantly, unnecessary for plan ranking because the secondary effects moved proportionately with the major economic and environmental effects.

The Study Board accepted the expert opinion. The IJC endorses this finding.

Concern 3: Distribution of Effects

The negative net effects of Plan 2014 are all above the dam, because Plan 2014 is designed to reverse some of the environmental damage caused by compression of the range of Lake Ontario levels called for in the 1956 Order to reduce Lake Ontario coastal damage.

The compression of Lake Ontario levels since 1960 helped some riparians and hurt coastal ecosystems.

More natural levels hurt some shoreline protection structures and help coastal ecosystems.

Plan 2014 eliminates much of the environmental damage caused by past regulation while preserving most of the benefits to riparians.

As Table 3 shows, without water level regulation the damage to existing development on Lake Ontario and the St. Lawrence River would be more than $27 million per year higher on average than under the current regulation regime. Plan 2014 would eliminate much of the environmental damage caused by past regulation while preserving most of the benefits to shoreline property owners.

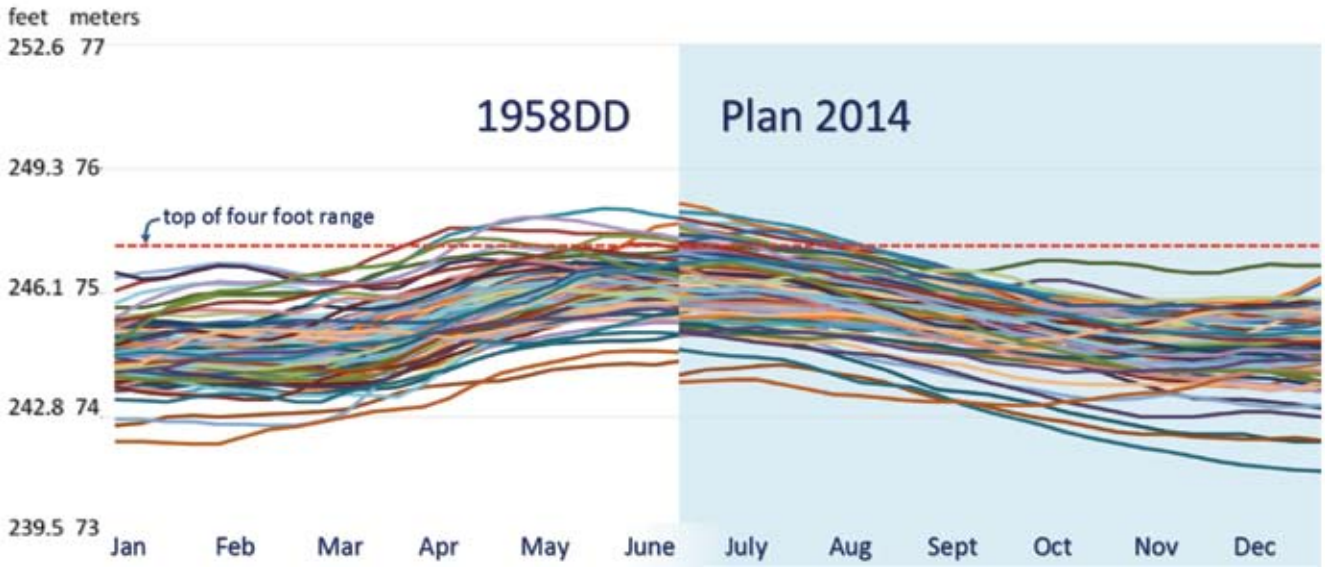
The meadow marsh performance indicator was used by the Study Board as an important indicator of how well a regulation plan produced diverse and robust wetland ecosystems. As shown in Tables 1 and 2, Plan 2014 would restore about 72% of the lost natural meadow marsh performance indicator[20] and a third of the lost natural northern pike young-of-year net productivity[21] at only about 8% of the Lake Ontario coastal damage expected in the natural unregulated system (Natural Plan/Plan E). Plan 2014 produces significant environmental gains while reducing the level of coastal damages caused by Plans B+ and Bv7. Wildlife biologists and coastal engineers worked together for years to achieve this result.

Concern 4: Past Siting and Design Decisions

During the 2013 hearings, the IJC heard testimony from some representatives of Lake Ontario's south shore that the IJC should not change the regulation plan because so many siting and design decisions had been made based on the lake levels expected with the 1956 Order.

Figure 16

Spaghetti Graphs of Plan 1958DD and Plan 2014. Lake Ontario Levels



Note: historical water supplies, spliced at mid-year to compare levels.

Plan 2014 increases the frequency of high lake elevations compared to 1958DD, but water levels under either plan will destroy shore protection designed for only the 1.22 m (4ft) range.

[20] The meadow marsh indicator is the ratio of the area of meadow marsh created by a plan after a long drought compared to the area produced by Plan 1958DD. The simulation of the Natural Plan (which is not, strictly speaking, a regulation plan, but rather refers to measures that are necessary in winter to avoid ice jams), produced a meadow marsh score of 1.56; Plan 2014 scores 1.41, a 41% increase in meadow marsh area. Damage to riparians was estimated in the Flood Erosion and Protection System (FEPS) model; three coastal damage indicators were used by the Study Board: flooding, erosion and shore protection damage, measured as the average annual change in damages or costs in each of the three sectors. The FEPS modeling indicated that the Natural Plan would on average cause $27.38 million more in damages along the Lake Ontario shore than Plan 1958DD, while Plan 2014 would cause $2.22 million. Comparing these two indicators, Plan 2014 gets 72% of the Natural Plan meadow marsh score for 8% of the E coastal damage cost.

[21] Young-of-year productivity is the amount of young fish (egg, fry, and juvenile, stages before sexual maturity) introduced into the system each year, measured in terms of the number and weight of the fish.

However, the IJC also heard testimony that development in this region typically has not been designed to withstand the actual levels experienced with the existing regulation plan, Plan 1958DD. Some testified that south shore development that flooded in the 1970s flooded again in the 1990s and will flood again at those same elevations. The IJC also heard testimony from south shore citizens during the hearings that shore protection structures are still being designed based on only a 1.22 m (4 ft) range in Lake Ontario levels. The "four-foot range" is a reference to the first part of a phrase in the 1956 Order to regulate Lake Ontario levels "*within a range of stage from elevation 74.15 meters (243.3 feet) (navigation season) to elevation 75.37 meters (247.3 feet), as nearly as may be*."

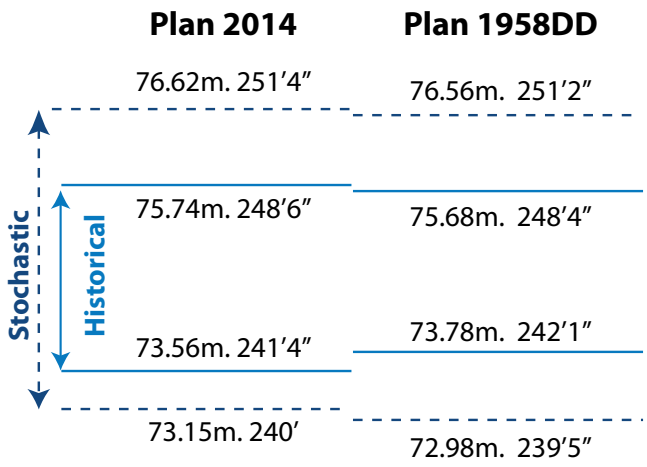
Note that the "nearly as may be" clause acknowledged even then that natural variation in water supplies could cause a wider range of levels. The criteria in the IJC's 1956 Order were clearly formulated on the knowledge that this range could not be guaranteed if supplies were more extreme than supplies of the past period of record (1860-1954). Water supplies to Lake Ontario in the 1970s, 1980s and 1990s were more extreme than those of the 1860-1954 period. As the split-screen spaghetti graph in Figure 16 shows, water levels under either plan will exceed the 1.22 m (4 ft) range even with historical supplies.

The fact that Lake Ontario levels will, despite the best efforts of the Board of Control under the existing 1956 Order, rise above and fall below the 1.22 m target range was demonstrated in the 1960s, 1970s and 1990s. Stochastic hydrology analysis developed by scientists during the Lake Ontario-St. Lawrence River Study suggests that it is possible that Lake Ontario levels under Plan 1958DD could rise above 76.5 m (251 ft) and fall below 73.0 m. (240 ft), a range of 3.5 m (11 ft) (Figure 17). These elevations were the most extreme reached in the simulation using the stochastic supplies. The damaging water elevations seen in 1952 (before regulation), 1973 and 1993 are not uncommon. As a result, some communities along the south shore will suffer coastal damages, again no matter the regulation plan.

As suggested by the stochastic supply analysis, it is likely that future water levels will again reach the high levels recorded in the 1970s and 1990s,

Figure 17

Lake Ontario Water Level Ranges, Plan 2014 and Plan 1958DD



The stochastic water supply data include much wetter and drier periods than have been recorded. Plan 2014 maximum Lake Ontario levels are 6 cm (2 in) higher than Plan 1958DD for the historical simulations, shown as solid lines in the figure above, as well as for the stochastic simulations, shown as dashed lines.

regardless of the regulation plan. The Lake Ontario-St. Lawrence River Study evaluation models verify this, showing that when the stochastic supplies are used as input to the plans, the average annual shore protection costs on Lake Ontario are $15.48 million under Plan 1958DD, and $17.43 under Plan 2014 (Table 3).

The projected effects of first-floor flooding of homes and other buildings and erosion to unprotected developed parcels are much smaller. Flooding damages under Plan 1958DD average $170,000 per year and $280,000 per year under Plan 2014. Study models do not indicate an increase in the number of homes flooded by Plan 2014 compared to Plan 1958DD.

Analysis using models developed for the Lake Ontario-St. Lawrence River Study suggests that Plan 2014 would not trigger a change in the floodplain delineation or in the base flood elevation. As noted, the difference in the maximum Lake Ontario levels of Plan 2014 and 1958DD in the historical water supply simulation is 6 cm (about 2.4 in). Given that floodplains are delineated at whole-foot increments, they are unlikely to be affected by such small increases in static levels.

Analysis by the Study Board suggests that Plan 2014 would not change the floodplain delineation or the base flood elevation, which is specified in whole-foot increments.

Study models do not indicate an increase in the number of first-floor flooding of homes under Plan 2014 compared to 1958DD.

The performance indicator used in the Study's evaluation model that accounts for the erosion of unprotected developed parcels of land measures the cost of future shore protection built when erosion brings the top of the shoreline within 10 m (33 ft) of the building to be protected. Plan 2014 would not change the number of these shoreline structures that eventually would be needed to protect their buildings, but typically would require homeowners to build the protection structures earlier, because the rate of erosion of the bank would be slightly higher. That is, the increase in average Plan 2014 erosion costs over Plan 1958DD costs represents the cost of building the same structure sooner. The two categories of damage relating to shore protection structures account for about 99% of the coastal damage under Plan 2014, with about 1% related to the flooding category.

Concern 5: Mitigation of Damages

The regulation of the outflows from Lake Ontario under the rules of Plan 2014 would continue to substantially reduce natural high levels and reduce the damages the south shore would experience without regulation of flows. As a result, Plan 2014 would benefit, not injure, south shore riparians relative to the unregulated condition.

The IJC's studies have underscored what other studies and past experience have shown: that future high Lake Ontario levels under any regulation plan, coupled with storms and wave action, can be expected to damage or threaten existing shore protection, water and wastewater systems and even some homes.

The IJC recognizes the complexity and difficulty of coastal zone and floodplain management, and the evolving and varied views evident in the responses to Hurricanes Hazel (1954), Katrina (2005) and Sandy (2013). However, the IJC believes that complex decisions to invest and manage coastal zones and floodplains should be based on the best available evidence of risk.

The level of risk accepted in the design of homes, structures and infrastructure systems is addressed by domestic regulations. The IJC can only inform those considerations with evidence from its own investigations. The IJC heard testimony and collected evidence in its own studies showing that damages or expense to avoid damages to shore protection structures and water and wastewater systems would occur under either Plan 1958DD or Plan 2014 more often than the common 1-in-100 years standard.

The IJC is considering the findings and recommendations from its International Great Lakes–St. Lawrence River Adaptive Management Task Team (IJC, 2013). The Task Team, led by experts from Environment Canada and the United States Army Corps of Engineers (USACE), investigated ways to adaptively manage the risks of and response to the impacts of low and high Great Lakes water levels, including those that cannot be managed through regulation of the levels of Lakes Superior and Ontario. The Task Team recommended that the negative impacts of very high and very low levels could be reduced if stakeholders and managers more effectively shared existing information on these risks to better support strategic decisions and investments.

Concern 6: Assessment of Damage to Wetlands

Some riparians who opposed Plan 2014 because of the effects on property on the south shore of Lake Ontario told the IJC that the environmental studies used as the basis for justifying Plan 2014 were flawed. The IJC reviewed the findings of the Lake Ontario-St. Lawrence River Study, the peer review commissioned by the IJC, and subsequent evidence and arguments on this subject before concluding that the evidence is overwhelming that current regulation rules damage the environment.

The Lake Ontario-St. Lawrence River Study Board sought out leading Great Lakes scientists to investigate and quantify the relationship between water levels and various aspects of coastal

Figure 18

Upper St. Lawrence River Wetland

(Photo: Doug Wilcox)

ecosystem health. The relationships were based on extensive field data and each study was required to validate the results.

As the Study used new data and methods, the IJC engaged the U.S. National Research Council and the Royal Society of Canada to conduct an independent peer review. The Study Board also conducted an extensive internal review process. The National Research Council review concluded that the breadth of the study was impressive, and commended the scale and inclusiveness of the studies and models (National Research Council, 2006). On the environmental studies, the reviewers concluded that "given the complexity of the LOSLR[22] system, binational interests, and the range of scientific and other information compiled, the undertaking of this comprehensive study is a major contribution by itself" and that the "identification and inclusion of performance indicators advance understanding of the Lake Ontario-St. Lawrence River system."

Concluding that there were few precedents for a study of this scale and that opportunities for improvement were to be expected, the peer reviewers raised three general criticisms:

- the level of empirical su pport varied among different studies (there were more data supporting some performance indicator algorithms than others);
- the level of integration among the models should be more dynamic, with feedback loops that would constitute a true systems model; and,
- ongoing monitoring and analysis are needed to provide a strong scientific basis for long-term decision making about water level and flow regulation in the Lake Ontario-St. Lawrence River basin.

The Study Board co-chairs and technical work group leads responded to the peer review (IJC, 2006e), concluding that none of the concerns raised by the reviewers challen ged the "appropriateness and sufficiency of the studies and models used to inform decisions related to regulation plan options." The co-chairs agreed with and addressed some of the peer review comments, but concluded that on other issues, such as lack of available documentation and the temporal resolution of the models, the peer review process should have allowed more communication between reviewers and study scientists. Study Board decisions were formulated after extensive debate among leading experts and in cooperation with the PIAG. The peer review process guaranteed the independence of peer reviewers, but as structured, that independence provided them with less information than study experts used in their decision making.

The peer review did raise questions about the wetlands study, and those questions were answered by the Study Board (IJC, 2006e). The wetlands study was published in a peer-reviewed journal after the Study Board finished its work (Wilcox and Xie, 2007), and, still later, the relationships between water levels and wetland plants were verified in a published study based on historical aerial photographs (Wilcox *et al*., 2008).

The IJC accepts the Study Board's response to the peer review and the scientific conclusions of the Lake Ontario-St. Lawrence River Study, including in particular, the Study Board findings on the relationships between Lake Ontario water levels and coastal ecosystems.

[22] Lake Ontario-St. Lawrence River

4.4.3 Prevention of Coastal Damage in the Province of Ontario

Modeling undertaken for the Lake Ontario-St. Lawrence River Study indicates that there would be coastal damage on the Canadian shore of Lake Ontario, particularly in the Niagara and Halton regional municipalities, under any regulation plan. However, the response from riparian interests along the Canadian shore of Lake Ontario has been markedly different. No concern was expressed in Ontario about Plan 2014 damage to coastal development during the 2013 hearings on Plan 2014. There was some concern expressed during the meetings in Ontario held by the PIAG in 2005, but in public meetings in the province from 2005 through 2013, the objective of more natural regulation received strong support.

The Ontario response can be attributed in part to a different history and institutional setting. In 1954, Hurricane Hazel caused about $1 billion ($Cdn 2013) dollars damage in the Toronto region, killing 81 people and leaving thousands homeless. After the hurricane, the provincial government amended the *Conservation Authorities Act* to enable an authority to acquire lands for recreation and conservation purposes and to regulate hazard lands for the safety of the community.[23]

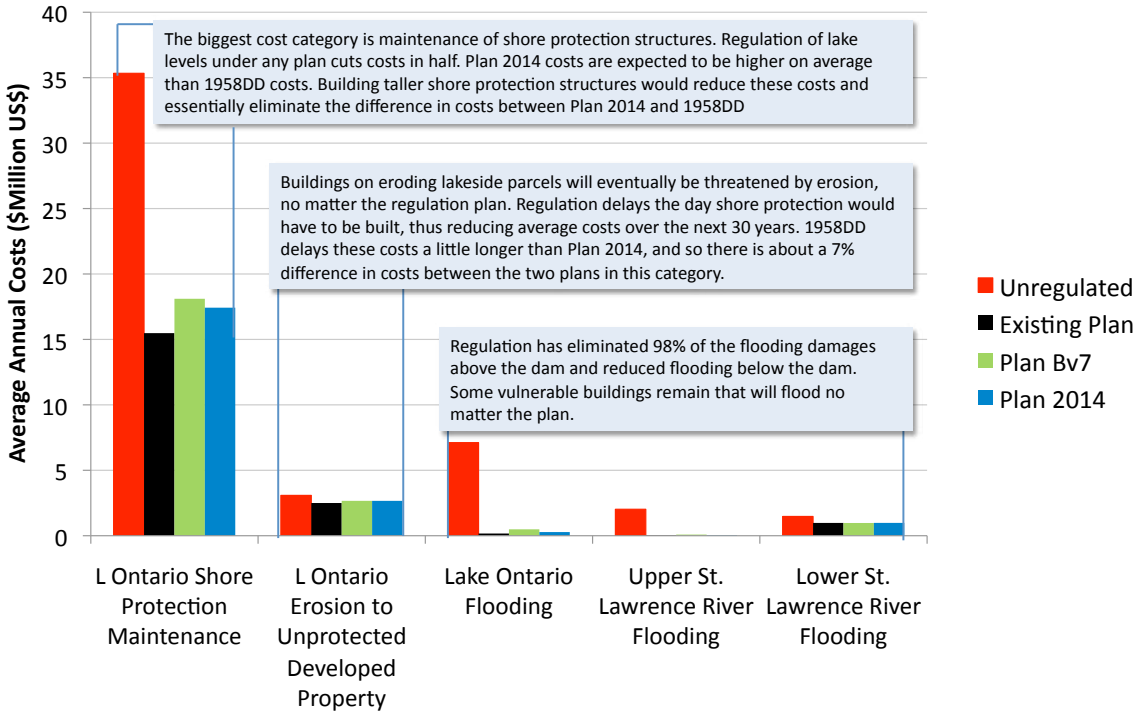
Along parts of the Ontario shore of Lake Ontario, local and regional governments are converting privately owned waterfront properties at risk of flooding or erosion to public space. For example, after the flooding of the 1970s, the City of Burlington, Halton Region and Conservation Halton began the Beach Property Acquisition Program with support from the Province of Ontario. After the purchase of 129 properties on a willing seller basis, less than 4% of the designated area remains under private ownership (City of Burlington *et al*., 2011).

4.4.4 Summary

In summary, the IJC recognizes that there are challenges to balancing ecosystem protection interests and benefits to shore property development interests along the Lake Ontario shoreline. Each regulation plan involves a tradeoff among interests. Plans that restore a significant

Figure 19

Summary of Shoreline Protection, Erosion and Flooding Effects



[23] Environment Canada website, Hurricane Hazel Mitigation http://www.ec.gc.ca/ouragans-hurricanes/

measure of coastal ecosystem health do so with more natural lake levels. More natural levels, by contrast, could increase damages to shoreline development.

In selecting a new regulation plan, the IJC chose to strike a balance between the two objectives. Plan 2014 would produce a large improvement in coastal ecosystems in return for a small reduction in the benefits provided in the 1956 Order for those who live along the shore of Lake Ontario. The effects of Plan 2014 on shoreline property on the lake and river are summarized in Figure 19.

South shore residents who opposed Plan 2014 in the public hearings identified a range of concerns. The IJC considered each of these concerns carefully before making its findings in support of Plan 2014. Table 4 summarizes the IJC's response to the concerns.

The IJC finds that costs will have to be borne to maintain hardened shore structures along the shore of Lake Ontario regardless of the future regulation plan. Furthermore, the IJC finds that the benefits to wetlands are scientifically credible and that the evidence of harm by the current regulation plan is too great to ignore.

Table 4

Summary of the IJC's Response to Key Concerns Expressed by Residents of Lake Ontario's South Shore

Public Concern	IJC Response
1. Coastal Damage	Plan 2014 is not expected to change the floodplain delineation along Lake Ontario's shoreline Coastal damage will be experienced under either existing plan or Plan 2014 Most of this damage is to shoreline protection structures Most of the increase in damage to shore protection structures expected with Plan 2014 could be avoided by building these structures a few cm (inches) higher New shore protection structures will eventually be needed for currently unprotected developed properties under either plan, but likely would be needed sooner under Plan 2014
2. Measurement of Effects	IJC accepts the findings of the Study Board and its expert panel of economists that measurement of secondary effects is unnecessary for plan ranking, because secondary effects move proportionately with the major economic and environmental effects
3. Distribution of Effects	The compression of Lake Ontario levels under the existing plan helped some riparians and hurt coastal ecosystems Plan 2014 strikes a balance; it does not fully restore ecosystem health so that it can preserve most of the protection to riparians

Public Concern	IJC Response
4. Past Siting and Design Decisions	IJC heard testimony that many designs are not based on the current plan; some shore protection structures are being designed to accommodate only a 1.2 m (4 ft) range of water levels, even though the range of levels under Plan 1958DD has been about 1.8 m (6 ft) More than 90% of the impact to coastal property involves existing or new protection structures; as a result, some communities along the south shore will suffer coastal damages to existing development, no matter the regulation plan Plan 2014 is not expected to change the floodplain delineation that has guided home design along the Lake Ontario's shoreline
5. Mitigation of Damages	Future high Lake Ontario water levels under any regulation plan can be expected to damage or threaten existing shore protection, water and wastewater systems, and even some homes Meaningful reductions in the level of risk can only be realized through the design of homes, structures and infrastructure systems; while these are addressed by domestic regulations, the IJC can inform those considerations with evidence from its own investigations
6. Assessment of Damage to Wetlands	The IJC reviewed the findings of the Lake Ontario-St. Lawrence River Study, the peer review of that Study, and subsequent evidence and arguments on the subject of the integrity of the environmental science before concluding that the evidence is overwhelming that current regulation rules damage the environment

4.5 Ecosystems

4.5.1 Overview of the Interest[24]

The ecosystems interest includes the biological components of the natural environment of Lake Ontario and the St. Lawrence River, together with the ecological services that the natural environment provides to people who live and work in the region.

The biological communities of Lake Ontario and the St. Lawrence River have, by necessity, evolved to adapt to the natural range of water levels and water level changes that occur on time scales ranging from wind-driven seiches that can occur several times daily, to the seasonal cycle, to changes that occur over decades and longer.

The biological effects of water level fluctuations are greatest in shallow water, where even small changes in water levels can result in conversion of a standing water environment to an environment in which sediments are exposed to the air, or *vice versa*. The localized effects of this change in the environment are evident in the relatively immobile plant communities that occur in wetlands. In fact, the patterns of water level change are the driving force that determines the overall diversity and condition of wetland plant communities and the habitats they

[24] Based on Lake Ontario-St. Lawrence River Study Environmental Technical Work Group Report (IJC, 2006f).

provide for a multitude of invertebrates, amphibians, reptiles, fish, birds and mammals.

There are more than 80 species of plants and animals in the Lake Ontario-St. Lawrence coastal zone that are sensitive to water level fluctuations and that are being tracked as species of concern by the Natural Heritage Program in New York and the Natural Heritage Information Centre in Ontario. Of these species, 30 are officially designated by state, provincial or federal authorities as threatened or endangered. In the Quebec section of the lower St. Lawrence River, there are 13 special concern, vulnerable, threatened and/or endangered species affected by water levels.

The coastal wetland area within Lake Ontario and the St. Lawrence River is about 26,000 ha (64,000 acres) in size. These wetlands are made up of four basic types: submerged aquatic vegetation; emergent marsh; meadow marsh; and upland vegetation (trees/shrubs) (Wilcox, et al., 2005). More than 80% of the wetland area occurs in the eastern half of the Lake Ontario basin and Thousand Islands region.

Further down the river, the ecological value of Lake St. Pierre marshes has been recognized by their designation as a Ramsar wetland by an international compact. The lake is a UNESCO Biosphere Reserve and is included as a protected site under the Eastern Habitat Joint Venture. With more than 12,000 ha (30,000 acres) of swamps and marshes, Lake St. Pierre accounts for 80% of lower St. Lawrence River wetlands. The lake also supports a large population of nesting blue heron, a major staging area for migratory wildfowl and 167 species of nesting birds. Permanently submerged areas, wetlands and the spring floodplain are home to 13 amphibian and 79 fish species, many of which are sought by sport and commercial fisheries.

4.5.2 Effects of Plan 2014

The Lake Ontario-St. Lawrence River Study Board concluded that the:

> "…current regulation plan has reduced the range and occurrences of extreme Lake Ontario levels as intended under the existing Order of Approval. From an environmental perspective, this has resulted in a smaller transition zone within wetlands from submerged to upland plants, thus reducing the diversity of plant life along the shore and negatively impacting birds, fish and mammals that depend on those plants. Regulation has also caused dewatering drawdowns in the fall through early spring, to the detriment of some habitat." (IJC, 2006)

Comparing the variability of the 101 years of Lake Ontario water levels resulting with no regulation and with regulation under Plan 1958DD (shown in Figures Ex-1 and Ex-3 in the Executive Summary) demonstrates that regulation of Lake Ontario has restricted the natural fluctuations of its water levels, both in terms of reducing its extremes and year-to-year variability. These figures also show that Plan 1958DD typically has reduced the lake levels significantly in the winter compared to the natural levels.

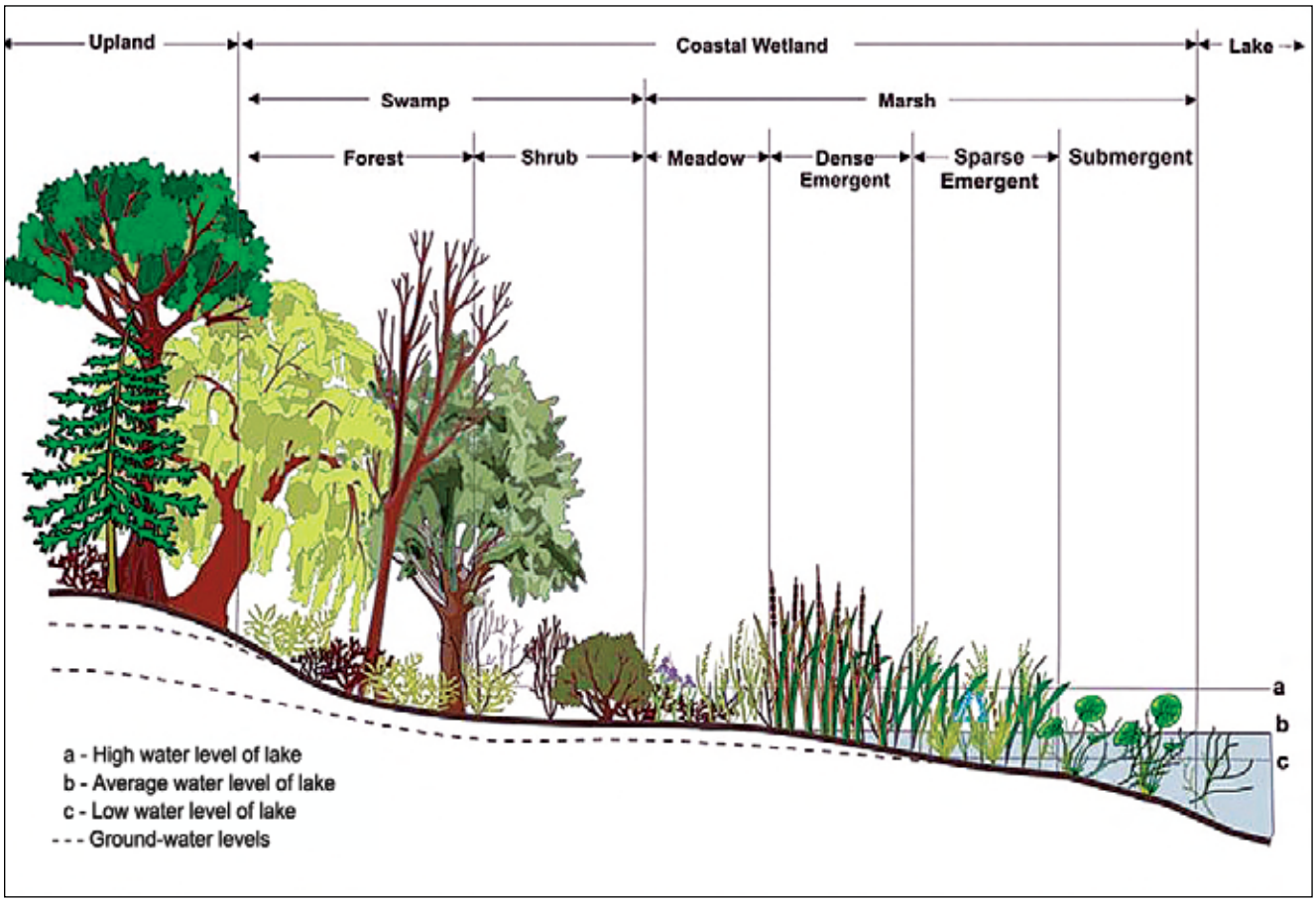
Different plants have different watering requirements. The compression of the range of lake levels has allowed the trees and shrubs to grow closer to the water and cattails and other emergent plants that tolerate persistent flooding to expand their range up the shoreline, squeezing out meadow marsh plants in-between (see Figure 20). The strong correlations between plant types and flooding history were evident in the extensive sampling of wetlands at 32 sites around Lake Ontario during the Lake Ontario-St. Lawrence River Study. Study researchers carefully inventoried the kinds of plants growing at different elevations, and were then able to show strong relationships between the type of plants found on the shore and how recently the shore had been flooded at that elevation (Wilcox *et al*., 2005). They determined that upland plants dominated above elevations that had not been inundated in the past 30 years. As well, there was little meadow marsh vegetation at elevations that had been kept wet in the growing season for the last five years.

These results were consistent with the published water tolerances for upland and meadow marsh plants. Regulation plans could then be evaluated based on these evident relationships. Plan 2014 would allow both more frequent low and more frequent high Lake Ontario water levels that would

Figure 20

Compressing Natural Water Level Variability Reduces Plant and Animal Diversity

Source: Wilcox, 2012



expand the meadow marsh areas from time to time, creating a dynamic diversity in wetland plants and the animal life associated with them, while still controlling most of the high levels that can damage coastal development.

Plan 2014 also would help restore bird species such as the Black Tern, Least Bittern, and King Rail (Figure 21), which are listed as at-risk by either New York State or the Province of Ontario (DesGranges *et al*., 2005).

The health of muskrat and northern pike species is an indication of the health of the ecosystem more generally. The more natural fall-winter-spring drawdown of Lake Ontario levels with Plan 2014 would benefit the environment for muskrat overwintering survival and northern pike access to spawning habitat in the spring. Environmental scientists and organizations that responded during the IJC's 2013 public hearings supported these findings, though in some cases they expressed concern that the implementation of a new plan was taking years and that Plan 2014 ceded some of the environmental benefits attributed to Plans B+ and Bv7.

The U.S. Department of Interior, the USEPA, Conservation Ontario, and many environmental non-governmental organizations in New York, Ontario and Quebec that responded during the 2013 hearings supported Plan 2014 because of its environmental benefits. Many of these respondents noted the finding from IJC studies that past regulation of Lake Ontario levels has caused the loss of wetland plant diversity. Even some residents of Lake Ontario's south shore said during the 2013 hearings that they had personally observed this

Figure 21

Plan 2014 Would Help Several Species of At-risk Birds

Black Tern **Least Bittern** **King Rail**

Regulation of Lake Ontario levels since 1960 has greatly reduced the variability of water levels, and for over 50 years, that has affected natural life along the coastal zone of the lake. Plan 2014 would restore enough of the natural variability to make significant improvements to the environment while protecting most of the benefits to riparians along the Lake Ontario shorelines.

Ecosystem performance indicators associated with particular species, such as the three at-risk bird species shown here, often have broader significance because they are applicable to many species with the same habitat requirements.

impact over the decades they had lived there. In addition to confirming the scientific assessment of the relationship between water level patterns and wetland health, several thousand expressions of support for a regulation plan that addressed the environment were received by the IJC, documenting the public interest in ecosystem health.

The restoration of more natural water level regimes in Lake Ontario and the St. Lawrence River is not a traditional wetland restoration project, which typically includes harvesting and planting, physical transformations of the wetlands, or cleanup of pollutants. Nonetheless, as the USEPA noted, "Plan 2014 will increase the diversity and functioning of 64,000 acres of coastal wetlands by allowing hydrologic conditions to support native wetland plant seed germination and growth"(USEPA, 2013).

Focusing on scale alone, there are few wetland restoration projects in the history of such projects in North America that have affected as large an area. By comparison, the Everglades Restoration is much larger, costing billions of dollars and affecting millions of acres, but is considered the largest ecosystem restoration project in the world. Napa Sonoma Marsh Restoration project in California, when completed, is expected to restore as many as 10,000 acres at a cost of $55 million (2004 U.S. dollars) USACE, 2004). The Emiquon Floodplain Restoration on the Illinois River, near Peoria, Illinois, will restore about 5,400 acres at a cost of over $13 million (USACE, 2014).

Ecosystem Effects of Plan 2014 on the Lower St. Lawrence River

As shown in Table 1, there are no significant differences to ecosystems on the lower river among the various regulation plans. The relationship between releases from the Moses-Saunders dam and each lower river ecosystem performance indicator is different. Factors such as mean water depth or levels, mean current velocity and water level decrease over certain parts of the year are important drivers of many of these indicators. However, the changes from the Plan 1958DD release patterns to Plan 2014 patterns were not enough to make a significant difference to the

lower river ecosystem given the defined sensitivity of the indicators to changes in those parameters. Variability of the flows from the Ottawa River and other tributaries dampen the effects of the release patterns at the Moses-Saunders dam. The spaghetti graphs of Lake St. Louis in Figure 22 (for Plan 1958DD) and Figure 23 (for Plan 2014) show how little the river levels change between the two plans. River levels downstream of Lake St. Louis are even less affected by the change in plans.

To conclude, the IJC finds that:

- robust coastal ecosystems are in the interests of both countries;
- the existing regulation plan has harmed and continues to harm those ecosystems; and,
- Plan 2014 would address much, though not all, of this damage over time.

The IJC, therefore, believes that Plan 2014 should be implemented as quickly as possible.

Figure 22

Lake St. Louis Levels, Plan 1958DD, Historical Supplies

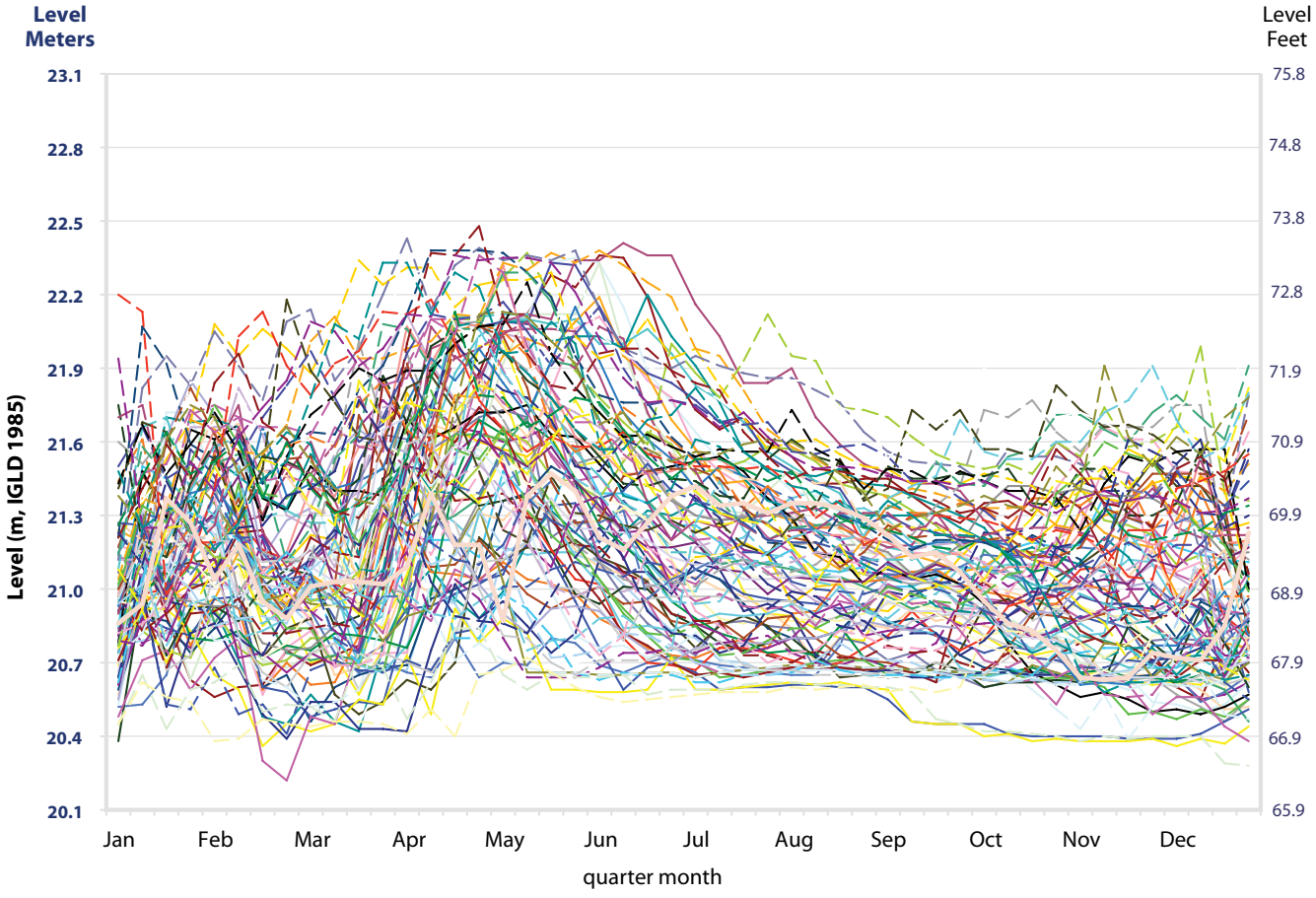
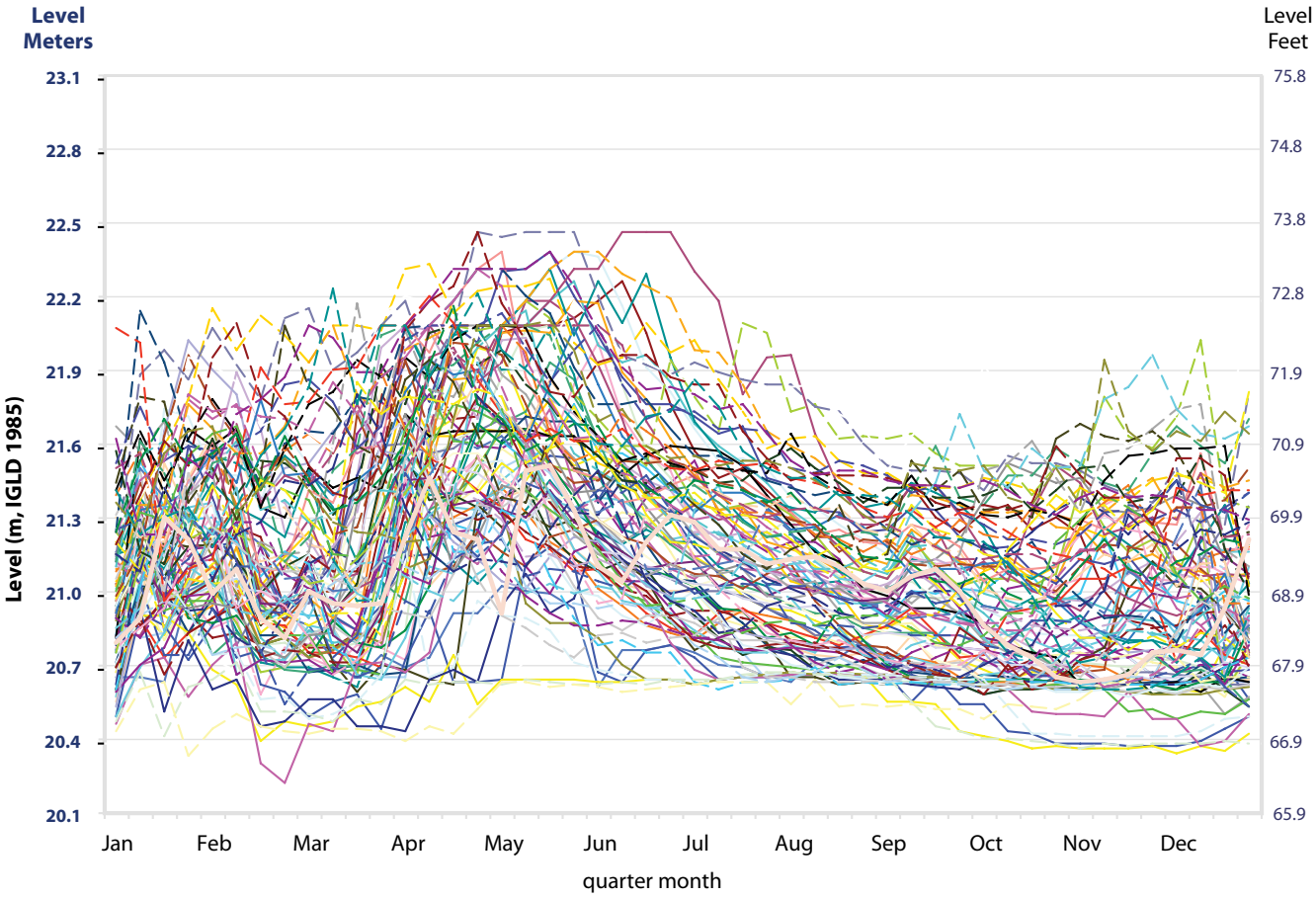


Figure 23

Lake St. Louis Levels, Plan 2014, Historical Supplies



4.6 Recreational Boating

4.6.1 Overview of the Interest[25]

The recreational boating interest includes pleasure boating and fishing, marinas and the commercial cruise ship industry. Lake Ontario and the St. Lawrence River support a large recreational boating and sport fishing industry. Analysis undertaken for the IJC's Lake Ontario-St. Lawrence River Study found that recreational boaters in the U.S. and Canada spent an estimated $430 million on boating-related trips taken on Lake Ontario and the St. Lawrence River in 2002.

4.6.2 Effects of Plan 2014

Compared to Plan 1958DD, Plan 2014 would reduce average recreational boating benefits on Lake Ontario and the river upstream of Ogdensburg, NY and increase them on Lake St. Lawrence and the river below the dam (see summary in Table 2). However, Plan 2014 did receive some support from many boaters upstream of Ogdensburg. Field studies and statements during public meetings and hearings suggest that there are two reasons for this upstream support.

Firstly, in most years, upstream boaters would prefer Plan 2014 because of the higher water levels later in the autumn, which would extend their boating season. The tradeoff is that there also would be summers in which Lake Ontario levels were noticeably and more naturally lower, which allows the re-establishment of meadow marsh vegetation at lower shore elevations. Those low lake level summers would be relatively rare. In terms of economic impacts, the adverse effects of the bad

[25] Based on Lake Ontario-St. Lawrence River Study Recreational Boating and Tourism Technical Work Group Report (IJC, 2006g).

summers would be slightly greater than the benefits enjoyed in the good summers and fall, largely because there are more boaters in the summer.

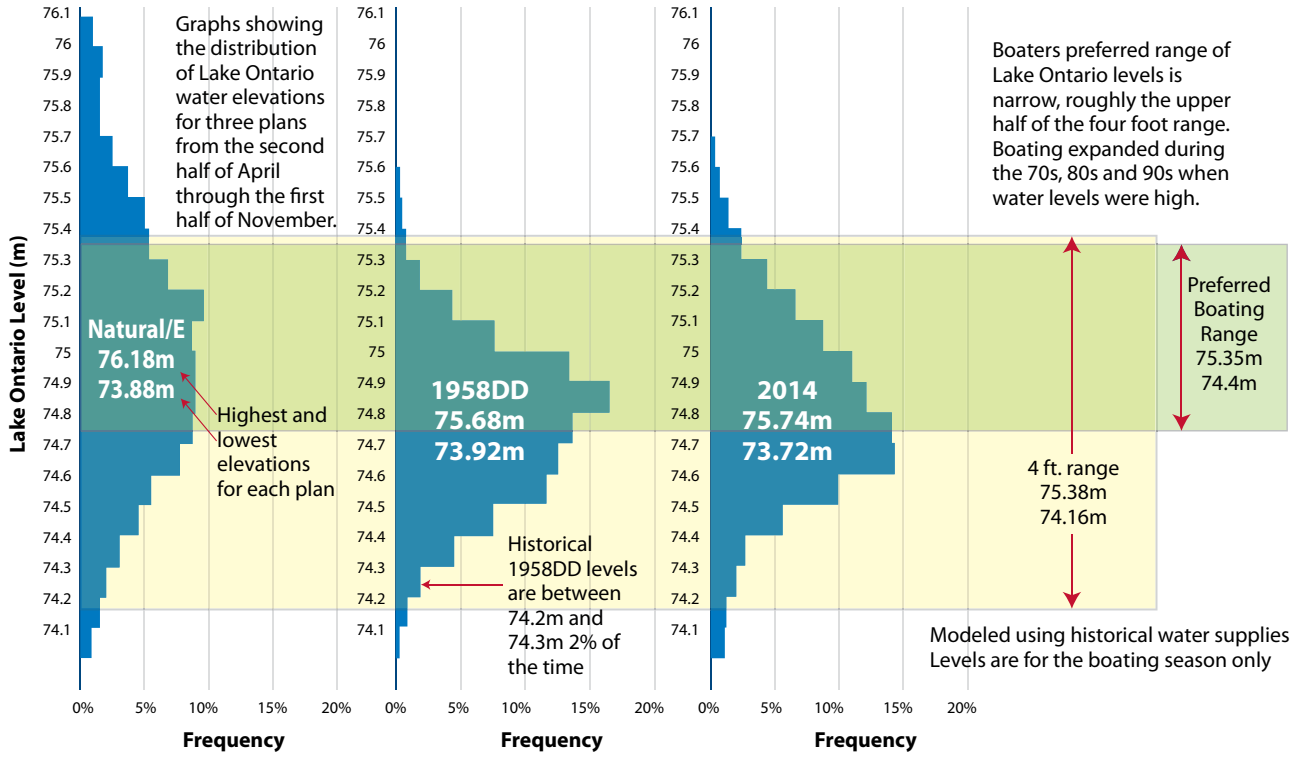
Secondly, it is important to note that despite the negative impacts, many upstream boaters will not be affected during the low summers. The negative economic impacts result in part from the fact that some docks are so shallow that they are unusable even when Lake Ontario is at average water levels. In fact, the range of lake levels with no impact on boaters is significantly narrower than the four-foot range referenced by south shore (Figure 24). Boaters who participated in plan formulation and evaluation exercises asked plan formulators to minimize the frequency, severity and duration of water levels on Lake Ontario below 74.74 m (245.2 ft) or above 75.35 m (247.2 ft) from April 15th through to October 15th. Under Plan 1958DD, levels are outside this range more than 30% of the time. However, many boaters have dockage better suited to a wide range of water levels and would not be as affected by the occasional low summer levels caused by Plan 2014.

4.7 Protection of Other Benefits to the Interests

Some benefits to interests are provided in an *ad hoc* manner now under Plan 1958DD. However, the balance among interests would be more assured and predictable under Plan 2014 than under Plan 1958DD. The performance estimates in this report for Plan 1958DD are modeled in part on the judgments that the Board of Control has applied when it deviated from the prescriptive rules of Plan 1958-D. However, changes in the membership of the Board could result in different judgments.

Figure 24

Preferred Lake Ontario Water Level Ranges of Recreational Boating Interests



This graph shows the frequency of water levels in 10 cm (4 in) bands for three regulation plans using the historical water supplies. The 1.22 m (4 ft) range of the 1956 Order and the range of levels preferred by boaters are superimposed. The preferred range was provided by boaters and verified in a study of dock depths and the drafts of registered boats undertaken for the Study Board (Connelly et al., 2005). The most common depths under Plan 1958DD are within the preferred boating range, though 1958DD levels are below the range about 20% of the time. The most common 2014 depths straddle the lower edge of the range boaters prefer. Not all boats are kept in shallow docks.

Plan 2014 received some support from boaters because it generally provides greater Lake Ontario and upper river depths in the fall, extending the boating season.

The Board of Control sometimes must address inherent potential for conflict. For example:

- in times of high supply, releases to reduce high Lake Ontario levels could cause flood damages downstream, especially during the spring freshet when flows from the Ottawa River and other downstream tributaries are also high; and,
- in times of low supply, increased releases to maintain adequate downstream levels for water intakes and ships using the Seaway or the Port of Montreal could adversely affect levels for boating and navigation above the dam.

By some estimates, about half of the weekly releases include deviations made by the Board of Control. As a result, these deviations are a key part of the performance of Plan 1958DD. For example, based on simulations using the historical supplies, the maximum Lake Ontario level under Plan 1958-D (no deviations) would be 77.07 m (252.85 ft). Modeled deviations from the rules of 1958-D reduce that to 75.68 m (248.29 ft). If a future Board negotiated deviations differently or future IJC Commissioners made different determinations about whether to invoke criterion k, then future results could vary considerably under the existing Order and plan.

By contrast, the results from Plan 2014 would be inherently more predictable. Plan rules were designed around a longer supply record with a much wider range of supplies than those used in the 1950s to design Plan 1958-D. Consequently, the written rules can be used much more frequently, perhaps in more than 90% of future decisions. Under Plan 2014, the maximum level of Lake Ontario using the historical supplies would be the same with or without deviations.

Table 2 indicates, that on the whole, Plan 2014 would maintain the balance struck under the 1956 Order and 1958DD. Effects on municipal and industrial water intakes are the same under both plans (that is, $0 net difference). There is a slight shift in recreational boating benefits from above to below the dam, primarily because of the modeled tradeoff between typically higher autumn and the occasional low summer levels induced by Plan 2014, which would create, on average, about 5% less recreational opportunities above the dam and 5% more below the dam. Overall, impacts to navigation are neutral.

Under the existing plan, if Lake Ontario levels get very high or very low and the IJC wants to trigger a major deviation so as to provide relief to affected interests, then it first must determine, on the advice of its Board of Control, whether the current supplies fall outside the range of past supplies. Under the Order for Plan 2014, no action by the IJC would be needed for the Board to act. When Lake Ontario levels hit the high-trigger levels, the Board would deviate from the Plan as needed to protect riparians upstream and downstream, and when the Lake levels hit the low triggers, the Board would deviate to protect municipal water intakes, navigation and hydropower production.

4.8 Summary of Effects of Plan 2014 on the Uses and Interests

Table 5 presents a summary of the effects of Plan 2014, compared to the current Plan 1958DD, on each of the uses and interests.

Table 5

Summary of Effects of Plan 2014 on the Uses and Interests

Uses/Interests	Effects of Plan 2014
Municipal and Industrial Water Use	Overall, no difference in economic effects between the two plans With low water levels: • no net effect on Lake Ontario water treatment plants • no change in frequency and magnitude of effects on St. Lawrence River municipal water suppliers during long droughts With high water levels: • most water supply and treatment plants not vulnerable • septic tanks in some rural New York state areas along the lake's shoreline would continue to be vulnerable to flooding and erosion under any regulation plan
Commercial Navigation	Overall, no difference in economic effects between the two plans No change in frequency of low levels on the St. Lawrence River at Montreal Lower levels several months per century would force some ships (mainly those that operate only on Lake Ontario) to carry lighter loads Slightly fewer draft restrictions due to low levels for ships transiting the route from Lake Ontario to Montreal Allows for safer currents Provides greater predictability/certainty of benefits Provides flexibility to improve operations on an ongoing basis
Hydropower Generation	Increases hydropower energy generation slightly Provides slightly more stable and predictable releases, allowing for more effective scheduling of maintenance
Coastal Development	Provides riparians on the upper and lower river essentially the same level of protection Results in a small reduction of benefits to riparians on Lake Ontario in the form of increased costs of maintaining shoreline protection structures No change in risks of serious damage to shoreline property from water levels outside historical levels
Ecosystems	Helps restores ecosystem diversity and function of coastal wetlands along Lake Ontario due to more natural water level regimes and cycles
Recreational Boating	Recreational Boating

5. The Role of Adaptive Management

Adaptive management is an ongoing planning process that can improve actions through long-term monitoring, modeling and assessment – "a learning by doing" approach that compares actual and predicted results. Through adaptive management, decisions can be reviewed and adjusted as new information and knowledge become available or as conditions change.

The 2012 Protocol amending the Canada-United States *Great Lakes Water Quality Agreement* (Governments of Canada and the United States, 2012) noted the role of adaptive management. The Protocol confirmed adaptive management as a guiding principle and approach for the Parties in working towards the goals of the Agreement. The Parties also committed to using adaptive management "as a framework for organizing science to provide and monitor the effectiveness of science-based management options."

The IJC concludes that adaptive management is a cost-effective way to improve the outcomes of Lake Ontario-St. Lawrence River level regulation. Adaptive management can provide an objective measure of how well a plan is meeting its goals, replacing the current ad hoc approach to regulation plan improvement. It can focus basin research on the issues of particular importance to the interests.

The Lake Ontario-St. Lawrence River Study Board designed the research and modeling approach of that study to facilitate adaptation of new information. For example:

- quantitative analyses were done to identify the issues where advances in knowledge, such as better long-term weather forecasting, would likely improve outcomes from Lake Ontario regulation;
- research was explicitly designed and organized to address the objectives for regulation developed by the Study Board in consultation with the public;
- the evaluation models used by the Study Board were designed to be both comprehensive and easy to use and adapt; and,
- research and models were saved so as to be more easily accessible to future users.

There were concerns raised during the 2013 public hearings on Plan 2014 that adaptive management could lead to changes in the regulation plan that were not considered and reviewed by stakeholders. The IJC appreciates these concerns but confirms that this will not be the case. While adaptive management is expected to more effectively produce suggestions for changes in the regulation plan, the process for implementing a revision to the plan would not change. The IJC intends to maintain its extensive consultations with the federal governments as Parties to the Treaty, with the state of New York and provinces of Ontario and Quebec, and with industry, shoreline stakeholders, and the public at large. Proposed changes to the regulation rules in Plan 2014 would be widely publicized and any significant changes would require a public review process, as is the case now.

Annex E provides more details on the role of adaptive management as an important tool for improving the outcomes of Lake Ontario-St. Lawrence River regulation.

6. Summary

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario is needed.

The IJC finds that the regulation of water levels and flows in the St. Lawrence River in accordance with the 1952 and 1956 Orders of Approval has damaged ecosystems along the shores of Lake Ontario and St. Lawrence River over the last 50 years. Under likely future water level and climate conditions, further damage to coastal ecosystems and shoreline property can be expected.

The IJC acknowledges that the effects of the regulation of water flows and lake levels on ecosystems were not fully understood in the development of the existing Order of Approval and regulation plan. However, the IJC finds that these effects should now be considered.

The IJC must act on this finding, and is therefore seeking the concurrence of the Governments of the United States and Canada that Plan 2014 be implemented as soon as possible.

Plan 2014 would respect the order of precedence of uses specified in the Boundary Waters Treaty of 1909, while protecting interests that may be harmed by regulation.

Compared to the existing regulation plan for Lake Ontario and the St. Lawrence River, Plan 2014 would:

- provide essentially the same level of benefits to domestic water uses;
- provide essentially the same level of benefits to navigation;
- increase, by a small amount, the generation of hydropower at the Moses-Saunders dam and the Hydro-Quebec facilities on the St. Lawrence River;
- provide riparians on the upper and lower river essentially the same level of protection;
- result in a small reduction of benefits to riparians on Lake Ontario, in the form of increased costs of maintaining shoreline protection structures;
- work to restore the natural environment of Lake Ontario and the St. Lawrence River that supports wetlands, birds, amphibians, fish, and small mammals;
- have a mixed effect on recreational boating interests; and,
- provide essentially the same benefits downstream of the dam as does the current regulation regime.

In addition, some of the benefits now enjoyed by domestic water, navigation, hydropower and riparians on the St. Lawrence River are the result of ad hoc, discretionary decisions by the International St. Lawrence River Board of Control. Plan 2014 would make these benefits more assured and predictable, by removing the discretionary aspect of many of these decisions and formally making them part of the Plan's regulation rules.

The implementation of Plan 2014 would produce a substantial improvement in coastal ecosystem health while preserving most of the benefits currently enjoyed by riparians along the shoreline of Lake Ontario. The IJC does not control coastal property management, but will support, when requested, efforts to reduce the vulnerability of coastal structures. In this regard, adaptive management can play a helpful role.

Annex A

Proposed Regulation Conditions Adaptive

International Joint Commission Order of Approval for Lake Ontario – St. Lawrence River

Note: All elevations use the 1985 International Great Lakes Datum and metric system of measurement.

A1. Regulation conditions

A. All interests on either side of the International Boundary which are injured by reason of the construction, maintenance and operation of the works shall be given suitable and adequate protection and indemnity in accordance with the laws in Canada or the Constitution and laws in the United States respectively, and in accordance with the requirements of Article VIII of the Treaty.

B. The works shall be so planned, located, constructed, maintained and operated as not to conflict with or restrain uses of the waters of the St. Lawrence River for purposes given preference over uses of water for power purposes by the Treaty, namely, uses for domestic and sanitary purposes and uses for navigation, including the service of canals for the purpose of navigation, and shall be so planned, located, constructed, maintained and operated as to give effect to the provisions of this Order.

C. The works shall be constructed, maintained and operated in such manner as to safeguard the rights and lawful interests of other engaged or to be engaged in the development of power in the St. Lawrence River below the International Rapids Section.

D. The works shall be so designed, constructed, maintained and operated as to safeguard so far as possible the rights of all interests affected by the levels of the St. Lawrence River upstream from the Iroquois regulatory structure and by the levels of Lake Ontario and the lower Niagara River; and any change in levels resulting from the works which injuriously affects such rights shall be subject to the requirements of paragraph A relating to protection and indemnification.

E. The hydro-electric plants approved by this Order shall not be subjected to operating rules and procedures more rigorous than are necessary to comply with the provisions of the foregoing paragraphs B, C and D.

F. Before Ontario Power Generation or any successor make any changes to any part of the works, it shall submit to the Government of Canada, and before the New York Power Authority makes any changes to any part of the works, it shall submit to the Government of the United States, for approval in writing, detailed plans and specifications of that part of the works located in their respective countries and details of the program of construction thereof or such details of such plans and specifications or programs of construction relating thereto as the respective governments may require. Following the approval of any plan, specification or program, if Ontario Power Generation or the New York Power Authority wishes to make any change therein, it shall first submit the changed plan, specification or program for approval in a like manner

G. A Board to be known as the International Lake Ontario-St. Lawrence River Board (hereinafter referred to as the "Board") consisting of an equal number of members from Canada and the United States, shall be established by the Commission. The Board shall include but is not limited to at least one member each nominated by the State of New York, the Province of Quebec, the Province of Ontario, and the United States and Canadian federal governments. The duties of the Board shall be to execute the instructions of the Commission as issued from time to time with respect to this Order. The duties of the Board shall be to ensure that the provisions of the Order relating to water levels and the regulation of the discharge of water from Lake Ontario and the flow of water through the International Rapids Section as herein set out are complied with, and Ontario Power Generation and the New York Power Authority shall duly observe any direction

given them by the Board for the purpose of ensuring such compliance. The Board shall report to the Commission at such times as the Commission may determine. In the event of any disagreement among the members of the Board which they are unable to resolve, the matter shall be referred by them to the Commission. The Board may, at any time, make representations to the Commission in regard to any matter affecting or arising out of the terms of the Order with respect to water levels and the regulation of discharges and flows.

H. The discharge of water from Lake Ontario and the flow of water through the International Rapids Section shall be regulated to meet the requirements of conditions B, C, and D hereof and shall be regulated within a range of levels as specified in the below listed criteria, as nearly as may be, and following the Commission's directive(s). The project works shall be operated in such a manner as to provide no less protection for navigation and riparian interests downstream than would have occurred under pre-project conditions and with the 1900 to 2008 adjusted supplies and conditions specified in the basis of comparison. The Commission will indicate in an appropriate fashion, as the occasion may require, the inter-relationship of the criteria, the range of elevations and the other requirements.

H1. The regulated outflow from Lake Ontario shall be such as not to increase the frequency of low levels or reduce the minimum level of Montreal Harbour below those listed in the table below which would have occurred with the 1900 to 2008 adjusted supplies and conditions (hereinafter called the "supplies of the past as adjusted") that are defined in the document "Basis of Comparison Conditions for Lake Ontario – St. Lawrence River Regulation".

Montreal Jetty #1 Level IGLD		
meters	**feet**	**Number of quarter-months in 1900-2008 below level**
5.55	18.21	811
5.50	18.21	679
5.40	17.72	366
5.30	17.39	153
5.20	17.06	83
5.10	16.73	45
5.00	16.40	15
4.90	16.08	1
4.80	15.75	1
4.70	15.42	minimum

H2. The regulated outflow from Lake Ontario shall be such as not to increase the frequency of low levels or reduce the minimum level of Lake St. Louis below those listed in the table below which would have occurred with the supplies of the past as adjusted.

Lake St. Louis at Pointe Claire Level IGLD		
meters	**feet**	**Number of quarter-months in 1900-2008 below level**
20.70	67.01	735
20.60	67.58	161
20.50	67.26	87
20.40	66.93	21
20.30	66.6	2
20.20	66.27	1
20.10	65.94	0
20.10	65.94	minimum

H3. The regulated outflow from Lake Ontario shall be such that the frequencies of occurrence of high water levels on Lake St. Louis as measured at the Pointe Claire gauge are not greater than those listed below with supplies of the past as adjusted.

Lake St. Louis at Pointe Claire Level IGLD		
Meters	**Feet**	**Number of quarter-months in 1900-2008 above level**
22.50	73.82	0
22.40	73.49	9
22.33	73.26	15
22.20	72.83	51
22.10	72.51	97
22.00	72.18	221
22.48	73.75	maximum

H4. The regulated monthly mean level of Lake Ontario shall not exceed the following elevations (IGLD85) in the corresponding months with the supplies of the past as adjusted.

Lake Ontario Level IGLD		
month	**(m)**	**(ft)**
January	75.26	246.92
February	75.37	247.28
March	75.33	247.15
April	75.60	248.03
May	75.73	248.46
June	75.69	248.33
July	75.63	248.13
August	75.49	247.67
September	75.24	246.85
October	75.25	246.88
November	75.18	246.65
December	75.23	246.82

H5. The regulated winter outflows from Lake Ontario shall be maintained so that the difficulties of river ice management for winter power operation are minimized in the International Rapids Section of the St. Lawrence River and the outlet of Lake St. Francis.

H6. Under regulation, the frequency of occurrences of monthly mean elevations of approximately 75.07 meters (m), 246.3 feet (ft) IGLD 1985 and higher on Lake Ontario shall not be greater than would have occurred with supplies of the past as adjusted and with pre-project conditions.

H7. The regulated monthly mean water levels of Lake Ontario, with supplies of the past as adjusted shall not be less than the following elevations (IGLD 1985) in the corresponding months.

Lake Ontario Level IGLD		
month	**(m)**	**(ft)**
January	73.56	241.34
February	73.62	241.54
March	73.78	242.06
April	73.97	242.68
May	74.22	243.50
June	74.27	243.67
July	74.26	243.64
August	74.15	243.27
September	74.04	242.91
October	73.83	242.22
November	73.67	241.70
December	73.57	241.37

H8. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to maintain adequate levels for navigation in the Montreal to Lake Ontario section of the St. Lawrence River.

H9. Consistent with other requirements, the maximum regulated outflow from Lake Ontario shall be maintained as low as possible to maintain safe velocities for Seaway navigation and to minimize spill at the hydropower facilities in the St. Lawrence River.

H10. Consistent with other requirements, the minimum regulated monthly outflow from Lake Ontario shall be such as to secure the maximum dependable flow for power.

H11. Consistent with other requirements, the levels of Lake Ontario shall be regulated for the benefit of property owners on the shores of Lake Ontario in the United States and Canada so as to reduce extremes of stage which have occurred under pre-project conditions and supplies of the past as adjusted on Lake Ontario.

H12. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to enhance biodiversity and the resiliency of wetlands on Lake Ontario and on the St. Lawrence River.

H13. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to benefit recreational boating on Lake Ontario and on the St. Lawrence River.

H14. In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event that Lake Ontario levels reach or fall below extremely low levels the works in the International Rapids Section shall be operated to provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream. The high and low water levels at which this provision applies will be established by a Commission directive to the Board.

The Commission shall approve a plan of regulation, and associated operational guides and issue directives for the discharge of water from Lake Ontario and its flow through the International Rapids Section of the St Lawrence River that satisfy the criteria and conditions of this Order with criterion "H14" governing principles of relief, should extreme levels be experienced. The flow of water through the International Rapids Section of the St Lawrence River in any period shall equal the discharge of water from Lake Ontario as determined for that period.

The Commission's directives to the Board shall make provision for peaking and ponding operations and for deviations from the plan of regulation to address such matters as winter operations, emergencies and other special short-term situations.

Subject to the requirements of conditions B, C and D hereof, and of the range of levels, and criteria, above written, the Board, after obtaining the approval of the Commission, may temporarily modify or change the restrictions as to the discharge of water from Lake Ontario and the flow of water through the International Rapids Section for the purpose of determining what modifications or changes in the plan of regulation may be advisable. The Board shall report to the Commission the results of such experiments, together with its recommendations as to any changes or modifications in the plan of regulation. When the plan of regulation has been improved so as best to meet the requirements of all interests, within the range of levels and criteria above defined, the Commission will recommend to the two governments that it be implemented and, if the two governments thereafter agrees, such plan of regulation shall be given effect as if contained in this Order. Should there be a change to the approved regulation plan, then the Commission will consult with governments as appropriate.

I. The works shall be operated so that the forebay water level at the power houses does not exceed a maximum instantaneous elevation of 74.48 m (244.36 feet).

J. Ontario Power Generation and the New York Power Authority, and any successor entities, shall maintain and supply for the information of the Board accurate records relating to water levels and the discharge of water through the works and the regulation of the flow of water through the International Rapids Section as the Board may determine to be suitable and necessary, and shall install and maintain such gauges, carry out such measurements, and perform such other services as the Board may deem necessary for these purposes.

K. The installation, maintenance, operation and removal of the ice booms in the St. Lawrence River by Ontario Power Generation and the New York Power Authority, and any successor entities, are subject t o the following:

1. Any significant modifications in the design or location of the booms shall require the approval of the Commission;
2. The placement and removal of ice booms shall be timed so as not to interfere with the requirements of navigation; and
3. The St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation, and any successor entities, shall be kept informed of all such operations.

L. The Board shall report to the Commission as of 31 December each year on the effect, if any, of the operation of the down-stream hydro-electric power plants and related structures on the tail-water elevations at the hydro-electric power plants approved by this Order.

No later than 15 years after the effective date of this Order,and periodically thereafter, the Commission will conduct a review of the results of regulation under this Order. This review will be to assess the extent to which the results predicted by the research and models used to develop any approved regulation plan occurred as expected, consistent with the adaptive management plan. The review will be based upon the information available at the time of the review and may provide the basis for possible changes to the regulation of water levels and flows.

A2. Definitions:

1. St. Lawrence River – the section of the St. Lawrence River that is affected by flow regulation, which stretches from Lake Ontario to the outlet of Lake St. Pierre.
2. International Rapids Section - the section of the St. Lawrence River that prior to the project was characterized by series of rapids from Ogdensburg, NY- Prescott, ON to Cornwall, ON – Massena, NY.
3. Pre-project conditions – the hydraulic channel characteristics that existed in the Galops Rapids Section of the St. Lawrence River as of March 1955 that formed the control section for Lake Ontario outflows prior to the project. This is defined by a stage-discharge capacity relationship for this condition that also accounts for the effects of glacial isostatic adjustment.

Annex B

Lake Ontario – St. Lawrence Plan 2014

Lake Ontario - St. Lawrence Plan 2014 is the combination of the mechanistic release rules labeled "Bv7" together with discretionary decisions made by the International Lake Ontario - St. Lawrence River Board to deviate from the flows specified by the release rules Bv7 according to the Directive on Operational Adjustments, Deviations and Extreme Conditions. In that regard, Bv7 is analogous to Plan 1958-D. Each is a set of functions that can be programmed to produce a release based on established categories of input conditions such as current water levels. The following is a technical description of the Bv7 algorithm or release rules.

B1. Technical Description of Plan Bv7 Release Rules

B1.1 Objectives

The objective of the Bv7 release rules is to return the Lake Ontario-St. Lawrence River System to a more natural hydrological regime, while limiting impacts to other interests. Bv7 rules build on the B+ rules developed during the International Lake Ontario - St. Lawrence River Study. Bv7 differs from B+ in that it includes additional rules to maintain navigation and flood reduction benefits on the lower St. Lawrence River (Lake St. Louis to Lake St. Pierre) and adjustments to the B+ rules to balance Lake Ontario and lower river levels. Bv7 maintains most of the benefits of the current regulation regime because the range of levels and flows that Bv7 produces are closer to the current regulation regime than to unregulated conditions.

B1.2 Goals

The goals of the rules are to:

- Maintain more natural seasonal level and flow hydrographs on the lake and river;
- Provide stable lak e releases;
- Maintain benefits to coastal interests as much as possible while enhancing environmental conditions;
- Maintain benefits to recreational boating as much as possible while enhancing environmental conditions;
- Obtain inter-annual highs and lows required for healthy vegetation habitats;
- Enhance diversity, productivity, and sustainability of species sensitive to water level fluctuations;
- Provide flood and low water protection to the lower St. Lawrence River comparable to Plan 1958-D with Deviations; and,
- Maintain benefits as much as possible for municipal water intakes, commercial navigation and hydropower interests while taking other interests into account.

Bv7 uses short-term forecasts and a longer-term index of water supplies in conjunction with the pre-project stage-discharge relationship to determine lake releases. Rules are included to reduce the risk of flooding on the lake and river. Flow limits are applied to prevent river flows from falling too low, facilitate stable river ice formation, provide acceptable navigation conditions, provide safe operating conditions for control structures, and ensure controlled week-to-week changes in flows.

B2. Approach

B2.1 Rule Curves

Lake releases are primarily a function of a sliding rule curve based on the pre-project stage-discharge relationship adjusted to recent long-term supply conditions. The open-water pre-project stage-discharge relationship, in units of cubic meters per second (m^3/s) is:

$$\text{Pre-project release} = 555.823(\text{Lake Ontario level} - 0.035\text{-}69.474)^{1.5}$$

In the equation above, the 0.035 meter term adjusts the Lake Ontario level (referenced to IGLD 1985)

for differential crustal movement fixed to the year 2010[26]. The pre-project relationship is that from Caldwell and Fay (2002), but here the ice retardation effect is not considered.

The flow computed with this equation is then adjusted depending on the recent supply conditions. As water supplies trend above normal, lake releases are increased. As supplies trend below normal, lake releases are decreased.

For supplies above normal (the index is greater than or equal to 7,011 m^3/s), the lake release is determined by:

Table B1.
Bv7 Rule Curve Parameter Values based on Historical Supplies

Climate	A_NTS_{max}	A_NTS_{avg}	A_NTS_{min}
Historical (1900-2000)	8552 m^3/s	7011 m^3/s	5717 m^3/s

The rule curve parameters should be updated periodically to account for climate change.

$$outflow_t = preproject\ release + \left[\frac{F_NTS - A_NTS_{avg}}{A_NTS_{max} - A_NTS_{avg}}\right]^{P_1} x(C_1)$$

For supplies below normal (the index is less than 7,011 m^3/s), the lake release is determined by:

$$outflow_t = preproject\ release - \left[\frac{A_NTS_{avg} - F_NTS}{A_NTS_{avg} - A_NTS_{min}}\right]^{P_2} x(C_2)$$

In the equation above, ***F_NTS*** is a supply index based on the net total supply for the past 52 weeks (48 quarter-months), and ***A_NTS*** represents the maximum, minimum and average statistics of the annual net total supply series. The constants C_1 and C_2 determine the rate of flow adjustment to the pre-project release. C_1 is further dependent on the long-term trend in supplies. If the categorical long-term trend indicator is 1 (demonstrating above normal supplies; that is, when the current supply value exceeds 7,237 m^3/s) and the confidence indicator is 3 (indicating high confidence in extreme supplies; that is, when the current supply value exceeds 7,426 m3/s), then C_1 is set to 2,600 m^3/s, otherwise it is equal to 2,200 m^3/s. The value of C_2 is 600 m^3/s. The exponents P1 and P2 serve to accelerate or decelerate the rate of flow adjustment. The values of P_1 and P_2 are 0.9 and 1.0, respectively.

The flow is further reduced by 200 m3/s if the 52 week (48 quarter-month) running lake level mean is less than or equal to 74.6 m IGLD 1985.

Variability of releases from one week (or quarter-month) to the next is smoothed by taking the average of short-term forecasts[27] of releases four weeks (or quarter-months) into the future:

$$outflow = \frac{\sum_{t=1}^{t=4} outflow_t}{4}$$

This averaging also has the impact of accelerating releases during periods of rising lake levels (typically spring), and decelerating releases during periods of falling lake levels (typically fall). Sensitivity analysis indicated that forecasts four quarter-months into the future were optimal.

Bv7 also has a rule to reduce the risk of Lake Ontario and St. Lawrence River flooding in the following spring and summer. If the level of Lake Ontario is relatively high, then it adds to the rule curve flow to reduce the level of Lake Ontario in the fall. It lowers otherwise high Lake Ontario by the onset of winter, thus preparing for spring and making temporary lake storage available for reduced flows during the Ottawa River freshet. It also provides

[26] The year 2010 was selected by the ILOSLRS Plan Formulation and Evaluation Group to compare what pre-project conditions would be near the completion of the Study. The year should be fixed as otherwise there would be a gradual increase in the lake level due to the continual adjustment for glacial isostatic uplift of the lake's outlet.

[27] See Lee (2004) for the derivation of the forecast algorithms

some benefit (relative to the Natural Plan) to the lower river muskrats by reducing winter den flooding. The rule strives to lower Lake Ontario to 74.8 m by January 1 whenever Lake Ontario level is above 74.8 m at the beginning of September. The rule curve flow is linearly increased by the amount needed to eliminate the storage on the lake above 74.8 m over the remaining time before January 1. A check is made to ensure that the adjusted flow for the first week of September does not exceed that of the last week in August to prevent falling levels affecting Lake St. Lawrence recreational boaters through the Labor Day weekend. The adjusted flow is constrained by the L Limits.

B2.2 Flow Limits

Several flow limits, adapted from previous plan development, are used in Bv7. If the rule curve flow (described above) falls outside of these limits, then the lowest of the maxima, or the minimum limit, as applicable, constrains the rule curve flow.

- J Limit – maximum change in flow from one week (or quarter-month) to the next unless another limit takes precedence. Flows are permitted to increase or decrease by up to 700 m^3/s. If the lake is above 75.2 m, and ice is not forming, then the flow may increase by up to 1,420 m^3/s from one week (or quarter-month) to the next.
- M Limit – minimum limit flows t o balance low levels of Lake Ontario and Lake St. Louis primarily for Seaway navigation interests. This limit uses a one week (or quarter-month) forecast of Ottawa River and local tributary flows to estimate the inflows to Lake St. Louis, other than those from Lake Ontario. In actual operation, the flow will be adjusted from day-to-day to maintain the level of Lake St. Louis above the applicable level determined by the Lake Ontario stage.
- I Limit – maximum flows for ice formation and stability.[28] During ice cover formation, either downstream on the Beauharnois Canal or on the critical portions of the International Section, the maximum flow is 6,230 m^3/s. Once a complete ice cover has formed on the key sections of the river, the winter flow constraint prevents the river level at Long Sault from falling lower than 71.8 m. (Note the J limit also applies.) This limit may apply in the non-Seaway season whether ice is present or not. This flow limit is calculated using the stage-fall discharge equation for Kingston-Long Sault, which includes an ice roughness parameter that must be forecast for the coming period. This limit prevents low levels that might impact municipal water intakes on Lake St. Lawrence, and also acts to limit the shear stress on the ice cover and maintain stability of the ice cover. The I limit also limits the maximum flow with an ice cover present in the Beauharnois and/or international channels to no more than 9,430 m^3/s.
- L Limit – maximum flows to maintain adequate levels and safe velocities for navigation in the International Section of the river (navigation season) and the overall maximum flow limit (non-navigation season). Maximum releases are limited to 10,700 m^3/s if the Lake Ontario level should rise above 76.0 m during the navigation season and 11,500 m^3/s during the non-navigation season.

[28] Managing flows during ice formation on the Beauharnois Canal and upstream is paramount, since a restriction caused by a build-up of rough ice in the Beauharnois Canal or upper river can constrain outflows the remainder of the winter which may, in some cases, exacerbate high Lake Ontario levels. During ice formation, operation of the Iroquois Dam must be done in consideration of ice conditions on Lake St. Lawrence.

Table B2.
M Limits as used in Plan Bv7.

Lake Ontario level (m, IGLD 1985)	Total Flow from Lake St. Louis (m^3/s)	Approximate Corresponding Lake St. Louis level at Pointe Claire (m IGLD 1985)
> 74.2	6,800	20.64
> 74.1 and ≤ 74.2	6,500	20.54
> 74.0 and ≤ 74.1	6,200	20.43
> 73.6 and ≤ 74.0	6,100	20.39
≤ 73.6	Minimum of 5,770 or pre-project flow	20.27 or less

Table B3.
L Limits as used in Plan Bv7.

Lake Ontario level (m, IGLD 1985)	L Limit Flow (m^3/s)
For Seaway navigation season (i.e. quarter-months 13-47):	
≤ 74.22	5,950
> 74.22 and ≤ 74.34	5,950+1,333 (Lake Ontario level – 74.22)
> 74.34 and ≤ 74.54	6,111+9,100 (Lake Ontario level – 74.34)
> 74.54 and ≤ 74.70	7,930+2,625 (Lake Ontario level – 74.54)
> 74.70 and ≤ 75.13	8,350+1,000 (Lake Ontario level – 74.70)
> 75.13 and ≤ 75.44	8,780+3,645 (Lake Ontario level – 75.13)
> 75.44 and ≤ 75.70	9,910
> 75.70 and ≤ 76.00	10,200
> 76.00	10,700
For outside Seaway season (i.e. quarter-months 48-12) all levels	
Any	11,500

Table B4.
Lake St. Louis (Pointe Claire) levels corresponding to Lake Ontario levels for limiting lower St. Lawrence River flooding damages (F limits).

Lake Ontario level (m, IGLD 1985)	Pte. Claire level (m, IGLD 1985)
< 75.3	22.10
≥ 75.3 and < 75.37	22.20
≥ 75.37 and < 75.5	22.33
≥ 75.5 and < 75.6	22.40
≥ 75.6	22.48

An additional rule limits the maximum flow in the Seaway season to prevent the weekly mean level of Lake St. Lawrence at Long Sault Dam from falling below 72.60 m. To deal with very low levels, if the Lake Ontario level is below chart datum (74.20 m) then the level of Lake St. Lawrence at Long Sault Dam in this rule is allowed to be equally below the 72.60 m level.

A final check ensures that the L Limit does not exceed the actual channel hydraulic capacity (in m^3/s) defined as (Lee *et al.*, 1994):

$$\text{channel capacity} = 747.2(\text{Lake Ontario level} - 69.10)^{1.47}$$

- F limit – the maximum flow to limit flooding on Lake St. Louis and near Montreal in consideration of Lake Ontario level. It is a multi-tier rule that attempts to balance upstream and downstream flooding damages by keeping the level of Lake St. Louis below a given stage for a corresponding Lake Ontario level as follows:

This limit uses a one week (or quarter-month) forecast of the Ottawa River and local tributary inflows and the following relationship between Lake St. Louis outflows and levels at Pointe Claire:

$$Pte.\ Claire\ level = 16.57 + \left[\left(R_{Pt.Claire} \times Q_{L.St.Louis} / 604.0\right)^{0.58}\right]$$

In this equation, ***R*** is the roughness factor and ***Q*** (in m^3/s) is the total flow from Lake St. Louis. In operation the flow will be adjusted from day to day to maintain the level of Lake St. Louis below the applicable level determined by the Lake Ontario stage.

B3. Application

Bv7 uses imperfect forecasts of Lake Ontario total supplies, Ottawa River and local tributary flows, ice formation and ice roughness. The water supply forecasts are based on time-series analysis of the historical data as described in Lee (2004). Overall, the statistical forecasts were found to have similar error to those in use operationally. Because the operational methods generally rely upon hydrometeorological data not available for either the historical time series or the stochastic time series, actual forecasts could not be used. However, it was envisioned that operationally, the best available real-time forecasts would be used. In addition, because week-ahead forecasts will generally be imperfect, it is expected that in actual operations the flows will be adjusted within the week[29] taking into account the actual ice and downstream inflow conditions to achieve the intent of the Bv7 rules and limits.

B3.1 Procedure

1. For each of the next four weeks (quarter-months), calculate the Lake Ontario annual net total supply index, forecast the weekly (quarter-monthly) Lake Erie inflow and Lake Ontario net basin supply, Ottawa River and local tributary flows to Lake St. Louis, and ice roughness.
2. For each of the next four weeks (quarter-months), sequentially route the supplies and determine forecasts of lake outflows using the sliding rule curve.
3. Average the next four weeks (quarter-months) forecast releases to determine the next period's release.
4. If the current time period is within September through December inclusive, and Lake Ontario was at or above 74.8 m on September 1 (end of quarter-month 32), then increase the basic rule curve by the amount needed to achieve 74.8 m by January 1, not exceeding the flow in the week before Labor Day (quarter-month 32) in the flow in the Labor Day week (quarter-month 33).
5. Apply the M, L, I, J and F limits. If the plan flow is outside of the maximum of the minimum limits and the minimum of the maximum limits, the appropriate limit becomes the plan flow.

B4. Simulation of Bv7 with 1900-2008 Hydrology and Ice Conditions

The tables on the following pages are based only on the Bv7 release rules, not the deviations in Plan 2014. The tables show how often under Bv7 water levels will be above a range of levels for Lake Ontario, Lake St. Lawrence, Lake Louis and Montreal Harbour, and how often releases from the Moses-Saunders dam will be above certain flows. The tables are based on a simulation of Bv7 on a quarter-monthly time step and with the 1900-2008 dataset of supplies and inflows, ice conditions, channel roughness factors,

[29] See **Annex C** for more on operational adjustments

and related conditions. This 109-year simulation includes 436 quarter-months for each calendar month, 5,232 quarter-months in all. For example, in Table B-5, Lake Ontario never rises above 75.80 meters, but rises above 75.70 meters six times in May and three times in June.

The tables are:

- Table B 5 Bv7 Historical Lake Ontario Levels
- Table B 6 Bv7 Historical Lake Ontario Outflows
- Table B 7 Bv7 Historical Lake St Lawrence at Long Sault Dam Levels
- Table B 8 Bv7 Historical Lake St. Louis Levels
- Table B 9 Bv7 Historical Montreal Harbour at Jetty 1 Levels

Table B5.

Bv7 Historical Lake Ontario Levels

Lake Ontario Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 supplies simulation													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**All Months**
Level (m IGLD 1985)													
75.8	0	0	0	0	0	0	0	0	0	0	0	0	0
75.7	0	0	0	0	6	3	0	0	0	0	0	0	9
75.6	0	0	0	6	10	12	6	0	0	0	0	0	34
75.5	0	0	0	12	23	27	13	2	0	0	0	0	77
75.4	0	0	1	24	43	52	30	9	0	0	0	0	159
75.3	2	6	3	39	90	91	61	18	1	0	0	0	311
75.2	12	15	19	70	143	146	107	46	6	4	1	4	573
75.1	17	28	33	115	183	204	176	99	26	4	4	5	894
75.0	32	50	68	166	241	269	245	179	69	11	4	7	1341
74.9	63	79	115	216	296	322	312	251	136	34	17	23	1864
74.8	121	138	166	274	340	357	357	312	230	116	66	76	2553
74.7	163	185	226	339	381	397	389	368	306	230	143	135	3262
74.6	209	223	266	371	410	420	412	402	361	310	257	215	3856
74.5	306	295	335	397	418	420	419	410	394	351	321	312	4378
74.4	360	366	379	410	426	428	426	417	410	392	363	364	4741
74.3	390	390	396	418	428	429	432	421	413	408	391	388	4904
74.2	407	405	401	425	434	436	435	427	418	412	411	408	5019
74.1	415	409	411	428	436	436	436	436	423	418	420	414	5082
74.0	420	419	420	434	436	436	436	436	434	424	421	422	5138
73.9	424	424	427	435	436	436	436	436	436	429	424	424	5167
73.8	424	425	432	436	436	436	436	436	436	434	428	424	5183
73.7	431	432	436	436	436	436	436	436	436	436	433	430	5214
73.6	432	435	436	436	436	436	436	436	436	436	436	432	5223
73.5	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	75.31	75.39	75.46	75.7	75.75	75.72	75.65	75.59	75.36	75.26	75.22	75.25	75.75
Minimum Level	73.55	73.56	73.72	73.84	74.16	74.24	74.2	74.12	73.96	73.76	73.61	73.55	73.55

Table B6.

Bv7 Historical Lake Ontario Outflows

Lake Ontario Quarter-monthly mean Outflows Number of Occurences Above Flow Shown ... 1900-2008 supplies simulation													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**All Months**
Flow (m^3/s)													
10400	0	0	0	0	0	0	0	0	0	0	0	0	0
10200	0	0	0	0	0	0	0	0	0	0	0	0	0
10000	0	0	0	0	4	1	0	0	0	0	0	0	5
9800	2	0	2	5	14	15	5	1	0	0	0	0	44
9600	2	0	2	8	18	21	10	1	0	0	0	0	62
9400	2	0	6	9	22	24	16	3	0	0	0	0	82
9200	2	1	10	9	27	26	21	6	0	2	0	0	104
9000	2	5	15	12	37	37	25	10	1	4	1	3	152
8800	2	5	19	18	40	53	33	15	8	4	2	4	203
8600	2	7	24	31	61	70	61	32	24	8	4	7	331
8400	2	10	34	42	75	93	80	52	45	20	20	27	500
8200	5	24	48	66	104	115	95	65	59	30	29	29	669
8000	11	36	61	92	123	137	114	86	79	49	46	42	876
7800	13	48	76	114	147	165	135	108	110	69	59	52	1096
7600	26	63	97	130	175	192	172	132	139	86	73	67	1352
7400	33	76	121	168	201	220	207	165	164	114	91	84	1644
7200	38	97	149	212	244	259	250	216	199	136	115	100	2015
7000	50	128	178	246	292	299	290	260	238	178	147	114	2420
6800	99	174	211	284	326	340	322	297	262	212	179	146	2852
6600	123	224	256	325	356	365	360	333	286	251	225	177	3281
6400	151	265	305	358	390	387	376	374	347	312	279	216	3760
6200	322	338	349	386	401	407	414	415	403	376	348	331	4490
6000	373	375	394	399	408	419	428	432	420	405	382	381	4816
5800	398	401	409	404	421	429	434	434	427	412	400	403	4972
5600	416	416	415	412	425	432	436	436	434	427	414	413	5076
5400	424	422	421	421	431	435	436	436	435	431	423	425	5140
5200	429	429	427	429	433	436	436	436	436	432	430	434	5187
5000	434	435	431	431	435	436	436	436	436	432	435	435	5212
4800	435	436	433	434	436	436	436	436	436	435	436	435	5224
4600	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Flow	9910	9290	9910	9910	10200	10200	9910	9880	9150	9220	9060	9180	10200
Minimum Flow	4620	4910	4650	4780	4870	5250	5640	5760	5290	4800	4980	4780	4620

Table B7.

Bv7 Historical Lake St. Lawrence at Long Sault Dam Levels

Lake St. Lawrence at Long Sault Dam Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 supplies simulation													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**All Months**
Level (m IGLD 1985)													
74.4	0	0	0	0	0	0	0	0	0	0	0	0	0
74.3	4	0	0	0	0	0	0	0	0	0	0	0	4
74.2	6	0	0	0	0	0	0	0	0	0	0	1	7
74.1	8	0	0	0	0	0	0	0	0	0	0	2	10
74.0	13	1	0	0	0	0	0	0	0	0	0	5	19
73.9	21	2	0	3	1	4	6	1	0	0	0	10	48
73.8	30	6	6	67	139	130	95	52	7	0	2	19	553
73.7	44	10	18	138	208	209	190	141	28	13	15	33	1047
73.6	60	11	46	212	277	280	255	210	94	82	57	63	1647
73.5	90	14	76	278	336	314	287	259	177	155	138	134	2258
73.4	114	20	110	323	373	353	318	300	223	211	203	195	2743
73.3	136	29	132	369	397	386	346	331	270	267	257	242	3162
73.2	156	41	156	392	418	409	382	351	314	301	292	285	3497
73.1	186	65	188	414	428	422	409	374	341	336	328	323	3814
73.0	208	88	216	431	431	432	423	399	368	362	359	350	4067
72.9	221	114	242	433	432	434	429	412	393	388	381	374	4253
72.8	241	152	264	434	433	436	433	427	415	404	400	391	4430
72.7	261	180	292	434	435	436	435	433	426	416	417	410	4575
72.6	275	212	312	436	436	436	436	436	436	435	428	425	4703
72.5	299	228	331	436	436	436	436	436	436	436	433	432	4775
72.4	320	257	349	436	436	436	436	436	436	436	435	434	4847
72.3	339	276	359	436	436	436	436	436	436	436	436	434	4896
72.2	351	291	373	436	436	436	436	436	436	436	436	436	4939
72.1	359	307	382	436	436	436	436	436	436	436	436	436	4972
72.0	370	323	392	436	436	436	436	436	436	436	436	436	5009
71.9	376	336	402	436	436	436	436	436	436	436	436	436	5038
71.8	401	380	424	436	436	436	436	436	436	436	436	436	5129
71.7	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	74.35	74.09	73.88	73.92	73.92	73.93	73.93	73.91	73.86	73.74	73.81	74.29	74.35
Minimum Level	71.74	71.71	71.72	72.66	72.66	72.84	72.69	72.66	72.63	72.6	72.39	72.22	71.71

Table B8.

Bv7 Historical Lake St. Louis Levels

Lake St. Louis at Pointe Claire Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 simulation													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**All Months**
Level (m IGLD 1985)													
22.5	0	0	0	0	0	0	0	0	0	0	0	0	0
22.4	0	0	0	3	4	2	0	0	0	0	0	0	9
22.3	0	0	0	10	17	6	0	0	0	0	0	0	33
22.2	0	0	0	14	26	11	0	0	0	0	0	0	51
22.1	1	4	5	27	45	15	0	0	0	0	0	0	97
22.0	3	8	15	80	85	26	2	0	0	0	0	2	221
21.9	7	14	25	107	101	45	7	0	0	1	4	5	316
21.8	13	20	39	131	123	58	19	4	0	1	6	10	424
21.7	23	35	57	162	155	77	30	8	1	3	10	18	579
21.6	43	63	72	200	196	101	44	17	8	7	22	28	801
21.5	68	96	96	237	240	145	79	30	22	23	34	40	1110
21.4	93	128	134	276	279	188	114	63	51	41	52	63	1482
21.3	133	157	156	311	318	229	152	91	77	73	91	86	1874
21.2	175	193	179	337	347	268	187	128	110	90	124	106	2244
21.1	234	240	222	366	375	308	241	167	148	125	157	144	2727
21.0	279	280	262	394	397	344	288	226	190	165	183	183	3191
20.9	347	337	298	405	409	380	326	271	241	203	211	223	3651
20.8	385	369	335	413	419	404	366	318	277	245	249	263	4043
20.7	405	406	384	421	426	415	393	369	329	301	295	321	4465
20.6	423	419	412	428	436	436	436	430	418	412	408	402	5060
20.5	431	427	423	432	436	436	436	436	426	421	419	417	5140
20.4	435	433	436	436	436	436	436	436	436	430	421	427	5198
20.3	436	434	436	436	436	436	436	436	436	436	436	435	5229
20.2	436	436	436	436	436	436	436	436	436	436	436	435	5231
20.1	436	436	436	436	436	436	436	436	436	436	436	435	5231
20.0	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	22.16	22.17	22.2	22.48	22.48	22.48	22.04	21.86	21.74	21.94	21.98	22.08	22.48
Minimum Level	20.35	20.21	20.41	20.41	20.63	20.61	20.62	20.55	20.42	20.38	20.38	20.1	20.1

Table B9.

Bv7 Historical Montreal Harbour at Jetty 1 Levels

Montreal Harbour at Jetty #1 Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 supplies simulation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Months
Level (m IGLD 1985)													
9.2	0	0	0	0	0	0	0	0	0	0	0	0	0
9.0	1	1	0	0	0	0	0	0	0	0	0	0	2
8.8	1	1	0	2	1	1	0	0	0	0	0	0	6
8.6	1	3	0	3	9	2	0	0	0	0	0	0	18
8.4	1	5	0	7	22	5	0	0	0	0	0	0	40
8.2	1	5	3	18	40	7	0	0	0	0	0	0	74
8.0	2	5	5	53	66	12	0	0	0	0	0	0	143
7.8	2	7	11	84	85	21	0	0	0	0	0	0	210
7.6	3	15	23	115	103	27	3	0	0	0	0	2	291
7.4	5	22	32	157	132	38	6	0	0	0	6	5	403
7.2	14	32	63	199	181	60	11	3	0	1	7	8	579
7.0	32	51	88	240	224	85	34	13	3	6	15	23	814
6.8	60	86	119	286	273	124	58	23	8	21	27	37	1122
6.6	96	144	152	321	328	185	106	43	37	43	67	65	1587
6.4	139	182	189	350	356	239	155	88	70	75	112	94	2049
6.2	183	224	239	382	375	291	201	144	114	107	144	130	2534
6.0	262	295	287	399	402	343	271	198	174	148	179	185	3143
5.9	300	327	306	410	411	362	296	237	205	176	195	206	3431
5.8	336	352	333	415	419	381	322	272	234	196	214	225	3699
5.7	368	373	361	420	423	396	352	305	267	235	236	252	3988
5.6	384	397	381	427	431	410	380	336	289	267	272	286	4260
5.5	404	414	402	428	434	422	393	373	321	309	316	316	4532
5.4	413	420	417	430	436	426	420	411	392	365	355	359	4844
5.3	427	430	428	432	436	433	434	430	416	406	396	397	5065
5.2	432	433	434	435	436	436	436	435	426	421	412	410	5146
5.1	436	434	435	435	436	436	436	436	431	423	420	426	5184
5.0	436	436	436	436	436	436	436	436	436	430	431	431	5216
4.9	436	436	436	436	436	436	436	436	436	436	436	434	5230
4.8	436	436	436	436	436	436	436	436	436	436	436	435	5231
4.7	436	436	436	436	436	436	436	436	436	436	436	435	5231
4.6	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	9.08	9.17	8.34	8.96	8.94	8.9	7.73	7.26	7.19	7.4	7.5	7.69	9.17
Minimum Level	5.11	5.03	5.03	5.06	5.43	5.27	5.21	5.2	5.01	4.94	4.91	4.7	4.7

B5. References

Caldwell, R. and Fay, D.(2002). Lake Ontario Pre-project Outlet Hydraulic Relationship Final Report. Hydrology and Hydraulics Technical Work Group, International Joint Commission Lake Ontario-St. Lawrence River Study.

Lee, D. (2004). Deterministic Forecasts for Lake Ontario Plan Formulation. Plan Formulation and Evaluation Group, International Joint Commission Lake Ontario-St. Lawrence River Study.

Lee, D.H., Quinn, F.H., Sparks, D. and Rassam, J.C. (1994). Simulation of Maximum Lake Ontario Outflows. Journal of Great Lakes Research 20(3) 569-582.

Annex C

Directive to the International Lake Ontario - St. Lawrence River Board on Operational Adjustments, Deviations and Extreme Conditions

This directive was created in conjunction with the proposed revised Order of Approval. It provides specific protocols and guidance to the International Lake Ontario-St. Lawrence River Board for implementing a regulation plan approved by the Commission, particularly as they relate to making operational adjustments, deviating from that plan, and managing extreme conditions. This directive updates and replaces all past directives on these topics to the former International St. Lawrence River Board of Control, including letters from the International Joint Commission (the Commission) dated May 5, 1961 and October 18, 1963 that vested the Board with limited authority to deviate from the approved regulation plan.

Plan 2014 is the combination of the mechanistic release rules labeled "Bv7" (described in Annex B) together with discretionary decisions made by the International Lake Ontario - St. Lawrence River Board to deviate from the flows specified by the rules of Bv7 according to this directive on deviations. In that regard, Bv7 is analogous to Plan 1958-D; each is a set of release rules that solves algorithms to produce an unambiguous release amount each week.

Under the revised Order of Approval, the International Lake Ontario – St. Lawrence River Board is responsible for ensuring compliance with the Order pertaining to the regulation of the St. Lawrence River and Lake Ontario and any requirements outlined in directives from the Commission. This includes setting weekly discharges for the St. Lawrence River through the flow control structures of the Moses-Saunders hydro-electric plant located at Cornwall-Massena according to the regulation plan approved by the Commission. Bv7 release rules are designed to handle a broader range of water supply situations than the previous release rules (Plan 1958-D). In most instances, it will be important to release flows as determined by the release rules in order to realize its expected benefits. Therefore, the Commission anticipates fewer, more limited instances where flow releases would differ from those of the release rules than was the case with 1958-D.

The following sections of this Annex describe and differentiate between operational adjustments, minor, major, and emergency deviations. The Annex also explains when and how the Board can adjust and deviate from the outflows prescribed by the regulation plan. If the Board cannot establish consensus regarding deviations from plan outflows, then the issue shall be raised immediately to the Commission through the Commission's Engineering Advisors located in Washington, DC and Ottawa, ON. In such cases, the Board must reach consensus on an interim outflow in consideration of the particular circumstances at the time and that is consistent with the Treaty, while the Commission makes a decision.

C1. Operational Adjustments due to Inaccurate Forecasts

The rules and logic of the regulation plan determine the flow to be released for the coming week based on observed and forecasted hydrologic and ice conditions. As forecasts of conditions have some uncertainty, there will be occasions when the actual within-the-week conditions experienced differ significantly from the forecasted conditions used to calculate the regulation plan flow. Due to inaccurate forecasts, in some cases adjustments to the flows determined by the regulation plan at the beginning of the regulation week will be required later in the week in order to maintain the intent of the plan. The Board will consider these flow adjustments as within-plan operations and not as deviations from the plan.

The rules and logic of the plan provide protection against extreme high and low levels downstream in balance with Lake Ontario levels. The Board shall oversee operational adjustments to successfully manage rapidly varying flood and low flows coming

from the Ottawa River in accordance with the rules set out in the regulation plan, unless conditions require minor or major deviations as defined below. The plan also includes rules, based on decades of operational experience, to form and manage the ice cover in the river reaches of importance upstream of the Moses-Saunders and Beauharnois hydro-electric plants. The Board shall also continue flow changes as needed for ice management in these river reaches consistent with the intent of the plan. Ottawa River discharges and ice conditions can change significantly from day-to-day, and the week-ahead forecasts of Ottawa River flows and ice conditions used for regulation calculations are subject to rapid variations due to changing weather conditions. Therefore, short-term within-the-week flow adjustments will be made when needed to avoid flooding near Montreal consistent with the intent of the plan when the Ottawa River flow is very high and changing rapidly. Such adjustments will also be made when required to maintain St. Lawrence River levels above the minimums specified in the plan when inflows to the river are varying. As ice conditions can vary quickly due to changing weather conditions, it is anticipated that adjustments will also be necessary for the formation of a smooth ice cover to prevent ice jams in the International Rapids Section of the St. Lawrence River and the Beauharnois Canal. Within-the-week flow adjustments may also be required to address other unexpected within-the--week changes in river conditions. These flow adjustments are consistent with and accounted for in the design of the regulation plan, which was developed with the assumption that the flows during the Ottawa River freshet, droughts and the ice formation would be adjusted in practice within the week as they have been with Plan 1958DD. Therefore, no future offsetting adjustments are needed to compensate for within-the-week flow adjustments due to uncertainties in forecasts of Ottawa River flows, ice conditions, or other weather-related circumstances that are made to maintain the intent of the Plan.

The Board may direct its Regulation Representatives to be responsible for monitoring conditions, making operational flow adjustments and tracking their use. Tracking records will be used to replicate plan results, as needed for subsequent plan reviews.

C2. Minor Deviations for the St. Lawrence River

To respond to short-term needs on the St. Lawrence River, the Commission will allow the Board to make minor discretionary deviations from the approved regulation plan that have no appreciable effect on Lake Ontario levels. Minor deviations are made to provide beneficial effects or relief from adverse effects to an interest when this can be done without appreciable adverse effects to other interests, and consistent with the requirements of the Order of Approval. Unlike flow adjustments made to maintain the intent of the plan, minor deviations from the plan require accounting and flow restoration.

Minor deviations, while not necessarily limited to only these situations, could include those to address contingencies such as:

- short-term flow capacity limitations due to hydropower unit maintenance;
- assistance to commercial vessels on the river due to unanticipated low water levels;
- assistance, when appropriate, with recreational boat haul-out on Lake St. Lawrence or Lake St. Louis at the beginning or at the end of the boating season; and,
- unexpected ice problems on the river downstream of Montreal.

These deviations will affect levels on Lake St. Lawrence and the St. Lawrence River downstream to Montreal, but due to the relatively small volume of water involved, such deviations would have a very minor effect on Lake Ontario levels and the river upstream of Cardinal, ON. The intention is for minor flow deviations to be restored by equivalent offsetting deviations from the plan flow as soon as conditions permit to avoid or minimize cumulative impacts on the Lake Ontario level and avoid changing the balance of benefits under the approved regulation plan. Some discretion will be left to the Board as to whether conditions permit the restoration of the volume of water released or held back by these deviations. However, the Board shall not allow the cumulative effect of these minor deviations to cause the Lake Ontario level to vary by more than +/- 2 cm from that which would have occurred had the releases prescribed by the

approved plan been strictly followed. The intent is to accommodate, where possible, those needs of the river interests that are difficult to foresee and build into the plan, while being consistent with the intent of the regulation plan and Order of Approval.

The Board will provide post-action reports to the Commission of these minor deviations from plan flows as part of normal semi-annual reporting requirements. However, if circumstances are such that minor deviations cause the Lake Ontario level to vary more than +/- 2 cm from the level resulting from the approved plan (*i.e.*, potentially having a significant impact on Lake Ontario levels), then the Board shall advise the Commission in advance as soon as the potential need for the longer-term deviation is known. If there is a need for a longer-term deviation, the Board must provide a flow restoration plan and obtain approval from the Commission, or obtain a waiver from the Commission not requiring flow restoration. It is intended that such a waiver be rarely used so as to avoid changing the balance of benefits associated with the approved regulation plan.

The Board may direct its Regulation Representatives to approve minor deviations from plan flow, within parameters set by the Board.

C3. Major Deviations

Major deviations are significant departures from the approved regulation plan that are made in response to extreme high or low levels of Lake Ontario in accordance with criterion H14 of the revised Order of Approval:

> In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event that Lake Ontario levels reach or fall below extremely low levels, the works in the International Rapids Section shall be operated to provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream. The high and low water levels at which this provision applies will be established by a Commission directive to the Board.

Major deviations are expected to significantly alter the level of Lake Ontario compared to the level that would occur by following the approved regulation plan. Although the approved regulation plan was developed to perform under a wide range of hydrological conditions and with the experience gained in four decades of regulation operations, extreme high or low Lake Ontario water levels could require major deviations from the plan. Extreme high and low Lake Ontario levels to trigger major deviations are set out in Table C-1 of this report based on quarter-month levels through the year. If the Board expects that lake levels will be outside the range defined by the trigger levels, then based on analysis using the technical expertise at its disposal, the Board will inform the Commission that it expects to make a major deviation from the plan once the trigger level is reached to moderate the extreme levels. The Board is authorized to use its discretion to set flows in such conditions and deviate from the approved plan to provide balanced relief to the degree possible, upstream and downstream, in accordance with criterion H14 and the Treaty. For example, if the lake level is above the high trigger, then the Board could decide to increase the flow to the maximum specified by the limits used in the approved regulation plan if the plan flow is not already at this maximum, or it could apply the maximum flow limits used in Plan 1958DD, or it could release another flow consistent with criterion H14. While major deviations take downstream interests into account, they are not triggered by downstream levels, as the Bv7 release rules are designed to prevent extreme levels downstream, provided that Lake Ontario levels are not at extremes.

The Commission emphasizes that for the objectives of the approved regulation plan to be met, the regulation plan needs to be followed until water levels reach any of the defined triggers. The Board shall keep the Commission informed of the difference between the Lake Ontario level and the defined trigger levels. The Board will provide regular reports on implementation of the major deviation to the Commission. As the extreme event ends, the Board shall develop for Commission approval a strategy to return to plan flows and recommendations as to whether or not equivalent offsetting deviations from the plan flow should be made, as appropriate on a case-by-case basis.

The effectiveness of major deviations initiated with the trigger levels defined in Table C-1 will be assessed as part of the adaptive management process through follow-up monitoring and modeling. The trigger levels or implementation of major deviations could be modified by the Commission through future directives if warranted.

C4. Emergency Deviations

Emergency situations are considered to be those that threaten the physical integrity of the water management system and that may lead to a loss of the ability to control the flows in the system, or unusual life-threatening situations. Examples could include the failure of a lock gate, flooding of the hydropower control works, failure of a spillway gate, dike failure, a regional power outage, or other such active or imminent incidents. Such incidents arise only on extremely rare occasions. In such cases, immediate action is required and the Board is directed to authorize the Regulation Representatives to direct and approve, on the Board's behalf, emergency flow changes as required. The Regulation Representatives will report any such emergency actions as soon as possible to the Board and immediately thereafter the Board will report such actions to the Commission.

The Board will determine the need to make subsequent equivalent offsetting deviations from the plan flow, as appropriate, on a case-by-case basis.

Table C1.
Lake Ontario Trigger Levels for Major Deviations

Quarter months		High trigger (m./ft.)		Low trigger (m./ft.)	
1	1-Jan	75.03	246.16	74.13	243.21
2		75.07	246.29	74.13	243.21
3		75.1	246.39	74.13	243.21
4		75.13	246.49	74.12	243.18
5	1-Feb	75.14	246.52	74.12	243.18
6		75.14	246.52	74.12	243.18
7		75.13	246.49	74.11	243.14
8		75.14	246.52	74.11	243.14
9	1-Mar	75.16	246.59	74.13	243.21
10		75.18	246.65	74.15	243.27
11		75.22	246.78	74.19	243.41
12		75.27	246.95	74.25	243.6
13	1-Apr	75.33	247.15	74.33	243.86
14		75.4	247.38	74.4	244.09
15		75.45	247.54	74.46	244.29
16		75.5	247.7	74.51	244.46
17	1-May	75.53	247.8	74.55	244.59
18		75.56	247.9	74.58	244.69
19		75.6	248.03	74.61	244.78
20		75.62	248.1	74.62	244.82
21	1-Jun	75.63	248.13	74.64	244.88
22		75.62	248.1	74.65	244.91
23		75.6	248.03	74.65	244.91
24		75.59	248	74.65	244.91
25	1-Jul	75.57	247.93	74.65	244.91
26		75.54	247.83	74.64	244.88
27		75.5	247.7	74.63	244.85
28		75.47	247.6	74.61	244.78
29	1-Aug	75.43	247.47	74.59	244.72
30		75.39	247.34	74.56	244.62
31		75.34	247.18	74.53	244.52
32		75.3	247.05	74.5	244.42
33	1-Sep	75.26	246.92	74.46	244.29
34		75.2	246.72	74.42	244.16
35		75.15	246.56	74.39	244.06
36		75.1	246.39	74.35	243.93
37	1-Oct	75.06	246.26	74.31	243.8
38		75.01	246.1	74.27	243.67
39		74.97	245.96	74.24	243.57
40		74.95	245.9	74.2	243.44
41	1-Nov	74.94	245.87	74.18	243.37
42		74.92	245.8	74.17	243.34
43		74.91	245.77	74.16	243.31
44		74.92	245.8	74.16	243.31
45	1-Dec	74.93	245.83	74.15	243.27
46		74.93	245.83	74.15	243.27
47		74.95	245.9	74.14	243.24
48		75	246.06	74.13	243.21

Annex D

Directive to the International Lake Ontario - St. Lawrence River Board

This directive updates and replaces the November 16, 1953 directive that created the International St. Lawrence River Board of Control. This directive creates and directs the International Lake Ontario-St. Lawrence River Board as a new Board, with any further direction to the new Board to be issued by the International Joint Commission (the Commission) from this date forward.

D1. Function and Composition of the Board

The International Lake Ontario-St. Lawrence River Board (Board) is responsible for ensuring compliance with the Order of Approval pertaining to the regulation of flows and levels of the St. Lawrence River and Lake Ontario, the regulation plan approved by the Commission and any requirements or duties outlined in directives from the Commission.

The Board shall perform duties specifically assigned to it in the Order of Approval as well as those assigned to it by the Commission directives. Under the Order, the Board has duties related to flow regulation and responsibilities related to adaptive management, communications and public involvement. To carry out these duties, the Board shall meet at least twice a year, hold teleconferences as needed, and provide semi-annual reports to the Commission. It will also hold at least two meetings with the public annually.

The Board shall have an equal number of members from each country. The Commission shall determine the number of members (normally a minimum of 10) and shall normally appoint each member for a three-year term. Members may serve for more than one term. Members shall act in their personal and professional capacity, and not as representatives of their countries, agencies or institutions. They are to seek decisions by consensus according to the tradition of the Commission.

Within this binational balance, at least one Board member will be from each of the five jurisdictions – federal, provincial and state. The jurisdictions may nominate members to serve on the Board. The Commission will review nominees, in consultation with the respective nominating federal, state or provincial jurisdiction, to ensure that all Board members are suited to fulfilling the new and continuing responsibilities of the Board. The expertise of potential Board members, their ability to act impartially and effectively with good judgment, their commitment to work towards Board consensus, engage appropriately with the public and reach decisions quickly when necessary will be key considerations for the Commission in the appointment of candidates to the Board. The Commission will appoint the nominees if it finds them suitable. If the Commission determines a nominee is not suitable, it will request the nominating jurisdiction to make an additional nomination (or nominations) until the Commission determines the nominee is suitable. In addition to members nominated by the jurisdictions, the Commission itself may appoint members to obtain an appropriate balance of expertise and geographic representation on the Board. The Commission shall appoint one member from each country to serve as co-chairs of the Board. Each co-chair is to appoint a Secretary, who, under the general supervision of the chair(s), shall carry out such duties as are assigned by the chairs or the Board as a whole. Upon request to the Commission, either co-chair may appoint an alternate member to act as Chair when they are not available to the Board.

The co-chairs of the Board, through the assistance of the Board secretaries, shall be responsible for maintaining proper liaison between the Board and the Commission, among the Board members and between the Board and its sub-groups. Chairs shall ensure that all members of the Board are informed of all instructions, inquiries, and authorizations received from the Commission and also of activities undertaken by or on behalf of the Board, progress made, and any developments affecting such progress.

In order to provide prompt action which may be necessary under winter operations or emergency conditions, each of the co-chairs of the Board shall appoint a Regulation Representative who is authorized by the Board to act on its behalf in such situations. Among other duties, the Regulation Representatives shall maintain a database of hydrological information for the Board, conduct the regulation plan calculations, make needed within-the-week flow adjustments, coordinate and keep account of flow deviations, and advise the Board on regulation operations.

The Board shall appoint an Operations Advisory Group (OAG) composed of representatives from the operating entities and shall keep the Commission informed of OAG membership. The Board and the Regulation Representatives may consult with OAG members individually or collectively as the occasion requires.

D2. Flow Regulation

The Board shall set flows from Lake Ontario into the St. Lawrence River through the Moses-Saunders Dam and Long Sault Dam in accordance with the Order of Approval, normally as specified by the approved weekly flow regulation plan and directives from the Commission. It shall also approve the gate setting at the Iroquois Dam in consideration of Lake St. Lawrence levels and ice management, which may be delegated to the Regulation Representatives for prompt action.

The Board shall oversee the normal flow variations carried out by the hydropower entities according to the directive on peaking and ponding issued by the Commission. The Board shall also supervise the Regulation Representatives in their conduct of within-the-week flow adjustments and shall direct minor and major flow deviations when required, consistent with the Commission's directive and Order of Approval.

Following the regulation plan will be important over the long-term to ensure that the expected objectives for system regulation are achieved.

D3. Adaptive Management

The Board will take part in an adaptive management plan designed to verify that the effects of the new regulation plan over time are as anticipated, react to the influence of changing conditions such as climate change, and adapt or improve the implementation of the regulation plan as required. The Board may also use the information acquired through the adaptive management strategy to propose to the Commission modifications to the plan should it learn over time that conditions (climatic, socio-economic or environmental) have changed enough such that the plan is no longer meeting its intended objectives or improvements to the plan could realize increased benefits.

D4. Communications and Public Involvement

The Board is directed to have a communications committee. The aim of the communications committee is to ensure that everyone interested in the regulation of the Lake Ontario-St. Lawrence River system is informed and has opportunities to express personal views regarding regulation. The communications committee will ensure that the Board is proactive in acquiring knowledge about stakeholder needs and perspectives on an ongoing basis and in providing them with regular information about Board decisions and the issues before the Board. The Commission encourages the Board to take advantage of multiple means, including modern technology and alternative communications fora, to better inform and receive input from stakeholders and the public within the framework of the Commission's communication strategy. The Board may collaborate with other Commission boards, governmental and quasi-governmental organizations to effectively strengthen information delivery and involve the public.

The Commission (through its public information officers) shall be informed, in advance, of plans for any public meetings or public involvement in the Board deliberations. The Board shall report in a timely manner to the Commission on these meetings, including representations made to the Board.

The Board shall provide the text of media releases and other public information materials to the Secretaries of the Commission for review by the Commission's Public Information Officers, prior to their release in English and French.

Reports, including semi-annual reports, and correspondence of the Board shall normally remain privileged and be available only to the Commission and to members of the Board and its committees (including appropriate individuals who support these entities with respect to Lake Ontario-St. Lawrence River activities) until their release has been authorized by the Commission. Board members and committees shall maintain files in accordance with the Commission policy on segregation of documents. All Board members shall be provided with these policy documents at the time of their appointment to the Board.

The Board shall provide minutes of Board meetings to the Commission within 45 days of the close of the meeting in keeping with the Commission's April 2002 Policy Concerning Public Access to Minutes of Meetings. The minutes will subsequently be put on the Commission's website.

To facilitate communication between the Board and the relevant federal, state and provincial jurisdictions of the Lake Ontario–St. Lawrence River system, the Commission shall request from these jurisdictions the name of an appropriate contact person and provide these names to the Board. The Board should note that its communications with the jurisdictions are only with respect to the carrying out of the functions of the Board, as set out in the Order of Approval and associated directives. It will remain the role of the Commission to engage all the jurisdictions (federal, state, provincial), as appropriate in the consideration of any changes to the regulation plan or directives to the Board. Any issues raised by the jurisdictions with the Board in these respects should be redirected to the Commission.

D5. Other Aspects

According to need and on an ad-hoc basis, the Board may establish any other committees and working groups as may be required to discharge its responsibilities effectively. The Commission shall be kept informed of the duties and composition of any committee or working group. Commissioners and relevant Commission staff are invited to any meetings of the Board and any committees the Board may establish. Unless other arrangements are made, members of the Board, committees, or working groups will make their own arrangements for reimbursement of necessary expenditures. The Commission should also be informed of the Board's plans and progress and of any developments or cost impediments, actual or anticipated, that are likely to affect carrying out the Board's responsibilities.

If, in the opinion of the Board or of any member, any instruction, directive, or authorization received from the Commission lacks clarity or precision, then the matter shall be referred promptly to the Commission for appropriate action. In the event of any unresolved disagreement among the members of the Board, the Board shall refer the matter forthwith to the Commission for decision.

Annex E

Adaptive Management Strategy

The International Joint Commission (IJC) is working with the governments in the basin to develop adaptive management as an important tool for improving management of the Lake Ontario-St. Lawrence River regulation plan. An adaptive management strategy will enable the IJC to take advantage of future scientific and management advances, to ensure that the effects of regulation are those that have been calculated by the model used to develop the regulation plan, and to adjust for possible long-term changes in the amount of water entering the system (net basin supplies). The IJC does not have the resources or capacity to undertake adaptive management alone, but will work with jurisdictions and stakeholder groups that have capacity for monitoring various effects of regulation to identify the most important monitoring needs. The IJC will act on the results, as appropriate, using its standard procedures of reviews, consultations and hearings, if necessary, to make adjustments or changes. The benefits of an adaptive management strategy would apply to any regulation plan. Given that the adaptive management components will be funded and managed collaboratively by different governments and stakeholders, the list of components will gradually be built up and evolve over time. The IJC has worked with funding sources and interest groups to establish a framework for a Lake Ontario-St. Lawrence River adaptive management strategy based on the key monitoring priorities and estimated costs. The aspects of regulation that are incorporated into or affected by adaptive management include the regulation rules, the directive on deviations from those rules, and governance procedures.

E1. The Adaptive Management Process

Adaptive management is a process for improving decisions that cycles through these steps:

- estimate the impacts of a decision using best available models, but identify areas of uncertainty in those model predictions;
- make a decision that produces an appropriate balance of estimated impacts;
- monitor indicators of the impacts of the decision related to the key areas of uncertainty and compare them to what the models predicted;
- change the models if necessary based on monitoring evidence; and,
- change the decision if warranted based on the revised models.

There are two main areas of uncertainty in evaluating the performance of regulation rules for the Lake Ontario-St. Lawrence River system:

1. Will future water supplies be different from those used to test the rules?
2. Will the impacts of levels and flows be different from the modeled impacts used in designing the rules?

The adaptive management strategy will address the water supply and impact uncertainties and will support periodic evaluations to determine if new evidence can be used to develop improved regulation rules. Review of the regulation rules may occur at any time monitoring evidence suggests that it is warranted, but the first review is to take place within 15 years of the implementation of the adaptive management program.

E1.1. The Adaptive Management Committee

The International Lake Ontario-St. Lawrence River Board will oversee an Adaptive Management Committee (Committee) made up of technical experts who will coordinate the monitoring, research and modeling needed to carry out the adaptive management strategy. The Committee members will be appointed by the IJC with the advice of its boards. They will report to the Board on their work and present periodically their assessment of the monitoring results. The Board may use information developed by the Committee to propose modifications of the regulation rules to the IJC. The Committee will work with the

Board to provide for public input to the adaptive management process. Changes to the regulation plan, as always, will require approval of the Commissioners.

E2. Water Supply Research and Monitoring

The outcomes of regulation rules will depend on the water supplies that occur in the coming years, so there is a potential to improve the rules if more is known about future climate. The adaptive management strategy identifies three areas in which reduced uncertainty could improve regulation rules; forecasting, triggers and climate research.

E2.1 Forecasting

Two categories of forecast in particular hold promise for better regulation, and will have the highest priority for adaptive management research.

1. Better forecasts of supplies could help further reduce flooding along the shores of Lake Ontario and the St. Lawrence River caused by extremely wet winters and severe ice conditions that limit the winter outflow. If it were possible to improve the six-to-eight month forecasts of the amount of water entering Lake Ontario during the coming winter and early spring, then the regulation rules could be adjusted in the fall and winter depending on the risk of unusually wet conditions in the coming months. This could reduce property damage along the Lake Ontario coast while still improving ecosystem health.
2. Integrated Lake Ontario-Ottawa River forecasts. Independent forecasting systems exist or are under development for Lake Ontario supplies as well as Ottawa River flows, but there is no joint probabilistic forecast of Lake Ontario supplies and Ottawa River flow. An integrated Lake Ontario and Ottawa River ensemble forecasting system would support better short-term (2-4 week) water level forecasts, which could, for example, help the shipping industry forecast the available water draft for ships arriving at the Port of Montreal.

E2.2 Refined Deviation Triggers

The Proposal for Lake Ontario – St-Lawrence River regulation includes authority for the Board to deviate from the regulation rules when Lake Ontario levels reach trigger levels. Currently these triggers are set using statistics based on the historical record. There are high triggers for each quarter-month of the year which represent levels that are expected to be exceeded 2% of the time; the low triggers are levels that Lake Ontario is expected to be below 5% of the time. Adjusting releases at these triggers improves economic benefits without significant impact to the ecosystem, but further research might produce even better economic and environmental results using a different mix of trigger levels.

E2.3 Creation of a Coordinated Lake Ontario-St. Lawrence River Climate Change Model

Water supply datasets for the lake and river are needed to simulate the effects of climate change with different regulation rules. Datasets that reflect many different possible future climates for Lake Ontario have been developed, but there are not as many for the river. Given that the impact of climate change on lake and river levels is uncertain, it is important to test regulation rules using a wide array of supplies. Developing river datasets is more difficult because the flow from the major tributary to the St. Lawrence – the Ottawa River – is affected by the operation of a number of reservoirs in its basin. This adds a significant amount of work compared to what is necessary for estimating lake supplies because in addition to modeling rainfall, evaporation and runoff, the operating policies for these reservoirs on the Ottawa River have to be determined and simulated to estimate the inflows to the St. Lawrence River. It is also necessary to have a coordinated model to properly simulate the coincidence of high and low supplies to Lake Ontario with high and low flows from the Ottawa River basin. The development of a coordinated climate model for these two regions would help assure that regulation rules will work well under different possible future climate conditions.

E2.4. Environmental Impact Research and Monitoring

The Shared Vision Model of the Lake Ontario-St. Lawrence River system combines all of the performance models and the data used to design and evaluate the proposed regulation rules. The Integrated Ecological Response Model (IERM) portion of the Shared Vision Model demonstrates that the proposed rules will help wetland vegetation, bird communities, northern pike and muskrat (the muskrat is important because it is an indicator for the general health of a riparian ecosystem). Performance indicators for these elements of the Lake Ontario and St. Lawrence River environment played a critical role in plan selection because they were sensitive to water level changes and representative of a broader ecosystem response. The monitoring design for these four indicators will seek to isolate water level changes from other stressors and drivers that could influence the performance indicator's response. Efforts have already been initiated to establish mid- and long-term monitoring protocols. The Integrated Ecological Response Model predicts that the proposed regulation rules will not make a significant difference in the lower St. Lawrence River environment relative to the current regulation rules. However, there will be an effort to integrate existing monitoring data requirements to ensure that the proposed regulation rules do not result in unexpected negative environmental impacts on the lower St. Lawrence River.

E3. Economic Impact Research and Monitoring

The Flood and Erosion Prediction System (FEPS) portion of the Shared Vision Model indicates that the rules will increase maintenance costs to existing shore protection structures on Lake Ontario. However, those estimates rely heavily on the assumptions made by coastal engineers when the model was developed. The Lake Ontario-St. Lawrence River Study Board recognized the uncertainty in this assumption and suggested that measurements of the actual elevations of the top of structures be made.

Surveys of some of these structures already have been made and indicate considerable variability in the height of these shore protection structures, with many structures being higher than previously assumed for these locations. The higher the shore protection height, the less likely they are to be overtopped. Given that, this limited survey suggests some shore protection structures in the surveyed areas would be less sensitive to the changes in water levels brought about by the proposed regulation rules than is currently estimated by FEPS.

Although FEPS shows very little change in flooding with the proposed regulation rules, work has also been initiated to assess the use of a different model - the Flood Tool - to estimate the sensitivity of shoreline flooding impacts with a broader range of storm surge and wave conditions. Under the adaptive management strategy, measurements of shore protection in more areas would be taken and the use of the Flood Tool evaluated for a number of sites. The results of these activities will support continued improvements to the Flood and Erosion Prediction System and a refined assessment of potential effects along the Lake Ontario shoreline.

While refinements to the Flood and Erosion Prediction System have the highest priority among the economic indicators, the Adaptive Management Strategy will also address updates to model the impacts to recreational boating, hydropower, and navigation as funding becomes available.

Models of recreational boating requirements and use in the Shared Vision Model predict that the proposed regulation rules will tend to provide deeper water in the fall on Lake Ontario and the river compared to the current rules, but less depth on the lake and River during those years that experience the driest summers. On balance, the models predict slightly negative boating impacts above Lake St. Lawrence, because the estimated boating activity in summer months is much higher than in fall. Future boat ownership and use could change these assumptions. Adaptive management could include a targeted survey of boat ownership and use patterns throughout the boating season.

The proposed regulation rules produce about the same loading conditions for commercial navigation on average as the current rules, but the proposed rules are expected to provide a modest increase in the value of hydropower produced at both the Moses-Saunders and Beauharnois plants. The Study Board recognized that there was less uncertainty in the models used to evaluate these sectors and that

hydropower and shipping agencies already gather much of the data needed for tracking performance. The adaptive management strategy assumes data for these sectors will continue to be available in the future for regulation rule evaluations, but updates to the model may be needed.

E4. Periodic Assessments of the Regulation Rules

Over time, the evidence collected from the water supply and impact research and monitoring may suggest there is need to develop an improved set of regulation rules. The adaptive management strategy calls for the maintenance of the tools and expertise developed during the Lake Ontario-St. Lawrence River Study to facilitate the formulation and evaluation of regulation rules in the future.

The tools include: the Shared Vision Model; the Integrated Ecological Response Model for Lake Ontario and the St. Lawrence River; the Integrated Ecological Response Model for the lower St. Lawrence River; the Flood and Erosion Prediction System; a subsequent flood impact analysis tool developed for Lake Ontario to more closely assess local flooding and wave surge impacts; and information management systems to make the latest research and best data readily available. The Shared Vision Model has already been re-designed for use in adaptive management. The adaptive management strategy calls for periodic model exercises and training to maintain agency familiarity with the tools needed to evaluate plans.

E5. Summary

The IJC always has strived to improve its regulation rules over time; adaptive management is a more structured, science-based and effective way of doing it because:

- data collection is more purposeful and better coordinated, increasing the chances that the data needed to inform regulation decisions will be available;
- on-going evaluation of the rules should be easier because the tools and knowledge needed to assess performance are maintained on a continuing basis, with a relatively small, steady effort; and,
- decisions are more transparent because the community of experts, decision makers and stakeholders that helped build the models used in adaptive management will be sustained in the outreach efforts of the new International Lake Ontario – St. Lawrence Board.

Annex F

References

Note: All International Joint Commission-related reports and publications, as well as full text of the *Boundary Waters Treaty of 1909 and the 2012 Protocol to the Great Lakes Water Quality Agreement*, are available through the website of the IJC: www.ijc.org

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Annex G

Glossary

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.

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

BASIN (LAKE ONTARIO – ST. LAWRENCE RIVER) – The surface area contributing runoff to Lake Ontario and the St. Lawrence River downstream to Trois Rivières, QC.

***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 a number of years.

CLIMATE CHANGE – A 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.

COASTAL EROSION – The wearing away of a shoreline as a result of the action of water current, wind and waves.

COSMOS MODEL – Name of the erosion prediction numerical model used in the 2006 Lake Ontario-St. Lawrence River Study.

DEVITATIONS – Temporary changes to a regulation plan 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 Study Board specifying the study's terms of reference, including tasks and responsibilities.

DRAINAGE BASIN – The area that contributes runoff to a stream, river, or lake.

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 – 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.

FLOOD AND EROSION PROTECTION SYSTEM (FEPS) – A series of numerical models including COSMOS that compile and evaluate shoreline data to compute flood and erosion damages.

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.

FRAZIL ICE – Stream ice with the consistency of slush, formed when small ice crystals develop in supercooled stream 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 level of a stream as a result of heavy rains or snowmelt.

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

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

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

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 of regulation plans.

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 LAKE ONTARIO - ST. LAWRENCE RIVER STUDY – A study, sponsored by the IJC and completed in 2006, to examine the effects of water level and flow variations on all users and interest groups and to determine if better regulation is possible at the existing installations controlling Lake Ontario outflows.

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

INTERNATIONAL ST. LAWRENCE RIVER BOARD OF CONTROL – Board established by the International Joint Commission in its 1952 Order of Approval. Its main duty is to ensure that outflows from Lake Ontario meet the requirements of the Commission's Order. The Board also develops regulation plans and conducts special studies as requested by the Commission.

LIGHT LOAD – A load less than the ship capacity, required when a fully loaded ship would be too close to the channel bottom because of low water levels.

LOWER ST. LAWRENCE RIVER – The portion of the St. Lawrence River downstream of the Moses-Saunders Dam is called the lower St. Lawrence in this Study. It includes Lake St. Francis, Lake St. Louis, Montreal Harbour, Lake St. 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.

MEASURE, STRUCTURAL – Any measure that requires some form of construction. Commonly includes control works and shore protection devices.

MODEL, COMPUTER – A series of equations and mathematical terms based on physical laws and statistical theories that simulate natural processes.

MONTHLY MEAN WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month.

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.

PEAKING – The variation of hourly water flows above and below the daily average flow (for instance, midday flow higher than evening and night flows), primarily due to hydroelectric generating operations during which water is stocked during periods of off-peak demand in order to increase hydroelectric power generation at peak periods.

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

PLAN FORMULATION METHOD – A particular way of searching for a better regulation plan; mathematical optimization based on economic benefits, for example.

PONDING – The variation of daily water flows above and below the weekly average flow (for instance, average weekday flow higher than average weekend flow), primarily due to hydroelectric generating operations.

PUBLIC INTEREST ADVISORY GROUP (PIAG) – The group of volunteers from the United States and Canada that worked to ensure effective communication between the public and the 2006 International Lake Ontario-St. Lawrence River Study Board.

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 control of waterflows through regulatory structures 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, established monthly outflow levels, and allocated flows to various water-using interests, such as hydroelectric generation.

REGULATORY STRUCTURES – Adjustable structures, such as a gated dam, that can be raised or lowered to adjust water levels and flows both upstream and downstream.

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 – Of, relating to or found along a shoreline.

RIPARIANS – Persons residing on the banks of a body of water. Typically associated with private owners of shoreline property.

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 – Random. A stochastic process is one whose behavior is non-deterministic, in that a system's subsequent state is determined both by the process's predictable actions and by a random element.

STOCHASTIC SUPPLIES – Simulated sequences of water supply conditions that reflect climate variability.

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 power dam and locks at Cornwall-Massena, including Lake St. Lawrence.

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 average sea level.

WATER SUPPLY – Water reaching the Great Lakes as a direct result of precipitation, less evaporation from land and lake surfaces.

WATERFOWL – Birds that are ecologically dependant on wetlands for their food, shelter and reproduction.

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

WAVE CREST – The highest part of a wave.

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

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