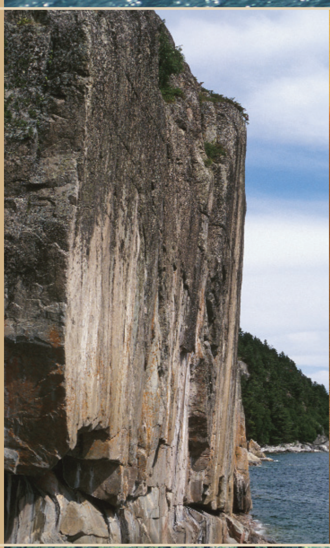
FINAL REPORT

Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows




Final Report by the International Lake Ontario - St. Lawrence River Study Board

to the

International Joint Commission
March 2006

Étude internationale sur le lac Ontario et le fleuve Saint-Laurent
International Lake Ontario - St. Lawrence River Study

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March 23, 2006

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Rt. Hon. Herb Gray
Chairman, Canadian Section
International Joint Commission
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Dear Chairman Schornack and Chairman Gray:

The International Lake Ontario–St. Lawrence River Study Board is pleased to submit herewith its Final Report at the request of the International Joint Commission. The Report identifies the regulation plan options, which address new hydrologic conditions, and all interest groups that benefit from the operation and regulation of the system. All candidate regulation plans provide net economic and environmental benefits over the current Plan 1958-D with Deviations. Each of these options represents a mixture of tangible benefits and minimal costs. All achieve the goals mandated by the Commission in its Directive of December 11, 2000.

This report, its findings and recommendations represent five years of international cooperation by hundreds of Study participants, countless citizens and dozens of agencies, for which we are extremely grateful.

Respectfully submitted,

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Executive Summary

The International Joint Commission issued an Order of Approval on October 11, 1952, amended on July 2, 1956, for the construction of the St. Lawrence River Hydropower Project. Regulation of Lake Ontario water levels and outflows in accordance with the Commission's orders began in 1960. The current plan, 1958-D, which has been in effect since October 1963, was designed for the hydrologic conditions experienced from 1860 to 1954. For that reason, 1958-D has not performed well under the extreme high and low water supply conditions experienced since that time. As a result, the International Joint Commission and its International St. Lawrence River Board of Control have had to deviate from the Plan. More recently, the Board of Control has deviated from the Plan to better address changing needs and interests.

The International Joint Commission's Levels Reference Study Board report of March 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."

In April 1999, the International Joint Commission informed the governments 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 interests, in light of environmental concerns and in response to potential climate change conditions.

On December 11, 2000, the Commission issued a directive to the International Lake Ontario-St. Lawrence River Study Board, which it had appointed, to:

i) review the current regulation of levels and flows in the Lake Ontario-St. Lawrence River system, taking into account the impact of regulation on affected interests;
ii) develop an improved understanding of the system among all concerned; and
iii) provide all the relevant technical and other information needed for the review.

The subsequent five-year, $20 million[1] Study was conducted with funding provided equally by the U.S. and Canadian governments and through participation of agencies, individuals and organizations in both countries.

This is the final report of the International Lake Ontario-St. Lawrence River Study Board in response to the Commission's 1999 Plan of Study and December 2000 Directive. It summarizes findings from the scientific and other undertakings of the Study, describes three new candidate plans for Commission consideration, presents recommendations on public involvement and regulation-related matters and outlines some steps towards implementation of a new regulation plan. While the Study Board and team have some differences of opinion, the Study Board is confident that each of the three candidate plans performs better than the

1 All monetary values indicated throughout this report are expressed in equivalent U.S. dollars.

current operating regime in terms of overall net economic and environmental benefits to interests throughout the system. The Study Board is confident that a plan selected from these three will satisfy most of the affected interest groups.

Over the five-year study period, hundreds of people and dozens of organizations have participated directly in the Study. The volunteers of the Public Interest Advisory Group have been central to the success of the undertaking, contributing significantly and uniquely to the work of the Study Board. Advisory Group members were fully integrated into the Study Team, providing advice, feedback and input during all phases of the study process. This gave the Study Team a practical focus on the real-world implications of its decisions. Stakeholder participation and collaboration had a decisive role in the formulation and evaluation of all plans, as well as the final set of candidate plans that the Study Board presents here for consideration. For example, aboriginal issues are complex, and contributions by Native members of the Study Team to the understanding and consideration of issues were very helpful. Considerable coordination and involvement were necessary on the part of both the Public Interest Advisory Group and the Study Board in the response to issues raised by all interest groups, including aboriginal communities, with study elements explicitly formulated to accommodate concerns.

This Study represents a unique opportunity to make a change – to literally rebalance the system once in 50 years. But trade-offs have to be made among the competing interests. The Study Team has identified all the significant trade-offs and quantified the relative benefits and costs. The result is an intensive, comprehensive and detailed analysis of the physical and ecological dynamics that are interacting with the human uses of the system.

The final decision by the International Joint Commission will be a difficult one, as it tries to balance all interests equitably. The Study Board has given the International Joint Commission a comprehensive set of tools, models, supporting data and information that will facilitate that process.

What the Study Board Found

Over the five-year study period, the Study Team collected a considerable amount of new data and performed relevant scientific investigations. It applied innovative technologies to develop and evaluate new regulation plans to provide a better balance among all the interests in the system. Many new findings, conclusions and clarifications of previously uncertain views and theories were developed during the course of this work.

The Study Team formulated and evaluated numerous possible regulation plans. It has selected three candidate plans labeled A^+, B^+ and D^+, which address the range of interests and issues that emerged as part of an extensive evaluation effort. These plans have the designation $^+$ as they represent improvements over the versions of plans A, B and D that were made public during the Study's summer 2005 outreach activity. Many other possible regulation plans were considered and evaluated (e.g., plans C, E and OntRip3), but were set aside.

The Study Board did not prioritize on the basis of either the desires of interest groups or the performance indicators that were used to evaluate plans. The Study Board derived many performance indicators from the extensive public participation program. The Study Board judged all plans based on an objective appraisal of results of the economic and environmental scores from simulations over stochastic and historical time series.

Each candidate plan fulfills two of the Study Board's principal goals of providing net economic and environmental improvements, when compared to the existing plan. However, as expressed by the performance indicators, it is difficult to satisfy, at all times, the myriad of specialized demands on the part of each of the competing interests in the Lake Ontario–St. Lawrence River system.

Changes to the criteria and existing operating plan are not possible without harm to some interests. The majority of Board members do not consider these damages a "disproportionate loss."

The Study Team's analysis uncovered a number of surprises and challenged conventional wisdom on many fronts, especially in the comparison of various alternative plans against Plan 1958-D with Deviations.

The current Regulation Plan 1958-D with Deviations comes close to minimizing damages for Lake Ontario shoreline property owners. Even regulation plans developed to optimize conditions benefiting shoreline property interests on Lake Ontario, or in the extreme, that might hold Lake Ontario levels constant, could only improve benefits to Lake Ontario shoreline properties by an average of less than $1 million U.S. per year, while causing major losses elsewhere in the system. Erosion of a certain amount of Lake Ontario shoreline will occur regardless of the regulation plan. The difference between plans lies in how quickly it will happen.

On the lower St. Lawrence River there are some flood damages that, although not large in economic terms relative to some other interests, result in differences between plans that can be significant for the portion of the River downstream of Montreal in the Sorel/Lac St. Pierre area. Shoreline erosion on the lower river downstream of the Moses-Saunders dam is not a major economic issue since most developed properties are already protected.

A key issue raised by recreational boaters throughout the system is the desire to maintain higher water levels until later in the fall, thereby extending the boating season and making it easier to haul boats out of the water.

All plans produce benefits for commercial navigation, with the main difference between the candidate plans being the cost due to delays in shipping on the Seaway. There is usually enough water on Lake Ontario to keep ships fully loaded, and none of the candidate plans is significantly better than the rest in terms of avoiding shallow depths in the Seaway. The plans do differ in how well they maintain minimal acceptable depths at the Port of Montreal, especially during extended droughts.

All plans produce benefits in terms of hydropower. Benefits are greatest when releases are similar to those that would occur without regulation, assuming actions to limit ice jams in the winter and early spring. Natural releases create a higher average head at the Moses-Saunders dam and tend to be the most stable and predictable, resulting in very little spillage.

Municipal, industrial and domestic water-use facilities are generally not vulnerable to water level changes. The exceptions are the Russell and Ginna power generating stations and the Monroe County potable water treatment plant in Greece on the south shore of Lake Ontario. The Monroe County facility would experience problems within the historical high water level range, the Ginna station at historical low water levels, and the Russell station at both historical high and low levels. Under any plan, all facilities will require upgrading to remain fully operational under high or low water level conditions in the future. The Study also found that the Montreal water supply system could be at risk under very low flow and level conditions similar to those modeled in the Study for climate change conditions.

The current regulation plan has reduced the range and occurrences of extreme Lake Ontario levels as intended under the existing Orders of Approval. From an environmental perspective, this has 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 has also caused dewatering drawdowns in the fall through early spring, to the detriment of some habitat.

Since it began its work, the Study's Environmental Technical Working Group has taken the position that the best plan for the natural environment is natural "pre-Moses-Saunders-dam" level and flow conditions. A plan developed during the Study and labeled Plan E is closest to the natural flow conditions, while still maintaining a smooth ice cover on the St. Lawrence River to limit ice jams. However, while Plan E simulates more natural conditions, it does not represent the natural condition before regulation. The system, especially the St. Lawrence River downstream from Ogdensburg, has changed dramatically since the Moses-Saunders dam was built. As a result, the lower river below the Moses-Saunders dam is much less sensitive to changes in water level regulation than the lake and upper river. This is because regulated releases are very diverse, spanning an even greater range than natural releases. Furthermore, the lower river hydrology is influenced not only by the outflows from Lake Ontario, but also by the Ottawa River and local tributary flows.

Many Study Board members believe that the environmental objectives of Plan E should be considered a long-term management goal for the system. But they recognize that, because of historical development, considerable adverse economic impacts are associated with Plan E and therefore do not support its consideration as a candidate plan.

Scientific and Technological Advances

The Study Board has introduced a new planning approach referred to as "Shared Vision Planning." This approach combines scientific and public input in an interactive analytical framework that has helped the Study Team and public interest groups explore numerous plan formulation opportunities, operating nuances and performance impacts in an organized fashion.

The Shared Vision Planning approach used in the Study integrates a hierarchy of advanced models. They include an ecosystem response model, shoreline dynamics models used for flood damage and erosion predictions, and a series of new economic models that provide the economic benefits and costs associated with recreational boating, hydropower and commercial navigation.

The Study Board used highly sophisticated hydrologic modeling to ensure the reliability, resilience and robustness of each plan under a stochastically generated 50,000-year sequence. In addition, the Board analyzed four different climate change scenarios and used them to thoroughly test candidate plans, ensuring that none had fatal flaws that would inhibit their performance under these extreme potential conditions. When choosing options, the Study Board decided that a legitimate comparative analysis of the benefits and costs associated with the various plans, should be based on the long-term stochastic hydrologic sequence rather than the 100-year historical record.

The implementation of a candidate plan will impose a new set of requirements on the International St. Lawrence River Board of Control. The new requirements (including information management; greater public communication and outreach; model running, maintenance and upgrading; the analysis of monitoring data) must be addressed to enable the Board to remain aware of plan impacts and to know when and to what extent adaptive changes in policy should be considered.

New Candidate Regulation Plans

The three new candidate regulation plan options entitled A+, B+ and D+, herein forwarded to the Commission, are all considered by a majority of the Study Board to represent improvements over the current Regulation Plan 1958-D with Deviations. Each of these plan options involves a mixture of benefits and costs. All create overall economic and environmental benefits relative to Plan 1958-D with Deviations, but to varying degrees and with varying trade-offs among interests. All candidate plans achieve the goals mandated by the Commission in its Directive of December 11, 2000.

From an interest perspective, all three candidate plans benefit commercial navigation and hydropower and have no impact on municipal, industrial and domestic water use relative to Plan 1958-D with Deviations. The greatest difference between the plans is in how they address recreational boating, the shoreline flood and erosion or coastal interests and the environment or natural ecosystem.

Plan A+ is the most regimented of the three plans, striving to keep Lake Ontario within as narrow a range as possible. It provides the highest overall net economic benefit, the greatest economic benefit for recreational boaters, both upstream and downstream, and benefits in terms of shore protection maintenance and flood concerns on Lake Ontario. In comparison with Plan 1958-D with Deviations, higher erosion rates along unprotected Lake Ontario shoreline are of concern, as are increased flood damages on the lower St. Lawrence River. Plan A+ provides small improvements for the environment, but, of the three candidate plans, has the smallest gain in this regard when compared with Plan 1958-D with Deviations.

Plan B+ strives to return the Lake Ontario-St. Lawrence system to a more natural regime, with conditions similar to those that existed prior to the St. Lawrence River Hydropower Project, while at the same time attempting to minimize damages to present interests. In comparison with Plan 1958-D with Deviations, it does indeed provide overall improvement for the natural environment on Lake Ontario and the upper St. Lawrence River. It also provides net benefits for hydropower and commercial navigation. Its downside is that it results in higher damages for Lake Ontario shoreline properties and is associated with increased flood damages on the lower St. Lawrence River. Although Plan B+ has some negative recreational boating numbers, at public meetings, many in the boating community, especially on the upper St. Lawrence, supported Plan B as presented at the summer 2005 public meetings prior to its final “fine tuning.” From their point of view, this plan has better St. Lawrence River and Lake St. Lawrence performance, generally higher Lake Ontario levels in spring and fall, and better overall performance for boaters more than half of the time than Plan 1958-D with Deviation. In the eyes of many, Plan B+ is the only candidate plan that consistently transforms and improves the diversity and productivity of the natural ecosystem, addresses species at risk legislation objectives, and represents an important step forward towards a level of ecological integrity that would otherwise be difficult to achieve.

The intent of Plan D+ is to increase the net economic and environmental benefits of regulation, relative to Plan 1958-D with Deviations, without disproportionate losses to any interests. In this respect, this plan succeeds in achieving gains in net benefits for recreational boaters, hydropower and commercial navigation. Despite some small losses in the Lake Ontario shore protection category, Plan D+ is very close to 1958-D with Deviations in terms of shoreline property interests. Plan D+ also provides a general level of improvement for the environment across the range of performance indicators considered.

If none of the candidate plans is selected, the International Joint Commission has several "default options:"

- The current operating Plan 1958-D with Deviations could remain in place with the new criteria that have been developed;
- Plan 1958-D with Deviations could continue with the existing criteria, but it would probably perform differently, depending on the composition of a new International St. Lawrence River Board of Control, and attempt to address environmental and recreational boating interests; or
- The Commission could rely on a combination of the above two options – new criteria and a new International St. Lawrence River Board of Control.

The Study Board Recommendations

The International Joint Commission has three significantly different candidate regulation plans to choose from, each of which provides net economic and environmental benefits. The Board is confident that any one of these plans will satisfy a majority of the interest groups.

Conditions and the priorities for lake level and flow regulation always change over time, and new scientific and technological advances will continue to be made. An adaptive management process should support the selected regulation plan and incorporate performance tracking: an initial performance review of the new plan should be undertaken five years after its implementation; and a more in-depth evaluation should be carried out ten years from its implementation to include consideration of adaptive changes to the selected plan.

This Study has considered in detail the trade-offs between interests, and this is reflected in the plan rules. The Study Board has agreed that long-term deviations from plan rules and flows have the effect of changing the intended performance of the plan(s) as designed and the benefits that flow from the plan(s). However, the Board recognizes and supports the need for short-term deviations from plan flows under specified emergency conditions. Under extreme low or high water level and flow conditions that are problematic for interests, the Study Board recognizes that adjustments based on hydrologic and hydraulic data available at the time could remain consistent with the intent of the plans. Therefore, the Study Board also supports Commission action under extreme conditions to consider whether the benefits of deviation from plan flows outweigh the disadvantages, recognizing that there would be a need for considerable public relations support at such times.

A significant opportunity exists to move forward on long-term resolution of a few vexing issues related to fluctuating water levels, for example, shoreline flood and erosion problems. During International Joint Commission consultations with governments, the Commission should act as a catalyst to promote and advance mitigation of persistent shoreline flood and erosion problems. For example, in light of the findings of this Study, responsible state, provincial and municipal authorities could undertake a review of shoreline management practices and policies. Shoreline management strategies and permitting processes could be revisited and renewed for critical reaches of the shoreline utilizing new data and information gathered during this Study, including water level regime information for a new regulation plan. This review should help to identify options for dealing with problems affecting land use and existing structures within shoreline flood and erosion hazard zones.

As used in this Study, the general planning approach, termed "Shared Vision Modeling," has proven to be very successful. The Commission should consider applying these same techniques in subsequent International Joint Commission studies.

The basic data and information collected, the research undertaken, the models developed and the body of knowledge accumulated during the Study have many possible and potential uses beyond the review of the Commission's Lake Ontario regulation criteria and plan. The Commission and the International St. Lawrence River Board should take steps to make this information as accessible and useful as possible to a broad range of organizations and applications.

The Study Board recommends that additional resources and personnel needed to meet new responsibilities of plan implementation by the International St. Lawrence River Board of Control be sought and provided. As a first priority, a full-time communications officer should be engaged to lead outreach activities relating to implementation of a new plan. Then, as a second priority, more science capacity should be added to develop links with science organizations, monitor regulation plan performance and assume responsibility for seeking out and identifying future adaptation actions and strategies.

Condition (i) of the 1952 Order of Approval as amended in 1956, specifying criteria (a) through (k), will need to be completely replaced if any one of the candidate plans A^+, B^+, or D^+ is selected for implementation, or will need to be revised if Plan 1958-D is to continue to be applied.

Further recommendations derived from the outreach activities and experiences of the Study Board and Public Interest Advisory Group include the following:

People living and working along Lake Ontario and the St. Lawrence River shorelines need to be educated and informed with respect to the basic hydrology of the Great Lakes-St. Lawrence system. An education program should be established by the International Joint Commission and/or its International St. Lawrence River Board of Control; if this step is not taken, misconceptions, poor decisions and antagonism towards water level and flow management will persist.

People affected by changing water levels and flows resulting from regulatory actions, in both the short term (hours) and the long term (years), need to understand and be informed of these conditions so that they can prepare for and adapt to them. It is recognized that shoreline development, infrastructure and regulatory programs have evolved with some dependence on the current Orders of Approval and regulation plan operations. Changes should be accompanied by education, outreach and help in accommodating a new water level regime and water management decision-making structure.

The International St. Lawrence River Board of Control should be restructured to better reflect the views of all interests. This restructuring should incorporate a public advisory body. Consideration should be given to renaming the Board, deleting the term "Control."

The Public Interest Advisory Group volunteers devoted much more time than expected to this Study. The Commission should take steps to publicly acknowledge this contribution.

For studies such as this, the Commission should appoint Public Interest Advisory Group members for their expertise and ability to reach out to local interest groups. Networking capabilities promote public participation. It is important to reach out to all interests, including First Nations communities, from the very beginning of an investigation.

Publication of the results of Study Board and Commission research should be encouraged and supported by the Commission. In that vein, the Commission's website could reference current and future study-related publications in order to broaden public awareness.

Divergent Viewpoints

The majority of the Study Board stands behind the planning approach, the research program and the findings and conclusions presented in this report. However, there are a few divergent viewpoints within the Study Board on the issue of "improvements" to regulation of water levels and flows on Lake Ontario and the St. Lawrence River. This is not surprising given the complexity of the issues and the fact that people treat trade-offs differently and that perspectives are vastly different. In reporting its findings here, the Study Board does not want to convey the message or impression that agreement or consensus was reached on all issues. Views vary on the candidate plans. For example, a minority of Board members feel that Plan B^+ represents too radical a change and that the increase in shoreline damage that could be experienced under this plan constitutes a disproportionate loss. Many believe that environmental degradation has occurred since Plan 1958-D was put into operation, and a few on the Study Board feel that none of candidate Plans A^+, B^+ or D^+ goes far enough to address this degradation. A few prefer to retain Plan 1958-D with Deviations with changes to criteria and deviation authority. Some will argue that uncertainties in the Study's science and analysis do not justify a change in regulation plans, yet the majority believe that the evidence in support of a change is overwhelming.

Table of Contents

List of Figures

List of Tables

Annexes *(Published Separately)*

1 Pertinent Documents

2 Technical Working Group Summaries and Contextual Narratives

3 Plan Descriptions and Summary Results

4 Mitigation and Adaptive Management Action Plans

Introduction

Lake Ontario receives its water from the four other Great Lakes as well as from drainage from its local watershed, and it discharges water into the St. Lawrence River. In the 1950s, Canada and the United States built the St. Lawrence River Hydropower Project, including a dam stretching across the St. Lawrence River from Massena, New York, to Cornwall, Ontario. The International Joint Commission (IJC) issued “Orders of Approval” for the project in 1952 and supplementary orders in 1956. The Orders established criteria for the operation of the system and also established a Control Board to develop and implement plans of regulation to meet the orders. A series of plans was investigated and implemented, and in 1963, a new plan called “1958-D” was approved and put into use. The plan consists of rules for making releases from the lake every week based on recent water supplies to the lake, how high the lake is, the time of year, ice conditions, Ottawa River flows, river stages, and a series of flow limits which bound other rules. The Orders of Approval allow the Control Board to deviate from the written plan, with Commission approval, particularly under extreme high and low water supply conditions. The Control Board has also been granted authority to institute emergency and discretionary deviations, as detailed later in this report. The Control Board has often deviated from the plan to meet the intent of the Orders of Approval and provide benefits to affected interests. These deviations have been necessitated partly by the changing needs of the system and partly by the wetter and drier supply conditions experienced since 1960 as compared with the period from 1860 to 1954, which the designers used in the development of Plan 1958-D.

From time to time, the International Joint Commission considered new plans in an attempt to better meet the criteria in the Orders of Approval or to provide additional benefits to affected interests. The Great Lakes Levels Reference Study (1993) recommended a revision and updating of Plan 1958-D. Subsequently, plans (e.g., Plan 1998) were developed by the Control Board but not implemented by the Commission because they did not adequately accommodate environmental concerns or recreational boating needs and there was a lack of information on impacts on other interests.

The International Lake Ontario-St. Lawrence River (LOSLR) Study was designed to address those shortcomings. Unlike the Levels Reference Study, which addressed water management issues on all the Great Lakes, the LOSLR Study focused only on water level changes and flow regulation on Lake Ontario and the St. Lawrence River with the existing dam and other water control structures.

Challenges and Opportunities

None of the previous attempts to revise the regulation plan for Lake Ontario has been as comprehensive and detailed as this Study. Previous evaluations considered changes to the regulation techniques – modifying outflow limitations and procedures. The Lake Ontario-St. Lawrence River Study approach was significantly different in that an extensive public involvement program played a key role in the development and selection of more comprehensive options. The study conducted a comprehensive evaluation of plan metrics, which are the basis for the development and evaluation of alternative operating plans. It relied on a considerable amount of new information on the economic performance of all users of the system, as well as the ecological response to hydrologic variability. The Criteria in the Commission's 1956 Orders of Approval (Annex 1) defined the objectives for regulation, including limits related to levels and flows for hydropower, commercial navigation and flood elevations. This Study undertook investigations to redefine these limits by collecting new data, applying state-of-the-art scientific investigations and seeking the participation of the public and renowned experts. The concerns of the aboriginal community were solicited through community outreach, and studies were conducted on recreational boating, environmental factors and other issues pertinent to the Tribes.

New preferred water level ranges were established based upon the preferences of all interests, and new regulation plan options were created, which considered not only the traditional uses identified explicitly in the International Boundary Waters Treaty, namely domestic and sanitary water uses, hydropower and navigation, but also recreational boating, flooding and erosion, and the environment.

This comprehensive approach provided numerous opportunities for change, but not without challenges. By their nature, the interests that benefit from the management of Lake Ontario and the St. Lawrence River generate resource management conflicts. For example, shoreline residences prefer lower levels that reduce the risk of flooding and erosion damages, while boaters prefer higher levels so that they can enjoy their recreation without grounding. Study investigations have indicated that ecological diversity increases with a wider variation in lake levels; this in turn increases the risk of flooding and erosion, adversely impacts recreational boating, and reduces the reliability of water intakes and shore wells, which can become inoperable when levels are very low. Considering these conflicts, the Study focused on devising regulation options that attempt to provide benefits to a greater number of users and interest groups without creating disproportionate losses for any interest or geographical area as compared with the existing operation of the system. The Study also developed alternatives that were tested against the uncertainties of potential climate change and variability in present climate conditions. The three candidate regulation plans presented in this report provide improvements for most interests in some geographic areas as compared with the existing method of outflow regulation under Plan 1958-D with Deviations, referred to as Plan 1958-DD.

Current Rules, Regulations and Limitations

Historical Perspective

Development of the upper St. Lawrence River for navigation was proposed as early as 1825. However, the most significant events associated with development occurred in the early part of the twentieth century.

The International Waterways Commission was established in December 1903 by the governments of Canada and the United States with a mandate to report on the use and protection of the Great Lakes. The Commission recognized that a guiding set of principles, agreed to by both countries, was necessary to deal with and resolve disputes in boundary waters. This recognition led directly to the Boundary Waters Treaty of 1909 between the United States and Great Britain. The International Joint Commission, which guides the regulation of Lake Ontario, was established under this treaty.

The treaty specified that navigation "shall for ever continue free and open for the purposes of commerce" and that the navigation laws of one country were to apply to citizens and vessels of the other. Although navigation was stressed, interest in the development of electricity began to appear as population and industry expanded. The rapids of the River could facilitate this development. The dual purpose of a St. Lawrence River project was substantiated by a 1921 study by the United States Army Corps of Engineers and the Department of Railways and Canals of Canada. The study report, referred to as the Wooten-Bowden report, concluded that navigation improvements would not be justified economically without developing the capability of the River for power generation. In 1924, the governments established the Joint Board of Engineers to examine the technical issues raised by the Wooten-Bowden recommendations. Reflecting decades of discussion and a number of Board reports, the Corps of Engineers submitted a report in April 1942 entitled “St. Lawrence River Project, Final Report 1942.” This document formed the basis for the ultimate planning and construction of the hydropower project and Seaway in the 1950s.

Early Regulation Plans

The first regulation plan developed for Lake Ontario was a basic rule curve routing procedure developed by the Canadian Department of Transport in September 1940. The plan specified eight “ideal” requirements that a lake regulation method should fulfill. The plan centered around maintaining natural levels on Lake Ontario and the St. Lawrence River and securing maximum dependable flows for power operation, while avoiding difficulties downstream of the project around Montreal and its harbour.

High levels on Lake Ontario in the early 1950s caused substantial flood damage. As a result, the governments sent a reference dated June 25, 1952, to the International Joint Commission requesting an investigation of methods of regulation which could provide a measure of flood control. In April of the following year, the IJC established the International Lake Ontario Board of Engineers as a result of this reference. On May 5, 1955, the Board presented Plan 12-A-9 to the IJC. The Plan provided flood control at the expense of power generation. The range of levels on Lake Ontario was set between a low of 74.15 m in the navigation season and a high of 75.37 m (243.29 and 247.29 feet, respectively, referenced to the International Great Lakes Datum (IGLD) 1985) based on the water supplies received in the 1860 to 1954 period. The Plan was not implemented, but was used to calculate critical river profiles and design channel excavations for safe navigation through the Seaway. The range of Lake Ontario levels, however, was retained in future plan development.

The International St. Lawrence River Board of Control (the Control Board), which was created by the International Joint Commission on November 16, 1953, conducted all subsequent regulation studies. On May 14, 1958, the Control Board recommended the adoption of Plan 1958-A “as the initial operating plan for the regulation of the levels and outflows of Lake Ontario having in mind that certain revisions may be necessary in the light of further studies and operating experience.” The Plan was put in operation on April 20, 1960.

In 1960, low flow requirements of downstream navigation interests, particularly in Montreal Harbour, resulted in re-examination of the Plan. The Control Board subsequently presented Regulation Plan 1958-C on October 5, 1961, which was a revision of Plan 1958-A, designed primarily to reduce the frequency of flows below those that would result in levels less than the low water datum in Montreal Harbour. Improvements were accomplished by reductions in summer flows and minimum winter flows. The Plan became operational on January 3, 1962.

On January 21, 1963, the IJC asked the Control Board to proceed with further studies “to provide, among other possible benefits, for improvement of the levels of Montreal Harbour to the extent consistent with all requirements of the Order of Approval.” The resulting Plan 1958-D, improved the Montreal Harbour levels without reducing the minimum winter flows of Plan 1958-C. Plan 1958-D was put in operation in October 1963 and has remained the Lake Ontario regulation plan since that time.

Regulation Plan 1958-D

The data used in the development and testing of Plan 1958-D were identical to the data used in the 1958-A and 1958-C versions; i.e., recorded water levels and supplies for the period 1860 to 1954, adjusted to reflect March 1955 outlet conditions and net Great Lakes diversions as specified in the Commission’s 1956 Order of Approval.

The plan consists of a water supply indicator, two sets of basic rule curves, seasonal adjustments and a number of maximum and minimum outflow limitations. The basic regulated Lake Ontario outflow is derived from a family of rule curves (Figure 1), which show outflow as a function of end of period lake level and "adjusted supply indicator." Given the lake level, an outflow is selected for an indicator which is related to wet or dry prevailing conditions. Seasonal adjustments are applied to the basic regulated outflow. The resultant seasonal adjusted outflow is compared to maximum and minimum outflow limitations, which vary throughout the year. If the seasonal adjusted outflow is between the minimum and maximum limitations for the period, it is adopted as the regulated outflow. If it is higher than the maximum or lower than the minimum limitation, then the applicable outflow limitation is adopted as the regulated outflow.

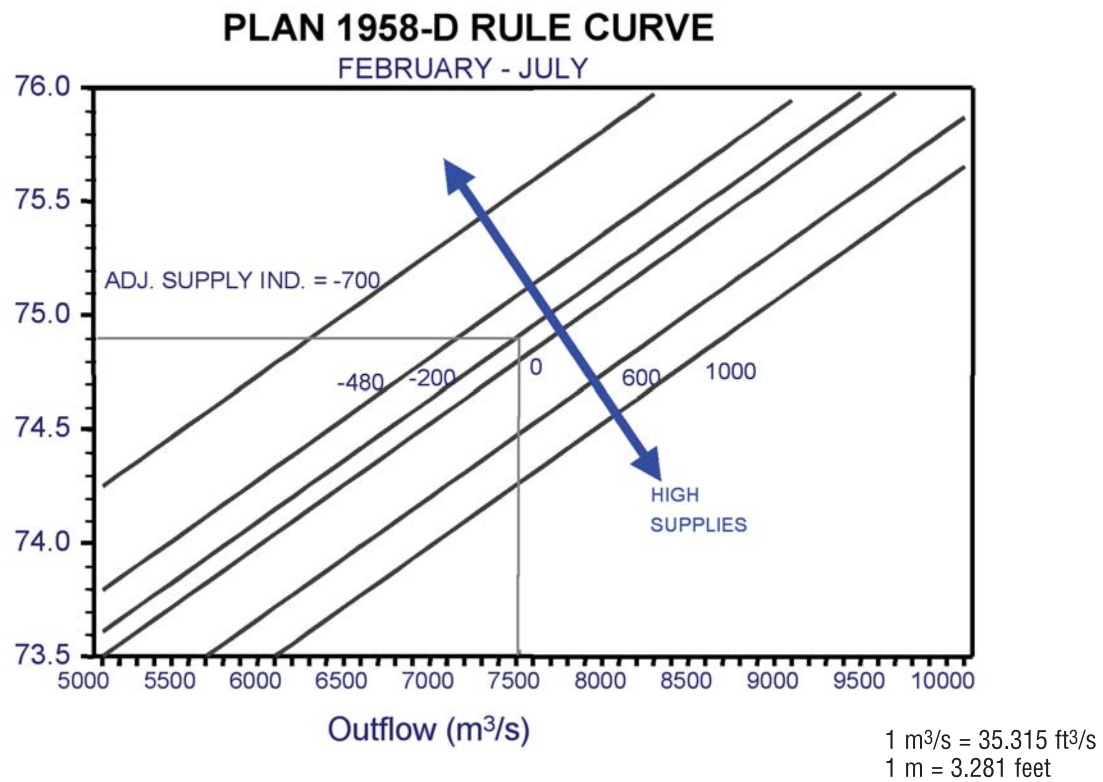


Figure 1: Basic rule curves used in Plan 1958-D weekly outflow regulation

Regulation Criteria

The adoption of Plan 1958-D was based on its successful performance in meeting the requirements of the ten criteria established in the Orders of Approval (Annex 1). The criteria consider regulated outflows from Lake Ontario as they affect 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, and both upper and lower target levels for property owners on the shores of Lake Ontario and the St. Lawrence River. The criteria also include a statement indicating that attempts should be made to reduce the extreme high and increase the extreme low Lake Ontario levels.

An eleventh criterion, Criterion (k), was included in recognition that water supplies to Lake Ontario would, at some times, be outside the range of the historical water supplies upon which the plan was developed. This criterion specifies that outflows be varied to provide relief to upstream and downstream shore property owners during times of extremely high supplies, and to hydropower and navigation interests in the case of extremely low supplies outside the design set. The Criterion must be invoked and then revoked by the IJC. Since regulation began, deviations under Criterion (k) occurred during the 1960s in response to low supplies, providing assistance to power and navigation interests, and during the 1970s, 80s and 90s in response to high supplies, providing assistance to riparians. Criterion (k) was most recently implemented by the IJC between February 3, and June 19, 1998, to deal with high water resulting from an early winter ice storm that restricted outflows, followed by a very wet spring.

It is important to note that the criteria in the Orders of Approval are not "absolutes," i.e., they are not standards that must be met under any circumstance. They are set as *desired targets*, to be met as often as is justifiable and physically possible, while fulfilling the needs of the specified priority Treaty purposes (i.e., navigation, hydropower and municipal, industrial and domestic water supply), and without violating other constraints. As a bottom line, however, the Orders state that the regulation of lake levels should not cause damage that is worse than the pre-project condition for downstream areas.

Annex 1 of this report includes the October 29, 1952, Order of Approval as amended by a supplementary order dated July 2, 1956, in which the criteria included in Plan 1958-D are defined.

Present Protocol and Procedures for Operating the Plan

Periodically, the Control Board establishes the regulation strategy for the coming weeks. In order to determine the release for the next week, the weekly situation on Lake Ontario and the St. Lawrence River is discussed and the regulated outflow is recommended by the Operations Advisory Group after a review of data provided by the offices of the U.S. and Canadian Regulation Representatives: the U.S. Army Corps of Engineers, Buffalo District, and Environment Canada, Cornwall. The Regulation Representatives can accept or reject the Operations Advisory Group recommendation. If the Regulation Representatives cannot agree on a regulated outflow, the matter is elevated to the Control Board for a decision. If the Control Board cannot come to a full agreement on an outflow, the issue is raised to the Commission.

Dynamics of Regulation

Figure 2 shows the Lake Ontario-St. Lawrence River Basin including the watersheds of the St. Lawrence and Ottawa Rivers. Figure 3 shows the location of St. Lawrence River control structures between Massena, New York, and Cornwall, Ontario, and the River through Montreal Harbour.

The dynamics of regulation are complex, requiring the balancing of several conflicting water management objectives that are inherent in the management of flows and lake levels. For example, alleviating high water levels on Lake Ontario requires releasing more water, which may cause flood-related damage downstream because of high water conditions in the River. Alleviating low water levels in the lower river requires releasing more water from Lake Ontario, which may cause problems for recreational boaters and municipal water supplies because of low water levels on the lake. Managing the variability of water levels to accommodate ecosystem needs introduces a higher level of complexity.

Uncertainty about future water supplies from the upper Great Lakes and tributaries within the Lake Ontario-St. Lawrence River Basin makes it that much harder to balance upstream and downstream needs. For example, if future supplies are unexpectedly low, releases made to alleviate low water levels in the River may drain too much water from Lake Ontario, making it much more difficult to alleviate low river levels later when the impacts may be even worse. Similarly, if future supplies are unexpectedly high, restraint in making releases to avoid minor downstream flooding may induce greater damage when later releases have to be increased dramatically.

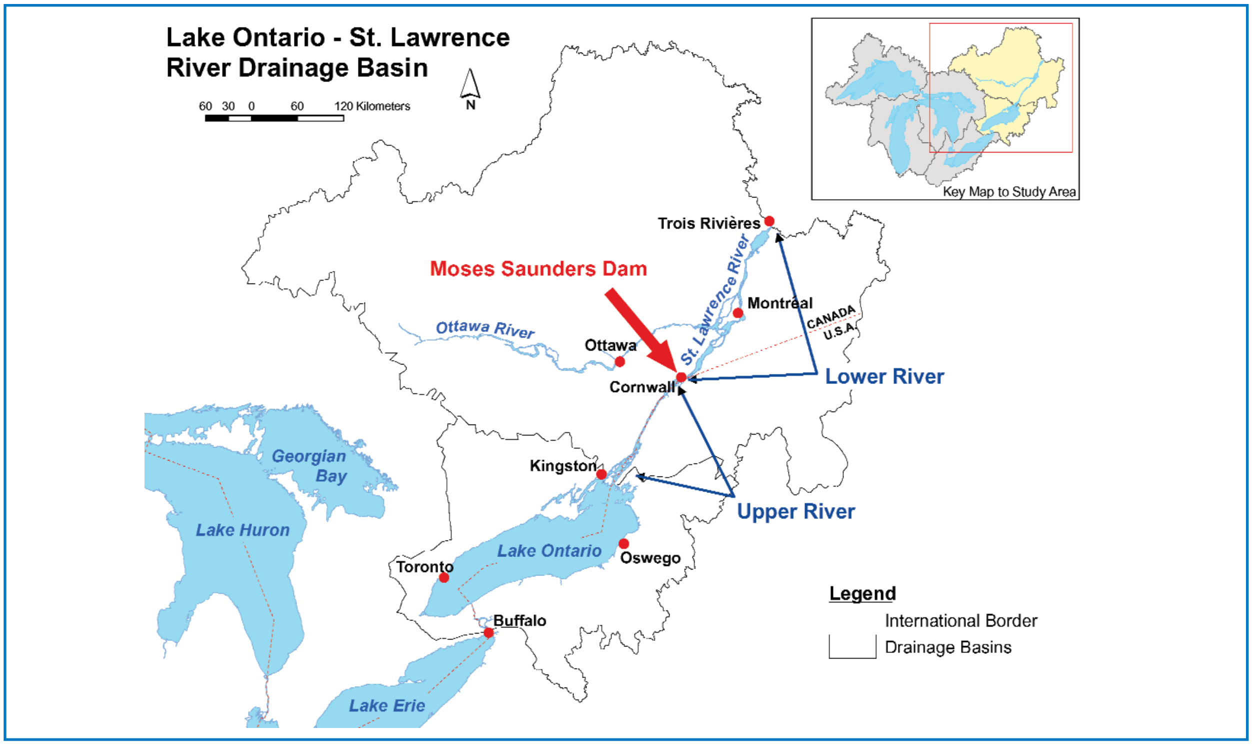


Figure 2: The Lake Ontario-St. Lawrence River Basin

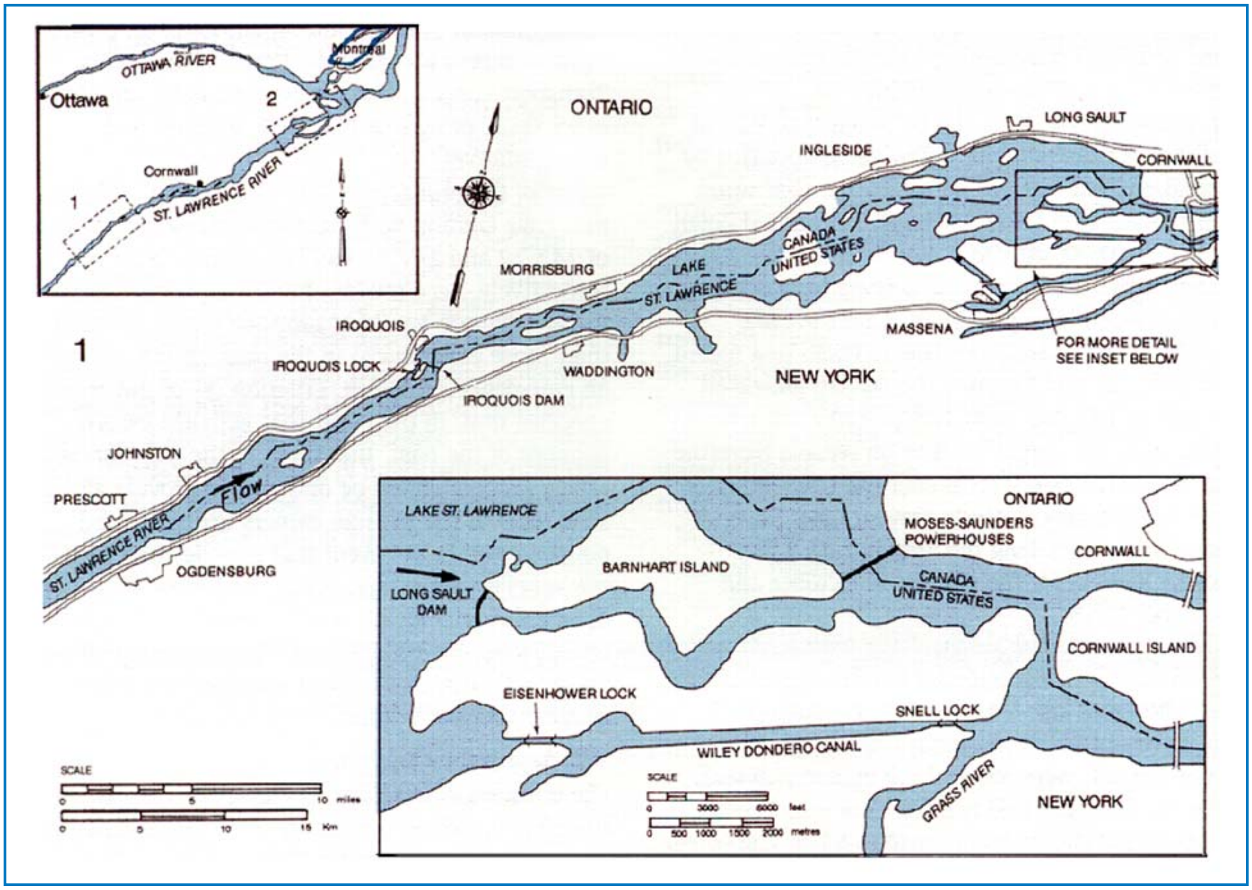


Figure 3: Location of the control structures in the St. Lawrence River and other features, to Montreal, Quebec

The timing of water availability within the year is important, in different ways for different purposes. The level of commercial navigation and recreational boating activity drops considerably in the winter. The value of energy generated in the summer during peak energy demand periods can be more than twelve times the value in the spring.

Higher releases reduce the level of Lake St. Lawrence, which is immediately upstream of the hydropower dam. If the releases are too high, the levels can be so low that they are hazardous to navigation and could result in ship groundings. In addition, high flows can produce cross-currents that make it difficult to control vessels. For hydropower, more electricity can be generated when there is a greater volume of water passing through the turbines; however, the consequent lowering of Lake St. Lawrence decreases the head on the hydropower stations and reduces the amount of electricity generated for each cubic meter of water.

The Orders of Approval require that riparian interests downstream receive no less protection from flooding than would have occurred under pre-project conditions. Regulation of Lake Ontario outflows has actually reduced spring flooding in the Montreal area, while still reducing flooding on Lake Ontario. Montreal is threatened by flooding since it is located at the confluence of the Ottawa and St. Lawrence rivers. The spring runoff from the Ottawa River Basin is largely uncontrolled and can be very significant. Timely adjustment of the Lake Ontario outflow has repeatedly helped avoid serious flooding around Lake St. Louis in the Montreal area during Ottawa River floods. Lake Ontario outflow reductions are typically offset by higher flows prior to the Ottawa River flood, or shortly following it.

The Basis for Decisions in the Study

The Commission's directive calls for the Study Board to undertake studies required to provide the Commission with the information it needs to evaluate criteria and options for regulating water levels and flows in order to benefit affected interests that rely on the resources of the Lake Ontario-St. Lawrence River system as a whole in a manner that conforms to the requirements of the Boundary Waters Treaty. To meet this mandate, the Board adopted a vision and goal and developed the following guidelines for its activities as the foundation for providing advice to the Commission.

Vision

To contribute to the economic, environmental and social sustainability of the Lake Ontario and St. Lawrence River System.

Goal

To identify flow regulation plans and criteria that best serve the range of affected interests, are widely accepted by all interests, and address climatic conditions in the basin.

Guidelines

1. Criteria and regulation plans will contribute to the ecological integrity of the Lake Ontario-St. Lawrence River ecosystem.

   This guideline will be measured by the positive or negative movement in environmental Performance Indicators (PI) to the degree those PIs are significant, certain and sensitive to changes in levels and flow as outlined below.
   a. *Significance - the PI must show some key importance to the ecosystem and region*
   b. *Certainty - there must be confidence in the results*
   c. *Sensitivity - the PI must be affected by changes in levels and flows*

2. Criteria and regulation plans will produce a net benefit to the Lake Ontario-St. Lawrence River system and its users and will not result in disproportionate loss to any particular interest or geographic area.

   The concept of "net benefits" applies to both economic and environmental performance indicators. Subject to the constraints imposed by other guidelines, the Board will prefer plans that maximize net economic and environmental benefits overall.

   The definition of a disproportionate loss will be assessed qualitatively based on the following information:
   a. Loss means a decline in the average net benefits in the category compared to 1958-DD or a change in the temporal distribution of benefits that stakeholders have said would be harmful even though the average net benefit is positive. The Board may consider some changes in a plan's ability to meet a criterion as a loss, if there is no representative Performance Indicator.
   b. Categories can be the six interests represented by the technical working groups, in any of three geographic reaches (Ontario to Ogdensburg, Ogdensburg to the dam, the dam to Lac St. Pierre).
   c. Losses that reflect a larger percent change from 1958-DD are more likely to be considered disproportionate.

   The Study Board will treat all the interests equally in its assessment of disproportionate loss (recognizing however, that it would be unproductive to deliver a plan that is worse for the areas the new plan was meant to improve – specifically the environment and recreational boating).

3. Criteria and regulation plans will be able to respond to unusual or unexpected conditions affecting the Lake Ontario-St. Lawrence River system.

   This guideline will not be used for evaluating and ranking plans. Rather the Study Board will consider carefully the need to allow for deviations under unusual or unexpected conditions and work towards a clear recommendation on when deviations may be warranted.

4. Mitigation alternatives may be identified to limit damages when considered appropriate.

   The Study Board will consider a range of plans that include:
   a. Plans that maximize net benefits, but require mitigation to eliminate disproportionate loss (not to be implemented until the mitigation implementation measures are in place); and
   b. Plans that minimize losses and require little or no mitigation.

5. Regulation of the Lake Ontario-St. Lawrence River system will be adaptable to the extent possible, to accommodate the potential for changes in water supply as a result of climate change and stochastic variability.

   The historical and stochastic time series which represent plausible future conditions will be used in formulating and evaluating plans, with a test for the best plans being run through the entire 50,000-year stochastic series. In addition, four climate change scenarios that represent a change or shift in climate will be used in a sensitivity analysis to determine how robust the plans are to climate change conditions.

6. Decision-making with respect to the development of the Lake Ontario-St. Lawrence River system Criteria and Plans will be transparent, involving and considering the full range of interests affected by any decisions with broad stakeholder and public input.

7. Criteria and regulation plans will incorporate current knowledge, state-of-the-art technology and the flexibility to adapt to future advances in knowledge, science and technology.

The Study Board considered the impacts of alternative regulation plans assuming current economic and environmental conditions. The evaluations were done using a wider range of water supplies to the basin than have been experienced in the 20th century. Water supplies that might occur sometime in the future because of climate change were used to make sure the plans would work under those conditions. Expert opinion on economic and environmental trends was used qualitatively to show which areas of the regulation plan might need to be changed in the coming decades.

Study Scope

During the Levels Reference Study, and since its completion in 1993, a number of interests or user groups were identified as being directly affected by fluctuations in water levels and flows in the Lake Ontario-St. Lawrence River system, in addition to those directly specified in the Orders of Approval.

The work undertaken in this Study was specified in great detail in a Plan of Study, developed in 1999, and reaffirmed by the IJC Directive (2000). It developed an assessment framework that examined how water level fluctuations affect all the specified interests, expressed in physical, economic and ecological dimensions. This assessment consisted of a review of the data, findings and reports of the 1993 Levels Reference Study, followed by field investigations, new data collection, more detailed topographic and bathymetric data, original scientific investigations, and public interviews, surveys and questionnaires. Where practical, studies or data already completed for other agencies or other purposes were relied on to minimize duplication of cost and effort. Emphasis was placed on identifying the analytical and technical foundations for evaluating the respective demands of the environmental, recreational boating and shoreline property interests on the management of the Lake Ontario-St. Lawrence River system, as reflected in the Scope of Work Document (1999) (the Executive Summary of the Document is included in Annex 1 of this report, published separately). A comprehensive analytical approach was initiated, in conjunction with a robust public involvement process, referred to as “Shared Vision Planning.”

Regulation of the outflows of Lake Ontario affects water level conditions on Lake Ontario and the St. Lawrence River as far downstream as Lac St. Pierre near Trois-Rivières, Quebec. It should be noted that water level fluctuations downstream of Cornwall, Ontario, to Massena, New York, are also affected by actions taken at the other control works, as well as by natural factors. The levels and flows of the St. Lawrence River in the vicinity of Montreal can also be significantly affected by discharges from the Ottawa River, particularly during spring runoff into the Ottawa River basin, referred to as its freshet. The Ottawa River Regulation Planning Board coordinates the Ottawa River discharges. These discharges can at times be as significant as the outflows from Lake Ontario. The outflow regulation of the Ottawa River is not under the jurisdiction of the IJC and is not part of the scope of this Study. Prior studies have concluded that no feasible location or conditions for additional structures on the Ottawa River have been found that would provide sufficient additional controls over water levels and flows in the lower St. Lawrence River.

Study Organization

The Study organization is shown in Figure 4. As mentioned previously, the Study was created by the International Joint Commission in response to a reference from the governments of the United States and Canada. The Commission responds directly to the public. The Study Board consists of fourteen members, with both countries equally represented; members are selected for their expertise rather than affiliation with any interest or agency. There are two general managers, who facilitate Study Board activities and handle finances in each country. There are nine technical work groups (TWG). Six consider the impact of water levels on specific interests, namely, wetlands and environmental, recreational boating and tourism, coastal processes, commercial navigation, municipal, industrial and domestic water uses, and hydroelectric power generation. The Hydrologic and Hydraulic Modeling Group provides historical and hypothetical water level and flow data to the other groups for their evaluations. The Information Management Group stores information generated by the technical groups and all other Study elements, for use among groups and for future archiving. The Plan Formulation and Evaluation Group is responsible for creating plan options with input from all Study elements.

A unique group within the organization is the Public Interest Advisory Group (PIAG). The Group consists of individuals from various locations around the system and provides a direct link to the public. The leads of that group are also members of the Study Board. Members interact with the technical work groups with which they have a particular knowledge. The Group also interacts with the Board and Commission. Its input helped shape plan options through the interaction of committee members with the Plan Formulation and Evaluation Group.

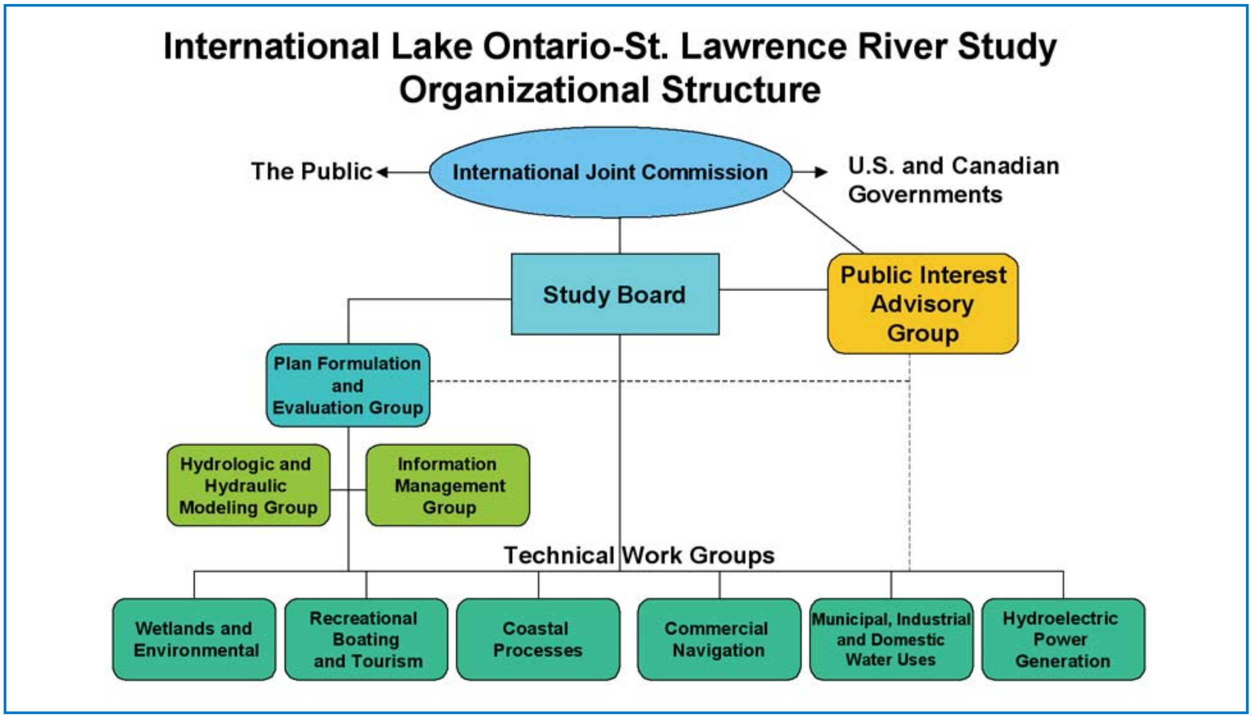


*Figure 4. **Study Organization***

Reviews

There were several layers of expert review undertaken during the Study, including internal, external, and independent reviews, all designed to ensure confidence in the use of the findings to shape the new regulation plans.

Reviews in Progress

Reviews in progress are built into the Shared Vision Planning process. The act of building one model that encompasses all other models requires an in-depth analysis and review of the underlying models. Because Shared Vision modelers need to understand the workings of the underlying models so thoroughly and because they remold the underlying models into a format that hundreds of people can access, this in-progress review proved to be much more thorough and effective than traditional quality control methods.

In this Study, the Shared Vision modeling team shaped or made significant changes to the assessment of environmental, navigation, hydropower and coastal impacts.

- The use of the Integrated Ecological Response Model was not part of the original scope of work. This Model became the environmental wing of the Shared Vision Model and was tested and refined in numerous workshops with environmental scientists who contributed to the study as well as outside experts from universities, the Royal Botanical Gardens, and The Nature Conservancy.
- The Shared Vision process was key to identifying data errors underlying preliminary results from the Flood and Erosion Prediction System Model and in refining the use of this Model to characterize the economic impacts of flooding, erosion and shore protection maintenance in ways directed by a panel of economic experts.
- The Shared Vision modeling process shaped the development of the Navigation Shipping Cost Model, as modelers worked together to formulate mathematical procedures and policy definitions. In the end, each model was used as a check on the other. Model discussions with the Commercial Navigation Technical Work Group led to the identification and resolution of underlying policy issues, such as the conditions under which ships were likely to make the trip from Europe into the Seaway with too heavy a load for the water conditions they would encounter some days after leaving port.
- The Shared Vision Model essentially duplicates the mathematical routines and results of models of energy production developed by Ontario Power Generation and Hydro Quebec, but the much broader use of the Shared Vision Model prompted an outside review of pricing assumptions and helped identify issues of importance to the power industry, such as the loss of energy production, flood risk and damage to turbines that could occur when low flows force a choice between using fewer turbines at the Hydro Quebec facility (to avoid damage to the turbines) or more turbines (to avoid flooding caused by limitations in the capacity of the channels carrying the water bypassing the turbines).

Finally, the Shared Vision modelers asked experts in the various technical working groups to provide a stamp of approval verifying that the Shared Vision Model faithfully captured the impact a decision would have on their interest.

Economic Experts Review Panel

The Study Board decided in the second year of the study that it was important to obtain an expert and objective review of the economic analyses that the Board would use, in part, to decide which options would be sent forward to the International Joint Commission. A panel of four experts (two from Canada and two from the United States) was retained under a series of contracts.

Their recommendations are available separately in a document titled “Issues and Findings in the Economic Analysis of Water Level Management Plans Consensus Report of the Economics Advisory Committee” (Thomas et al, 2005). The economic advisors were requested to provide advice on the following issues:

- Are all economic performance indicators considered in interchangeable terms (fungible)?
- How should time and discounting in the evaluation of the impacts of water level management plans be handled?
- How should input-output economic model results and expenditures data developed by the Recreational Boating and Tourism Technical Work Group be used and reported?
- How should adapting behaviours to changing water levels be considered?
- Should marina damages be capped at the cost of dredging?
- Should beach accretion be valued in economic terms?
- What does mitigation mean and what about flood insurance?
- What should the reporting metrics be?
- Are we measuring economic value to society or value to the hydroelectric companies?
- How do we value lost energy production?
- How do we include the value of hydroelectric power peaking?
- What should be used for the simulation time, analytical time, and sampling?

Independent Review

Independently of the study, the International Joint Commission engaged the National Academy of Science, in collaboration with the Royal Society of Canada, to perform an independent review of critical study components. These consist of results regarding wetlands science and species at risk, the Flood Erosion and Prediction System Model, the Integrated Ecological Response Model and the Shared Vision Model.

The overarching charge was to evaluate the appropriateness and sufficiency of the studies and models used to inform decisions related to regulation plan options. The review, to the extent practicable, was also performed to recommend possible actions related to the areas under consideration that the International Joint Commission might consider for future implementation to improve water levels and flows management. The science of the Study program, as represented in the reports and model documentation provided, was reviewed by the committee in terms of the degree to which:

- the models and reports are sufficient and appropriate to evaluate the various alternatives and impacts of changes in water levels and flows,
- the study(ies) reflect reasonable scientific methods, assumptions, and supported findings,
- the models sufficiently and appropriately integrate and display the key information needed for a comprehensive evaluation and understanding of the trade-offs for selecting among the candidate alternatives.

The National Academy of Science and Royal Society of Canada review panel report is published separately (NAS and RSC, 2005).

Plan Formulation and Evaluation Process

The Role of the Plan Formulation and Evaluation Group

The original Plan of Study identified the need for six technical work groups representing the areas of activity directly impacted by the water system. These included hydropower, commercial navigation, municipal, industrial and domestic water uses, coastal interests, recreational boating and tourism, and wetlands and the environment. Each area gains benefits from the system in different and sometimes conflicting ways. The task of the technical work groups was to conduct studies on the relationship between water levels and flows and develop a set of defined performance indicators in these areas. The Plan of Study also called for a hydrologic and hydraulic technical work group to develop the required hydrologic supply sequences against which new regulation plans could be evaluated. What the Plan of Study did not offer was much specification on how plans would be formulated, evaluated and ranked, and how researchers would design their work to fit into an overall evaluation scheme.

Late in the first year of the Study, the Study Board agreed to use the Shared Vision Planning approach pioneered by the U.S. Army Corps of Engineers during the National Drought Study[2] (USACE, 1994). All subsequent planning work was carried out using this method. The Plan Formulation and Evaluation Group was formed in the second year of the Study, soon after the Shared Vision method was established, for the purpose of linking research, public input and decision making in a dynamic, modeled fashion. The Plan Formulation and Evaluation Group was assigned the responsibility for coordinating and integrating the efforts undertaken by each of the six technical work groups into the Shared Vision Planning process. In doing so, the Plan Formulation and Evaluation Group had to work with the six technical work groups to realign the studies that had already begun and assist in the design of studies that were not yet underway. The Plan Formulation and Evaluation Group met with researchers from all technical work groups and developed a plan to integrate their findings into the overall plan evaluation scheme.

General Context

The impacts of proposed regulation plans were measured relative to what is expected to occur if regulation remains unchanged, under the present set of policies. Unlike the typical feasibility study for dams or levees – new structures with essentially irreversible impacts – in this Study, economic, environmental and social conditions were assumed to be similar to what they are currently. Each technical work group prepared a “contextual narrative” describing the current situation and expected trends for their specific area. These contextual narratives are found in Annex 2 of this report and are available through the Study website (www.losl.org). Briefly summarized, the general context and key trends for the impact are as follows:

2 U.S. Army Corps of Engineers Institute for Water Resources, “Managing Water For Drought,” September 1994.

Coastal Processes

The assessed values of approximately 25,000 affected properties (buildings only) on Lake Ontario and the upper St. Lawrence River is approximately $3.3 billion U.S., with an additional $380 million U.S. in property values on the floodplain of the lower St. Lawrence River downstream of Cornwall. This value is expected to increase as demand for waterside living continues to grow.

From 1990 to 2000, there was an increase in shoreline development of about 6% on the Lake and 2% on the upper St. Lawrence River and, with shoreline property values having doubled in the past decade, this is expected to continue. On the lower river, laws and regulations have been progressively implemented to manage construction within the floodplain in such a way that limited changes to shoreline development are expected. However, there has been conversion of seasonal homes to permanent dwellings, a trend also seen on the Lake. Approximately 600 homes on the Lake are at imminent risk to losses from flooding or erosion due to their proximity to the existing shoreline. On the River, any flooding above the 100-year flood-line would result in greatly increased damages.

Commercial Navigation

The St. Lawrence Seaway opened in April 1959. The Seaway, combined with the eight locks on the Welland Canal, allow ocean-going vessels and lakers to access all of the Great Lakes. The Montreal-Lake Ontario section of the Seaway is an integral part of this system. This section encompasses a series of seven locks which allow ships to navigate between the lower St. Lawrence River and Lake Ontario. From the Atlantic Ocean through Montreal Harbour, the system allows for deeper draft and is used by ocean-going vessels, many of which are too large to use the Seaway.

Each year, marine commerce on the Great Lakes/Seaway System generates more than $4.3 billion in personal income, $3.4 billion in transportation-related business revenue and $1.3 billion in federal, state and local taxes. Over 30 million tons per year, representing some 2,950 ship movements, pass through the Montreal-Lake Ontario section of the system. About 85% of total tonnage consists of iron ore, coal, limestone and grain. Montreal Harbour is the most important container port in eastern Canada and one of the fifteen largest in North America, handling about a fourth of the container volume of the New York/New Jersey Harbour. According to the Port of Montreal, container traffic grew from about 7.1 million metric tonnes in 1994 to 10.8 million metric tonnes in 2004. Vessel size and draft has increased substantially over the past 40 years. On the Seaway, vessels of up to 225.4 m (740 ft) in length and 23.8 m (78 ft) in the width now regularly transit the system, and vessel draft has increased to 8.08 m (26.5 ft). However, transportation growth is generally north-south while the Seaway is east-west, and the Seaway infrastructure is aging. A Seaway feasibility study is currently underway to look at what can be done to make more efficient use of the Seaway. With all of this, it is difficult to determine if the sector is growing or declining, but containerized shipping through the Port of Montreal is expanding as part of a worldwide boom in containership trade.

Recreational Boating and Tourism

For the 2002 boating season (April to November), $429.7 million U.S. was spent on boating-related trips. Of the $178 million in total U.S. expenditures, $68 million U.S. resulted from tourist-related spending. The rural portions of Lake Ontario, Thousand Islands area and Lac St. Pierre are very dependent on tourism related to recreational boating. The 2002 survey identified an estimated 133,000 U.S. boaters and 177,000 Canadian boaters. The number of U.S. boaters increased 10% between 1994 and 2002, and the number of boats in Quebec increased 22% between 1995 and 2000, with a slight trend towards larger, faster boats. It is expected that these trends will continue throughout the region.

Hydroelectric Power Generation

The three hydropower operators on the St. Lawrence River are the New York Power Authority, Ontario Power Generation and Hydro Quebec. There is an annual hydropower production of approximately 25 million MWh (13 million MWh at Moses-Saunders and 12 million MWh at Beauharnois-Les Cedres). The market value of energy produced annually is approx. $1.5 billion U.S. at current market rates. Enough energy is produced to meet the needs of about 2 million homes. Each of the three companies operates in different market environments. The New York Power Authority works under a competitive market and price is determined by the most expensive block of power per hour. Ontario Power Generation works under a real-time wholesale pricing structure based on both regulated and market prices determined by daily forecasted demand. Hydro Quebec operates under a regulated system based on the lowest possible cost. Up to 165,000,000 MWh of electricity per year must be supplied to service Quebec residents and anything above this can be sold at market prices.

The demand for hydropower is expected to grow, along with government supplied economic incentives for its use in both countries to help meet new carbon emission goals. Given the environmental and economic advantages of hydropower and its importance to the regional economy, the overall value of hydropower is expected to increase in the next few decades.

Municipal, Industrial and Domestic Water Uses

There are 6.3 million residents on Lake Ontario and the upper St. Lawrence River (both Ontario and the U.S.) and 2.3 million residents on the lower St. Lawrence River who rely on the Lake and the River for water. There are high social, political and economic costs if water is not provided.

Municipal, industrial and domestic water demands will stay about the same in the near future, but municipalities along the St. Lawrence River will invest millions of dollars to improve water quality and water supply reliability during droughts. Small and one-home water supply systems will continue to be converted to community systems or modified so that water supplies can be maintained during lower water level conditions on the Lake and the River.

Wetlands and Environmental

As in the case of the economic evaluations, the environmental impacts of proposed regulation plans were measured relative to what is expected to occur if regulation remains unchanged, under the present set of policies.

The focus in the environmental evaluation was on the effect of water levels on coastal marshes. Briefly, water level regulation has reduced the variety of plant species along the coast, which creates stresses on the animal populations that thrive on plant types that suffer under regulated water levels. In general, a more diverse environment will better resist impacts from environmental threats in the Great Lakes, such as toxins and invasive species (Tilman and Downing, 1987; Schindler, 1998). Lake Ontario coastal marshes provide breeding and feeding grounds for all coastal life, including several species-at-risk. Water level patterns have a direct physical influence on the breeding and nesting success of marsh birds and fish that inhabit the marshes. More varied water levels create more variety in marsh plants, which creates a more productive and robust coastal ecology and habitat. Water levels on the St. Lawrence River can strand fish or drown bird eggs. The societal value of the environment is expressed through laws protecting habitat (i.e., wetlands) and specific faunal species (special interest or endangered).

The current estimate of the area of coastal wetlands within Lake Ontario and the upper St. Lawrence River is approximately 26,000 hectares (64,250 acres), made up of four basic types: submerged aquatic vegetation, emergent marsh, meadow marsh, and upland vegetation (trees/shrubs) (Wilcox, et al. 2005). Over 80% of the wetland area occurs in the eastern half of the Lake Ontario basin and Thousand Islands region. Results from study site analysis indicate that there has been a 50% reduction in meadow marsh and in emergent-floating vegetation since regulation was implemented in the late 1950s. During that same time period, there has been a 29% increase in cattail-dominated emergent marsh area (about 1,700 hectares or 4,200 acres) (Wilcox and Ingram, 2005).

With over 12,000 hectares (30,000 acres) of swamps and marshes, Lac Saint-Pierre accounts for 80% of lower St. Lawrence River wetlands. Lac Saint-Pierre supports a large population of nesting blue herons (more than 1,300 nests), a major staging area for migratory wildfowl (more than 800,000 ducks and geese annually) 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 exploited by sports and commercial fisheries alike (Centre Saint Laurent, 1996). The ecological value of Lac Saint-Pierre has been recognized by its status as a Ramsar wetland and a UNESCO Biosphere Reserve, and its inclusion as a protected site under the Eastern Habitat Joint Venture.

In addition to impacts caused by regulation, changes in climate, water temperature, and water supply can affect the environmental response of habitats and the species they support. Issues such as invasive species, changes in fisheries management, pollution and population changes, or changes in the use of the resource can also impact the environment. Regardless of the regulation plan, the environment will continue to be vulnerable to various stressors such as invasive species, pollution, and land use changes. However, how lake levels are managed can have an impact on the ecological integrity of the system and its resilience to these other stressors.

New Information and Science

This Study was a catalyst for new research into the physical inventory of the basin and the relationships between water levels and flows and economic and environmental impacts. In this Study, the quantified impacts were called “performance indicators.” A performance indicator measures impact on a use. For example, the cost of flood damages avoided affects the use of the coast for human habitation. Each technical work group conducted research to quantify the relationship between impacts and different water levels and flows, ultimately developing mathematical relationships, defining impact in quantitative terms as a function of water levels and flows, that were used to evaluate the impacts of alternative plans. The quantitative evaluation of impacts was carried out in terms of economic and environmental measures, while social considerations, which may also be important, were captured qualitatively in the contextual narratives.

The key performance indicators chosen by each of the technical work groups are listed in Table 1. Annex 2 of this report provides more details on these indicators, and still greater detail can be found in supporting documentation available through the Study website (www.losl.org), including a summary fact sheet on each of the performance indicators listed. It is important to note that the Environmental Technical Work Group began with 400 performance indicators, but reduced this to 32 key performance indicators 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. Environmental scientists within and outside the Study discussed the plan evaluations online and in workshops, trying to rank plans based on the overall benefit to the environment. These ranking efforts showed that scientists attached particular significance to an even smaller subset of these 32 indicators, either because of special importance (species at risk) or the representativeness of one species for larger ecosystem effects (muskrat house density in the upper river). The indicators in the smaller subset are marked by an asterisk in Table 1.

Table 1: Key Environmental Performance Indicators

Lake Ontario

Vegetation:
1. *Wetland Meadow Marsh Community - Total surface area, supply-based (ha)

Fish:
2. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply
3. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply
4. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply
5. *Northern Pike – Young-of-year recruitment (#ha)
6. Largemouth Bass – Young-of-year recruitment (#ha)

Birds:
7. *Virginia Rail (RALI) - Median reproductive index (index)
8. Least Bittern (IXEX) - Median reproductive index (index) (Species at risk)
9. *Black Tern (CHNI) - Median reproductive index (index) (Species at risk)
10. Yellow Rail (CONO) - Preferred breeding habitat coverage (ha) (Species at risk)
11. King Rail (RAEL) - Preferred breeding habitat coverage (ha) (Species at risk)

Upper St. Lawrence River

Fish:
12. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
13. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
14. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
15. *Northern Pike – Young-of-year (YOY) recruitment (#ha) from Thousand Islands to Lake St. Lawrence
16. Largemouth Bass – YOY recruitment (#ha) from Thousand Islands to Lake St. Lawrence
17. *Northern Pike – YOY net productivity (grams (wet wt.)/ha) in Thousand Islands area

Birds:
18. *Virginia Rail (RALI) - Median reproductive index (index) on Lake St. Lawrence

Mammals:
19. *Muskrat (ONZI) - House density in drowned river mouth wetlands (#ha) in Thousand Islands area

Lower St. Lawrence River

Fish:
20. *Golden Shiner (NOCR) - Suitable feeding habitat surface area (ha) from Lake St. Louis to Trois-Rivières
21. Wetland Fish - Abundance index (ha) in lower St. Lawrence River
22. *Northern Pike (ESLU) - Suitable reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières
23. Eastern Sand Darter (AMPE) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)
24. *Bridle Shiner (NOBI) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)

Birds:
25. Migratory Wildfowl - Foodplain habitat surface area (ha) from Lake St. Louis to Trois-Rivières
26. Least Bittern (IXEX) - Reproductive index (index) from Lake St. Louis to Trois-Rivières (Species at risk)
27. *Virginia Rail (RALI) - Reproductive index (index) from Lake St. Louis to Trois-Rivières
28. *Migratory Wildfowl - Productivity (# juveniles) from Lake St. Louis to Trois-Rivières
29. Black Tern (CHNI) - Reproductive index (index) from Lake St. Louis to Trois-Rivières

Herpitiles:
30. Frog species - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières
31. Spiny Softshell Turtle (APSP) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)

Mammals:
32. *Muskrat (ONZI) - Surviving houses (# of houses) from Lake St. Louis to Trois-Rivières

* Priority subsets of key environmental performance indicators.

Table 2: ***Economic Performance Indicators***

Coastal Performance Indicators

Lake Ontario

1. Flood Damages - The economic damages to developed properties based on high water levels, calculated on a county basis.
2. Erosion of Developed Parcels - Damage based on the cost of adding shore protection once the shoreline is within a defined distance from the house, calculated on a county basis. The value of lost material is not determined.
3. Shore Protection Maintenance - The cost of replacing shore protection damaged by water levels, calculated on a county basis.

Upper St. Lawrence River

4. Flood Damages - The economic damages to developed properties based on high water levels, calculated on a county basis. Based on U.S. counties only due to lack of availability of Canadian parcel data for upper St. Lawrence River regional municipalities.

Lower St. Lawrence River

5. Flood Damages - Damages associated with high water levels in the St. Lawrence River below the dam on a municipality basis; based on water levels at the closest gauge location (8 used for the River).
6. St. Lawrence River Shore Protection - The cost of replacing shore protection damaged by water levels. Each structure was placed in one of 80 structure zones on the lower St. Lawrence River. These zones were selected on the basis of location and similarity of hydrodynamic conditions (local wind wave, river flow and level, and shipping climate).

Non-Economic Performance Indicators (Reported in Board Room and Contextual Narrative)

- St. Lawrence River Flooding Non-Economic Impacts - Number of expropriated homes; kilometres of roads flooded, and area of flooded land. Damages are determined on a municipality basis; based on water levels at the closest gauge location (8 used for the River).
- St. Lawrence River Erosion - Land lost due to erosion. Impacts are determined for twenty-seven high-erosion sites along the lower St. Lawrence River. No measurable economic loss as a result of land lost.

Commercial Navigation

7. Transportation Costs on Lake Ontario - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth on the Lake.
8. Transportation Costs on the Seaway - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth along the Seaway, Seaway low-level wait time, and Seaway gradient delays (fall between gauges) and associated delay costs due to high-flow velocities between Ogdensburg - Cardinal, Cardinal-Iroquois HW, Iroquois TW - Morrisburg, Morrisburg - Long Sault.
9. Transportation Costs below the Port of Montreal - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth at Sorel and Trois Rivieres.

Hydropower

10. Value of energy produced based on station head, flow, efficiency rate and price of electricity.
11. Cost of foregone peaking opportunities (NYPA and OPG only) based on weekly averaged regulated release and value of peaking opportunity.
12. Predictability/stability of flows to maximize efficiency based on changes in flow and foregone energy production.
13. Frequency and severity of spill at Long Sault Dam during spawning season.

Recreational Boating

14. Net economic benefits lost by recreational boaters and charter boat patrons as water level varies from ideal levels for boating for six reaches (Lake Ontario, Alexandria Bay, Ogdensburg, Lake St. Lawrence, Lake St. Louis, Montreal Harbour, and Lac St. Pierre)

Municipal and Industrial Water Uses

15. Water Quality Infrastructure Costs Avoided on the lower St. Lawrence River - based on cost of upgrading municipal drinking water treatment plants to treat taste and odor compounds.
16. Water Supply Infrastructure Costs Avoided on the lower St. Lawrence River - based on costs required to adapt plants to lower than critical levels.

Significant new study research included:

- New or refined nearshore elevation data obtained using state-of-the-art airborne light detection and ranging technology, traditional hydrographic surveying, existing shoreline mapping, and aerial photo-imagery, and including parcel level data on housing value and location for much of the Lake Ontario and St. Lawrence River shoreline;
- Field studies of lake and river wetland plants and animals to test hypothetical relationships between the health of those life forms and water level and flow patterns;
- At-site measurements of the depth of water available at almost every slip or marina entrance, private dock, and public launch ramp;
- Surveys of boaters to elicit their willingness to pay for better boating conditions;
- A sophisticated model of the interaction between Lake Ontario water levels, wind and coastal property, that could estimate the time of and damage caused by erosion and flooding, as well as the amount of maintenance required for existing shore protection;
- A model that tracked the movements of individual ships to determine how regulation plans would affect depths (which can cause shipping delays or require more ships to carry the same amount of cargo) and velocities (which can cause costly delays while navigation is stopped because of dangerous current conditions);
- A model that integrated all of the various environmental research studies into a platform on which environmental responses to different regulation plans could be visualized and assessed;
- An inventory of water supply and wastewater plants throughout the region, including information about the depth and location of intakes;
- A study of the circumstances driving hydropower prices and their effects on the benefits derived from water level regulation changes;
- A survey by the Public Interest Advisory Group of the concerns of people living near these waters;
- A statistically derived, 50,000-year water supply sequence that allowed plans to be tested under wetter and drier conditions than experienced in the last 150 years;
- Four water supply sequences that might occur later in the 21st century because of climate change induced by a higher concentration of carbon dioxide in the atmosphere.

The key findings from the technical work groups are summarized in Annex 2. Further information is available through individual documents that can be found through the Study website (www.losl.org). Highlights of the key findings from each of the technical work groups are summarized below:

Coastal

- The probability of flood damage along Lake Ontario can be estimated based on a combination of water level and time of year; damage is least likely when storms are least likely (i.e., in the summer).
- Erosion on Lake Ontario will occur regardless of the regulation plan. The difference between plans lies in how quickly it will happen. The current regulation of Lake Ontario under Plan 1958-D with Deviations has slowed erosion down by as much as 40 cm/year (16 inches/year) in some highly erosive locations along the Lake, compared with what it would have been without regulation.
- In general, higher water level regimes result in accelerated shoreline erosion. However, it has been found that low water levels can also exacerbate erosion and shore protection damage through erosion of the “toe” of the bank, leading to collapse of unprotected banks and the undermining of existing shore protection.
- The current regulation plan comes close to minimizing damages for Lake Ontario shoreline property owners. Even a plan that held the Lake Ontario level constant at 74.8 meters (245.4 feet) would improve benefits to Lake Ontario shoreline properties by less than $1 million U.S./year while causing large losses elsewhere in the system.
- As is the case for erosion, flooding on Lake Ontario has been significantly reduced by the current regulation plan relative to the unregulated condition.

- Shore protection maintenance on Lake Ontario is the aspect most affected by changes in a regulation plan. Even small differences in levels and the timing of levels can impact the overtopping and undercutting of shore protection.
- By comparison with some of the other interests, flooding on the lower St. Lawrence River does not represent huge economic damages, but the differences between plans can be significant, especially for the lower portion of the River downstream of Montreal around the Sorel/Lac St. Pierre area.
- Erosion on the lower river is not a major economic issue since most of the developed properties are already protected.
- Shore protection maintenance on the lower river does not vary much regardless of the plan evaluated.

Recreational Boating

- It is possible to develop a plan that results in increased boating benefits for all regions, with water stored on Lake Ontario providing extra depth for Lake Ontario boaters and extra supply to help river boaters during droughts.
- A key issue raised by recreational boaters throughout the system is the desire to maintain higher levels until later in the fall to extend the boating season and to make for easier boat haul-out.

Commercial Navigation

- The main difference between plans lies in the costs induced by shipping delays on the Seaway. There is usually enough water on Lake Ontario to keep ships fully loaded, and none of the plans is significantly better than the others in terms of avoiding shallow depths in the Seaway above the Moses-Saunders dam. The plans do differ in how well they maintain minimal acceptable levels on Lac St. Louis and at the Port of Montreal, especially during extended droughts.

Hydropower

- The operators of hydropower facilities benefit from high flows through their turbines, minimal spillage and higher operating heads, but also from predictable and stable flows. The less releases changes from month to month and from week to week, the better the plans are for hydropower.
- Hydropower benefits are greatest when releases are similar to what would occur without regulation (assuming regulation to limit ice jams in the winter and early spring). Natural releases create a higher average head at Moses-Saunders, result in very little spillage, and tend to be the most stable and predictable.

Municipal and Industrial Water Uses

- Municipal, industrial and domestic water use is generally not vulnerable to water level changes. The Study found that the Montreal system could be at risk later in the century, assuming that climate change induces the dry, hot scenario modeled in the Study.
- Other exceptions are the Russell and Ginna power generating stations and the County of Monroe potable water pumping and treatment plant on the south shore of Lake Ontario in New York State. The two power generating facilities report critical low water elevations for their cooling water intakes at levels within the historical record under the current regulation regime. However, the Study Board was informed that Russell is closing and Ginna would take measures to deal with this design flaw.
- The Monroe water pumping and treatment plant experiences flooding problems at Lake Ontario elevations within the historical maximum range.
- Shoreline wells, groundwater contamination and sewage overload were evaluated in terms of the recurrence of water levels likely to induce such problems, but not in economic terms, since impacts were either small relative to other categories or could not be estimated by plant operators.

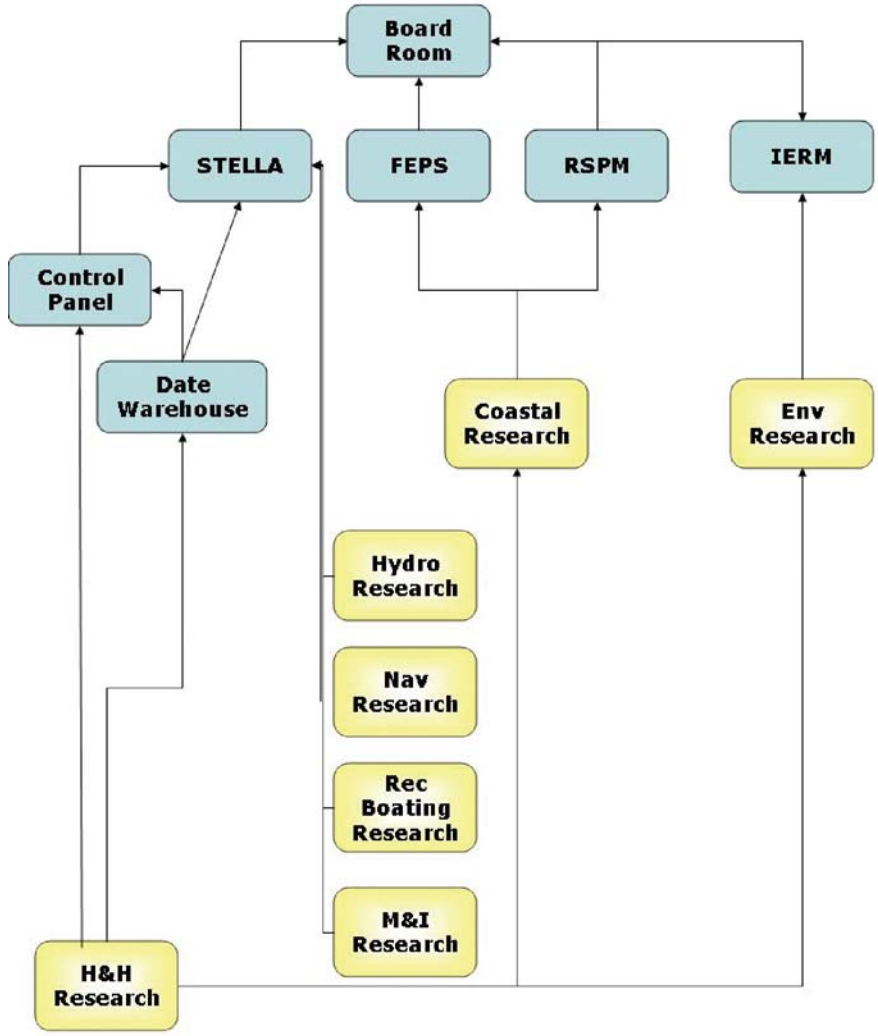
Environment

- Although construction of the regulation and navigation structures made dramatic changes in the environment of the St. Lawrence River, the lower river is less sensitive to changes in water level regulation than Lake Ontario and the upper river. This is because regulated releases are very diverse and span an even greater range than natural releases. The hydrology and hydraulic responses are different in the lower St. Lawrence River than on Lake Ontario because the lower river hydrology is influenced not only by the outflows from Lake Ontario, but also by the Ottawa River flow and by local tributaries.
- Current muskrat housing density above the Moses-Saunders dam is extremely low, so any improvement tends to create large positive ratios for this performance indicator. Muskrats constitute a very important part of both the structure and function of wetlands and they therefore represent much more than just their own species. As a result, muskrat housing density is an important environmental indicator to take into consideration.
- The current regulation plan (1958-DD) has stabilized lake levels, creating a more narrowly defined transition from submerged to upland plants, thus reducing the diversity of plant types along the shore and lowering the populations of animal species who fed on and lived in the environments harmed by more stable water levels.
- Indications are that the current regulation plan (1958-DD) has had an effect on the productivity of several species at risk.

The Shared Vision Model

The Shared Vision Model is the name of the computer model developed in the context of this Study to integrate the results from each of the technical work groups in one place. With this Model various regulation plans could be run through an evaluation process and the results compared between interests and locations. The Shared Vision Model connects all Study research to the guidelines the Study Board developed to identify the best alternative plans, and it integrates plan formulation and evaluation so that new regulation plans can be designed and immediately evaluated. The fact that specific mathematical connections had to be made between research products and the questions the Study Board wanted to address helped ensure that research funding was well spent and that important questions did not go unanswered. The Shared Vision Model creates a hypothetical link between the levels and flows produced by a regulation plan and the impacts of those levels and flows. The Shared Vision Model was built from scratch by the entire Study Team, enabling everyone involved to understand how actions taken to affect one part of the system or one interest affect all other stakeholders.

The Shared Vision Model developed for this study is actually composed of a pyramid of four models used to produce estimates of plan performance. They include the STELLA model, with dynamically linked Excel input files, the Flood and Erosion and Prediction System (FEPS), the St. Lawrence River Model (SRM) and the Integrated Ecological Response Model (IERM). The STELLA portion includes all of the system hydrology and all of the performance indicator relationships to water levels and flows for recreational boating, commercial navigation, hydropower, municipal. industrial and domestic water uses and lower St. Lawrence River flooding. FEPS estimates the potential flood, erosion and shore protection maintenance impacts on Lake Ontario and the upper St. Lawrence River. The St. Lawrence River Model (SRM) calculates the impacts of erosion and shore protection maintenance on the lower St. Lawrence River coastal interests. The Integrated Ecological Response Model is the environmental wing of the Shared Vision Model and calculates expected responses of environmental performance indicators to a regulation plan. The Control Panel and Data Warehouse are Excel files that store and feed data to the other models. The Board Room is an Excel file where all plan results are presented using tables and graphs.



Abbreviations

STELLA – Model programming software

FEPS – Flood and Erosion Prediction System

SRM – St. Lawrence River Model

IERM – Integrated Ecological Response Model

H&H – Hydrology and Hydraulics

Env – Environment

Hydro – Hydropower

Nav – Commercial Navigation

Rec – Recreational Boating

M&I – Municipal, Industrial and Domestic Water Uses

Figure 5. Structure of the Shared Vision Model

All of these models are linked in one or more ways:

- Outputs from one model are automatically written into other models;
- Model code from individual researchers is integrated into another model;
- Relationships in one model are developed from results of other models.

The structure was designed to make plan formulation and evaluation faster, less expensive and more reliable. This in turn fostered creativity and made the Study Team more willing to entertain suggestions for plans. The traditional method is much more fragmented:

- Individual researchers would conduct research and capture the results in their individual computer models.
- Plan formulators would then develop a few plans and send them to researchers to run through their models. Later runs often required the negotiation of new contracts with the individual modelers.
- Typically, inconsistencies in research frameworks would only be found late in a study, when one modeling, formulating and evaluation round was complete; this prohibited some evaluations or required costly and time-consuming model modifications.
- It typically took months to complete one cycle of formulation and evaluation, so few iterations were possible.

By dynamically integrating all the models into a Shared Vision Model from the outset, incompatibilities in the models, and even in the conceptual research frameworks have been discovered and corrected.

In this Study, plan formulation initially took place in the Control Panel and STELLA portions of the Shared Vision Model (Figure 5), and it was relatively easy to see what the plan rules were. Later, most formulation was carried out using some type of optimization, as well as software better suited to optimization, in a manner that allowed for iterative routing and forecasting. Evaluations using the "historical" water supplies (101 years of water supplies to Lake Ontario and the St. Lawrence River similar to those of the twentieth century) and the stochastic water supplies (495, 101-year sequences of water supplies) and climate change sequences were carried out in STELLA, FEPS, IERM and SRM by importing the releases from the optimization models into the Shared Vision Model. An explanation and clarification of the supply sequences used are reported in the next chapter.

Plan Formulation

The goal of the Study was to find a better way to regulate outflows from Lake Ontario, and plan formulation was the process used to invent new regulation policies. The formulation process was iterative. As the Study progressed, more data and research results were available to evaluate the plans that had been designed, and the reaction of the Study Board to the more sophisticated evaluations redirected the plan formulation efforts. Formulation evolved from two people adjusting alternative plans from previous studies, to four competing teams formulating plans using different methodologies based on ideas presented by the public, technical experts and Board members. The teams collaborated with each other in several plan formulation workshops, "benchmarking" the most successful results of each team so that the breakthroughs of one team could inform the other teams.

The four approaches that were developed included a rule-curve-based approach similar to 1958-D, two approaches using two different quasi-optimization methods with different hydrologic goals, and finally an approach which began with the pre-project condition and worked to reduce the extreme highs and lows.

All plans developed had to be based on the same assumptions so that their results would be comparable. The assumptions are outlined in a report titled "Summary of Constraints and Assumptions for Plan Formulation" (Fay, 2005) and can be found in Annex 3. The assumptions included maximum allowable outflow limits for the plans, maximum flow with ice limits, maximum outflow with open water in winter, maximum flow due to upper St. Lawrence River channel capacity, maximum level at the Iroquois Lock, and assumptions about when releases would be based on forecast or current input data.

Regardless of the approach taken, all plan formulators addressed the same planning objectives and attempted to achieve the greatest benefits for as many interests as possible while minimizing losses to any one sector. Hundreds of plan variations were developed using the four approaches and were then evaluated in the Shared Vision Model, with the results used to design changes in the next round of formulation. The Study Board held several "practice decision" workshops so that formulators had frequent feedback and oversight from the Study Board.

Approach 1: Basic Rule Curve Approach

This approach is very similar to that used for Plan 1958-D. Basic rule curves and seasonal flow adjustments are used to control the level of Lake Ontario, and a weighted supply indicator is used to forecast the supply condition and adjust the outflow accordingly. There are limits for the maximum plan release based on the estimated river outflow capacity. The rule curves are developed through a trial and error procedure.

Approach 2: Optimization/Rule Curve Approach

An optimization model solves for the release or set of releases that produces the best mix of benefits. In simple problems, a "perfect" solution can be found. In complex situations, optimization can help make trial-and-error solutions more efficient. In this formulation approach, an optimization model first developed at Cornell University was used to generate a family of rule curves for determining the release based on the current Lake Ontario level. Applying these rule curves alone produced some undesirable results, so plans were modified by adding adjustments and limits based on forecasts and other conditions in the system. Using this approach consistently created greater overall net economic benefits than other plan methods, and resulted in fairly simple plans because the seasonal adjustment and forecast were already built into the curves. The weakness of this approach was that releases tended to change too much from quarter-month to quarter-month, and losses to some stakeholders were larger than in other plans. Further work to reduce losses and limit the amount that releases could change from quarter-month to quarter-month achieved better results in the final plan developed with this approach.

Approach 3: Optimization of Water Levels (Balanced Benefits) Approach

The second optimization tested a wide range of releases each quarter month to see which optimizes the combined interests of the stakeholder groups. This approach, which did not produce rule curves, is an adaptation and refinement of the so-called Interest Satisfaction Model developed following the 1993 Water Levels Reference Study. In this approach, a point scale is established for a range of water levels, flows or other hydrologic metrics that measure how close a given metric is to the preferences of the major interests. Levels or flows that best serve the interests in question are awarded more points than those that harm the interests. A computer program iteratively calculates the total score for all the different metrics each quarter-month for many different releases then picks the release that maximizes the total score. A forecasting feature and some environmental constraints were added to improve the overall performance of plans generated using this approach.

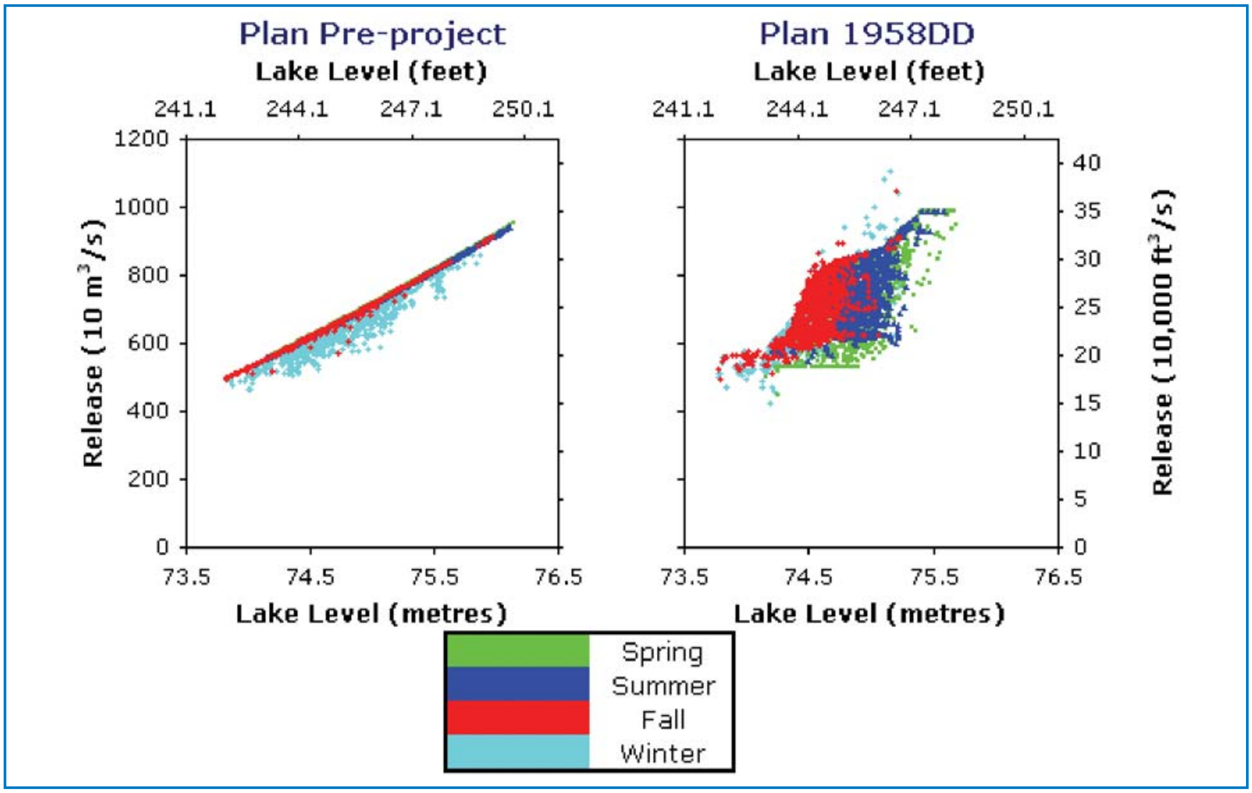
Approach 4: Based on Pre-project Plan

The final approach was quite different from the others, the goal being to return the Lake Ontario-St. Lawrence River system to a more natural regime, with conditions similar to those prior to the hydropower project development, while minimizing damages to present interests. Many have argued that natural flow patterns created the ecological balance found before the construction of regulation dams, and to a great extent, define the ideal with which regulated flow patterns should be compared. This approach uses "pre-project" releases as a starting point, and then adjusts releases based on short-term and long-term water supply forecasts. Rules are included to reduce the risk of flooding on the Lake and the River, and flow limits are applied to ensure minimum and maximum river flows, stable river ice development, acceptable navigation conditions, safe operating conditions for control structures, and controlled week-to-week changes in flows.

The term "pre-project" refers specifically to the conditions of March1955, referenced in the Orders of Approval for the project. Prior to regulation, Lake Ontario outflows were limited by the hydraulic capacity of the St. Lawrence River channel. Natural rock sills at the head of the Galop Rapids, just downstream of Ogdensburg and Prescott, formed the natural hydraulic constraint. This state is hydraulically similar to the natural state of the channel prior to 1900 (ILOBOE, 1958). Although the releases are similar to natural releases, the resulting water levels below the regulation dam may be different from what they would have been in 1900 because of modifications made to the River in the 1950s for the construction of the Seaway.

A stage-discharge relationship to estimate pre-project outflows was developed in the 1950s for the International St. Lawrence River Board of Control (ISLRBC) and was reviewed and re-developed by Caldwell and Fay in 2002. As with all regulation plans, plans based on the pre-project releases would function with the modern channel and structures in place in the international section of the River.

Pre-project releases tend to be very linear, with a direct relationship between water levels on Lake Ontario and releases through the dam, so the higher the Lake is the higher the releases. Comparison of the two graphs below, showing the pre-project releases versus Plan 1958-D with Deviations, reveals the much more linear relationship between releases and water levels under the Pre-project Plan versus those of 1958-DD. The second graph shows pre-project levels versus Plan 1958-DD since regulation began in 1960.



Figures 6 and 7: Plan releases versus Lake Ontario water levels for the Pre-project Plan and Plan 1958-DD

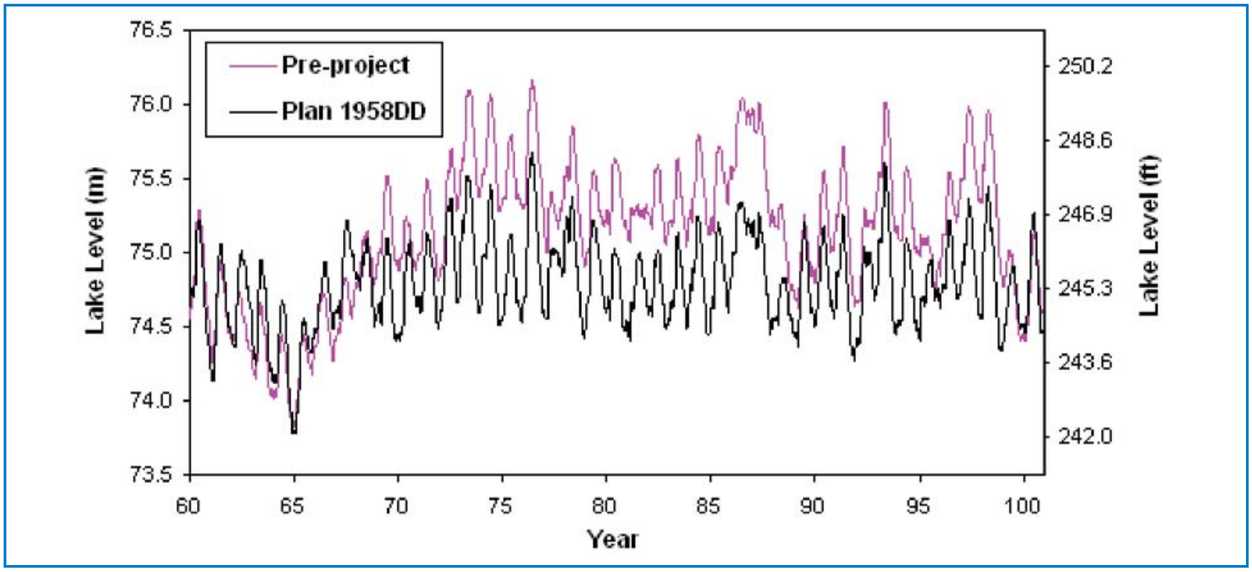


Figure 8: Comparison of Lake Ontario water levels for the Pre-project Plan versus Plan 1958-DD over the past 40 years of supplies

Evaluation and Screening Process

The evaluation of plans does not automatically indicate which plan is the most desirable. The Study Board needed to compare the evaluation results to see which mix of outcomes it prefers.

In this Study, the Board decided to rank plans using both economic and non-economic metrics, a widely accepted practice that reflects the idea that sustainable natural resource decisions must balance economic and environmental consequences and must be equitable. Because there was no universal environmental metric and because there was no presupposed translation between economic impacts and environmental benefits, the Study Board used a two-year long process to refine and document the logic it applied to reject plans because of their particular mix of economic and environmental impacts.

There has been a great deal of research and practice on the subject of making trade-offs. The "Trade-Off Analysis Planning and Procedures Guidebook" (Yoe, 2002) presents a good summary of decision methods. Yoe writes that "All multicriteria decision-making techniques are virtually identical in general concept. They each include a set of alternatives, a set of criteria, weights for the criteria and a trade-off algorithm (procedure)" and that they differ most in the last three steps of the decision-making process: the development of weights, synthesis and decision making itself. In this Study, the Shared Vision Model allowed planners to change plans and re-evaluate them within about an hour. That means there is a practical alternative to making trade-offs, which is to create a new plan that reduces the need for trade-offs.

The Study Board concluded that there was a better way to develop options for the International Joint Commission than using an analytical outranking approach. The plan ranking and rejection/selection process was designed to be similar to the medical concept of "informed consent." A dialogue over time was used to exchange research conclusions produced by experts and values expressed by the Study Board and the public in much the same way as a doctor provides expert medical knowledge and the patient tells the doctor what is most relevant and important in his or her situation until an informed consent to a particular approach is reached that both expert and impacted parties support.

The Study Board held seven "practice" workshops where it assessed evaluation results against its decision guidelines and then gave direction to the plan formulators. This process allowed the Board and other Study participants to explore the relative significance of different performance indicators to different parties, and it helped the Study Board to determine where trade-offs were unavoidable because the hydrologic conditions to produce benefits in different categories were truly incompatible. This philosophy was supported by the Study Board and the Public Interest Advisory Group, which asked the Plan Formulation and Evaluation Group to lead as many "practice" decision sessions to ensure that the real decision would be better. Practicing the decision:

- Forced all parties to make sure the studies being conducted produced the information needed to support a decision in a timely fashion;
- Stimulated debate about how to balance competing interests;
- Allowed the Study Board to focus on one part of the decision at a time;
- Gave the Study Board several opportunities to decide which are the key Study results that should be tested and displayed;
- Provided the Study Board with an opportunity to test and refine its decision guidelines and screening factors.

Each practice decision increased the Study Board's understanding of how regulation would affect the system and each led to improvements in the Study process. Full documentation of the highlights and lessons learned from each of the practice workshops can be found in a report entitled "Lake Ontario-St. Lawrence River Study Plan Evaluation, Ranking and Tradeoffs (Leger et al., 2005).

The Public Interest Advisory Group played a key interactive role throughout the Study process, systematically engaging various interests to provide their ideas, views, values and preferences to the Study Board and the Technical Work Groups. Stakeholder collaboration had a decisive role in the formulation and evaluation of all the options, as well as the final set of candidate plans that are presented in this report.

Plan Screening

The International Joint Commission requested that the Study Board not come forward with only one recommended plan, but rather that it provide a suite of three or four options. This meant the Study Board did not have to come to complete agreement on plans, but they did have to narrow the list of numerous potential regulation plans down to a set of desirable candidates.

The Study Board first tried to use their guidelines for ranking plans at a practice workshop in March 2004. The guidelines and an associated worksheet helped focus the discussion on evaluating draft plans. But while the Study Board found the guidelines helpful, they also found that the guidelines alone would not determine plan rankings, since the plans that were the best in terms of one guideline might be the worst in terms of another. At the end of this practice decision, the Study Board agreed that it preferred plans that did better than 1958-DD on each of the first three key guidelines.

1. Support the ecological integrity of the system
2. Maximize net benefits
3. Minimize disproportionate losses

As the practice decision workshops presented the Study Board with more specific, research-based performance evaluations, the Study Board found it needed to better define its decision guidelines. To do this, individual Study Board members volunteered to “captain” each guideline, preparing a discussion paper further defining the guideline and explaining how it would be applied in the decision process. These papers were reviewed by other Study Board members and debated in a teleconference series during the fall and winter of 2004-05.

Through this process the Study Board agreed that:

- The measure of a plan’s impact on ecological integrity would be represented by the plan’s performance indicator scores estimated in the Integrated Ecological Response Model;
- Net benefits would include both economic and environmental benefits;
- There would be no rigid mathematical calculation of what constitutes a disproportionate loss, but rather this would be a qualitative determination, based on the judgment of the individual Study Board members.

As a result of this process, the Study Board also developed new metrics or combinations of metrics that would make their decision easier or more defensible. For example, in order to make a more sound determination of what constituted a disproportionate loss, the Study Board asked the Plan Formulation and Evaluation Group to calculate the percent change in baseline activity under Plan 1958-DD for each plan and for every performance indicator.

Making Trade-offs

Despite the best efforts of plan formulators, no optimal plan was found that produces benefits to all interests and all regions, without any losers, when compared with Plan 1958-D with Deviations. As a result, the Study Board had to consider trade-offs. In doing so, the Study Board needed to ensure that comparisons could be made between interests. Fungibility is the degree to which performance indicators are measured in the same units. Early on in the Study process, the Study Board requested the development of an economics advisory committee to provide an arms-length assessment of the economic work being done within this Study. One of the issues the economics advisors were to address was that of fungibility. A full summary of the recommendations provided by the Economics Advisory Committee can be found in a report titled “Issues and Findings in the Economic Analysis of Water Level Management Plans Consensus Report of the Economics Advisory Committee” (Thomas et al, 2005). It is useful to note two recommendations in particular that influenced the format of the evaluation tables seen in this report. The economic advisors concluded that:

- All performance indicators should be constructed so that a positive number means that an interest gains net benefits from a plan and a negative number means that an interest loses net benefits from a plan, relative to Plan 1958-DD.
- Given the Study Board decision to avoid formulaic translations of environmental impacts to economic metrics, the Environmental Technical Work Group should develop performance indicators based as closely as possible on the economic concept of net economic benefits.

The Study Board's primary method of comparing the economic performance of the plans was based on average annual net benefits, measured in millions of U.S. dollars. Its primary method of comparing the environmental performance of the plans was to compare the ratios of each plan's performance indicator scores to the scores for Plan 1958-DD.

The Study Board relied heavily on the expert advice of the Environmental Technical Work Group in determining the best mix of environmental performance indicator scores (no plan improved all scores). At the request of the Study Board, the Work Group supplied error margins for their ratios to assist the Study Board in eliminating the noise and concentrating on those performance indicators that were truly impacted by a plan. For most environmental indicators, a ratio between 0.90 and 1.10 was generally taken to mean there was no significant change from 1958-DD, while anything above 1.10 was better and anything below 0.90 was worse.

In addition, the Study Board requested an overall index, and while the Environmental Group cautioned against the use of this index as an oversimplification of the results, the overall environmental index did assist the Study Board in understanding the significance of the environmental results. Information on the overall environmental index and how it was developed can be found in the Environmental Technical Work Group section of Annex 2 to this report.

The Study Board had considerable confidence in using the economic performance indicators to determine which plans are better for the various sectors. Many members of the Study Board placed greater emphasis on minimizing losses to any interest or region than on maximizing overall benefits for all interests and regions, which could create large losses in one or two areas.

Economic impacts were first developed using the historical water supply sequence, but the final results relied on discounted average annual benefits based on 495 samples of 101 years from the 50,000 years of stochastically generated water levels. This gives the Study Board more confidence that plan rankings are not just a function of the past 101 years of the hydrologic record. This is particularly important for the coastal erosion and shore protection maintenance performance indicators since these have serial dependence, and true benefit comes not from avoiding damage but from delaying it. This approach estimates when erosion or damage will occur, discounting future damages so that the later the damage the less important it is.

The Study Board also used water levels and flows produced by each plan to supplement their plan rankings based on performance indicators, including information on average, maximum and minimum levels provided by plans, timing of annual cycles, how plan hydrology differed in wet and dry extremes, and timing, magnitude and frequency of flow releases. This helped the Study Board to understand how a plan was reacting and adjusting to supplies. A number of Study Board members also found it easier to assess plans directly in relation to their levels and flows.

In summary, this Study has produced more and better data and information by which to evaluate plans than has ever been available before. With the information integrated into a Shared Vision Model, it has allowed for numerous iterations of plan development in attempts to reach the best balance between interests and locations. While there will always be gaps in understanding, the Study Board is confident that the information developed and analyzed is sufficient to ensure the best selection of regulation plans for managing the Lake Ontario-St. Lawrence River system.

Criteria and Regulation Plans

The Current Order of Approval criteria do not explicitly address environmental or recreational boating goals and needs and were designed for 1860 to 1954 water supply conditions, which have been since been exceeded. The new candidate plans represent a paradigm shift in regulation plan design from the rule curve concept of 1958-D to one of long-term optimization of plan performance in economic and environmental terms with no disproportionate losses. The candidate plans were tested over long-term stochastic water supply sequences that better represent future expected conditions to ensure plan robustness. Each of the candidate plans balances its objectives in different ways and degrees for all interests on Lake Ontario and the St. Lawrence River to attain benefits. This improves upon and is a more balanced approach than that followed in the 1952 Orders, which included, for example, the goal of reducing the range of Lake Ontario water levels and the concept of "no less protection" than that which existed prior to development of the St. Lawrence River Hydropower Project for downstream navigation and riparian conditions. The Study Board recognizes that there are conflicts among the water level related interests in time and space and has not attempted to prioritize the interests or conflicts among them. Instead trade-offs and balances have been sought among the interests.

Condition (i) of the 1952 Order of Approval as amended in 1956 specifies a series of criteria (a) through (k), which should be revised if Plan 1958-D continues to be applied, or need to be completely replaced if any one of the candidate plans A^+, B^+, or D^+ is selected for implementation.

Defining new criteria in the same form as those contained in the 1952 Orders as amended, poses enormous challenges in terms of translating, into the 50-year old criteria format, the many water level preferences, performance indicators for all interests, and three regulation plan optimization procedures. However, the Study Board has established plan objectives which are common for all plans, recognizing that each plan balances these objectives in different ways and degrees. The objectives are listed below in no particular order or priority.

1. Manage Lake Ontario outflows to promote a stable, smooth ice cover on the St. Lawrence River and prevent ice jams;

2. Minimize the frequency, severity and duration of damaging high and low water levels on Lake Ontario and the St. Lawrence River;

3. Allow high or low Lake Ontario and St. Lawrence River water levels during high or low water supply conditions to encourage the periodic flooding and drying of nearshore habitat during the growing season, under conditions similar to those experienced in unregulated conditions;

4. Allow Lake Ontario and St. Lawrence River water levels to rise during the spring to support fish spawning;

5. During the Seaway navigation season, minimize the frequency, severity and duration of flows in the St. Lawrence River that result in channel velocities that are not safe for commercial navigation;

6. Minimize the rate of change of levels on Lake Ontario and the St. Lawrence River;

7. Adjust the annual range and timing of water level variability on Lake Ontario and the St. Lawrence River to follow, as closely as possible, the natural water level variability that occurred before construction of the St. Lawrence River Hydropower Project;

8. Manage water levels and flows in the Lake Ontario-St. Lawrence River system to maximize the value of hydro-electricity generated from water flowing through the St. Lawrence River system and the amount of dependable energy available during peak winter and summer demand periods.

How each of the candidate plans interprets and applies these objectives is described briefly in the candidate plan descriptions later in this chapter and in more detail in the Plan Description section of Annex 3 to this report.

To attain a full, rich and complete description of plan criteria for an amended Order, a detailed operational guide document needs to be written for the selected plan. The steps for conversion of a selected plan to operational status are addressed later in this report as a transition issue. Once a plan is selected and this transition work is accomplished, it is proposed that a new "condition (i)" of a revised Order of Approval be cast in the following terms: "the outflows from Lake Ontario through the St. Lawrence River shall be regulated in accordance with the objectives stated herein and approved by the Commission. The inter-relationships and balance among these objectives are expressed in the attached operation guide for the approved regulation plan entitled Plan 2006."

Regulation Plan Descriptions

Plan Simulations

Alternative regulation plans were developed by plan formulators, as discussed in the previous chapter, and assessed using the historical supplies from 1900 to 2000, along with selected centuries from the stochastic supplies that included the driest century most severe Lake Ontario supply drought (S1); the wettest century which also had the largest range from wet to dry supplies (S2); a century that was very similar to the historical sequence (S3); and a century with the longest drought (S4). In addition, four supply sequences representing potential changed climate conditions that could occur roughly fifty years hence were analyzed. These four sequences represent very small samples of four possible climate change scenarios, and were used to ensure that the candidate plans would still function adequately if the climate transitioned in any of these ways. The results from the above-mentioned supply sequences are presented under the Sensitivity Analyses section of this report. Each of the candidate plans was also tested with the complete, 49,995-year stochastically generated sequence[3].

The plans were assessed by first computing the outflows from Lake Ontario that would be specified for a given 101-year series of water supplies to Lake Ontario and other hydrologic input data. These Lake Ontario outflows and hydrologic data were then used to calculate the levels of Lake Ontario and levels and flows at key points in the St. Lawrence River. These levels and flows were then used within the various components of the Shared Vision Model to calculate:

3 The water supply sequences were "time series data" used in a sequence by the models. The new rules were applied over and over again, in dry years and wet years, but the idea was to sample many examples of what the near future might be, not to move forward to a futuristic time.

- Hydropower energy and value;
- Commercial navigation shipping costs, including additional costs due to light loading, delays caused by steep gradients in the River, and delays incurred by ships waiting for enough depth;
- Municipal water plant costs for treating water during droughts and for improving infrastructure to allow the intake of water during droughts;
- Recreational boating impacts, using functions that related the value of the boating experience and the physical ability to boat during low and high water conditions;
- Flood damages;
- Damages due to erosion of unprotected properties on Lake Ontario;
- Damages to shore protection along Lake Ontario and the upper and lower St Lawrence River;
- The 32 key environmental performance indicators.

Baseline Plan

Plan 1958-D with Simulated Deviations (1958-DD)

Plan 1958-D "with deviations" was selected by the Study Board as the baseline for comparison purposes. Economic results are displayed as the net difference between the impact of an alternative plan and the impact of Plan 1958-D with simulated deviations (termed 1958-DD) in such a way that if a plan can improve things relative to 1958-DD, it produces a positive economic benefit, and if the outcome is worse than under 1958-DD, it produces a negative economic benefit. Environmental results are displayed as ratios of performance indicator scores under the alternative plan to performance indicator scores for Plan 1958-DD, so ratios greater than one indicate an improvement over 1958-DD and less than one a deterioration relative to 1958-DD.

Lake Ontario releases are now made using Plan 1958-D, but with deviations made under the direction of the International St. Lawrence River Board of Control. These deviations from the specified Plan 1958-D outflow have been made under different authorities granted to the Control Board by the International Joint Commission. Deviations are also allowed for conditions that Plan 1958-D is not flexible enough to address, such as management of ice in the River, which happens at different times in different ways each year. The "Criterion (k)" deviations refer to the criterion in the Orders of Approval that permits the Control Board to ask the Commission for deviations from the Plan 1958-D specified flow when water supplies are more extreme than the 1860 to 1954 supplies that Plan 1958-D was designed to manage.

A record of these deviations from Plan 1958-D exists for the period since regulation began under Plan 1958-D in 1963. Although needs have evolved since then, and the membership and perspective of the Control Board has changed, one might assume that similar deviations from Plan 1958-D would again be made by the Control Board given the same circumstances, both in terms of hydrology and user needs. Based on that assumption release rules were programmed that attempt to capture the logic of the Control Board, and those release rules were labelled "Plan 1958-DD." The resulting levels and flows from Plan 1958-DD can only be approximations of the actual historical flow decisions made by the Control Board. The Control Board logic has evolved over the decades and Plan 1958-DD used the logic of recent Boards with emphasis on the last decade. So the baseline plan is not meant to replicate the historical water levels and flows, but is meant to be a best estimate of how the Control Board would regulate levels in the near future. The degree to which Plan 1958-DD captures the current operating regime was tested by comparing the simulated and recorded levels and flow for the 1960 to 2001 period, again with emphasis on the last decade, since this was assumed to be representative of the present regime. Results of that testing and a full description of Plan 1958-DD are available in the Plan Descriptions section of Annex 3 to this report.

The programmed Plan 1958-DD was run through all of the time series sequences to provide the baseline against which all plans would be compared. To allow this comparison, all economic damages related to 1958-DD were set to equal zero such that any increase in damage was considered a negative benefit and any decrease in damages was considered a positive benefit. While all damages were set to zero for comparative purposes, this does not mean there are zero damages under Plan 1958-DD. For example, shoreline erosion damages are an ongoing phenomenon and occur with every regulation plan. The issue for plan evaluation is whether an alternative regulation plan will make things better or worse than Plan 1958-DD. The absolute economic damages for Plan 1958-DD can be found in Annex 3.

Since the environmental performance indicators were reported as ratios, there are no absolute damages available. However, it has been reported that the current Lake Ontario regulation plan has resulted in a loss of about 1,000 hectares (2,500 acres) of meadow marsh and 700 hectares (1,750 acres) of emergent-floating vegetation, with an equivalent increase of 1,700 hectares (4,250 acres) in cattail-dominated emergent marsh (Wilcox and Ingram, 2005).

The dynamics of regulation are very complex and have been fine-tuned for those interests that were considered to be most important 50 years ago. However, the present regulation has been detrimental to the Lake Ontario and St. Lawrence River (upper and lower) ecosystem, while riparian interests, commercial navigation and hydropower have generally benefited during the past four decades of operation.

Reference, Interest-Specific and Natural Flow Plans

Reference Plans

While the key focus of the study is to design new regulation plans, it is also incumbent upon the Study Board to use the Study's performance indicators to comparatively assess plans recommended in the past to the IJC, and to determine the impacts of adhering strictly to the written 1958-D regulation plan without deviations. The research and analytical tools developed within the Shared Vision Model for this Study allow, for the first time, a full, quantified assessment of the impacts of these alternative plans relative to Plan 1958-D with simulated deviations (1958-DD). The two plans modeled as reference plans were Plan 1958-D **without** deviations and Plan 1998.

As described in the introduction, Plan 1958-D is composed of three basic elements:
- Two rule curves (the second for drought that is used during a portion of the year, but only when Lake Ontario is below 74.47 m (244.33 feet)) that assign a specific release to every level of Lake Ontario;
- Adjustments to the rule curves to change the release based on the time of year and the recent trend in water supplies;
- Limits to constrain releases within maximum and minimum levels, to restrict the rate of change from week-to-week, and to reflect winter flow reductions designed to avoid flooding related to ice.

When evaluated based on supplies in the last half of the twentieth century, which was marked by both wetter and dryer periods, Plan 1958-D would allow Lake Ontario to rise higher than it would have without regulation, probably in violation of the Orders of Approval for the project.

Plan 1998 was developed by the International St. Lawrence River Board of Control following the 1993 Levels Reference Study. This Plan was developed within the scope of the existing 1956 Orders of Approval criteria. It is a modification of Plan 1958-D, and uses the same three-element structure. The limits of Plan 1958-D were modified so that the objectives of the Orders of Approval would be better met under the water supply conditions encountered since 1958-D went into effect. Plan 1998 also uses an ice indicator time series to allow more realistic simulation of the variability of ice formation timing from year to year. The plan was recommended to the International Joint Commission in June 1997. Public responses to the new regulation plan ranged from mild support to strong opposition. After full consideration of issues raised during the public meetings and comment period, the International Joint Commission determined that it did not have sufficient information on the environmental impacts and that Plan 1998 would not constitute sufficient improvement over the existing situation. The Commission decided not to adopt Plan 1998 for the regulation of Lake Ontario outflows at the time.

In brief, all the candidate plans the Study Board is advancing will outperform both Plan 1958-D and Plan 1998 in terms of net overall economic and environmental impacts. Plan 1998 is similar to Plan 1958-DD in its results and provides little overall economic or environmental gain. Plan 1958-D produces large economic losses in the coastal sector relative to 1958-DD. If lake levels were regulated using Plan 1958-D, given the range of supplies considered, lake levels would rise higher, causing hundreds of millions of dollars in flood damages, and during droughts, Montreal Harbour would first be a little higher, but eventually, as Lake Ontario drained, would be much lower than it would be under Plan 1958-DD. When tested under the wider range of the stochastic water supply conditions, both Plan 1958-D and Plan 1998 "fail" because Lake Ontario rises so high (over 80 metres (265 ft)) and falls so low (below 60 metres (197 ft)) that the mathematical relationships used in the model are no longer reliable estimates of conditions.

The economic and environmental performance of plans 1958-D and 1998 for the 101-year historical water supply case are presented in Annex 3 – Plan Descriptions and Results.

Interest Specific Plans

Using the plan formulation methods identified in the previous chapter, as well as other regulation ideas, plan formulation teams deliberately developed special interest plans for different stakeholder groups. Although these plans did not meet the Study Board's "no disproportionate loss" guideline, they were helpful in defining the upper range of possible benefits for a stakeholder group and assisted the teams in understanding the relationships between water levels and benefits.

A plan formulation approach that led to a plan called "OntRip3" sought to minimize flooding and erosion damages for the people who lived on Lake Ontario shorelines based on the interest satisfaction method. That effort helped explain why plan formulators were unable to create a balanced plan that performed much better than 1958-DD for shoreline property interests. OntRip3 created $550,000 U.S. in average annual benefits for Lake Ontario shoreline residents, with improvements in shore protection maintenance, flood and erosion damages. But it also reduced boating benefits on Lake Ontario by over $4 million U.S. and power benefits at the Moses-Saunders dam by over $5 million U.S. per year compared with Plan 1958-DD. Subsequent experiments with even more unbalanced plans – including some, such as maintaining Lake Ontario at a constant 74.80 meters (245.41 feet), which would be impossible to realize because of the huge releases required – showed that OntRip3 did define the maximum improvement possible for shoreline residents on Lake Ontario. The most expensive cost for coastal residents is maintenance of existing shore protection. Although residents associate higher water levels with greater shoreline erosion and damage to shore protection due to overtopping, lower levels cause more undercutting of the nearshore allowing greater wave energy to attack the bluff and shore protection when water levels rise once again.

An attempt to maximize recreational boating benefits led to the development of a plan called RecBoat. RecBoat created almost $4 million U.S. per year in recreational boating benefits, but created large losses at the Hydro Quebec power generating plants. The strategy behind the development of RecBoat was to use Lake Ontario as a reservoir, releasing just enough water to keep it in the best range for boaters while also maintaining Lac St. Louis levels above 21 metres (68.9 feet) during the boating season. This strategy often required substantial flow cutbacks after the boating season ended to preserve water for the following year. Because of the lower flows, Plan RecBoat reduced Hydro Quebec power benefits by an average of over $18 million U.S. per year and caused large flood damages in the lower St. Lawrence River as well as significant damages in terms of commercial navigation.

Other efforts showed that it was possible to greatly expand hydropower benefits, but that in terms of commercial navigation benefits, it was difficult to improve on Plan 1958-DD. Keeping Lake Ontario higher increases the head at Moses-Saunders, which greatly increases energy production and the value of that energy. The difference in annual energy value between Lake Ontario at elevations 74.0 and 75.0 meters (242.78 and 246.07 feet) approaches $100 million U.S. per year at higher flows. This is one of the reasons that the candidate plans tend to keep Lake Ontario a little higher on average (doing so also creates more stored water to help people along the St. Lawrence River during droughts). Commercial navigation can be impacted by very low water levels because ships cannot carry full loads, which means that more ships are required to carry the same amount of cargo. This is rarely a problem in Lake Ontario and often a problem in Montreal Harbour, where the water depths available are a function of the flows from the St. Lawrence and Ottawa Rivers. More important are the delay costs incurred by ships that encounter shallower depths than expected or dangerously high river velocities, which can stop ship traffic in the Seaway.

Natural Flow Plan: Plan E

Plan E attempts to replicate pre-project or natural flow conditions as closely as possible. It was developed based on pre-project releases as outlined in the plan formulation section of the previous chapter. Plan E follows the pre-project stage-discharge relationship, but additional rules have been incorporated to limit maximum flow releases in the winter in order to form and maintain a stable ice cover on the River and prevent ice jams, a requirement of all plans. These added rules cause the conditions and the results of this plan to differ from those that would occur under a purely unregulated system.

While Plan E is designed to approximate pre-project hydrologic conditions, it has not been designed to optimize the scores of the environmental performance indicators. Indeed, under this Plan, some environmental indicators are actually reduced. Nonetheless, it is believed that returning the system to its pre-project state would be most conducive to supporting the regeneration of the flora and fauna in the system, and this approach is backed by the Environmental Technical Work Group as the best possible plan for the environment.

Although many Study Board members believe that the environmental objectives of Plan E should be considered a longer-term management goal for the system, they recognize that because of historical economic development, there are considerable adverse economic impacts associated with Plan E.

The releases for this plan are calculated according to the pre-project Lake Ontario stage-discharge relationship developed by Caldwell and Fay (2002). The term to account for differential crustal movement has been fixed to simulate conditions as they would be in the year 2010. The historical pre-project winter ice retardation effects are included in the determination of the pre-project flow.

During winter ice formation, the plan invokes rules to limit the maximum release in the winter in order to form and maintain a stable ice cover on the River and prevent ice jams. These ice limits are similar to those established for Plan 1998 and as identified in the plan formulation guidelines (Fay, 2005) and used for the candidate plans. The ice limits as specified are flexible and respond to the state of ice conditions in the River. The ice limits apply whenever an ice cover is forming or has been established in the Beauharnois Canal and/or the international section of the River. An ice status indicator is used to determine if the ice limits apply for the period. The ice limit maximum outflow is 6,230 m^3/s (220,000 cfs) if an ice cover is forming in the Beauharnois Canal and/or the international section of the River in the period concerned. Once the ice cover has formed, the ice limit maximum outflow is the flow estimated to produce a level of 71.8 meters (235.57 ft) at Long Sault Dam. In addition, to prevent large flow changes from breaking up the ice cover and potentially causing an ice jam, a week-to-week flow fluctuation limit is imposed if there is an ice cover on the River. Plan E also has an overall maximum outflow limit of 11,500 m^3/s (406,000 cfs) that applies at all times to protect the integrity of the control structures at Beauharnois and Coteau.

On Lake Ontario, Plan E produces many more high levels than 1958-DD, with much higher peaks and similar lows. Lake Ontario levels are more variable, with as much as a 3.5 metre (11.5 ft) range possible with stochastic supplies.

Figure 9 shows a comparison of the average Lake Ontario levels under Plan E and Plan 1958-D. Figure 10 shows a “zipper plot” displaying the range of levels on Lake Ontario that occur under Plan E with stochastic supplies. The legend below Figure 10 helps explain the graph symbols. (This legend should be referred to for all subsequent “zipper plots” in this report). Similar plots for Montreal Harbour are shown in Figures 11 and 12, respectively.

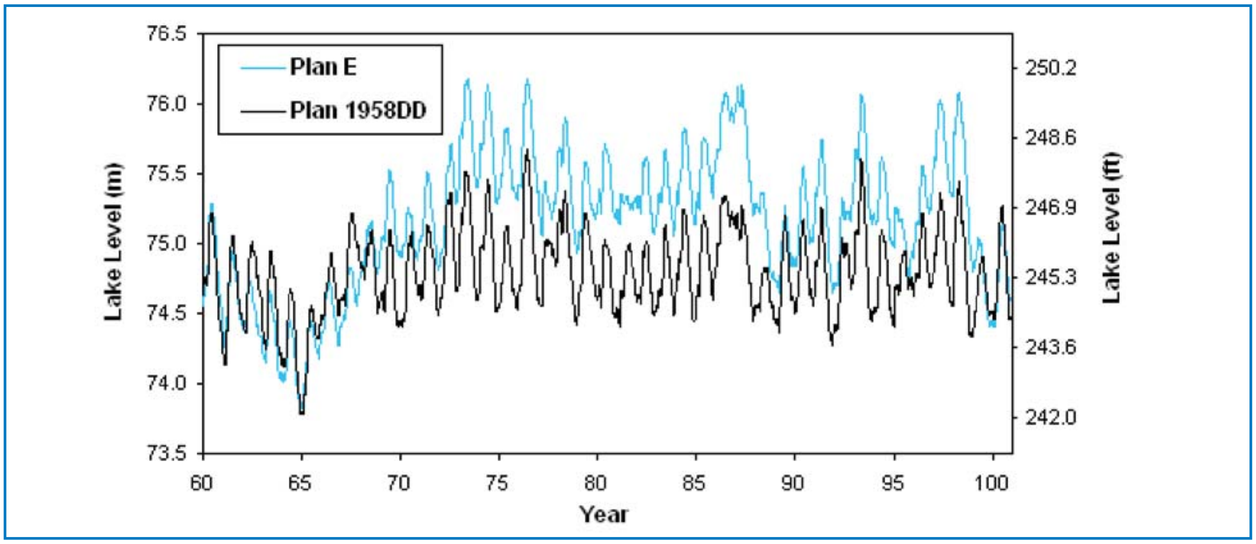


Figure 9: ***Comparison of Lake Ontario water levels for Plan E vs. Plan 1958-DD for the past 40 years of the historical simulation***

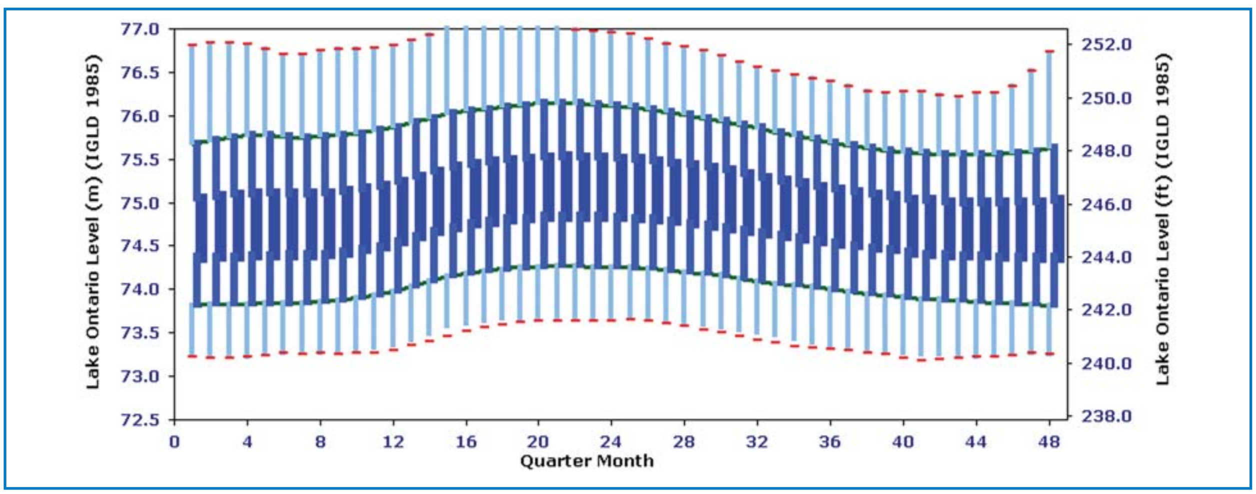


Figure 10: ***Plan E – Levels on Lake Ontario over the 50,000-year stochastic supply sequence***

Legend for all “zipper plots” in this Report:

Plan E generally produces a smaller range of flows in the St. Lawrence River with a more natural seasonal pattern and smoother week-to-week releases.

On the lower St. Lawrence River in the Montreal region, Plan E produces lower low levels and much higher peak levels.

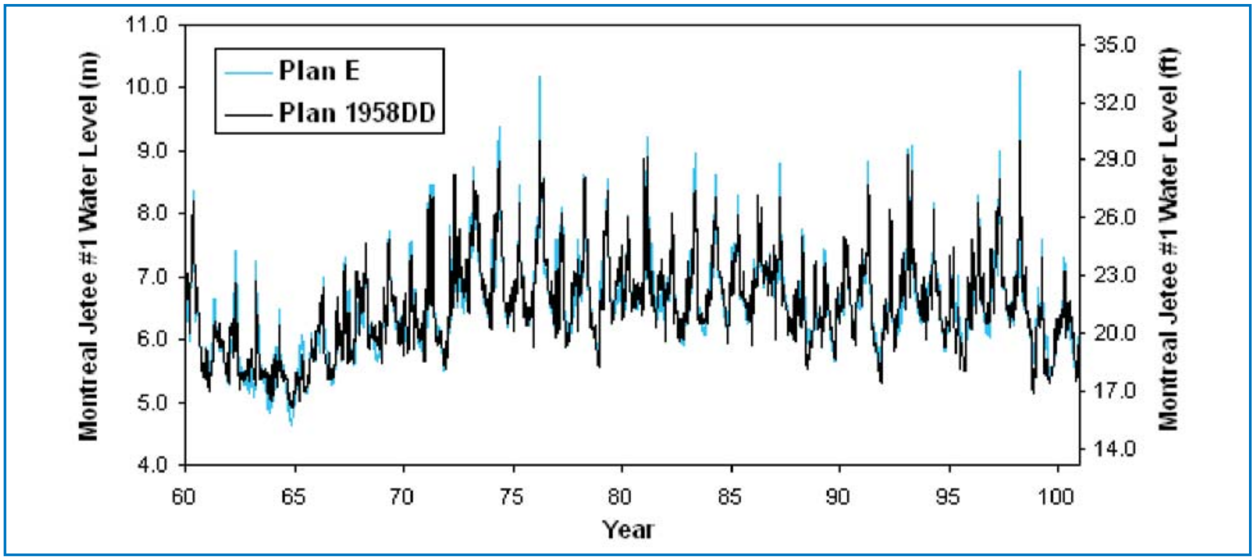


Figure 11: ***Comparison of Montreal Harbour water levels for Plan E vs. Plan 1958-DD for the past 40 years of the historical simulation***

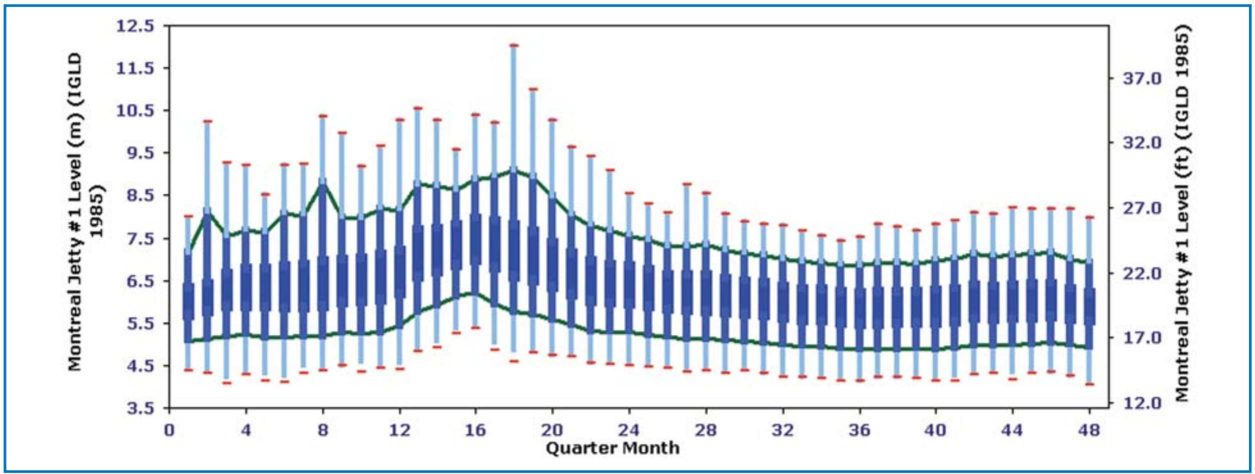


Figure 12: ***Plan E – Levels at Montreal Harbour over the 50,000-year stochastic supply sequence***

Other Plans

The Study Board considered a number of other plans that were evaluated using the Shared Vision Model, but discarded because their results did not meet the Study Board's primary guidelines of providing net economic and environmental benefits, or because they produced results similar to those of another of the candidate plans, but slightly inferior. One example is Plan C. Plan C was developed using the rule curve approach described in the plan formulation section of the previous chapter. Plan C has a similar foundation as the 1958-D plan, but adjusts and adds a number of limits to better satisfy the Study Board's guidelines. While this plan had fairly good results, the Study Board did not feel it was distinct enough from Plan D+ to warrant going forward, and Plan D+ provided better overall economic and environmental results.

Candidate Regulation Plans

This Section explains the objectives and impacts of the regulation plans that the Study Board examined and decided were the best plans to present to the International Joint Commission as options. Preliminary versions of each of these plans were presented to the public during the summer of 2005, and each was then modified based, in part, on the public input they received. The three candidate plans have all been labeled with a "+" sign to indicate that these plans have been modified/improved since they were last presented to the public.

The Study Board believes that each of these three "candidate plans" represents distinct, yet reasonable efforts to improve on Plan 1958-D with Deviations in terms of providing more balanced economic and environmental benefits. The candidate plans are the focus of the full evaluation, comparison and rankings. Plan E is presented along with results of the candidate plans to provide reference for the unregulated condition.

In what follows, three types of information are provided for each Plan:
- **Plan Descriptions:** The plan's objectives and over-all approach are briefly explained. This material is taken from the plan descriptions contained in Annex 3 to this report.
- **Plan Evaluations:** A brief description of the plan's major impacts and benefits is presented. The impacts of each of the plans are divided into the following categories: hydrologic, economic, environmental and equity. A set of graphs and tables provides quantitative evidence of the plans' impacts compared with those of Plan 1958-DD.
- **Plan Comparisons:** The candidate plans are assessed in relative terms against one another and in relation to Plan 1958-DD. The key facts and important pros and cons of each of the plans are highlighted and discussed.

Plan A+: Balanced Economics

Plan A+ was developed based on the optimization/rule curve approach described in the plan formulation section in the previous chapter of this report. It is termed the Balanced Economic Plan because it focused on producing the best overall economic scores for each interest. Environmental targets were not included in the optimization, but were evaluated and addressed with adjustments to the plan to cover environmental shortcomings. This plan produced the highest overall economic scores of the three candidate plans, but the lowest environmental scores.

Plan A+ used an optimization model to generate a rule curve for each quarter month relating lake level to a prescribed Lake Ontario outflow. The optimization model minimizes expected differences from targets for the outflow and for Lake Ontario, Lac St. Louis, Montreal Harbour, and Sorel levels. Each of these targets varies through the year and was derived from relevant performance indicators or other similar sources. The optimization procedure minimizes the likely deviation from these desired targets given uncertain future inflows. The model uses a probabilistic approach to account for the uncertainty of these future inflows.

An early version of Plan A was presented at the January 2005 workshop. It produced major benefits for hydropower and downstream boaters, but had damages for upstream boaters and coastal property owners above the dam. In addition, the flows produced by applying this Plan's rule curves were seen as too unstable – flows changed too much from quarter-month to quarter-month. As a result, this regulation plan was modified in several ways.

First, a new family of rule curves was generated by adjusting the targets and weights in the optimization and then adjusting the new rule curves slightly in order to make releases more stable. Applying the new rule curves in the Shared Vision Model showed some improvements, but there were still increased flood damages, flow instability and other problems. As a result, flow limits and other modifications were added to the plan. Ice limits were already being applied. A limit to prevent floods at Lac St. Louis was added using a forecast indicator developed by the Plan Formulation and Evaluation Group. This limit tries to keep Lac St. Louis below 22.5 m (73.8 ft) during the spring freshet. An additional limit was added to address the flow stability issue. Finally, an adjustment factor was added to reduce releases during dry periods or increase releases when supply conditions are wet.

Plan A^+ strives to follow a set of 48 different release rule curves (one for each quarter month) that were developed based on an optimization of a set of target levels. The Plan makes adjustments based on forecasted wet or dry conditions to increase or decrease the set of rule curve releases. The plan will invoke a rule to smooth releases if the current Lake Ontario level is less than or equal to 75.55 m (247.9 ft); however, this rule is not applied if the lake level is higher than 75.55 (247.9 ft) so releases can be increased fast enough to avoid flooding on Lake Ontario. A limit is applied to constrain flow changes from week to week. However, as specified in the plan formulation guidelines, this limit is superseded by an ice limit designed to satisfy flow reductions aimed at avoiding downstream flooding; the limit is based on a freshet perfect forecast indicator and adjusted according to current Lake Ontario levels.

Plan B^+: Balanced Environmental

Plan B^+ strives to return the Lake Ontario-St. Lawrence River system to a more natural regime, similar to conditions that existed prior to the St. Lawrence Seaway and Hydropower Project, while minimizing damages to present interests. The basic premise behind this Plan is that any movement towards a more natural regime would be beneficial for the environment. This Plan does provide the best scores of the three candidate plans for the environment on the Lake and upper river, while also creating overall economic benefits.

The goals of the Plan are to maintain stability of lake releases, maintain the timing of a natural seasonal hydrograph, and obtain the inter-annual highs and lows required for healthy vegetation habitats. The Plan uses short-term and long-term forecasts of supplies in conjunction with the pre-project stage-discharge relationship to determine lake releases. Lake releases are primarily a function of a sliding rule curve, based on the pre-project stage-discharge relationship, that adjusts to long-term supply conditions. Lake releases are forecast for the next four weeks, then averaged to determine the current week's release. Flow limits, adopted from Plan 1998 with some modifications, are applied to ensure minimum and maximum river flows, stable river ice development, acceptable navigation conditions, safe operating conditions for control structures, and controlled week-to-week changes in flows. Plan B^+ also has two additional rules to reduce the risk of flooding upstream and downstream and two rules to ensure the integrity of control structures. Additionally, the fall drawdown during years with a high risk of next spring flooding was delayed until after the Labor Day holiday weekend to accommodate recreational boating. This approach preserves the natural timing of the lake's seasonal rise and fall and gradual week-to-week flow changes. It also strives to preserve the longer term rhythm of year-to-year changes in lake levels while reducing extreme highs and lows.

To reduce the risk of Lake Ontario and St. Lawrence River flooding in the following spring and summer, it makes storage available for reduced flows during the Ottawa River freshet. It does this by applying a rule to adjust releases whenever the Lake Ontario level is above 75.0 m (246 ft) at the beginning of September, and it strives to lower Lake Ontario to 74.8 m (245.4 ft) by January 1. If the one-week forecast of the Lac St. Louis level at Pointe Claire indicates the gauge may rise above flood levels, the plan applies a 3-tier rule that attempts to balance upstream and downstream flood damages. If Lake Ontario is less than 75.0 m (246 ft), lake releases are constrained to keep levels at Pt. Claire below the alert level of 22.1 m (72.5 ft). If Lake Ontario is at or above 75 m, but less than 75.2 m (246.7 ft), flows are limited to keep Pt. Claire below the action level of 22.33 m (73.3 ft). Above 75.2 m (246.7 ft), lake releases are limited to keep Pt. Claire below 22.5 m (73.8 ft). This rule uses a one quarter-month forecast of Ottawa River and local tributary inflows.

The Plan then checks to see if its releases need to be reduced to limit flows through the Hydro Quebec Coteau control structure for safe operation. Given a perfect forecast of Lake St. Francis local inflows and of the maximum capacity of Beauharnois, Lake Ontario releases are reduced to limit flows through the Coteau structure to 2,500 m^3/s (88,300 cfs) during ice conditions, and 4,000 m^3/s (141,300 cfs) otherwise. Finally, the Plan checks to see that water levels at the Iroquois Lock will not exceed 75.6 m (248 ft). This final constraint overrides all others to preserve the ability to control lake releases.

Plan D⁺: Blended Benefits

Plan D⁺ is a benefit balancing plan combined with short-term forecasting of contributing water supplies. The intent of this Plan is to increase the net economic and environmental benefits of regulation compared with those of Plan 1958-DD without disproportionate loss to any interest.

The benefit balancing considers the needs of the interests in the Lake Ontario–St. Lawrence River system downstream to beyond Montreal. A set of seasonally varying mathematical relationships was developed based on the expressed water level or flow preferences of the interests and other information used in the performance indicators in this Study. These relationships assign a score to a particular flow or water level at one of a number of sites on the Lake or River. The closer the water level is to the preferred level at a location for the given time of year, the higher the score. The rate at which the score in each relationship changes as the level rises above or falls below the optimum was adjusted using the performance indicators of this Study. In order to maintain stability of Lake releases, another relationship reduces the score as the week-to-week flow fluctuation increases. To improve key wetland habitat diversity, which requires periodic years of lower Lake Ontario levels, the preferred Lake Ontario level in the growing season is lowered if there has not already been a period of low levels in the past twenty years and water supply conditions are favourable. These relationships are used together in a quasi-optimization approach to determine Lake Ontario releases in each quarter-month or week. Releases are constrained by ice formation and ice roughness factors and by multi-stage minimum and maximum flow limits that vary with the hydrologic supply conditions. For details on the relationships and limits used in this Plan refer to the plan description in Annex 3 to this report.

This Plan chooses its releases based on the maximum total benefits indicator score. The plan begins by checking on the forecasted water supplies to Lake Ontario, the Ottawa River and local flows to Lac St. Louis, the annual net total supplies, and the ice roughness and cover for the coming week; it then calculates the smallest trial Lake Ontario release (typically, the present flow minus 400 m^3/s (14,100 cfs) or the minimum flow limit, but this may be less if needed for ice formation or in more extreme level conditions). With the forecast conditions and the trial release, the plan then calculates the trial water levels for Lake Ontario and the St. Lawrence River using known stage-storage and stage-discharge relationships. It then calculates the benefit indicator for each relationship for this trial flow and applies the optimization factors and sums the individual benefit indicators to determine the total score for the trial flow. If the trial flow is less than the maximum flow (typically, the present flow plus 400 m^3/s (14,100 cfs) or the maximum flow limit, but this may be more in extreme level conditions), the plan increments the trial flow by 10 m^3/s (350 cfs) to obtain the next trial flow and repeats the process until it finds the release with the best total benefit indicator score.

Plan Evaluations and Comparisons

Plan evaluation is the process of measuring and assessing the expected outcomes of newly designed regulation plans. The Shared Vision Model was used to estimate the outcomes in terms of the water levels and flows and the economic and environmental changes the plans would produce. The results were displayed in the “Board Room,” a series of Excel spreadsheets that integrated the results of the components of the Shared Vision Model.

In addition to the evaluation of plans using the historical supply sequence, all of the candidate plans along with 1958-DD and Plan E were run through the full 50,000-year sequence of stochastic water supplies. This stochastic analysis is very important in terms of obtaining the most reliable economic evaluation of the plans. This is particularly significant for the coastal erosion and shore protection maintenance performance indicators since these have serial dependence, and damages cannot be completely avoided, only delayed. The best way of assessing plans, then, is to determine which one delays or postpones coastal damages to a later time. The damages are then discounted to a present value. Impacts were analyzed over a thirty-year period using a 4% discount rate as recommended by the economic advisors. Plan rankings did not change when different discount rates and evaluation periods were used. In terms of choosing plans, the Study Board decided that the only legitimate comparative analysis of economic benefits and costs among the various plans should be based on the stochastic hydrologic sequence alone, rather than the historical record. The environmental results are based on the historical sequence because the Integrated Ecological Response Model had not been adapted to run through the 50,000-year sequence. However, the environmental results are available for the four 101-year stochastic scenarios. In addition the Environmental Technical Work Group ran an adapted wetlands model through the 50,000-year stochastic series and found plan rankings to be consistent with the historical results.

The Importance of the Stochastic Analysis

We know the future will not be a repeat of the past; especially when it comes to the weather that drives the water supplies in the Great Lakes–St. Lawrence River system. Even without the effects of increased greenhouse gases in the atmosphere, we can be confident that there will be periods of higher and lower supplies sometime in the future due to the natural variation in climate. The challenge in developing a new plan is to devise tests for candidate plans that prove whether they will work well whatever the future climate brings. To make sure the candidate plans would perform well, the Study Board tested them using a stochastically generated supply sequence to evaluate their hydraulic range and economic benefits. Wetland type extents were also calculated over this range for all candidate plans.

When Plan 1958-D was designed and tested, its authors measured its performance using the water supplies that had been experienced from 1860 to 1954. Almost as soon as it went into effect, it became apparent that it would not perform well because the test had been too limited. Had Plan 1958-D been strictly adhered to during the drought of the early 1960s and the wet periods since, Lake Ontario levels would have been lower and higher than they would have been without regulation, and in the late 1980s, they would have destroyed many houses along the shoreline.

The Study Board asked for a stochastically generated hydrologic test series to avoid these problems. This large sample of possible future hydrologic conditions also proved necessary to properly estimate the time value of erosive losses. "Stochastically" generated here means that a computer model was developed to produce a 50,000-year sequence of supplies to each of the Great Lakes, the Ottawa River and other downstream tributary flows, based on the statistical characteristics of the twentieth century supplies. The stochastic hydrology model included the important probabilistic relationships between the supplies from one year to the next, their seasonal patterns and their quarter-month to quarter-month correlations. The stochastic model also preserved other important statistical properties of the system, such as the varying length of drought periods and high supply periods, and the cross-correlation of supplies among basins (i.e. the probability that wet or dry conditions would occur in the various drainage basins at the same time). Each of these characteristics of the hydrology has a natural random component. This randomness is also captured in the stochastic model so that the 50,000-year generated sample contains a distribution of possible hydrology composed of mostly typical supplies with the appropriate number of rare and extremely rare events needed to fully test the regulation plans. A full description of this model is presented in the report "Stochastic Modeling and Simulation of the Great Lakes–St. Lawrence River System" (Fagherazzi et al, 2005).

Once generated using the stochastic model, the 50,000-year series of supplies to each of the Great Lakes was then entered into the Coordinated Great Lakes Regulation and Routing Model (CCGLBHHD, 2004) to produce a series of Lake Erie outflows, which, combined with the supplies to the local Lake Ontario basin, make up the total supplies to the Lake Ontario basin.

In order to keep the programming protocols the same as the 101-year historical supply based models, the 50,000 year sequence was shortened slightly to 49,995 years, or 495 sequences of 101 years each.

The full stochastic evaluation of plans is best for comparing average annual benefits and for estimating the expected timing of coastal erosion damages. Our analyses showed that coastal erosion and damage to shore protection structures is inevitable (i.e., it happens under all regulation plans), so the only difference between plans is how fast the damage happens, and that is a function of both the plan and the future sequencing of wet and dry supplies. Since that sequence is unknown ahead of time, the Board calculated damages for 495 supply sequences, each 101 years long, then determined the average erosion likely in the first year of plan implementation by averaging the erosion caused in the first year of each of 495 trials, and so on for the second, third and each year beyond. Had the Board attempted the same simulation using only the historical supplies, it would have been a good estimator of the future only if the supplies of 1900 were similar to the supplies in 2007, 1901 the same as 2008, and so on. The odds of this happening are next to zero. The panel of economic experts approved this approach. This is the first time erosion damage around a lake has been calculated using this rigorous, correct method.

Table 3 highlights the difference in absolute damages under Plan 1958-DD between the historic time series and the 50,000 year stochastic time series.

Final evaluation results can be found in the Study website "Board Room," and all results presented in this report have been taken directly from the Board Room dated September 19, 2005. All economic results are presented in U.S. dollars and, unless otherwise noted, are based on the September 2005 exchange rate with the Canadian dollar of 0.833. All levels are reported relative to the International Great Lakes Datum (IGLD 1985).

Table 3: Differences in Absolute Damages[1] between the Historic[2] Sequence and 50,000 year Stochastic[3] Sequence under Plan 1958-DD

Performance Indicator	*1958-DD Difference Between Historic[2] and 50,000 yr Stochastic[3] ($ US million)*	*Explanation*
COASTAL	**-$4.33**	
Lake Ontario	*-$4.87*	Discounting impacts makes a difference for coastal impacts, which occur at irregular intervals in the future. Discounting can only be applied to stochastic damages. The stochastic estimates of Ontario coastal damages are greater than historic.
Shore Protection Maintenance[4]	-$3.26	
Erosion (unprotected developed parcels)[4]	-$1.44	
Flooding	-$0.17	
Upper St. Lawrence River	*-$0.01*	
Flooding	-$0.01	
St. Lawrence	*$0.55*	
Flooding	$0.43	Historic impacts are greater than stochastic.
Shore Protection Maintenance[5]	$0.12	
COMMERCIAL NAVIGATION	**$1.06**	
Lake Ontario	$0.00	Stochastic estimates of Seaway and Montreal navigation costs are slightly less than historic.
Seaway	$0.87	
Montreal down	$0.18	
HYDROPOWER	**-$3.86**	
NYPA-OPG	-$2.92	The stochastic estimate of the marginal value of energy to society is slightly lower than the historic.
Hydro Quebec	-$0.94	
RECREATIONAL BOATING	**$0.92**	
Above Dam	*$0.61*	
Lake Ontario	$0.36	
Alex Bay	$0.23	
Ogdensburg	$0.00	
Lake St. Lawrence	$0.02	
Below Dam	*$0.31*	
Lac St. Louis	$0.05	The stochastic estimates of lost recreational value are slightly lower than the historic estimates.
Montreal	$0.20	
Lac St. Pierre	$0.07	
M&I	**$0.00**	
SL One time infrastructure costs	$0.00	There is no difference in the estimate of the costs of M&I impacts.
LSL Water Quality Investments	$0.00	

Notes to Table 3:

1. Results are differences in absolute average annual values ($ million U.S.) with all numbers representing damages avoided. Positive numbers indicate that the stochastic analysis results in greater benefits for an interest than does the analysis based on the historical series. Negative numbers indicate that the stochastic analysis results in smaller benefits than the historical analysis
2. Historic sequence represents supplies from 1900 to 2000.
3. The 50,000 year Stochastic is a statistically generated sequence based on historic supplies (actually 49,995 years).
4. Coastal Erosion and Shore Protection on Lake Ontario are discounted damages for All Stochastic but regular (non-discounted) damages for all other supply sequences.
5. Lower St. Lawrence River shore protection is based on the average of four 101-year stochastic simulations and the historic supply sequence since the St. Lawrence River Model component of the Shared Vision Model was not able to be adapted to run the full 50,000 year stochastic series.

Plan Hydrology

Plan A+ tends to produce higher Lake Ontario levels than 1958-DD most of the time but has lower peak levels. It has higher minimum Lake Ontario levels than 1958-DD. Its average St. Lawrence River flows are higher than 1958-DD in the late spring and early fall, but lower in the winter. It has larger and more frequent peak flows on the lower river. Plan A+ results in higher peak levels, lower low levels, and different timing of levels.

Plan B+ produces higher Lake Ontario levels on average than 1958-DD, except in the summer. As a result, the lake levels tend to decline less from summer to winter. On average, in the case of Plan B+, the timing of the annual peak Lake Ontario level is earlier in the spring. Plan B+ also results in higher lake levels somewhat more frequently than 1958-DD. In order to mimic nature, Plan B+ lake levels vary more from year-to-year than 1958-DD. On average, Plan B+ produces higher flows in the spring and lower flows in the fall than 1958-DD, but results in smaller week-to-week flow changes providing more stable, predictable flows. On the lower river, Plan B+ typically causes higher spring peaks and lower fall levels than 1958-DD.

Plan D+ produces similar Lake Ontario levels as 1958-DD, with slightly higher summer levels and slightly lower winter levels. The peak lake levels are about the same as those produced by 1958-DD. On average, Plan D+ is associated with lower spring flows than 1958-DD and higher summer and fall flows. It results in smaller peak St. Lawrence River flows than 1958-DD. Levels on the lower river tend to be slightly lower in the spring and higher in the summer and fall than those produced by 1958-DD. Plan D+ also results in about the same peak and minimum levels in the Montreal area as 1958-DD.

The following graphs (figures 13-28) represent simulated annual water levels produced by each of the candidate plans and Plan 1958-DD, under the 50,000-year stochastic supply sequence, for four locations: Lake Ontario, the upper St. Lawrence River at Long Sault, and the lower St. Lawrence River at Lac St. Louis and Montreal Harbour.

Following these graphs, a second set of graphs (figures 29-33) compare the three candidate plans and 1958-DD in terms of their average levels, the levels exceeded 1% of the time (maximums) and the levels exceeded 99% of the time (minimums) in each week of the year, for the same four locations, based on the 50,000-year stochastic supply sequence.

Lake Ontario

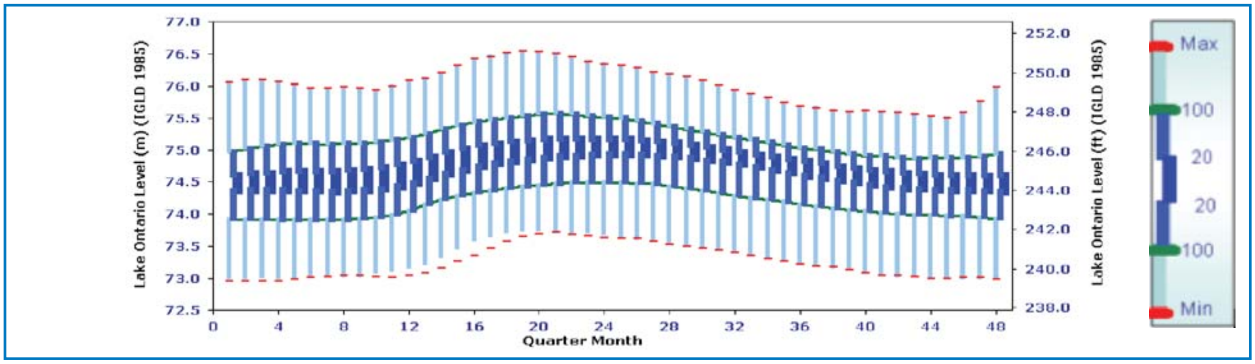


Figure 13: Lake Ontario annual water levels for the 50,000-year stochastic sequence for Plan 1958-DD

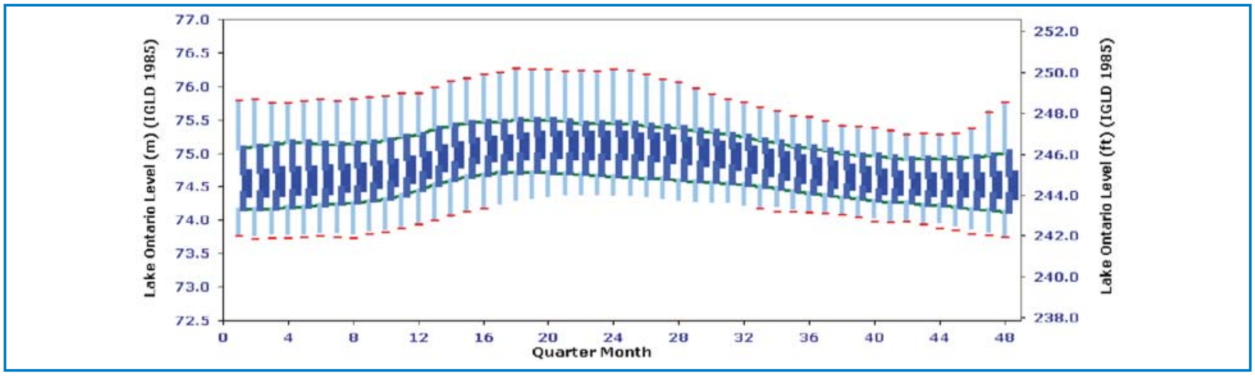


Figure 14: Lake Ontario annual water levels for the 50,000-year stochastic sequence for Plan A+

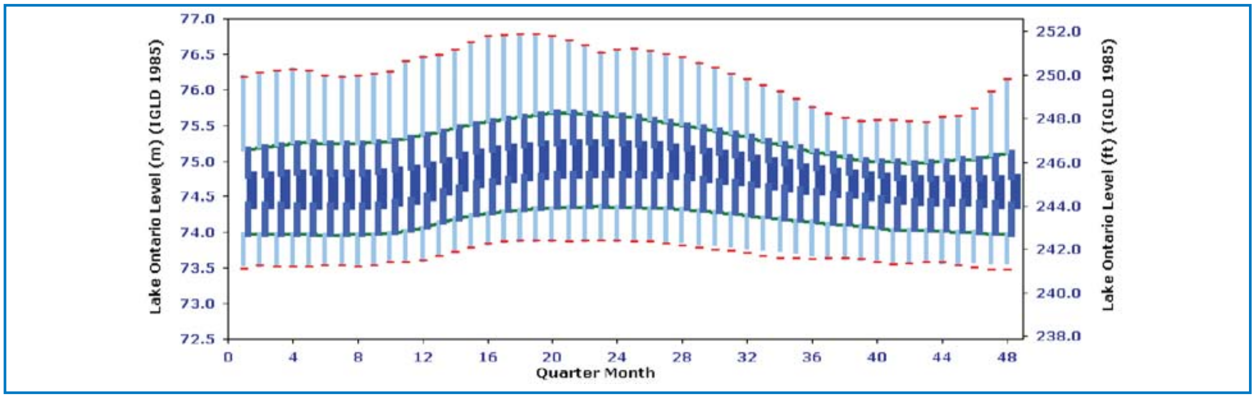


Figure 15: Lake Ontario annual water levels for the 50,000-year stochastic sequence for Plan B+

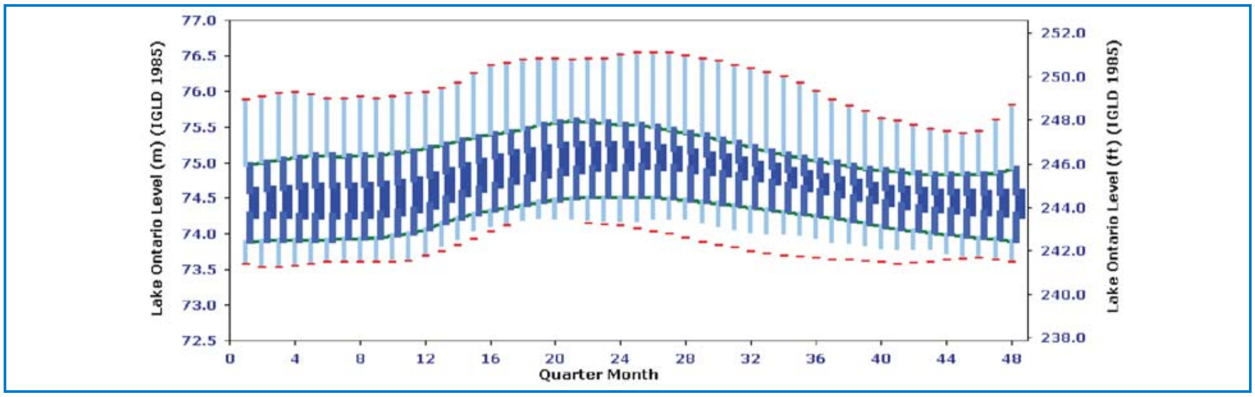


Figure 16: Lake Ontario annual water levels for the 50,000-year stochastic sequence for Plan D+

St. Lawrence River at Long Sault

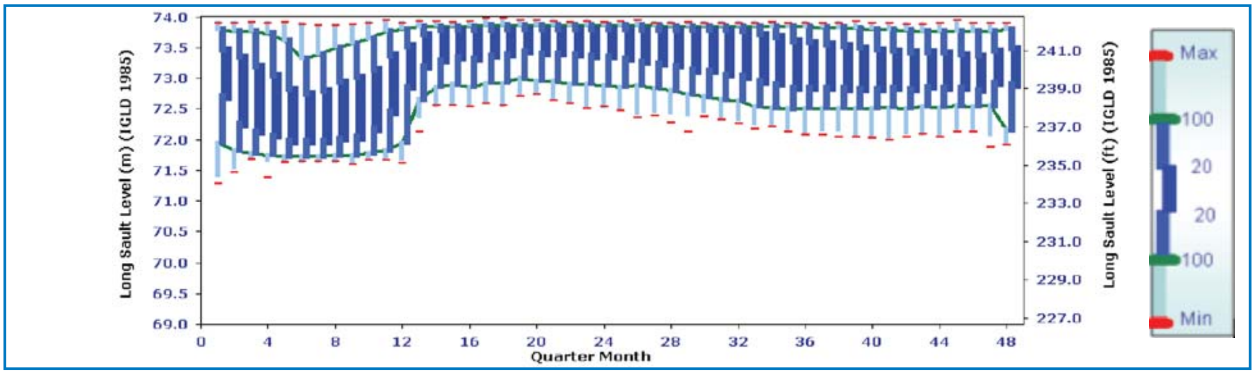


Figure 17: ***Long Sault annual water levels for the 50,000-year stochastic sequence for Plan 1958-DD***

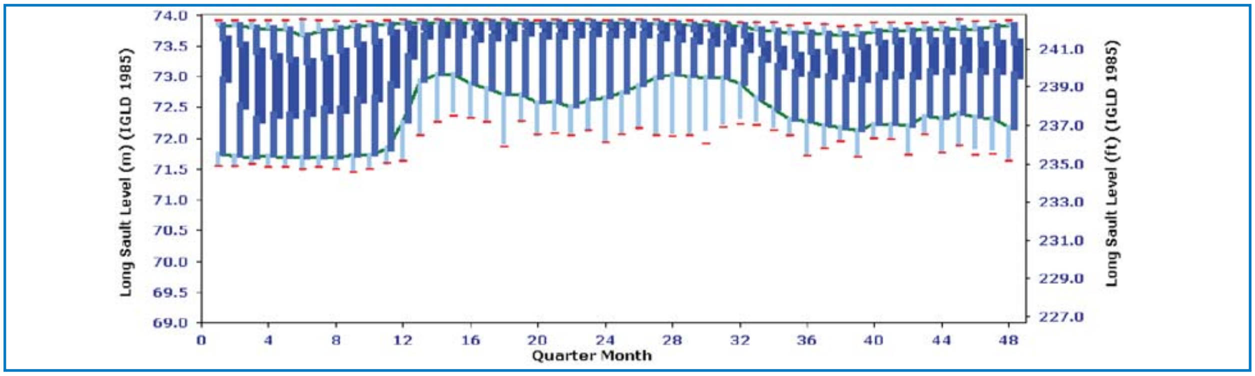


Figure 18: ***Long Sault annual water levels for the 50,000-year stochastic sequence for Plan A+***

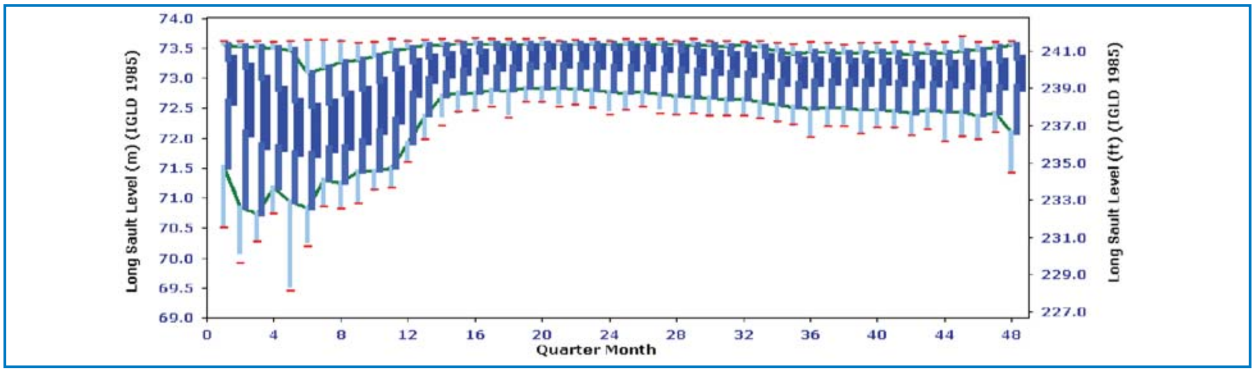


Figure 19: ***Long Sault annual water levels for the 50,000-year stochastic sequence for Plan B+***

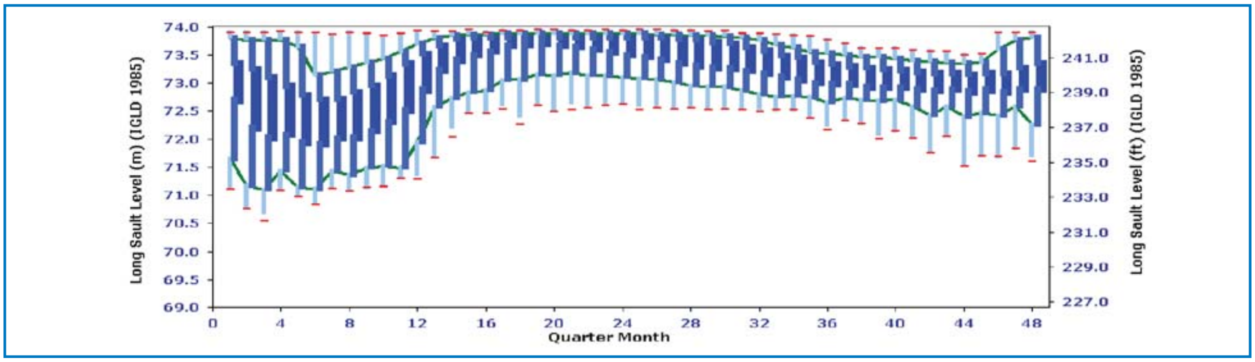


Figure 20: ***Long Sault annual water levels for the 50,000-year stochastic sequence for Plan D+***

St. Lawrence River at Lac St. Louis

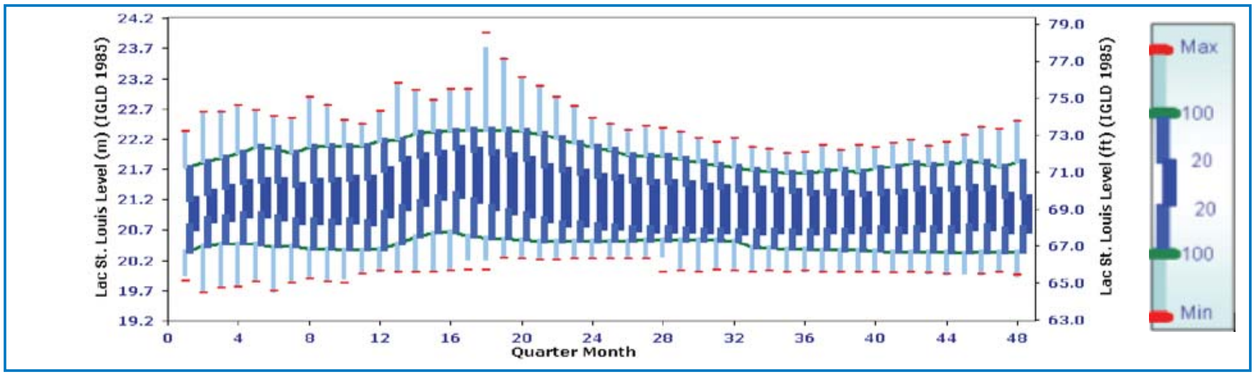


Figure 21: Lac St. Louis annual water levels for the 50,000-year stochastic sequence for Plan 1958-DD

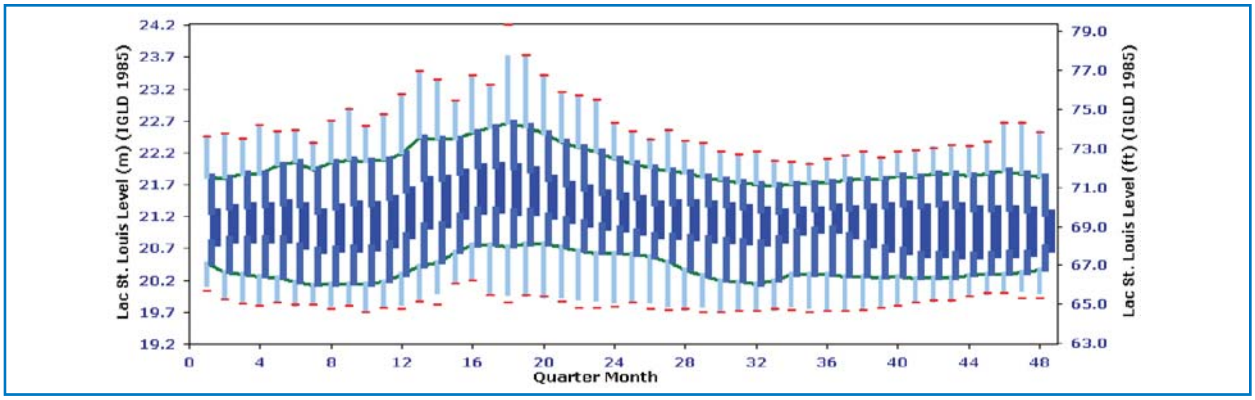


Figure 22: Lac St. Louis annual water levels for the 50,000-year stochastic sequence for Plan A+

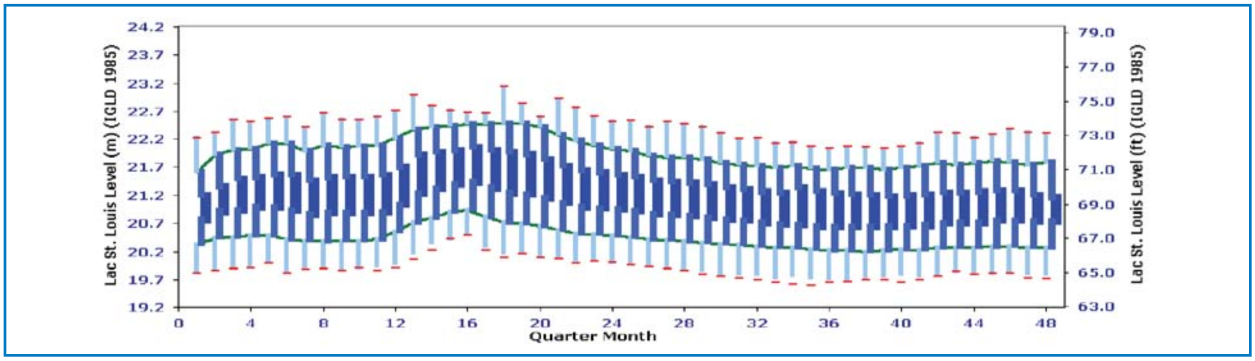


Figure 23: Lac St. Louis annual water levels for the 50,000-year stochastic sequence for Plan B+

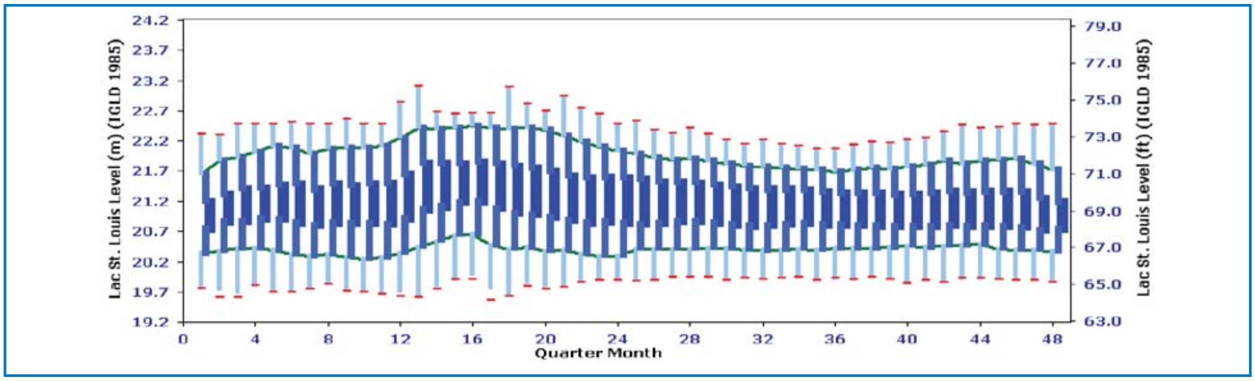


Figure 24: Lac St. Louis annual water levels for the 50,000-year stochastic sequence for Plan D+

St. Lawrence River at Montreal Harbour

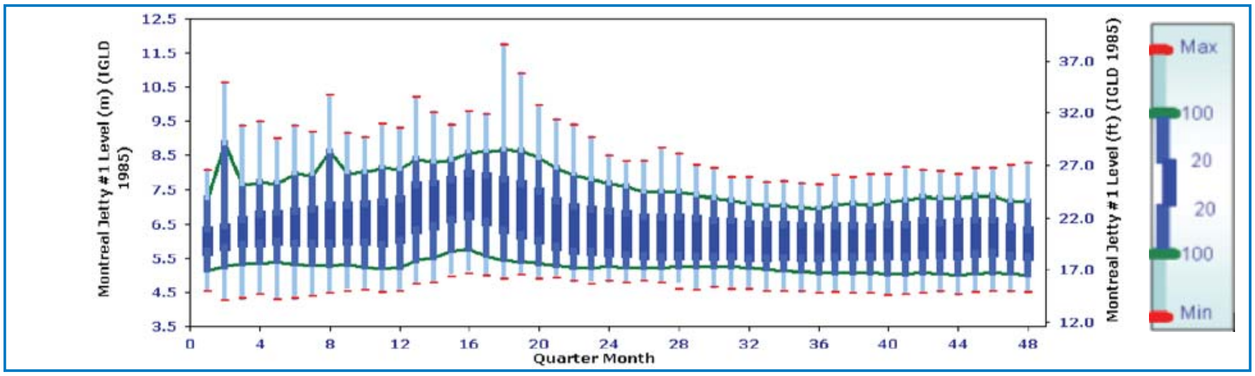


***Figure 25:* Montreal Harbour annual water levels for the 50,000-year stochastic sequence for Plan 1958-DD**

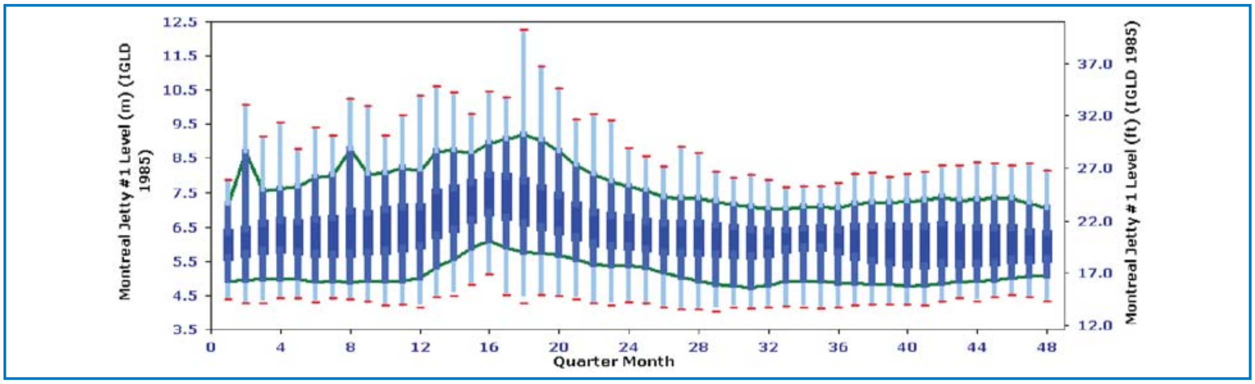


***Figure 26:* Montreal Harbour annual water levels for the 50,000-year stochastic sequence for Plan A+**

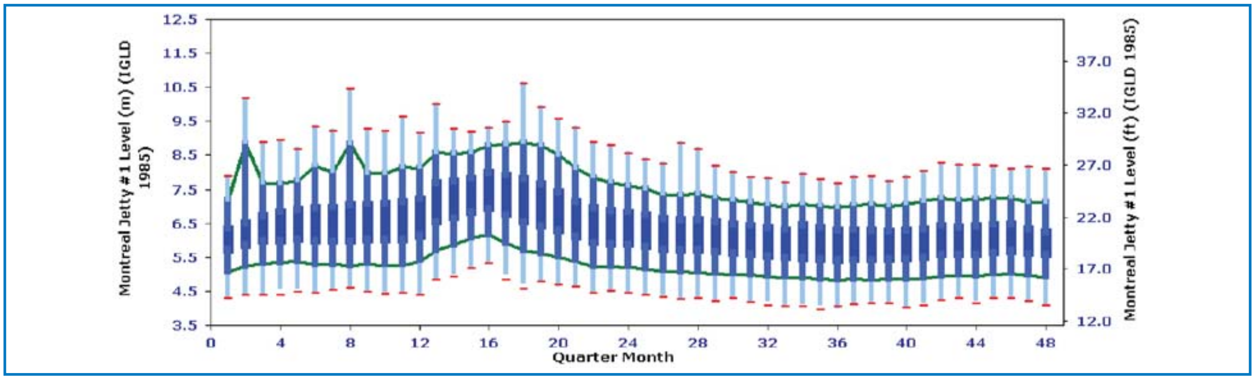


***Figure 27:* Montreal Harbour annual water levels for the 50,000-year stochastic sequence for Plan B+**

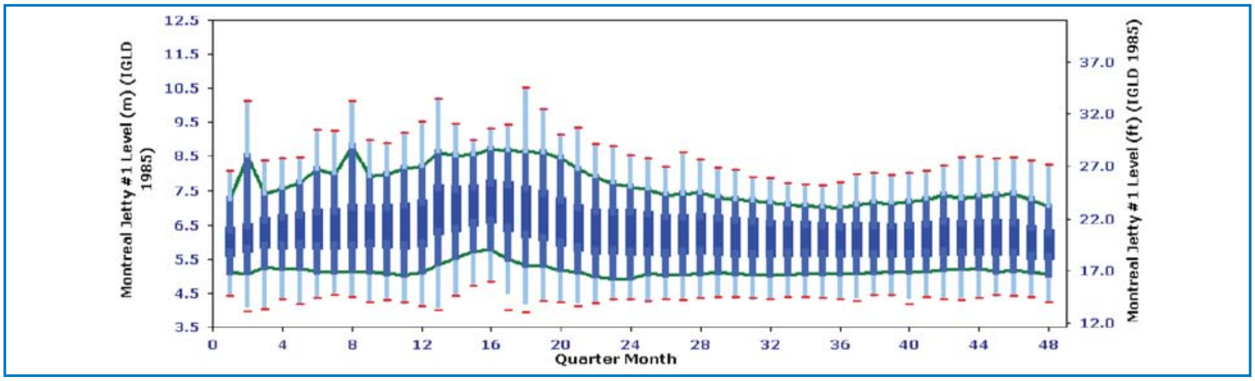


***Figure 28:* Montreal Harbour annual water levels for the 50,000-year stochastic sequence for Plan D+**

Figures 29, 30, 32 and 33 show comparisons of the three candidate plans and 1958-DD and represent the average levels, the level exceeded 1% of the time and the level exceeded 99% of the time in each quarter-month of the year based on the 50,000 year stochastic sequence at four locations. Figure 31 shows a similar comparison for Lake Ontario outflows.

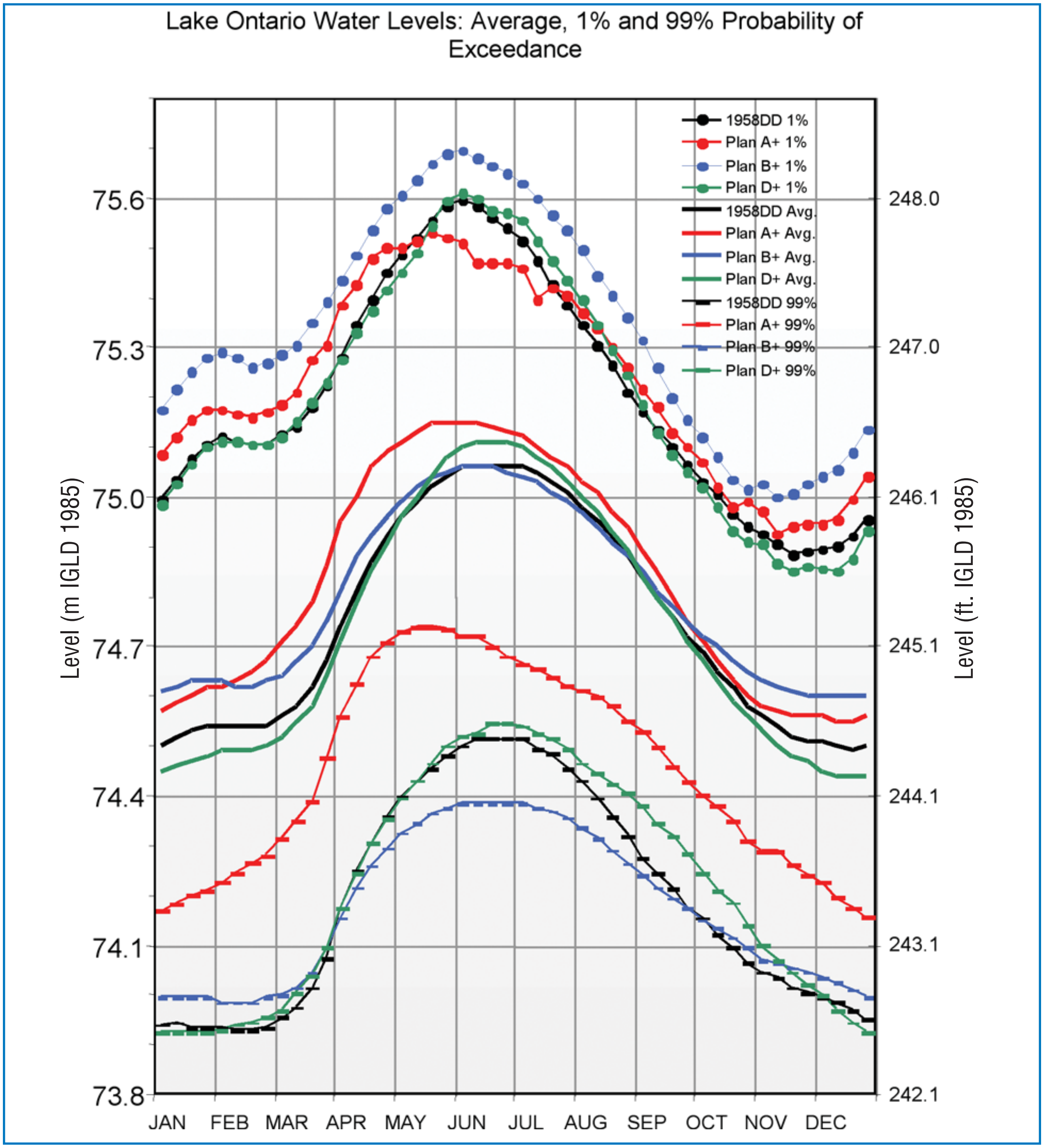


Figure 29: ***Lake Ontario water levels: average, 1% exceedance and 99% exceedance based on the 50,000-year stochastic simulation***

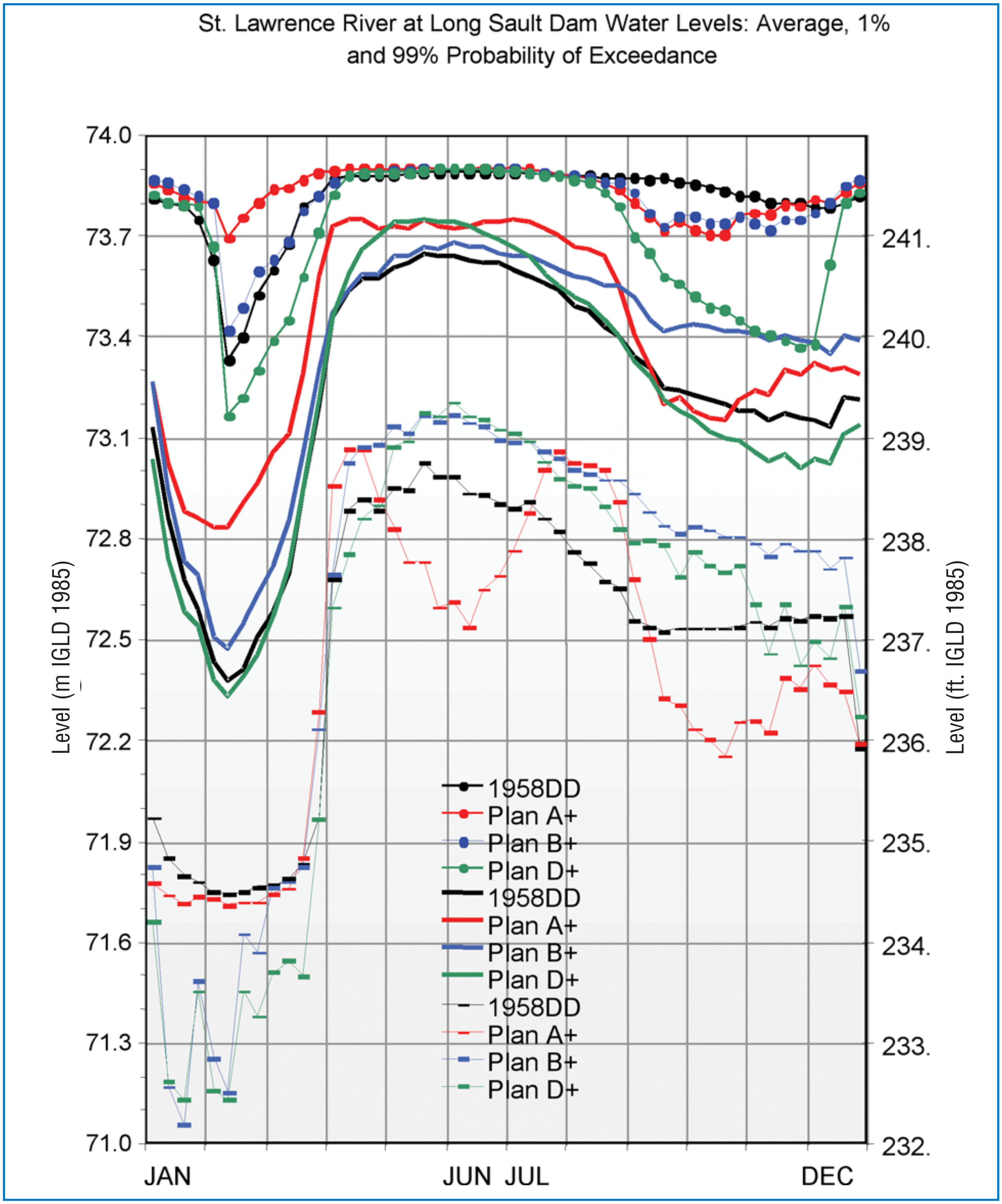


Figure 30: ***Long Sault water levels: average, 1% exceedance and 99% exceedance based on the 50,000-year stochastic simulation***

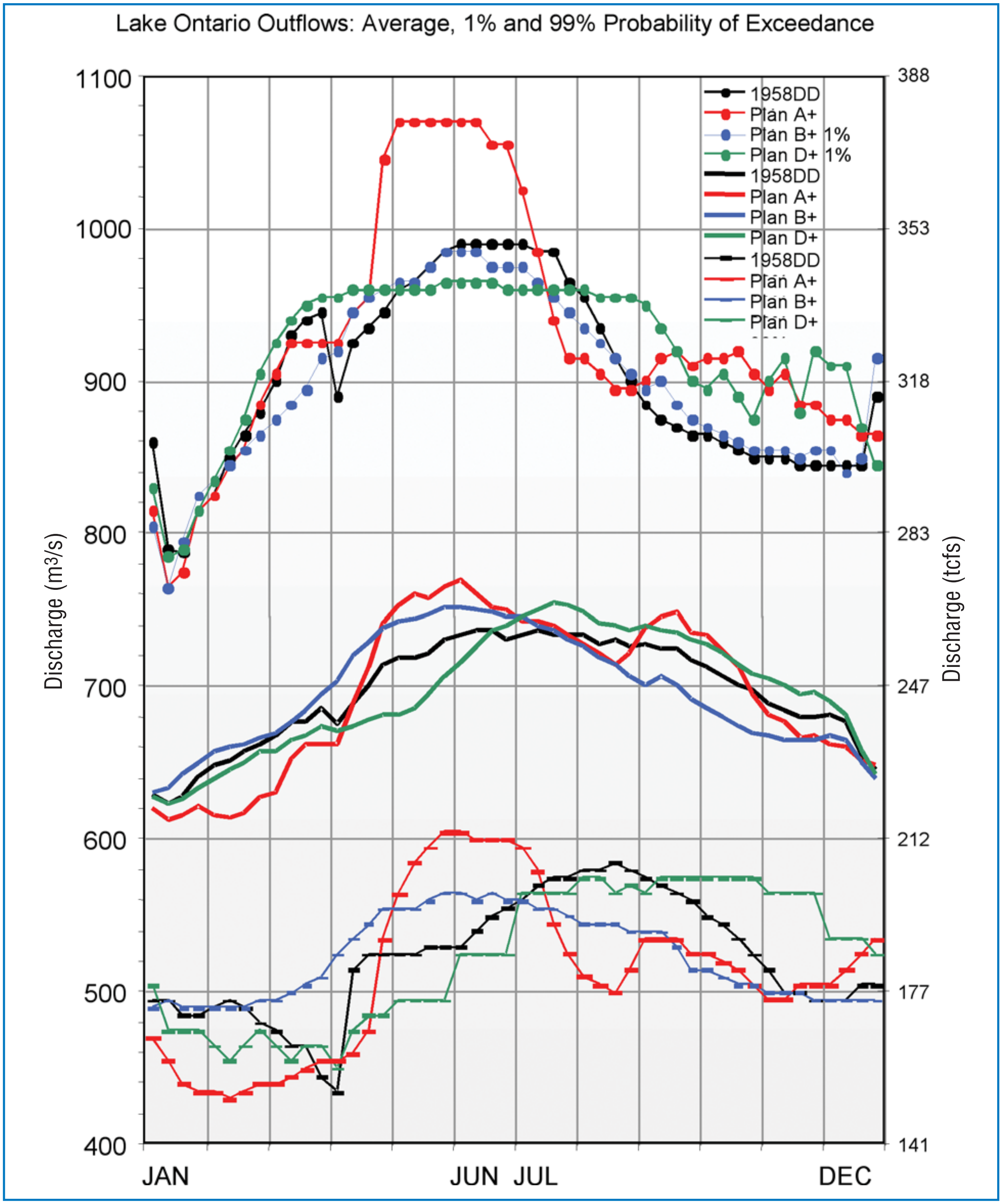


Figure 31: ***Lake Ontario outflows: average, 1% exceedance and 99% exceedance based on the 50,000-year stochastic simulation***

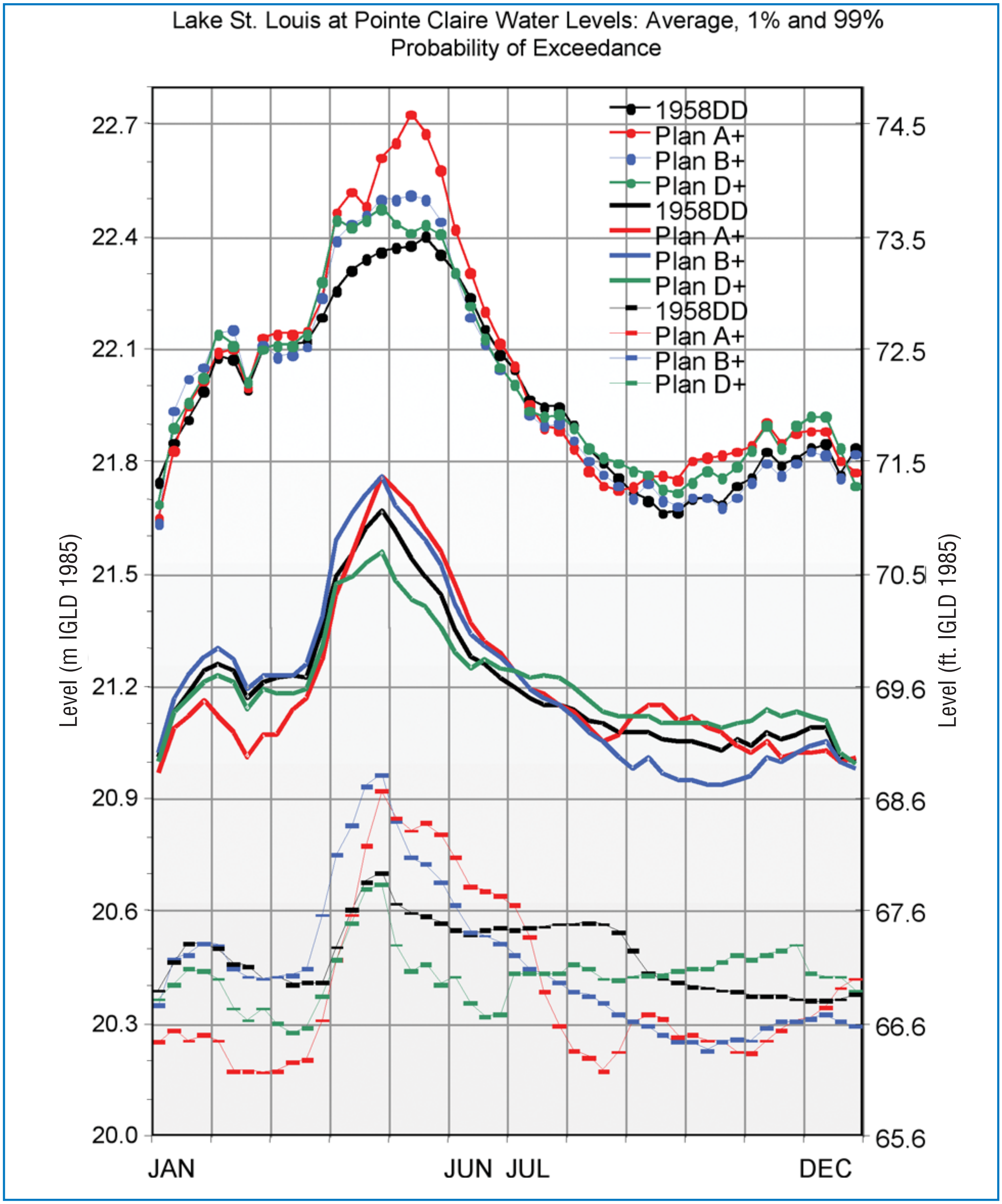


Figure 32: ***Lac St. Louis water levels: average, 1% exceedance and 99% exceedance based on the 50,000-year stochastic simulation***

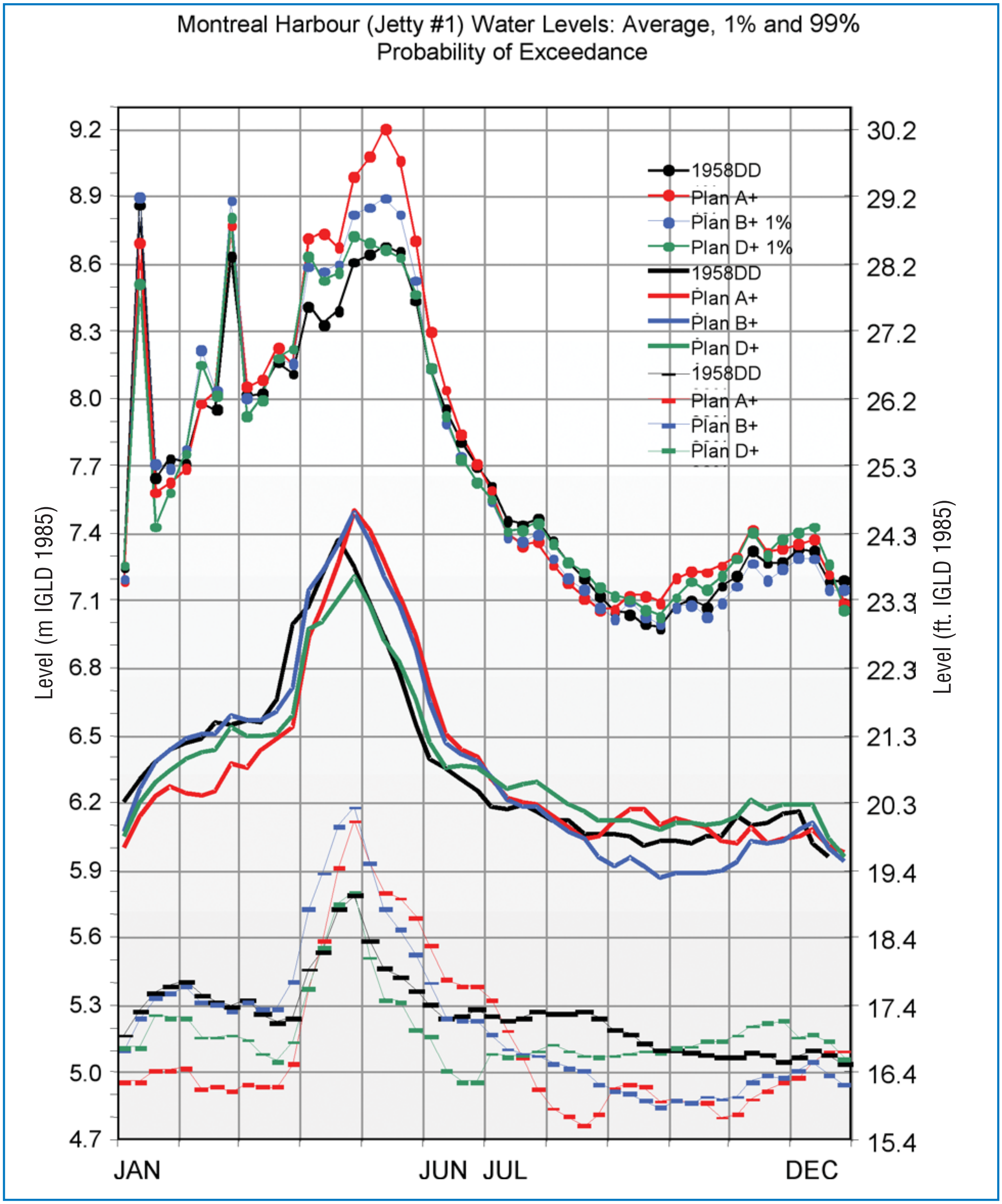


Figure 33: Montreal Harbour water levels: average, 1% exceedance and 99% exceedance based on the 50,000-year stochastic simulation

Overall Plan Results

All of the candidate plans create overall economic and environmental benefits compared with 1958-DD, but differ in their distribution of these benefits. Table 4 below provides a summary of overall results. A further breakdown and discussion of these results will follow. The total net benefits are a summation of all economic performance indicators (positive and negative). The total of losses provides an indication of disproportionate loss by showing a sum of all losses caused by a plan. The overall environmental index provides an indication of the environmental benefits of each of the plans, shown as a ratio. This is further supported by the meadow marsh wetlands score, which is an important indicator discussed later in the report. Also shown are the number of environmental performance indicators that show more than a 10% improvement relative to Plan 1958-DD or greater than a 10% deterioration relative to 1958-DD. Finally, this table also shows the number of species at risk impacted by a given plan by more than a 10% difference relative to 1958-DD. Plan E evaluations are presented for comparison purposes only, as Plan E is not a candidate plan for consideration.

Table 4: Summary Results (economic results determined from stochastic, environmental ratios based on historical supply sequence)

Impact[1]	Plan A+	Plan B+	Plan D+	Plan E
Total Net Benefits[2]	**$6.44**	**$4.63**	**$4.48**	**-$16.36**
Total of Losses (all sectors)[3]	**-$0.90**	**-$4.35**	**-$0.73**	**-$33.87**
Overall Environmental Index[4]	1.06	1.35	1.10	4.04
Meadow Marsh Index[5]	1.02	1.44	1.17	1.56
Environmental PIs better off[6]	3	7	5	9
Environmental PIs worse off[7]	5	3	1	3
Species at Risk better off[8]	0	2	0	3
Species at Risk worse off[9]	1	0	0	0

Notes to Table 4:
1. All impacts are measured relative to the estimated impact of Plan 1958-DD.
2. Economic figures represent the average annual impact relative to Plan 1958-DD; figures are reported in millions of U.S. dollars and are based on the 50,000-year stochastic supply series, using a 4% discount rate over a 30-year period, for coastal erosion and shore protection maintenance.
3. Total of Losses (all sectors) is the sum of all negative economic benefits for a plan.
4. The Overall Environmental Index was developed by Limno-tech for the Study Board. The Index is described in Annex 1 of this report. Scores are presented as ratios, with 1 representing no change from Plan 1958-DD, less than 1 a deterioration relative to 1958-DD, and greater than 1 an improvement relative to 1958-DD. Results are based on the historical sequence.
5. The Wetland Meadow Marsh Community performance indicator has been highlighted as a priority performance indicator for environmental health on Lake Ontario. It is presented as a ratio (see 4 above).
6. This measure indicates the number of environmental performance indicators that score significantly (>10%) higher than 1.0, indicating that the given plan performs better than Plan 1958-DD.
7. This measure indicates the number of environmental performance indicators that score significantly (>10%) less than 1.0, indicating that the given plan does not perform as well as Plan 1958-DD.
8. This measure indicates the number of Species-at-Risk performance indicators that score significantly (>10%) higher than 1.0, indicating that the given plan performs better than Plan 1958-DD.
9. This measure indicates the number of Species-at-Risk performance indicators which score significantly (>10%) lower than 1.0, indicating that the given plan does not perform as well as Plan 1958-DD.

Economic Results

All plans produce net economic benefits, with Plan A+ providing greater net economic benefits than Plan B+ or D+. The following summary of economic results is based on the 50,000-year stochastic evaluation of plans. All economic stochastic results are shown in Table 6.

Based on the stochastic analysis, Plan A+ produces the highest net economic benefits of the three candidate plans. It has benefits for recreational boaters, hydropower, and small gains for commercial navigation. Plan A+ is the only candidate plan that does not create losses for coastal interests on Lake Ontario, but it does cause some increases in flood damages relative to 1958-DD in the lower river.

Plan B+ provides positive net benefits relative to 1958-DD for hydropower and navigation, but causes damages for Lake Ontario shoreline properties and is associated with some increases in flood damages on the lower St. Lawrence River. Plan B+ is slightly worse for recreational boaters than 1958-DD on average, especially above the dam during droughts.

Plan D+ has some gains in net benefits for boaters, hydropower and commercial navigation. It is very close to Plan 1958-DD with respect to coastal interests. This plan is the most balanced in its distribution of benefits and causes no disproportionate losses to any interest or region.

Table 5 summarizes the economic benefits for each plan when evaluated using the historical water supply sequence. Table 6 shows the benefits evaluated over the next 30 years using the stochastic water supplies, with future impacts discounted at a rate of 4% per year. As discussed earlier, only Table 6 provides a credible measure of the impacts. This is particularly true for coastal processes such as erosion and shore protection damages, because the stochastic supplies can be used to estimate the average progression of shoreline movement over the next thirty years. Historical water supplies were used for the evaluation until the stochastic supplies became available in 2005. Table 5 is provided as a reference so that the candidate plans can be compared with earlier plans that were not evaluated using the stochastic supplies. Complete historical results for all plans can be found in Annex 3 to this report.

Table 5: Summary Economic Impacts based on Historical Analysis

Interest	Plan A+	Plan B+	Plan D+	Plan E
TOTAL	**$7.51**	**$6.47**	**$6.53**	**-$12.30**
Coastal	-$0.62	-$1.12	$0.35	-$25.96
Commercial Navigation	$0.41	$2.20	$2.31	$4.13
Hydroelectric Power Production	$3.50	$5.97	$1.82	$14.16
Municipal & Industrial Water Intake	$0.00	$0.00	$0.00	$0.00
Recreational Boating	$4.23	-$0.58	$2.04	-$4.64

Notes to Table 5:
1. Figures represent the average annual impact relative to Plan 1958-DD and are reported in millions of U.S. dollars.
2. These are economic results based on the historical supply sequence, with no discounting for coastal erosion and shore protection maintenance.

Table 6: Economic Results by Interest and Region (based on stochastic supply sequence)

Average Annual Net Discounted Benefits	Plan A+	Plan B+	Plan D+	Plan E
Total	**$6.44**	**$4.63**	**$4.48**	**-$16.36**
COASTAL	**-$0.10**	**-$2.84**	**-$0.10**	**-$28.50**
Lake Ontario	*$0.46*	*-$2.52*	*-$0.23*	*-$27.16*
Shore Protection Maintenance[2]	$0.57	-$2.16	-$0.17	-$19.85
Erosion to Unprotected Developed Parcels[2]	-$0.23	-$0.17	$0.02	-$0.58
Flooding	$0.12	-$0.20	-$0.08	-$6.72
Upper St. Lawrence River	*$0.01*	*-$0.01*	*-$0.01*	*-$0.75*
Flooding	$0.01	-$0.01	-$0.01	-$0.75
Lower St. Lawrence River	*-$0.57*	*-$0.31*	*$0.14*	*-$0.59*
Flooding	-$0.51	-$0.22	$0.09	-$0.49
Shore Protection Maintenance[3]	-$0.06	-$0.09	$0.05	-$0.10
COMMERCIAL NAVIGATION	**$0.47**	**$2.13**	**$1.53**	**$3.21**
Lake Ontario	-$0.03	-$0.01	-$0.01	-$0.02
Seaway	$0.57	$2.16	$1.56	$3.21
Montreal down	-$0.07	-$0.02	-$0.02	$0.02
HYDROPOWER	**$2.26**	**$6.09**	**$1.64**	**$12.39**
NYPA-OPG (Energy$ + Peaking$)	$2.18	$3.87	$0.48	$8.57
Hydro Quebec (Energy $)	$0.08	$2.22	$1.16	$3.82
RECREATIONAL BOATING	**$3.81**	**-$0.74**	**$1.42**	**-$3.46**
Above Dam	*$1.20*	*-$1.42*	*-$0.36*	*-$5.31*
Lake Ontario	$0.70	-$1.18	-$0.44	-$4.93
Alex Bay	$0.47	-$0.29	$0.03	-$0.36
Ogdensburg	$0.01	$0.00	$0.01	-$0.07
Lake St. Lawrence	$0.01	$0.05	$0.05	$0.05
Below Dam	*$2.61*	*$0.68*	*$1.78*	*$1.85*
Lac St. Louis	$1.39	$0.49	$0.89	$1.03
Montreal	$0.93	$0.19	$0.68	$0.64
Lac St. Pierre	$0.29	$0.00	$0.21	$0.18
M&I	**$0.00**	**$0.00**	**$0.00**	**$0.00**
SL One-time Infrastructure Costs	$0.00	$0.00	$0.00	$0.00
LSL Water Quality Investments	$0.00	$0.00	$0.00	$0.00

Notes to Table 6:

1. Figures reflect the average annual impact relative to Plan 1958-DD and are reported in millions of U.S. dollars. **Blue** represents a positive net benefit relative to 1958-DD and **red** indicates a negative net benefit relative to 1958-DD.
2. These are economic results based on the 50,000-year stochastic supply series, using a 4% discount rate over a 30-year period, for coastal erosion and shore protection maintenance.
3. The St. Lawrence River Model component of the Shared Vision Model could not be adapted to run the full 50,000-year stochastic series. The results presented represent an average of the historical sequence plus the four 101-year trial segments from the stochastic (S1, S2, S3 and S4 series).

Disproportionate Loss

The Study Board's second guiding principle is that a new plan should create a system-wide overall net benefit without causing disproportionate loss to any particular interest or geographic area. Given that all alternative plans traded increases in overall net benefits for some loss to some interests, the Board had to distinguish between losses that were disproportionate and those that were not. This approach was necessitated by the realization that losses could not be avoided but that disproportionate losses could be.

Unlike the simpler idea of lost benefits, the concept of disproportionate loss is a relative one. That is, it is a measure of a loss relative to something else. As happens on large and complex studies such as this one, the Board's thinking on this matter has evolved over the course of the study. As described below, the initial approach was to measure losses only relative to those that would be experienced under 1958-DD. However, this approach failed to adequately capture differences across sectors and regions. Thus, the Board's ultimate approach was to estimate a dollar value of gains and losses of a specific plan's performance compared to 1958-DD and then to assess that dollar value relative to an estimate of the scale or significance of a sector or region. As described below, the idea of scale or significance has been represented by a sector's annual net value to society.

Until this Study, gains and losses from Lake Ontario regulation were measured in terms of failure to meet desired water levels. Using performance indicators, the benefits research in this Study allowed the Study Board to estimate the economic or environmental consequence of those water level failures. As a first effort, the Study Board recognized that a million dollar per year loss could hurt some sectors more than others. As a result, the Study Board initially decided to measure each sector's or region's impact relative to what it would have been under Plan 1958-DD. Thus, the percentage change from 1958-DD impacts was also measured. If damages increased by $1 million in two sectors, with one from $1 to $2 million, and the other from $100 to $101 million, then the percentage changes (100% and 1%) would give an indication whether the loss was disproportionate or not.

This percentage was conceptually misleading and biased. It was misleading, because using this logic, a doubling of a rich man's home heating bill would seem more hurtful than a 20% increase in a poor man's rent. That illustrates the point that the analysis had to factor in the size of the activity impacted, not just the change in impact. It was biased because interpreting loss in terms of percentage change from 1958-DD could skew results for interests that had been favored with low damages under the current regulation rules and would not allow the Study Board to fairly consider the "new" interests (environment and recreational boating) that were not considered by the current plan rules and had suffered larger impacts.

Through a series of deliberations, the Study Board agreed that:

- Disproportional loss would ultimately be defined qualitatively –that is, the Board would not set a 'hard and fast' rule that defined a threshold of whether a disproportionate loss had occurred;
- Quantitative information would be helpful in making that assessment, including:
  - the "impacts relative to the size of the interest and the region";
  - the duration and frequency of the impacts;
  - an assessment of which plan minimizes the maximum losses;
  - an assessment of the robustness of the plans under extreme water supply conditions;
  - a comparison of benefit changes in relation to the hydrologic criteria

The Study Board also decided to factor in the explanation for the loss. "For example, if one interest seems to continuously have problems no matter what the plan is, or is always in conflict with all the other interests, then perhaps there are other factors that are influencing their problem (e.g. bad land use planning, or inability to dredge)". Finally, the Board recognized that "the more the Study Board tries to reduce disproportionate losses, the less likely they are to make real gains." (Decision memo from Nov. 18 2004)

The Plan Formulation and Evaluation Group added all of these quantitative measures to the Board Room and addressed the underlying "explanation" in a series of presentations to the Study Board. Ultimately, the Plan Formulation and Evaluation Group determined that some damages could not be eliminated without foregoing benefits to other interests. For example, Ontario coastal damages could not be reduced much further from Plan 1958-DD, even with plans like OntRip3 that created large losses to other stakeholders. The deviations from Plan 1958-D had reduced the maximum lake elevations that would have been experienced to date by over a meter (about four feet), saving hundreds of millions of dollars in property damage. Further reductions in lake levels and impacts would threaten downstream properties, and reduce hydropower and boating benefits.

The Study Board's panel of economic advisors suggested defining "the size of the interest and the region" in terms of economic surplus, the difference between the value of a good or service and the cost to produce it. Economic surplus is a standard measure in public policy analysis because it measures the value to society rather than benefits to a particular firm or group, but it is relatively new for International Joint Commission studies. For this reason (and the fact that a number of the economic studies were undertaken relatively late in the study process), different approaches were used so the reasonable estimates could be developed in the time available. Many of the issues surrounding the estimation of the baseline figures can be found in Annex 2 and in the Plan Formulation and Evaluation Group Report (Werick and Leger, 2005).

With those caveats, the experts developed estimates of the value of the affected interests and activities, always applying the concept of economic surplus, but arriving at it in different ways. The different approaches to estimating economic surplus are summarized below and explained in more detail in the Technical Work Group Summaries in Annex 2.

Baseline Economics

"Baseline economics" was the phrase used by the Study Board to refer to the estimated economic surplus, or value to society, of each of the economic activities impacted by regulation. The economic advisors were asked to determine a common concept for measuring the baseline magnitude of an activity. The economic advisors stated that reasonable baselines were:

a. Recreational boating: Willingness to pay for boating multiplied by the number of trips taken by boaters under Plan 1958-DD. Use net economic value as measured in 2002 as a surrogate.
b. Coastal erosion: A value for shoreline buildings in annualized terms using a 3.6% depreciation of the shoreline building and shore protection, representing an annual loss of investment irrespective of regulation plan.
c. Hydroelectric power: The economic value to society of the electricity produced, taking into account representative market values and operating costs at the Moses-Saunders and Beauharnois-Cedars hydroelectric plants on the St. Lawrence River and the Moses-Beck hydroelectric plant on the Niagara River, which are affected by Lake Ontario flows and levels.
d. Commercial navigation: Estimated net revenues under Plan 1958-DD.
e. Municipal, industrial and domestic water uses. Not necessary because the plans all have the same impact.
f. Environment: The interest is not developing an economic performance indicator so an economic baseline is not needed for context.

These baseline economic numbers produced are rough but consistently conceived estimates of the scale of each economic activity. They are meant as planning level estimates only for the sole purpose of providing some context for the net benefit results. They are used as the denominator when considering the percent damage to the interest where the numerator is the relative impact for each performance indicator compared to Plan 1958-DD shown in Table 6. Table 7 puts the economic damages into context by showing the percent damage to an interest relative to the economic baseline estimated for that interest.

Table 7: ***Percent Damage by Performance Indicator Relative to an Economic Baseline***

Performance Indicator	Plan A+	Plan B+	Plan D+	Plan E
COASTAL	**0%**	**-3%**	**0%**	**-27%**
Lake Ontario	*1%*	*-3%*	*0%*	*-33%*
Shore Protection Maintenance	1%	-4%	0%	-37%
Erosion to Unprotected Developed Parcels	-2%	-2%	0%	-5%
Flooding	1%	-1%	0%	-37%
Upper St. Lawrence River	*0%*	*0%*	*0%*	*-28%*
Flooding	0%	0%	0%	-28%
Lower St. Lawrence River	*-3%*	*-1%*	*1%*	*-3%*
Flooding	-4%	-2%	1%	-4%
Shore Protection Maintenance	-1%	-1%	1%	-1%
COMMERCIAL NAVIGATION	**0%**	**1%**	**1%**	**2%**
Lake Ontario	0%	0%	0%	0%
Seaway	1%	2%	1%	3%
Montreal down	0%	0%	0%	0%
HYDROPOWER	**1%**	**2%**	**0%**	**4%**
NYPA-OPG (Energy$ + Peaking$)	1%	2%	0%	3%
Hydro Quebec (Energy $)	0%	2%	1%	4%
RECREATIONAL BOATING	**1%**	**0%**	**1%**	**-1%**
Above Dam	*1%*	*-1%*	*0%*	*-2%*
Lake Ontario	0%	-1%	0%	-3%
Alex Bay	4%	-3%	0%	-3%
Ogdensburg	0%	0%	0%	0%
Lake St. Lawrence	0%	1%	1%	1%
Below Dam	*7%*	*2%*	*5%*	*5%*
Lac St. Louis	8%	3%	5%	6%
Montreal	8%	2%	6%	5%
Lac St. Pierre	3%	0%	2%	2%
M&I	**0%**	**0%**	**0%**	**0%**
SL One time infrastructure costs	0%	0%	0%	0%
LSL Water Quality Investments	0%	0%	0%	0%

Notes to Table 7:

1. Figures represent percent impact of the average annual impact relative to Plan 1958-DD shown in Table 6 in relation to an economic baseline established for each economic performance indicator (refer to the Technical Work Group summaries in Annex 2). **Blue** represents a positive impact and **red** indicates a negative impact relative to 1958-DD.
2. The baseline numbers used to derive the percentages are rough but consistently conceived estimates of the scale of each economic activity. They are meant as planning level estimates only for the sole purpose of providing some context for the net benefit results shown in Table 6.

Environmental Results

All candidate plans show better results for the environment under the historical sequence. Plan B^+ provides greater environmental benefits than Plan A^+ or Plan D^+.

Plan A^+ provides small improvements for the environment, but has the least gains of the three candidate plans compared with 1958-DD. The environmental benefits of Plan A^+ are all limited to the upper river. Plan A^+ provides no improvement in the key Lake Ontario meadow marsh indicator, and is the only plan that is associated with losses for a species at risk on Lake Ontario.

Plan B^+ provides significant overall improvement compared with 1958-DD on the Lake and upper St. Lawrence River, but like all candidate plans, shows almost no improvement on the lower St. Lawrence River. Plan B^+ is generally good for all environmental performance indicators, including species at risk.

Plan D^+ offers modest improvements for the environment overall. On Lake Ontario, it results in no changes except for an improvement in the key Lake Ontario meadow marsh indicator. With the exception of this improvement, the environmental gains associated with D^+ are realized primarily in the upper St. Lawrence River.

Plan D^+ provides some gains for a species at risk on the lower river. Otherwise, none of the plans results in improvements on the lower St. Lawrence River – not even Plan E, which is the natural flow plan. Although plan formulators attempted to find a way to improve environmental scores on the lower river, they were unsuccessful. This was largely because of the dynamic nature of the lower river and the influence of flows from the Ottawa River and local tributaries.

Table 8: Environmental Performance Indicator Results (Ratios) based on Historical Supplies

Environmental Performance Indicators	Plan A+	Plan B+	Plan D+	Plan E
Lake Ontario				
Wetland Meadow Marsh Community	1.02	1.44	1.17	1.56
Low Veg 18C - Spawning habitat supply	0.89	0.95	0.94	0.88
High Veg 24C - Spawning habitat supply	1.05	1.00	1.01	1.08
Low Veg 24C - Spawning habitat supply	1.00	1.02	1.00	1.11
Northern Pike – Young-of-year (YOY) recruitment	1.02	1.00	1.05	1.03
Largemouth Bass - YOY recruitment	0.94	0.98	0.97	0.96
Least Bittern (IXEX) - Reproductive index	0.88	1.04	0.95	1.13
Virginia Rail (RALI) - Reproductive index	0.96	1.11	0.99	1.15
Black Tern (CHNI) - Reproductive index	1.03	1.12	1.01	1.16
Yellow Rail (CONO) - Preferred breeding habitat	0.96	1.01	0.98	1.01
King Rail (RAEL) - Preferred breeding habitat	1.05	1.10	1.03	1.27
Upper River				
Low Veg 18C - Spawning habitat supply	1.01	1.01	1.01	1.04
High Veg 24C - Spawning habitat supply	1.03	1.01	1.02	1.02
Low Veg 24C - Spawning habitat supply	1.01	1.01	1.01	1.04
Northern Pike - YOY recruitment	1.05	1.03	1.01	1.06
Largemouth Bass - YOY recruitment	0.99	1.00	1.00	1.00
Northern Pike - YOY net productivity	4.02	2.08	1.17	4.08
Virginia Rail (RALI) - Reproductive index	1.16	1.27	1.31	1.33
Muskrat (ONZI) - House density in drowned river mouth wetlands	1.42	4.39	1.73	37.25
Lower River				
Golden Shiner - Suitable feeding habitat area	1.00	1.00	1.00	1.03
Wetlands Fish - Abundance index	0.87	0.90	0.84	0.97
Migratory Wildfowl - Habitat area	1.03	1.03	0.97	1.00
Least Bittern - Reproductive index	1.03	1.06	1.00	1.06
Virginia Rail (RALI) - Reproductive index	0.94	0.97	1.06	1.00
Migratory Wildfowl - Productivity	1.06	1.00	1.00	1.03
Black Tern (CHNI) - Reproductive index	0.84	0.77	1.00	0.77
Northern Pike (ESLU) - Reproductive area	0.97	0.94	0.94	0.94
Frog sp. - Reproductive habitat surface area	0.87	0.87	1.03	0.94
Eastern Sand Darter (AMPE) - Reproductive area	1.10	1.03	1.13	1.06
Spiny Softshell Turtle (APSP) - Reproductive habitat surface area	1.03	1.06	1.03	1.03
Bridle Shiner (NOBI) - Reproductive habitat surface area	1.00	0.97	1.00	1.03
Muskrat (ONZI) - Surviving houses	1.04	0.88	0.96	0.80
Percentage "good" scores for each plan	**9%**	**22%**	**16%**	**34%**
Overall Environmental Index	**1.06**	**1.35**	**1.10**	**4.04**

Notes to Table 8:

1. Figures reflect the impact relative to Plan 1958-DD expressed as ratios, where 1 represents no change from 58-DD, >1.00 an improvement relative to 58-DD, and < 1.00 a deterioration relative to 58-DD.
2. Run using the historical supply sequence because the Integrated Ecological Response Model component of the Shared Vision Model could not be adapted to run the full 50,000-year sequence.
3. Aqua shading identifies species at risk.
4. Yellow shading indicates essentially no change from 1958-DD (within 10% difference). Anything above 1.10 is marked in **blue** and anything below 0.90 is marked in **red**.

Equity Considerations

Plan A⁺'s higher lake levels and higher flows are of great benefit to recreational boaters and hydropower, and the Plan provides modest gains for Seaway navigation and Lake Ontario coastal interests. However, Plan A⁺ causes greater flooding on the lower river. It offers no significant overall environmental gains and is the only candidate plan that has a negative impact on a species at risk.

Plan B⁺ benefits the environment on the Lake and the upper St. Lawrence River, as well as hydropower and commercial navigation, and imposes costs on riparians on the Lake and the River, and costs on recreational boaters, especially on Lake Ontario.

Plan D⁺ generates net benefits with modest gains in all sectors except Lake Ontario coastal, and is associated with very little damage to any interest or location.

Figure 34 shows the economic benefits by region based on the stochastic analysis. The Lake Ontario, upper St. Lawrence River, and lower St. Lawrence River totals include the economic benefits of the overall coastal, recreational boating and municipal and industrial performance indicators. Hydropower and commercial navigation are shown separately as their impacts cannot be as easily separated into the three geographic categories (Lake, upper and lower river).

Figure 35 shows the environmental benefits in terms of ratios (where 1 is the same as 1958-DD, > 1 represents an improvement, and < 1 a deterioration relative to 1958-DD) by geographic area, based on the historical supply sequence analysis, as represented by the Environmental Index scores developed for the Study Board (see note 4 to Table 4).

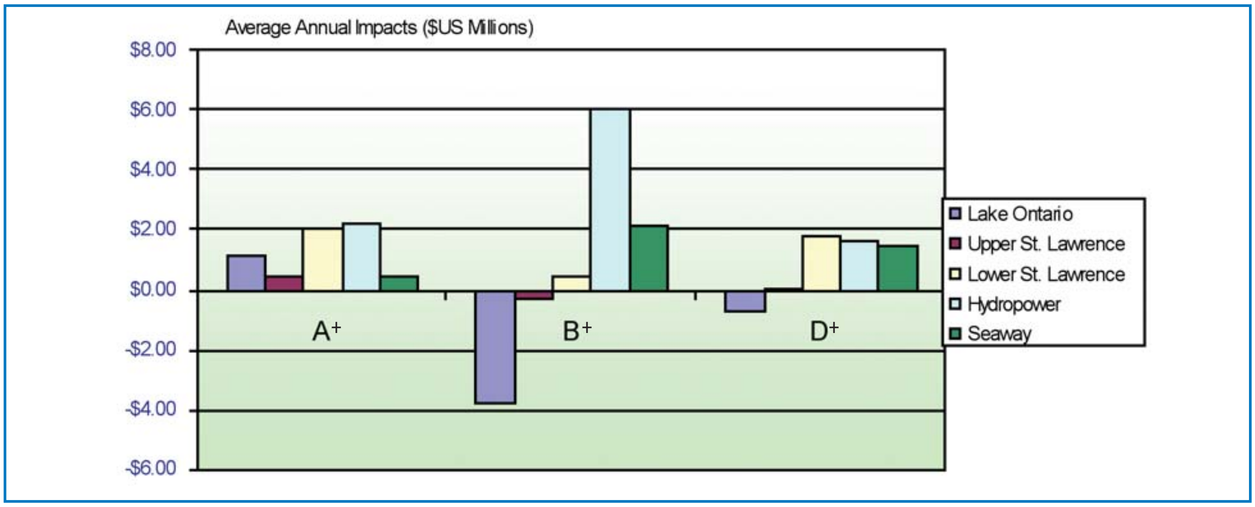


Figure 34: Economic benefits by region based on stochastic analysis

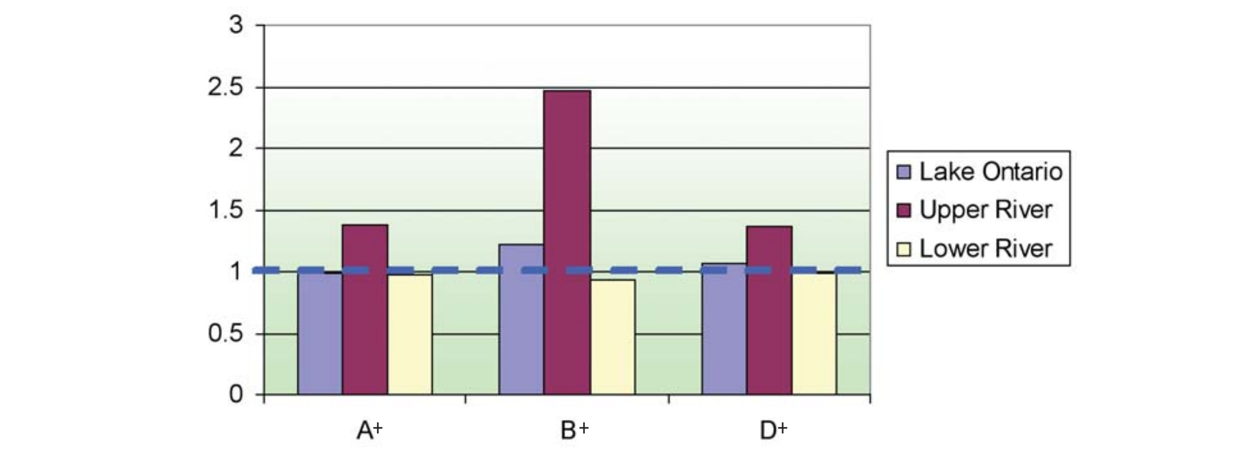


Figure 35: ***Environmental benefit ratios by sector based on historical analysis***

Beyond the Summary Numbers

All of the candidate plans create overall economic and environmental benefits relative to 1958-DD, but to varying degrees. The Study Board is confident that any one of these plans would provide an overall improvement over the existing plan. In selecting these candidate plans, the Study Board viewed and assessed the plan data in numerous ways and in varying detail. All of the plan results were available to the Study Board through the Board Room. There is far too much information within the Board Room to be covered in this report. The purpose of this section is to identify the critical issues and nuances and highlight the key pros and cons of each of the plans to allow a more informed decision.

Commercial Navigation, Hydropower and Municipal, Industrial and Domestic Water Uses

From an interest perspective, all three candidate plans benefit commercial navigation and hydropower and have no measurable impact on municipal, industrial or domestic water uses. If we examine the results of the plans for these three interest categories in detail, we find the following:

None of the plans harm municipal, industrial and domestic water uses compared with Plan 1958-DD. This is because water-use facilities are generally not vulnerable to water level changes except under extremely low water supply conditions, which would occur more frequently under the climate change scenarios. Under these conditions, all of the plans would have unavoidable impacts at Montreal, but this risk is being addressed by city managers. As noted earlier, the County of Monroe potable water pumping and treatment plant on the south shore of Lake Ontario reports flood damages at high lake levels, but did not quantify the damages associated with this situation. Two power stations, Ginna and Russel, also on the south shore of Lake Ontario would experience problems within the historical record, and will require upgrading to remain fully operational under future high and low water level conditions under any plan, including the existing one.

All of the plans help commercial navigation overall. The main difference between plans is the costs induced by delays to shipping on the Seaway. There is almost always enough water on Lake Ontario to keep ships fully loaded, and none of the plans can eliminate shallow depths in the Seaway and Port of Montreal. However, Plan D^+ is preferred by navigation representatives for its Montreal performance, where it tends to even out seasonal levels in dry years; Plans A^+ and B^+ provide higher levels in the spring (which bring little or no benefit to shippers) and then must drop levels below chart datum in the fall of drier years, while Plan D^+ can often maintain chart datum. These differences are not significant, on average, because all the plans have essentially the same average annual shipping costs in Montreal. But the slightly greater reliability of adequate depths under Plan D^+ makes it more desirable for the Port of Montreal.

A key finding of the hydropower group was that the greatest benefits are realized when the range of releases is reduced, releases are stable and predictable, and the head at Moses-Saunders Powerhouse is higher. Releases similar to the natural cycle, with rules to limit ice jams in the winter and early spring, come closest to achieving these conditions. It is not surprising then that Plan B+, which strives toward a more natural regime, is the most beneficial of the three candidate plans in terms of hydropower, providing the greatest stability and predictability, a condition favourable to hydropower planning. Nevertheless, all of the plans create benefits for hydropower relative to 1958-DD.

Other Interests

Interestingly, the greatest difference between plans lies in the distribution of benefits among the recreational boating, coastal, and environmental interests. The candidate plans each result in different trade-offs of benefits to these three interests. The following section examines more closely how the plans perform in terms of these three interests.

Recreational Boating

From an economic perspective, Plan A+ is the best plan for recreational boating. This is because Plan A+ is the most regimented of the three plans and tries to keep Lake Ontario within as narrow a range as possible (see Figure 12). It provides slightly better boating benefits below the dam, despite lower extremes, because most of the time summer levels remain within a narrow and favorable range.

Even though Plan B+ has some negative recreational boating numbers, at public meetings, many members of the boating community, especially on the upper river, came out in support of Plan B as it was presented because it:

- Has better Lake St. Lawrence performance, including less frequent use of Iroquois Dam, which, when in use, forces boaters to pass through the Iroquois Lock rather than the open dam gates;
- Generally has higher Lake Ontario levels in spring and fall (refer to Figure 27), a big plus for boat launching and haul-out and for extending the season;
- Provides benefits over 50% of the time when compared with 1958-DD, but is worse for some Lake Ontario and Alexandria Bay boaters during the driest years, when it keeps levels lower for longer periods of time. However, a number of recreational boaters, especially on the upper St. Lawrence River, expressed a willingness to trade this off for a plan that makes improvements for the environment.

Plan D+ performs similarly to 1958-DD for recreational boaters. Plan D+ does allow occasional low water levels on Lake Ontario, during low supply conditions, to benefit the environment, which creates some small overall losses for recreational boating on the Lake. Plan D+ achieves the majority of its gains for recreational boating on the lower river primarily because, most of the time, it does not allow river levels to drop quite as low as they do under Plan 1958-DD and it generally keeps levels higher on the lower St. Lawrence River in the fall, extending the season and facilitating haul-out. Figure 36 shows the benefits gained by Plan D+ over the historical time sequence for recreational boaters on Lac St. Louis.

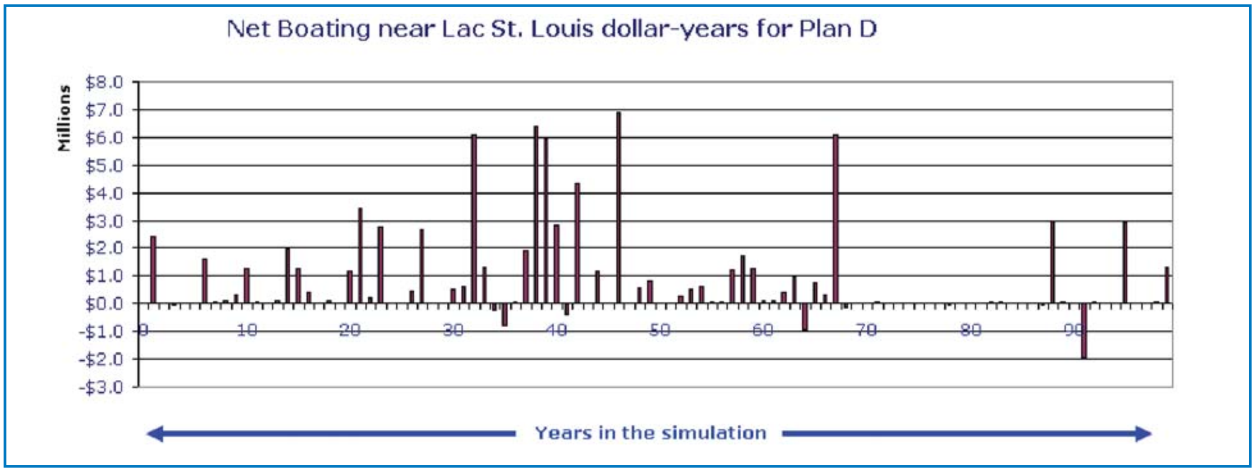


Figure 36: Net economic benefits over the 101-year historical sequence for Plan D⁺ at Lac St. Louis

In summary, Plan A⁺ provides the greatest economic benefits for recreational boaters, both upstream and downstream. Plan D⁺ provides benefits to downstream recreational boaters and no major losses to Lake Ontario boaters, except during occasional low supply conditions (e.g., every 25 years). Plan B⁺ does not hurt downstream boaters, but it does have negative benefits for Lake Ontario and boaters in the Thousand Islands area because it is associated with a greater range in levels and therefore more periods of low levels outside the desired range for boaters. Nonetheless, many upper St. Lawrence River boaters have expressed their pleasure at the fact that Plan B⁺ generally allows for an extended boating season because it shifts the peak to a point earlier in the spring and does not allow levels to drop as low in the fall.

Coastal

In understanding the results of a plan in terms of coastal interests, it is first important to keep in mind the key findings of the Coastal Technical Work Group outlined in the previous chapter. The coastal results focus on three key performance indicators: flooding, erosion and shore protection maintenance. For all three of these indicators, on Lake Ontario, the biggest issue is the timing of the high levels. When high levels coincide with the storm season in late fall and early spring, the greatest damage can occur. On the lower St. Lawrence River, the biggest issue is flooding and there is very little difference between plans in terms of erosion and shore protection, largely because the lower river is not as susceptible to large wind-generated waves.

Note that erosion and shore protection maintenance are the only economic performance indicators to have serial dependence, and their damages cannot be avoided, only delayed. The best way to assess the plans, therefore, is to determine which one delays or postpones these damages to a later time. The damages are then discounted to a present value. In this case, the results of the stochastic runs become very important and are the best indication of potential impacts that are not a function of the historical supplies.

Flooding

While there are over 7,600 property parcels, with a total building and contents value of about $1.3 billion, that are 3 metres (9.8 ft) or less in elevation above chart datum (74.15 m or 243.29 ft.), all plans try to keep levels below 76.2 metres (250 ft). At this level, there are about 3,000 vulnerable property parcels, with a total value of about $571 million U.S. Plan 1958-DD has significantly reduced flooding on Lake Ontario compared with the unregulated regime. Expected average annual flood damages under 1958-DD are about $170,000 U.S. Plan A⁺ is the only plan to have small benefits in terms of Lake Ontario flooding, relative to 1958-DD, because of less frequent very high lake levels. Plan B⁺ and D⁺ have some small losses relative to 1958-DD, but these are rare events during high supply conditions. Plan B+, which is the worst of the three candidate plans in terms of flooding on Lake Ontario, creates another $200,000 U.S. in average annual damages relative to 1958-DD. While this doubles 1958-DD damages, the total might be viewed as insignificant compared with the total properties at risk. The Regional Municipalities of Durham and Northumberland on the north shore of Lake Ontario have the highest potential for flood damage.

On the lower St. Lawrence River, there are nearly 5,800 residential buildings within the 100-year return floodplain between Beauharnois hydropower dam and Trois-Rivières, representing a value of about $380 million U.S. Under 1958-DD, an annual average of about $980,000 U.S. in potential flood damages is expected. To put this in perspective, under the historical sequence, an expected 214 homes flooded on an average annual basis, and this increased to 248 and 276 under plans A+ and B+, respectively. When compared to the 5,800 homes potentially at flood risk, this represents an increase of 1% or less. The flooding that does occur on the lower river is concentrated in the Île de Sorel and Lac St. Pierre areas (see Figure 37 as an example). However small the impacts in dollars terms, it still should be recognized that, under the stochastic analysis, Plan A+ increases these damages by 50% relative to 1958-DD. This represents an average annual increase of about $510,000 U.S., and constitutes a slightly larger increase than would occur under Plan E, the unregulated plan. Plan B+ increases damages downstream by about $220,000 U.S. on an average annual basis, while Plan D+ is the only candidate plan that reduces losses from downstream flooding relative to 1958-DD, with an average annual gain of about $90,000 U.S.

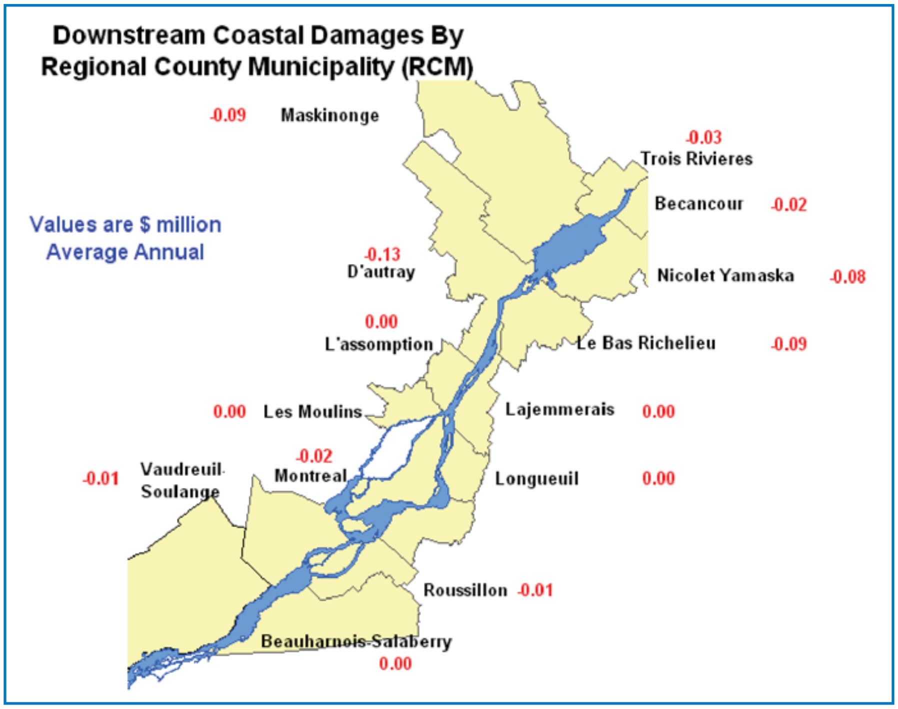


Figure 37:* *Downstream flood damages under Plan A+ relative to 1958-DD based on stochastic analysis

Erosion

There is 388 km (241 miles) of eroding shoreline along the lower St. Lawrence River, of which 27 km (17 miles) is heavily eroding (average recession rate of 1.1 m/yr or 3.6 ft/yr). While erosion on the lower river was modeled, it was determined not to be a major economic issue since most developed properties are already protected and land lost in the case of undeveloped properties was not of significant economic value.

The performance indicator for erosion to unprotected developed parcels on Lake Ontario quantifies damage based on the cost of adding shore protection once the shoreline is within a defined distance from the house. The value of lost material is not determined since it was the advice of the economic advisors that this could be considered equivalent to the value of land gained elsewhere in the system through accretion. On the Lake, 160 km (about 100 miles) are susceptible to erosion, representing about 2,700 developed properties with a total building assessed value of almost $300 million U.S.

On Lake Ontario, lakebed downcutting is the principal process that sustains long-term erosion rates for a retreating shoreline, and the rate of downcutting is at a maximum during periods of low lake levels. When lake levels are high, less wave energy is expended on lake bed downcutting and more energy reaches the bluff or dune, resulting in accelerated shoreline erosion and retreat. While the downcutting process is difficult for riparian land owners to understand, observe and especially measure, they are able to see the immediate impact of high lake levels on erosion rates, and high levels along with the seasonal timing of the highs remain the most important factors in determining recession rates.

Plan D+ results in about the same amount of erosion as 1958-DD. Both plan A+ and B+ create small economic losses in terms of erosion relative to 1958-DD. Expected average annual erosion damages under 1958-DD are about $2.5 million U.S. (see Annex 3, Table C1). This increases by $230,000 U.S. under Plan A+, and by $170,000 U.S., on an average annual basis, under Plan B+. Oswego and Jefferson counties on the eastern end of Lake Ontario generally have the largest erosion-related economic damages. However, erosion damages seem to be fairly evenly distributed around the Lake, with the exception of the western end from Hamilton through to Toronto; this area has very little susceptibility to erosion, largely because there is already a high level of shore protection in place.

It is clear that rates of erosion are faster under plans A+ and B+ than under 1958-DD or Plan D+. The following is an image of a sample shoreline reach in a high erosive area of Monroe County.

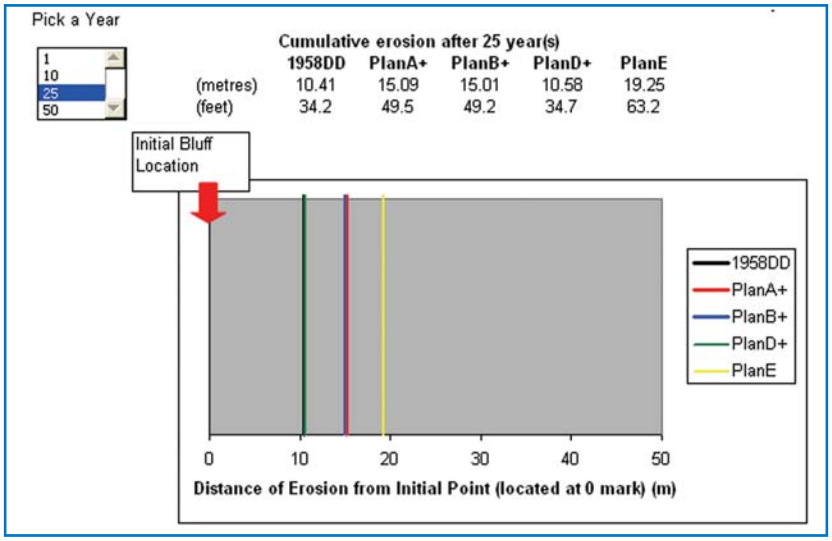


Figure 38: Cumulative erosion (m) after 25 years for all plans, based on stochastic analysis, for a sample property in a high erosive area of Monroe County, NY

Shore Protection Maintenance

Shore protection maintenance on Lake Ontario is the coastal performance indicator that is most sensitive to the differences among the candidate regulation plans. This is because shore protection maintenance on the Lake is influenced by both lake level and wave energy, making the timing and duration of highs and lows very important. On the River, shore protection maintenance is not as sensitive to differences among plans.

Three types of possible failures – overtopping, undercutting and age – were examined in relation to the shore protection maintenance performance indicator. This is a complicated performance indicator that takes into account the amount of downcutting caused by a plan, which in turn impacts on the cost of rebuilding the shore protection, and the design water level of the shore protection, which is a function of the shoreline's susceptibility to wave energy and storm surge, a factor that varies by county around the lake.

There is currently an annual expected loss of about $54 million U.S., based on depreciation alone, relative to the $500 million U.S. investment in shore protection and $1 billion U.S. in building value on Lake Ontario. This is split fairly evenly between U.S. and Canada. Shoreline property owners could expect to pay an average of $15.48 million U.S. annually as a result of failures under the base case Plan 1958-DD. Under Plan A+, expenditures resulting from shore protection failures would be reduced by $570,000 U.S. per year relative to 1958-DD, while Plan B+ would add $2.16 million U.S. in average annual costs, as a result of failures, to expenditures under Plan 1958-DD. Plan D+ is associated with an average annual increase of $170,000 U.S. relative to 1958-DD.

In terms of the coastal interests, the benefits of Plan A+ are realized primarily through a gain in the area of shoreline protection maintenance. Although the benefits are relatively small, Plan A+ is the only plan that achieves a gain in terms of shore protection benefits relative to 1958-DD on Lake Ontario. This is likely attributable to the tightly regimented range that Plan A+ tries to maintain. This range reduces the amount of downcutting that occurs during low water level periods and yet tries to keep the Lake low enough to prevent overtopping. Interestingly, this tight range, which tends to have a slightly higher average than 1958-DD, does not slow erosion of unprotected properties.

The increases in damages resulting from Plan B+ are likely attributable to the broader range of levels allowed by the Plan, which provides more opportunity for both downcutting and overtopping. Plan D+ does not differ greatly from 1958-DD.

Table 9 shows the shore protection maintenance benefits under Plan A+ to be fairly equally distributed around the Lake. The disbenefits of Plan B+ affect all counties around the lake, but are worse on the south shore. Plan D+ provides a mix of small gains and losses around the lake, which probably indicates that it is so similar to 1958-DD that it is difficult to distinguish them.

Table 9: ***Shore Protection Maintenance, by Lake Ontario County, based on the Stochastic Supply Simulation (average annual values (in million U.S. dollars) discounted at 4% over 30-year period)***

	Plan A+	Plan B+	Plan D+	Plan E
Shore Protection	**0.57**	**-2.16**	**-0.17**	**-19.85**
Cayuga Co	-0.01	-0.03	0.00	-0.23
Durham RM	-0.01	-0.08	-0.01	-0.70
Frontenac	0.00	0.00	0.00	0.00
Halton RM	0.04	-0.18	-0.04	-1.68
Hamilton RM	0.01	-0.08	-0.02	-0.80
Hastings	0.00	0.00	0.00	0.00
Jefferson Co	0.02	-0.07	-0.01	-0.61
Leeds	0.00	0.00	0.00	0.00
Lennox	0.00	0.00	0.00	0.00
Monroe Co	0.04	-0.32	0.04	-3.08
Niagara Co	0.06	-0.34	-0.06	-2.79
Niagara RM	0.16	-0.29	-0.08	-2.42
Northumberland RM	0.03	-0.10	0.00	-0.91
Orleans Co	0.04	-0.22	0.05	-2.09
Oswego Co	0.08	-0.18	0.01	-1.96
Peel RM	0.06	-0.07	0.00	-0.68
PrinceEdward	0.00	0.00	0.00	0.00
StLawrence Co	0.00	0.00	0.00	0.00
Stormont	0.00	0.00	0.00	0.00
Toronto	0.03	-0.06	0.00	-0.65
Wayne Co	0.01	-0.13	-0.03	-1.26

In summary, Plan A+ is the best of the candidate plans for shoreline interests on Lake Ontario. Its gains come from benefits associated with the shore protection maintenance performance indicator. However, Plan A+ also causes erosion to happen more quickly than 1958-DD and is similar to Plan B+ in that respect. Plan A+ also causes increased flooding downstream, as does Plan B+. Plan D+ is slightly worse for shore protection maintenance than 1958-DD but, overall, does not cause significant harm to shoreline interests on the Lake or upper river relative to 1958-DD. Plan D+ is the only plan that provides coastal benefits on the lower river relative to 1958-DD.

Coastal damages occur regardless of the regulation plan and none of the candidate plans creates significant benefits relative to what would be expected under 1958-DD. The biggest problems result from increased shore protection maintenance on Lake Ontario under Plan B+ and downstream flooding under Plan A+.

Environment

Plan B+ is the best of the candidate plans for the environment above the Moses-Saunders Dam, but no plan is significantly better than any other below the Dam. Plan B+ is judged best above the Dam on the strength of its performance indicator scores, especially for Meadow Marsh, Virginia Rail, Black Tern and Muskrat house density scores. Plan B+ creates more natural variation in Lake Ontario water levels and preserves the natural timing of the seasonal rise and fall.

The table of plan performance below (Table 10) shows a subset of the 32 key environmental performance indicators that together tell a coherent story about species habitats, seasonal and life cycles and whether a plan partially restores natural long-term variability. For the results of all 32 key performance indicators, refer back to Table 8.

Table 10: Priority Performance Indicators Identified by Members of the Environmental Technical Work Group based on Historical Analyses

Priority Performance Indicators	Plan A+	Plan B+	Plan D+	Plan E
Lake and Upper River				
Meadow Marsh	1.02	1.44	1.17	1.56
Black Tern - Reproductive index	1.03	1.12	1.01	1.16
Virginia Rail - Reproductive index	0.96	1.11	0.99	1.15
Muskrat - House density	1.42	4.39	1.73	37.25
Northern pike – Young-of-Year (YOY)	1.05	1.03	1.01	1.06
recruitment and net productivity	4.02	2.08	1.17	4.08
Largemouth Bass - YOY	0.99	1.00	1.00	1.00
Fish Guild (High-veg 24 C)	1.03	1.01	1.02	1.02
Lower River				
Golden Shiner - Suitable feeding habitat area	1.00	1.00	1.00	1.03
Virginia Rail - Reproductive index	0.94	0.97	1.06	1.00
Migratory Wildfowl - Productivity	1.06	1.00	1.00	1.03
Northern Pike - Reproductive area	0.97	0.94	0.94	0.94
Bridle Shiner - Reproductive habitat surface area	1.00	0.97	1.03	1.03
Muskrat - Surviving houses	1.04	0.88	0.96	0.80

Notes to Table 10:

1. Figures reflect the impact relative to Plan 1958-DD expressed as ratios, where 1 represents no change from 58-DD, >1.00 an improvement relative to 58-DD, and < 1.00 a deterioration relative to 58-DD.
2. Run using the historical supply sequence because the Integrated Ecological Response Model component of the Shared Vision Model could not be adapted to run the full 50,000-year sequence.
3. Aqua shading identifies species at risk.
4. Yellow shading indicates essentially no change from 1958-DD (within 10% difference). Anything above 1.10 is marked in **blue** and anything below 0.90 is marked in **red**.

The Environmental Technical Work Group has suggested from the beginning of this Study that the best plan for the environment is the natural flow plan. Plan E produced the closest to natural flows that can be achieved while still maintaining a smooth ice cover on the St. Lawrence River. But while Plan E simulates more natural conditions, it does not represent the natural condition before regulation. The system, especially on the lower St. Lawrence River, has changed dramatically since the Moses-Saunders Dam was built. For example, much of the tributary mouth wetlands on the lower river have been converted to farmland. What might have once been good for the environment in terms of levels and flows may no longer be the case. The environment on the lower river is responding to a different set of conditions than it did before the dam was built. In addition, the lower St. Lawrence River hydrology is much more dynamic than the Lake and upper river throughout each period of the year. It is influenced not only by outflows from Lake Ontario, but also by the Ottawa River flow and by local tributaries. As a result, the lower St. Lawrence River is less sensitive to regulation, and none of the candidate plans, or even the natural flow plan, has much affect on the environment on the lower St. Lawrence River.

There are five performance indicators on the Lake and upper St. Lawrence River that stand out under Plan E as performance indicators that can be influenced by a regulation plan. These are meadow marsh, black tern, Virginia rail, northern pike, and muskrat house density.

Within the Integrated Ecological Response Model, black tern and Virginia rail are only dependent on emergent marsh vegetation for their results, so the three scores of meadow marsh, black tern and Virginia rail can be looked at as a group representing wetland habitat. In effect, this aggregation produces three key indicators for examination, Lake Ontario wetlands, northern pike young-of-year, and upper St. Lawrence River muskrats.

Current muskrat population levels in the upper St. Lawrence River are extremely low, so any improvement tends to create large positive ratios. Muskrats constitute a very important part of both wetland structure and function and therefore represent much more than just their own species. They can influence vegetation species richness in wetlands, offer suitable substrate for seed germination, help facilitate decomposition processes, provide nesting sites for birds and turtles, including some species at risk, and create microtopography in wetlands. Many bird, mammal, plant, and likely fish species, such as the northern pike, respond favorably to the increases in open water and edge and channel effects created by muskrat disturbance.

The presence/absence and annual density of active muskrat houses is used to estimate house density to represent the performance of muskrats. Fall and winter wetland water depths and winter air temperatures are used to compute the muskrat performance indicator for each simulation year. Fall and winter bring the most challenging conditions for muskrat populations. Data on existing populations for muskrats was collected in recent years (2001-2004), representing post regulation conditions.

All of the candidate plans improve scores for muskrats on the upper St. Lawrence River, but Plan B^+ clearly has the highest score. However, Plan B^+ also causes some negative impacts for lower St. Lawrence River muskrats.

Northern pike are excellent indicator species due to their role in the fish community and their dependence and sensitivity to wetland habitats during spawning and early life history. Because of their sensitivity, northern pike are a good indicator of system changes, and their populations have experienced significant declines. Two indicators of northern pike young-of-year were researched by the Environmental Technical Work Group. These were young-of-year recruitment and young-of-year net productivity. Both indicators move in the same direction and are consistent by plan. The performance indicator assesses the effects of water level and temperature variation on critical early life stages. All of the candidate plans show a positive benefit relative to Plan 1958-DD, with Plan A^+ providing the greatest benefits, followed by Plan B^+ and then D^+. The primary factor in plan performance is spring water levels in the upper St. Lawrence; higher levels are better because they flood more wetlands. The ranking of plans for northern pike in the upper St. Lawrence is the same whether based on the probability of higher water levels, the young-of-year productivity performance indicator for the Thousand Islands area or the young-of-year recruitment indicator for the entire upper river area.

The wetlands and coastal habitats of Lake Ontario evolve in response to the natural rhythms of water levels. Wetland plant zonation is determined by the frequency, duration and depth of flooding, based on the sequence outlined in Figure 39.

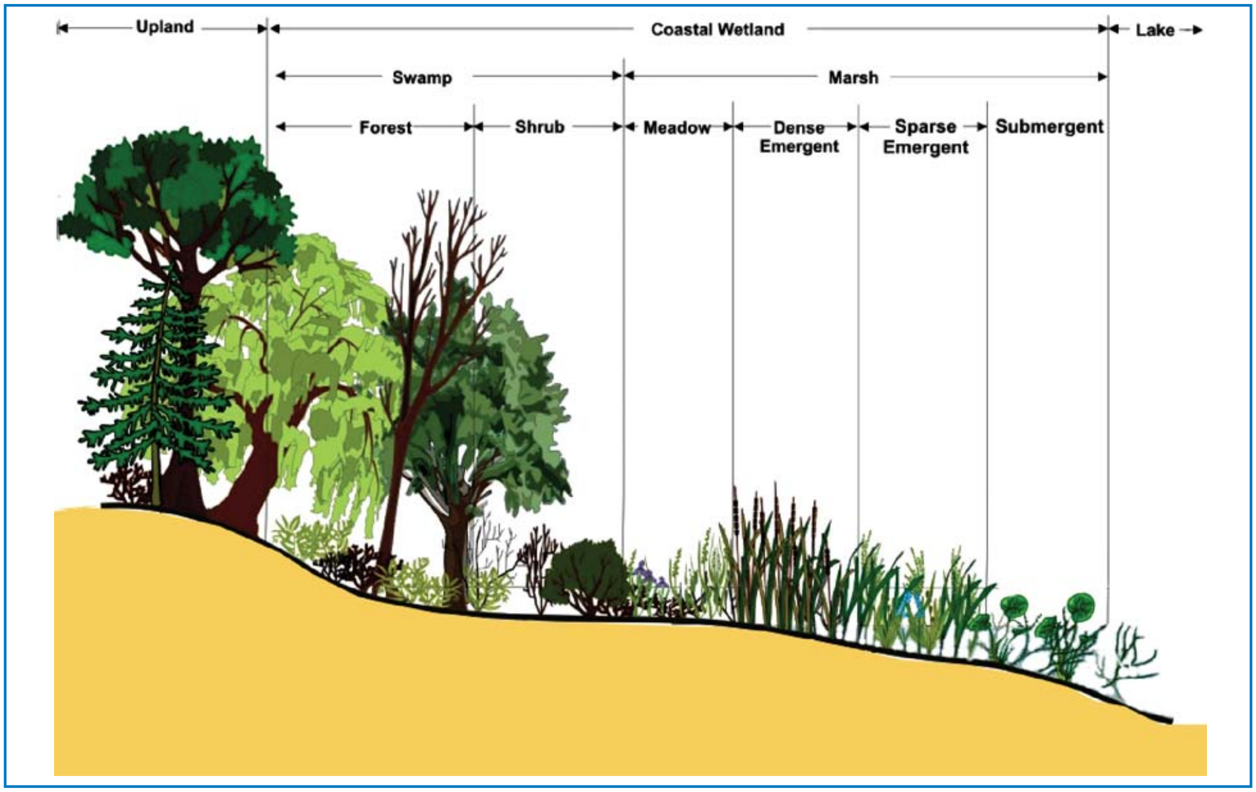


Figure 39: ***Wetland plant community zones***

In Lake Ontario, complete stabilization of levels would produce a sharp cutoff between the plants that grow on land (upland vegetation last flooded > 30 years ago) and the plants that can grow under water (submerged vegetation), with a very narrow band in the middle (meadow marsh and emergent vegetation). When water levels rise, the woody plants near the water die back, as do the dominant emergent plants (now submerged), and the amount of aquatic vegetation increases. Conversely, during extended dry periods, water levels drop and new seeds take root in the newly uncovered bank, establishing meadow marsh above and emergent marsh closer to the water, and the amount of aquatic vegetation decreases. During these extended dry periods, cattails, which can dominate emergent marsh, are dewatered and die off. Surveys conducted in this study found little or no cattails at elevations that had not been flooded for five years or more. This cycle of high and low water levels creates more diverse wetland vegetation that is more resilient to other stresses put on the system, and produces more diversified habitat for a broader range of species (Wilcox, et al, 2005).

Plan 1958-DD has reduced the natural range and longer term cycles of Lake Ontario and this has negatively impacted wetland habitat, as can be seen in the differences between Plan E and 1958-DD. Of the three candidate plans, Plan B^+ is the clear winner for improving wetland habitat on Lake Ontario. Plan D^+ provides some modest improvement, while Plan A^+ offers little to no improvement over 1958-DD.

While the results presented in the previous tables are based on the historical water supply sequence, the Environmental Technical Work Group did run the wetland model portion of the Integrated Ecological Response Model through the 50,000- year stochastic time series. The long-term wetland simulation evaluated the annual elevation range and total wetland area associated with each of the four major Lake Ontario plant communities (upland, meadow marsh, emergent marsh, and submerged vegetation) for each of the candidate plans and 1958-DD, as well as Plan E for reference. The model results for the 50,000-year simulation, as shown in figures 40 and 41, were found to be consistent with the results obtained for the historical sequence. In some cases, the differences between the regulation plans appeared to be greater for the stochastic simulations. In brief, it was found that regulation, as represented by Plan 1958-DD, clearly tends to minimize the long-term abundance of meadow marsh and emergent marsh, which provide important habitat for fish, birds and other fauna. Plan E performs best with respect to maximizing meadow marsh area in the long-term. Plan B+ performs significantly better than Plan D+. Plan A+ performs worst with respect to long-term restoration of meadow marsh area that has been lost under regulation.

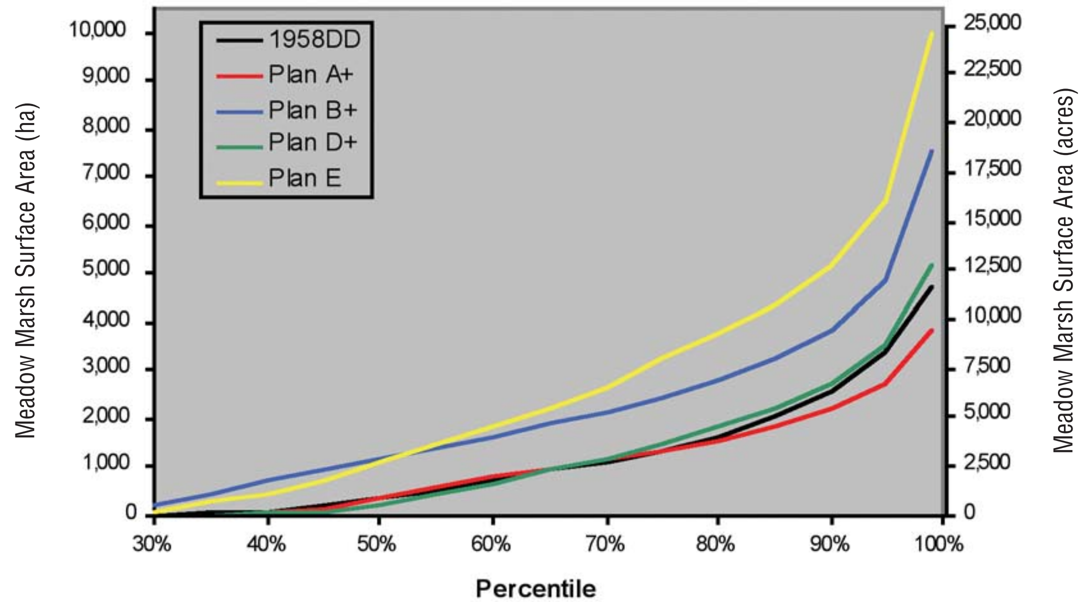


Figure 40: Lake Ontario meadow marsh frequency distribution for the 50,000-year stochastic simulation

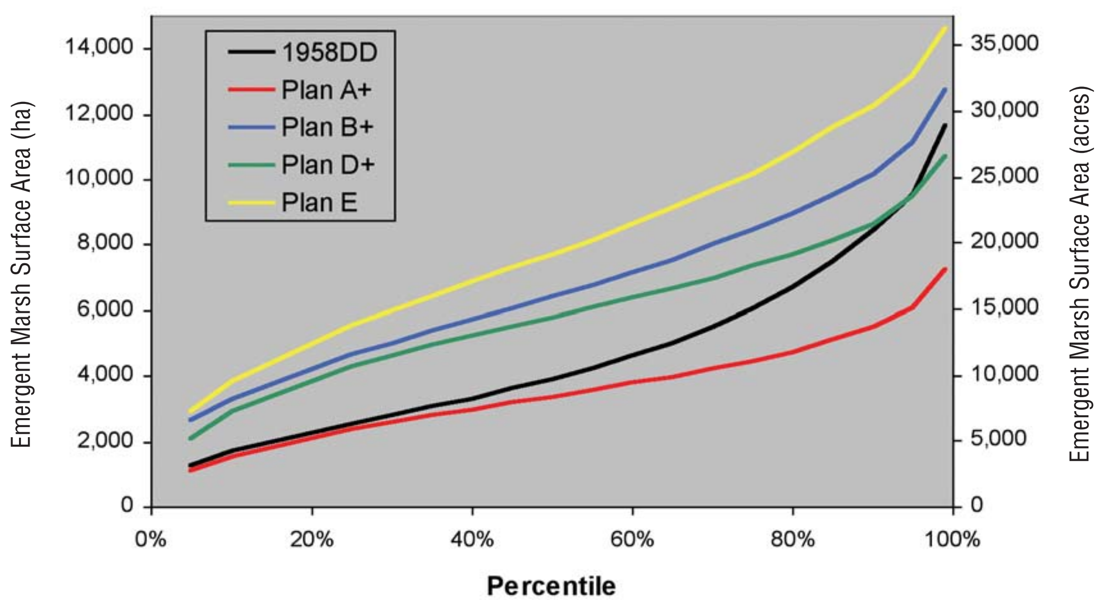


Figure 41: Lake Ontario emergent marsh frequency distribution for the 50,000-year stochastic simulation

Sensitivity Analyses

During the course of the six "practice" decision workshops, the Study Board was able to isolate the performance indicators that were critical to the decision. Because the estimated values of these indicators were so important, the indicators were given extra scrutiny. But no amount of review will guarantee perfect models of the future, so, in some cases, the Study Board asked that an analysis be conducted to determine how sensitive the plan performance was to variations in modeling elements that could be considered within the range of irreducible uncertainty. The investigations fell into three categories:

- **Extreme conditions:** Would a plan that scores well during periods of average hydrologic conditions fail when water supplies are extremely dry, extremely wet, or sequenced differently?
- **Climate change:** Would a plan that performs well under the current climate fail in fifty years or so if climate change alters the seasonal timing and amount of water supply and evaporation?
- **Performance indicator error:** Would plan performance change from acceptable to unsatisfactory if the modeling assumptions behind the performance indicators driving the ranking change to a different but defensible value?

Extreme Conditions Analysis

The Board used average annual benefits to conduct its initial evaluation of plans, but asked whether high ranking plans also performed well in extreme conditions. The Plan Formulation and Evaluation Group addressed this in two ways:

1. It compared the candidate plans under four particular centuries selected from the stochastically generated 50,000-year sequence: the century with the most severe Lake Ontario supply drought (S1); the century with the most severe wet Lake Ontario supply period, which also had the largest range from wet to dry supplies (S2); a century with a similar range and average of supplies as the historical (S3); and a century with the longest sustained Lake Ontario drought (S4). These four "centuries" show differences among the plans during the most unusual water supply sequences in the 50,000-year sample and in the case of average supplies in a different sequence from the historical. Because the complete Integrated Ecological Response Model component of the Shared Vision Model could not feasibly be adapted to run the full 50,000-year sequence, these four centuries give a sampling of how the environmental performance of the plans might vary under extreme conditions. This is used in conjunction with the Lake Ontario wetland model results that were run over the full 50,000-year sequence to provide insights into how the environmental performance indicators respond to conditions outside the historical range.
2. It developed frequency distributions for a few key water levels (Lake Ontario, Lake St. Lawrence, Lac St. Louis, and Montreal) and releases. These graphs occasionally revealed changes in plan behavior between average and extreme conditions.

Figure 42 shows a five-year moving average of the net total supply (NTS) for the four stochastic centuries (S1-S4) and the historical net total supplies. S1 (pink line) has extremely dry supplies towards the middle of the century. S2 (green line) starts with extremely wet supplies towards the beginning of the century, then drops to low supplies towards the end of the century. S3 (blue line) has about the same length of time between wet and dry periods as the historical case and its wet and dry sequences are never more extreme than the historical case (black line). S4 (red line) has a very long drought that lasts over half the century.

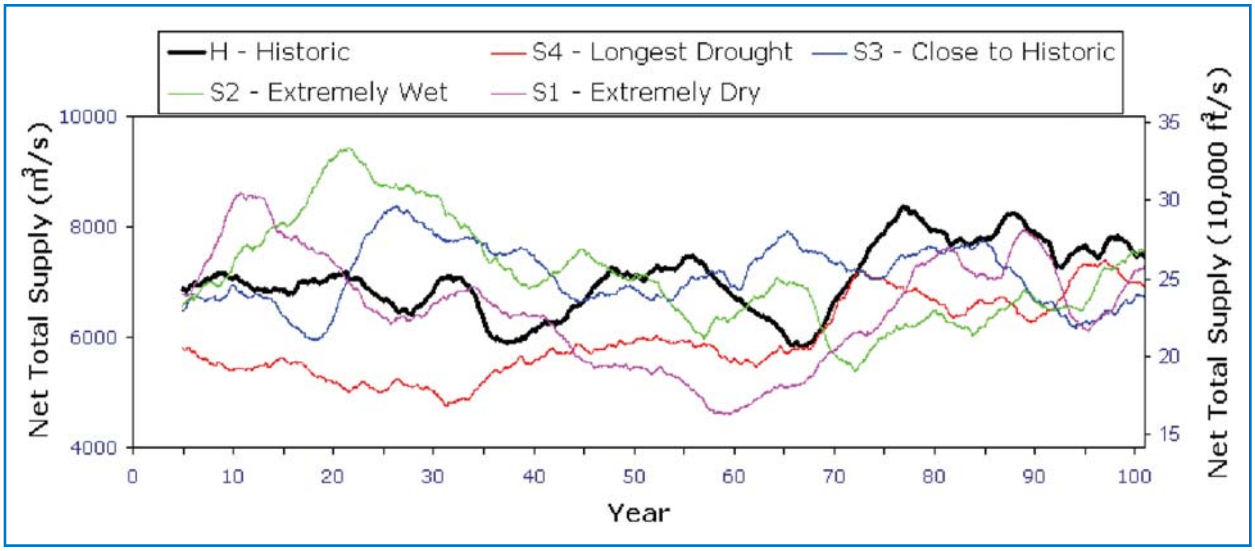


Figure 42: Five-year moving average of the net total supply (NTS) for the four stochastic centuries (S1-S4) and the historical

Under extreme conditions, damages will occur regardless of the plan in effect. Below is a summary table (Table 11) of differences in absolute average annual damages between the historical time series and what would be expected under each of the extreme stochastic scenarios for Plan 1958-DD.

The next question is, how well will a candidate plan perform under those difficult conditions relative to 1958-DD? The full results tables for each of the supply sequences analyzed can be found in Annex 3 – Plan Description and Results. Below is a summary table of overall results for each plan for each of the four extreme stochastic centuries. As with the historical and full stochastic results presented earlier in this report, all comparisons of plans are in terms of net benefits relative to the absolute damages under 1958-DD. So if a plan can improve the situation relative to 1958-DD, the result is a positive benefit, and if circumstances are worse than under 1958-DD, the result is a negative benefit.

Plan A^+ has the highest net economic benefits under the historical and full stochastic sequences and also consistently has the highest net economic benefits under the extreme stochastic sequences. Recreational boating always shows improvement under Plan A^+ regardless of the extreme condition. Lake Ontario shore protection also tends to benefit by Plan A^+ except during the S4 – longest drought sequence. The gains and losses for the other economic interests are mixed, depending on the sequence, although it is arguably the worst plan for lower St. Lawrence River flooding. For the environment, Plan A^+ does not perform well under most of the sequences, only once producing an overall environmental performance ratio to 1958-DD greater than one under the wet scenario (S2 - a 4% improvement). And even in this S2 sequence, Plan A^+ performs poorly for the wetland meadow marsh, as it also does under S1 and S3. When it does produce a meadow marsh score greater than 1.0, under the S4 longest drought sequence, it has very low scores for the Lake Ontario emergent-marsh-dependent bird performance indicators, including some of the species at risk. During the extreme dry conditions of S1 and S4, Plan A^+ tries to keep the levels up and uses the Lake as a reservoir, benefiting both upstream and downstream boaters, while providing minor to modest gains and losses for the other economic interests. However, by keeping levels up during the dry periods, Plan A^+ does not allow the lows needed for regeneration of wetlands. These results are consistent with the 50,000-year stochastic run of the Lake Ontario Wetlands Model, which shows Plan A^+ to be the worst of all the plans (including Plan 1958-DD) for both the meadow marsh and emergent marsh.

Table 11: Summary of Economic Results for Four Extreme Stochastic Supply Sequences under Plan 1958-DD

Performance Indicator	1958-DD Historic vs S1 (Extremely Dry)	1958-DD Historic vs S2 (Extremely Wet)	1958-DD Historic vs S3 (Similar to Historic)	1958-DD Historic vs S4 (Longest Drought)
	Annual Average in $US Millions			
COASTAL	**$0.95**	**-$9.83**	**-$2.38**	**$3.06**
Lake Ontario	*-$0.25*	*-$9.98*	*-$2.41*	*$1.70*
Shore Protection Maintenance	-$0.33	-$7.70	-$2.38	$1.47
Erosion to Unprotected Developed Parcels	$0.09	-$0.06	-$0.02	$0.23
Flooding	-$0.01	-$2.22	$0.00	$0.00
Upper St. Lawrence River	*$0.00*	*-$0.17*	*$0.00*	*$0.00*
Flooding	$0.00	-$0.17	$0.00	$0.00
St. Lawrence	*$1.20*	*$0.32*	*$0.03*	*$1.35*
Flooding	$0.73	$0.35	$0.34	$0.88
Shore Protection Maintenance	$0.48	-$0.03	-$0.31	$0.48
COMMERCIAL NAVIGATION	**-$0.75**	**-$2.80**	**$0.34**	**$2.04**
Lake Ontario	-$0.23	-$0.04	$0.01	-$0.25
Seaway	-$0.10	-$2.93	$0.06	$3.04
Montreal down	-$0.42	$0.16	$0.26	-$0.75
HYDROPOWER	**-$30.34**	**-$1.39**	**$2.70**	**-$55.96**
NYPA-OPG	-$24.51	-$0.57	$2.40	-$45.13
Hydro Quebec	-$5.83	-$0.82	$0.30	-$10.83
RECREATIONAL BOATING	**-$18.06**	**-$2.21**	**$3.67**	**-$27.65**
Above Dam	*-$12.75*	*-$2.04*	*$1.47*	*-$16.29*
Lake Ontario	-$10.49	-$1.74	$1.08	-$13.17
Alex Bay	-$2.05	-$0.27	$0.39	-$2.93
Ogdensburg	-$0.20	-$0.05	$0.00	-$0.20
Lake St. Lawrence	-$0.01	$0.02	$0.00	$0.01
Below Dam	*-$5.31*	*-$0.17*	*$2.19*	*-$11.36*
Lac St. Louis	-$2.61	-$0.19	$0.91	-$5.53
Montreal	-$1.84	$0.07	$0.93	-$4.22
Lac St. Pierre	-$0.86	-$0.05	$0.35	-$1.62
M&I	**$0.00**	**$0.00**	**$0.20**	**$0.00**
SL One time infrastructure costs	$0.00	$0.00	$0.00	$0.00
LSL Water Quality Investments	$0.00	$0.00	$0.20	$0.00

Notes to Table 11:

1. Results are absolute average annual values (million U.S. dollars) with all numbers representing damages avoided Positive numbers indicate that the stochastic analysis results in greater benefits for an interest than does the analysis based on the historical series. Negative numbers indicate that the stochastic analysis results in smaller benefits than the historical analysis.
2. Historical sequence represents supplies from 1900 to 2000.
3. S1 through S4 represent four separate 101-year extreme centuries selected from the 50,000-year stochastic series, where S1 is extremely dry, S2 is extremely wet and has a large range, S3 is similar to historical and S4 has the longest drought.

Table 12: Summary of Overall Economic and Environmental Results for Four Extreme Centuries Selected from the 50,000-year Stochastic Series

S1 – Extremely Dry – Impact	Plan A^{+}	Plan B^{+}	Plan D^{+}	Plan E
Total Net Benefits[2]	**$17.53**	**$2.62**	**$10.84**	**-$21.41**
Total of Losses (all sectors)[3]	**-$0.69**	**-$3.66**	**-$0.04**	**-$33.59**
Overall Environmental Index[4]	0.99	1.31	0.97	2.33
Meadow Marsh Index[5]	0.88	1.22	1.01	1.44
Environmental PIs better off[6]	5	6	5	9
Environmental PIs worse off[7]	8	1	6	1
Species at Risk better off[8]	1	0	0	4
Species at Risk worse off[9]	4	0	4	0
S2 – Extremely Wet and Large Range – Impact	**Plan A^{+}**	**Plan B^{+}**	**Plan D^{+}**	**Plan E**
Total Net Benefits[2]	**$9.76**	**$3.97**	**$5.42**	**-$33.96**
Total of Losses (all sectors)[3]	**-$1.69**	**-$2.90**	**-$0.79**	**-$53.09**
Overall Environmental Index[4]	1.04	1.17	1.04	1.91
Meadow Marsh Index[5]	0.93	1.23	1.17	2.21
Environmental PIs better off[6]	6	9	6	11
Environmental PIs worse off[7]	3	0	2	0
Species at Risk better off[8]	2	2	1	4
Species at Risk worse off[9]	2	0	1	0
S3 – Similar to Historical – Impact	**Plan A^{+}**	**Plan B^{+}**	**Plan D^{+}**	**Plan E**
Total Net Benefits[2]	**$7.28**	**$5.69**	**$5.02**	**-$7.69**
Total of Losses (all sectors)[3]	**-$0.85**	**-$4.07**	**-$0.94**	**-$28.11**
Overall Environmental Index[4]	0.99	1.26	0.99	4.72
Meadow Marsh Index[5]	0.93	1.51	0.90	1.57
Environmental PIs better off[6]	7	8	5	13
Environmental PIs worse off[7]	1	1	2	0
Species at Risk better off[8]	3	3	2	4
Species at Risk worse off[9]	0	0	0	0
S4 – Longest Drought – Impact	**Plan A^{+}**	**Plan B^{+}**	**Plan D^{+}**	**Plan E**
Total Net Benefits[2]	**$16.07**	**-$6.81**	**$8.74**	**-$19.42**
Total of Losses (all sectors)[3]	**-$2.11**	**-$8.96**	**-$0.65**	**-$23.14**
Overall Environmental Index[4]	0.93	1.41	0.88	2.95
Meadow Marsh Index[5]	1.16	1.42	1.18	1.76
Environmental PIs better off[6]	6	4	4	7
Environmental PIs worse off[7]	12	3	9	5
Species at Risk better off[8]	1	0	0	3
Species at Risk worse off[9]	6	1	4	1

Notes to Table 12:

1. All impacts are measured relative to the estimated impact of Plan 1958-DD.
2. Economic figures represent the average annual impact relative to Plan 1958-DD; figures are reported in millions of U.S. dollars and based on the historical sequence and the four 101-year stochastic extreme sequences (S1-S4), with no discounting applied.
3. Total of Losses (all sectors) is the sum of all negative economic benefits for a plan.
4. The Overall Environmental Index was developed by Limno-tech for the Study Board. The Index is described in Annex 1 of this report. Scores are presented as ratios, with 1 representing no change from Plan 1958-DD, less than 1 a deterioration relative to 1958-DD, and greater than 1 an improvement relative to 1958-DD. Results are based on the historical sequence
5. The Wetland Meadow Marsh Community performance indicator has been highlighted as a priority performance indicator for environmental health on Lake Ontario. It is presented as a ratio (see 4 above).
6. This measure indicates the number of environmental performance indicators that score significantly (>10%) higher than 1.0, indicating that the given plan performs better than Plan 1958-DD.
7. This measure indicates the number of environmental performance indicators which score significantly (>10%) less than 1.0, indicating that the given plan does not perform as well as Plan 1958-DD.
8. This measure indicates the number of Species-at-Risk performance indicators that score significantly (>10%) higher than 1.0, indicating that the given plan performs better than Plan 1958-DD.

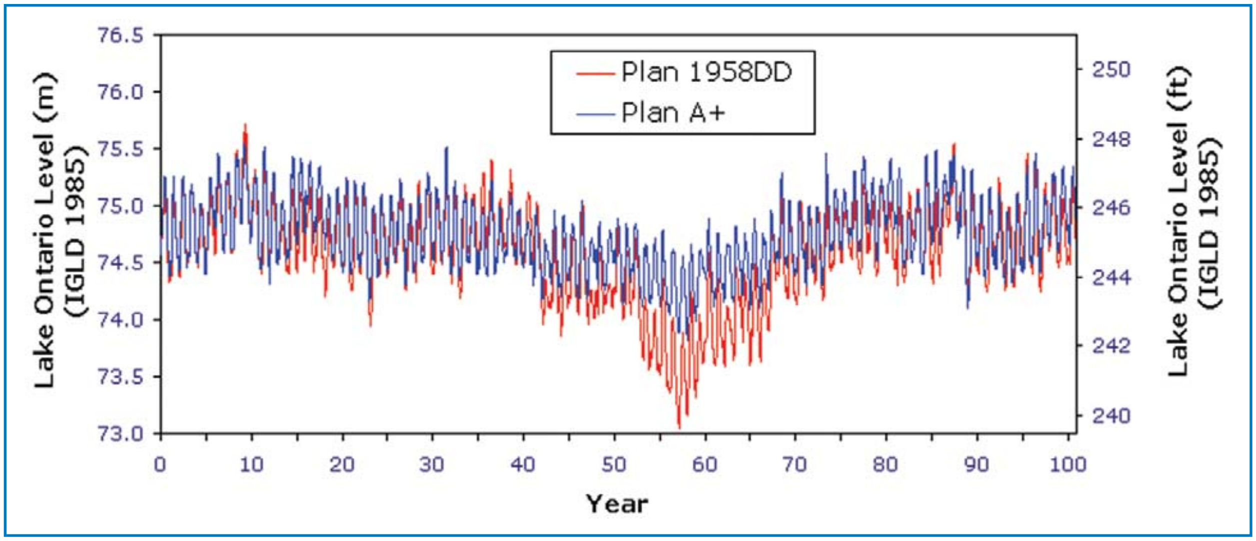


Figure 43: ***Lake Ontario levels under Plan A⁺ (blue) versus 1958-DD (red) for the 101-year extremely dry stochastic sequence (S1)***

While Plan A⁺ is the consistent economic winner, Plan B⁺ is the consistent environmental winner. Of the three candidate plans, Plan B⁺ always provides overall environmental improvement and always provides improvement to the Lake Ontario meadow marsh under each sequence. The only environmental indicator that is typically worse under Plan B⁺ is the habitat for frog species on the lower river. Otherwise, Plan B⁺ provides at least marginal improvements to most indicators on the Lake and upper river as well as the lower river. Economically, the benefits that Plan B⁺ provides outweigh the losses under three of the four sequences, but this plan consistently results in the greatest economic losses of the three plans. Plan B⁺ does not perform well economically under the longest drought, where it produces big negative benefits to recreational boating ($-7.20 million U.S. average annual). Under this sequence, Plan B⁺ does raise the maximum lows relative to 1958-DD, but it does not raise the summer peaks, which are still lower than 1958-DD and therefore create negative benefits during the boating season.

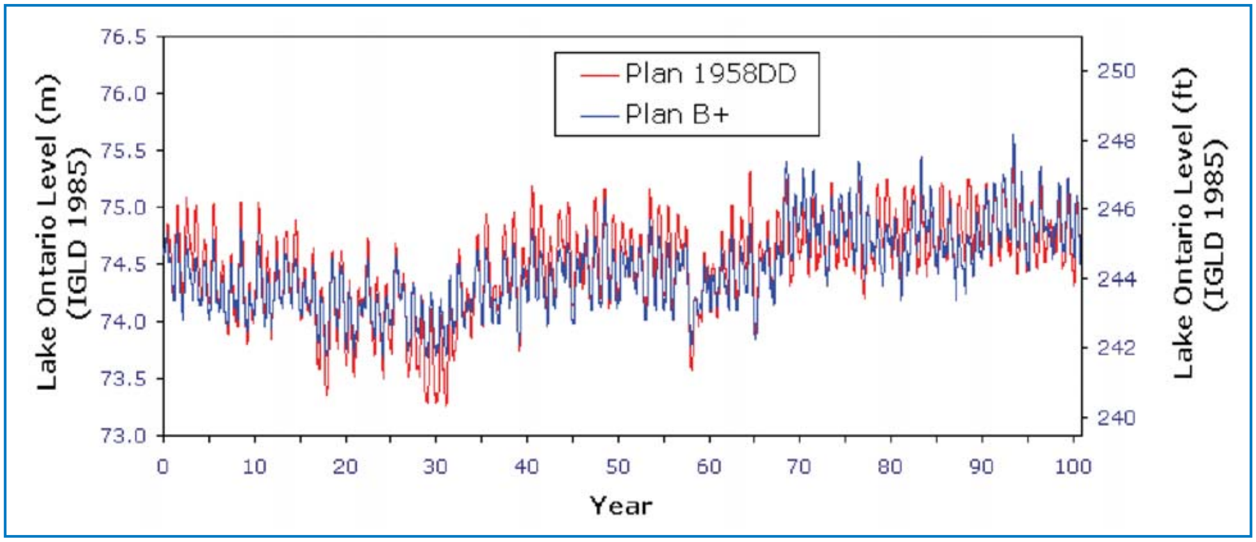


Figure 44: ***Lake Ontario levels under Plan B⁺ (blue) versus 1958-DD (red) for the 101-year stochastic sequence with the longest drought (S4)***

Plan D+ performs well economically in all four stochastic sequences. Its gains are fairly well spread out among the interests as in the case of the historical and full stochastic. It typically results in the fewest economic losses of any of the plans. Figure 45 compares Plan D+ and 1958-DD under the extremely wet century S2.

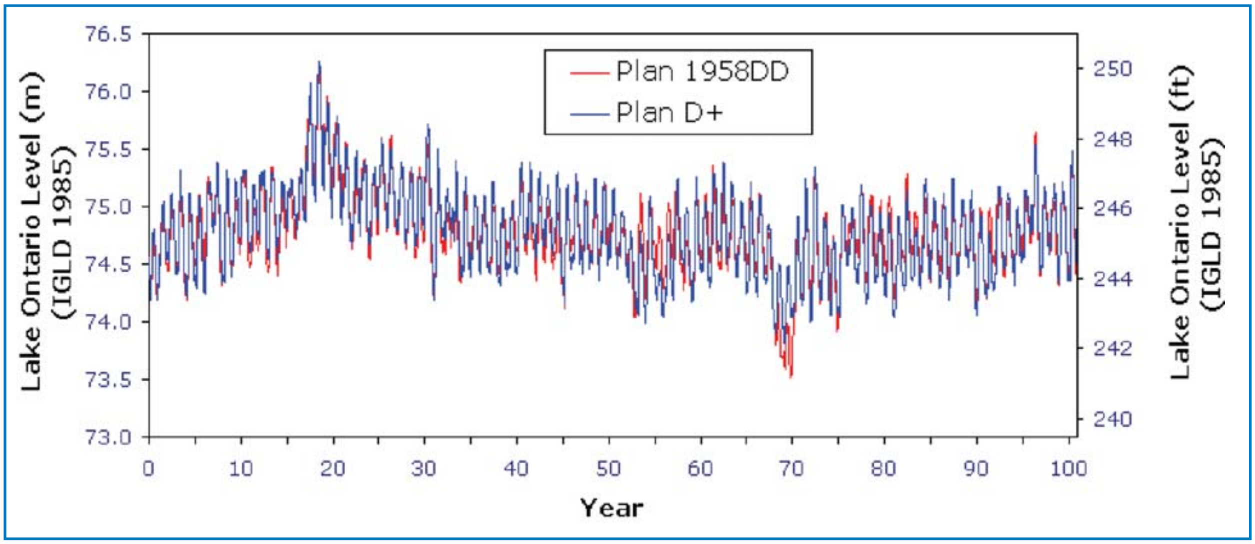


Figure 45:* *Lake Ontario levels under Plan D+ (blue) versus 1958-DD (red) for the 101-year stochastic sequence with the wettest supplies and biggest range (S2)

Plan D+'s environmental results are not consistent. While Plan D+ shows modest improvements for the overall environmental index under the historical time series with a 1.10 ratio in the extreme stochastic sequences, Plan D+ only shows a small improvement in the overall environmental index (1.04) under the S2 wet sequence. Plan D+ provides positive meadow marsh benefits in two of the four extreme scenarios as well as the historical scenario. The 50,000-year stochastic runs for the wetlands model show Plan D+ with only a minor improvement over 1958-DD for meadow marsh despite the 17% improvement indicated under the historical sequence. Plan D+ generally performs better than 1958-DD over the long-term 50,000-year analysis for emergent marsh. However, in the extreme dry scenarios, S1 and S4, Plan D+ performs poorly for emergent-marsh-dependent birds, including some species at risk. To summarize, Plan D+ appears robust and fair in its distribution of benefits for the economic interests under extreme conditions, but its environmental performance is not resilient, with gains in some scenarios, but losses in others.

Earlier graphs (figures 29-33) show how the candidate plans manage water in some of the driest and wettest circumstances within the stochastic series. These figures provide comparisons of the three candidate plans and 1958-DD and present the average levels, the levels exceeded 1% of the time (highs) and the levels exceeded 99% of the time (lows), in each week of the year, based on the 50,000-year stochastic sequence. The Study Board used information on these highs and lows in addition to the 50,000-year stochastic averages and the four stochastic century analyses, to ensure that the plans would be acceptable in rare, but possible circumstances.

The primary finding of this analysis is that Plan A+ has some of the highest average Lake Ontario levels and some of the lowest lake levels during very wet periods, and it accomplishes this by switching to substantially higher summer releases than the other plans produce. As a consequence, downstream at Pointe Claire and Montreal on the lower St. Lawrence River, Plan A+ produces the highest and lowest levels. The outcome is that Plan A+ creates shore protection benefits along Lake Ontario but also causes more lower St. Lawrence River flood damage than any other plan, including Plan E. Plan B+ has some of the highest maximum and lowest minimum levels on Lake Ontario during the extreme conditions, resulting in somewhat higher coastal damages than the other candidate plans.

Climate Change Analysis

Four climate change scenarios were also used to test the plans to ensure that none of the candidate plans would fail the Board's guidelines under the potential change in climate that is predicted to occur due to increased greenhouse gases in the atmosphere. No one knows for sure how this change in the climate will affect water supplies, but generally warmer temperatures and increased precipitation are expected in the Great Lakes–St Lawrence River basin. The amount of climate change will depend on the quantity of greenhouse gases that accumulate in the atmosphere in the coming decades, and how quickly they build up. In addition to this uncertainty in future greenhouse gases, the complexity of the earth's climate system limits scientists' ability to completely model these changes. Nonetheless, several global climate models (GCMs) have been developed to simulate the changes that might be expected under different assumptions about the magnitude of future greenhouse gas increases. Each of these GCMs differs somewhat in how it models the complex interconnected processes that are taking place in the atmosphere, the oceans and on land and that affect climate. Recognizing this uncertainty in both future greenhouse gas amounts and the results of different models, the Study Board asked that four different climate change scenarios be selected: the most warming and wettest conditions, the least warming and wettest conditions, the most warming and driest conditions and the least warming and driest conditions. Details about the selection of the GCMs and greenhouse gas assumptions are reported in Mortsch et al (2004).

The four climate scenarios were labeled: warm and dry (C1); not as warm but dry (C2); warm and wet (C3); and not as warm but wet (C4). 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 properties of the climate. These changed climate series were restricted to 37 years in length because of the limited available recorded values of these parameters in parts of the study area. These 37-year climate sequences were then used as inputs to the hydrologic models to produce estimates of potential future water supply conditions under the four possible climate change scenarios. Since the supply sequences run for only 37 years, and the Shared Vision Model was set up to use 101-year-long sequences, the 37-year sequences were repeated to fill in the 101 year sequence. This process lends an artificial repetitive nature to the resulting supplies, as shown in Figure 46. As a result, the Plan Formulation and Evaluation Group did not run the Integrated Ecological Response Model for the climate-change sequence because the repetition of the 37-year supplies would have misrepresented the wetland plant calculations, which are driven by flooding history. So only the economic damages are presented for climate change.

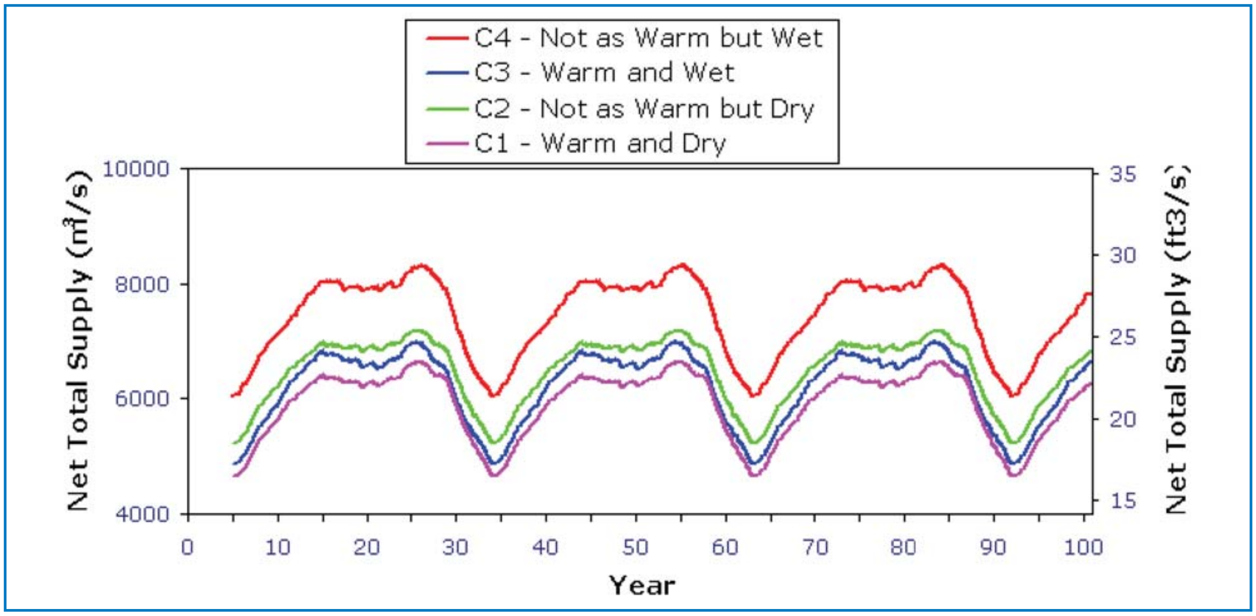


Figure 46: Five-year moving average of the net total supply (NTS) sequences for the four climate change scenarios (C1-C4)

The candidate plans were not evaluated in terms of their transition from the present to changed climates; rather they were tested as if the shift had already occurred. The evaluation was based on the existing economic and environmental conditions, and no hypothesis was made as to the potential changes in economic or environmental conditions that may be induced by a shift in climate.

As in the case of the stochastic series, the Board wanted to know how much impacts would differ under climate change conditions, and how well the candidate plans would perform in controlling those impacts compared with Plan 1958-DD. Table 13 is a summary table of the differences in absolute average annual damages between the historical time series and what would be expected under each of the four climate change scenarios for Plan 1958-DD. All plan comparisons are in terms of net benefits relative to the absolute damages under 1958-DD.

Again, the full results tables for each of the supply sequences analyzed, including the four climate change series, can be found in Annex 3 – Plan Description and Results. As noted earlier, only economic results are available for the climate change sequences. Table 14 is a summary table of overall economic results under each plan for each of the four climate change scenarios. All plan comparisons are in terms of net benefits relative Plan 1958-DD. So if a plan can improve things over 58-DD, this is a positive benefit, and if it is worse than 1958-DD, it is a negative benefit.

None of the plans "fails" under any of the four climate conditions (meaning none draws Lake Ontario down below the dam elevation so that it cannot drain into the River), which was the first test of the climate change analysis. None of the plans is an overall winner under every scenario. As in the case of the extreme stochastic scenarios, Plan A^+ consistently performs well again for the recreational boating interest, but is inconsistent in terms of gains and losses to the other interests. Plan B^+ varies in its gains and losses depending on the sequence, and ranges from worse than 1958-DD overall under the most extreme climate case warm/dry (C1) to actually outperforming plans 1958-DD, A^+ and D^+ under the not so warm/wet (C4) scenario. Plan D^+ is again the moderate plan that delivers economic benefits somewhere between those of plans A^+ and B^+.

Summary

Each of the candidate plans was designed to achieve the same objectives, but different plans emphasize certain objectives more than others. Among the candidate plans, the results show that Plan B^+ is the best plan for Lake Ontario wetlands (seems consistent and robust under the stochastic analysis, including the extreme events), and upper river muskrat. However, it causes the most erosion and shore protection damage above the dam. Plan A^+ is the best for people who live along the shores of Lake Ontario, because it compresses the range of lake levels more than any other plan, but it does so at the expense of Lake Ontario wetlands and causes increased flood damages below the dam. Plan A^+ consistently performs best economically under the stochastic and extreme events analysis and most of the climate change scenarios. Plan D^+ does not excel in any one area relative to Plan 1958-DD; it slightly readjusts the balance of above- and below-dam shoreline damages by creating a small disadvantage for Lake Ontario riparians compared with 1958-DD, while producing a slight reduction in lower St. Lawrence River flooding. Plan D^+ typically results in the fewest economic losses of any of the plans, while creating net benefits each year for boating, hydropower and commercial navigation. Plan D^+ also makes about a 10% improvement overall for the environment under the historical conditions. However, the environmental performance is not resilient under the stochastic and extreme conditions, with gains in some scenarios, but losses in others.

Table 13: Summary of Economic Results for Four Climate Change Scenarios under Plan 1958-DD

Annual Average in $US Millions

Performance Indicators	1958-DD Historic vs C1 (WD)	1958-DD Historic vs C2 (NWD)	1958-DD Historic vs C3 (WW)	1958-DD Historic vs C4 (NWW)
COASTAL	**$2.32**	**$1.58**	**$0.74**	**-$0.79**
Lake Ontario	*$1.49*	*$1.08*	*$1.27*	*-$0.28*
Shore Protection Maintenance	$1.14	$0.97	$1.12	-$0.25
Erosion to Unprotected Developed Parcels	$0.35	$0.11	$0.15	-$0.04
Flooding	$0.00	$0.00	$0.00	$0.00
Upper St. Lawrence River	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Flooding	$0.00	$0.00	$0.00	$0.00
St. Lawrence	*$0.83*	*$0.51*	*-$0.53*	*-$0.51*
Flooding	$1.26	$0.96	$0.02	-$0.13
Shore Protection Maintenance	-$0.44	-$0.46	-$0.56	-$0.38
COMMERCIAL NAVIGATION	**$0.18**	**$2.72**	**$1.82**	**-$0.89**
Lake Ontario	-$0.69	-$0.19	-$0.42	$0.00
Seaway	$2.11	$3.31	$2.94	-$1.32
Montreal down	-$1.24	-$0.40	-$0.71	$0.43
HYDROPOWER	**-$68.52**	**-$33.39**	**-$50.33**	**$14.13**
NYPA-OPG	-$57.10	-$28.35	-$42.20	$11.73
Hydro Quebec	-$11.42	-$5.04	-$8.13	$2.40
RECREATIONAL BOATING	**-$49.63**	**-$20.43**	**-$31.36**	**$1.53**
Above Dam	*-$33.59*	*-$13.52*	*-$20.69*	*-$1.00*
Lake Ontario	-$26.47	-$10.77	-$16.53	-$0.46
Alex Bay	-$6.22	-$2.58	-$3.72	-$0.49
Ogdensburg	-$0.71	-$0.20	-$0.38	$0.00
Lake St. Lawrence	-$0.19	$0.03	-$0.07	-$0.05
Below Dam	*-$16.04*	*-$6.92*	*-$10.66*	*$2.53*
Lac St. Louis	-$8.65	-$3.54	-$5.26	$0.86
Montreal	-$5.35	-$2.38	-$3.76	$1.30
Lac St. Pierre	-$2.05	-$1.00	-$1.64	$0.37
M&I	**$0.00**	**$0.00**	**$0.00**	**$0.20**
SL One time infrastructure costs	$0.00	$0.00	$0.00	$0.00
LSL Water Quality Investments	$0.00	$0.00	$0.00	$0.20

Notes to Table 13:
1. Results are differences in absolute average annual values (million US dollars) with all numbers representing damages avoided. Positive numbers indicate that the stochastic analysis results in greater benefits for an interest than does the analysis based on the historical series. Negative numbers indicate that the stochastic analysis results in smaller benefits than the historical analysis.
2. The historical sequence represents supplies from 1900 to 2000.
3. C1 through C4 represent four separate 101-year climate change time sequences based on different supply series, where C1 is warm/dry (WD), C2 is not so warm/dry (NWD), C3 is warm/wet (WW) and C4 is not so warm/wet (NWW).

Table 14: Summary of Overall Economic Results by Interest for Four Climate Change Scenarios

C1 – Warm/Dry – Interest	Plan A+	Plan B+	Plan D+	Plan E
Total Net Benefits[2]	**34.89**	**-1.42**	**20.09**	**-4.91**
Coastal	-0.20	0.07	-0.06	0.14
Commercial Navigation	0.70	0.63	0.68	0.23
Hydropower	6.57	3.01	1.98	2.57
Recreational Boating	27.86	-5.09	17.49	-7.79
Municipal and Industrial Water Uses	-0.03	-0.05	0.00	-0.05
C2 – Not So Warm/Dry – Interest	**Plan A+**	**Plan B+**	**Plan D+**	**Plan E**
Total Net Benefits[2]	**9.85**	**4.09**	**5.25**	**-34.03**
Coastal	4.40	-0.93	0.11	-43.38
Commercial Navigation	-0.61	0.73	1.41	5.08
Hydropower	0.40	4.39	0.99	12.22
Recreational Boating	5.46	-0.10	2.76	-7.95
Municipal and Industrial Water Uses	0.20	0.00	0.20	0.00
C3 – Warm/Wet – Interest	**Plan A+**	**Plan B+**	**Plan D+**	**Plan E**
Total Net Benefits[2]	**21.53**	**2.61**	**17.77**	**-2.46**
Coastal	-1.44	0.10	-0.26	-0.96
Commercial Navigation	-0.06	-0.01	0.33	-0.24
Hydropower	4.95	4.17	4.11	3.67
Recreational Boating	18.11	-1.62	13.58	-4.88
Municipal and Industrial Water Uses	-0.03	-0.05	0.00	-0.05
C4 – Not So Warm/Wet – Interest	**Plan A+**	**Plan B+**	**Plan D+**	**Plan E**
Total Net Benefits[2]	**8.33**	**11.78**	**9.65**	**-21.38**
Coastal	-3.42	-2.67	-0.90	-38.13
Commercial Navigation	-0.61	2.74	3.06	5.21
Hydropower	7.29	8.89	4.01	17.95
Recreational Boating	5.07	2.83	3.48	-6.40
Municipal and Industrial Water Uses	0.00	0.00	0.00	0.00

Notes to Table 14:

1. All impacts are measured relative to the estimated impact of Plan 1958-DD.
2. Economic figures represent the average annual impact relative to Plan 1958-DD and are reported in millions of U.S. dollars and based on the four climate change sequences (C1-C4), with no discounting applied.

Performance Indicator Sensitivity Analyses and Validation

The Plan Formulation and Evaluation Group carried out a series of validations and sensitivity analyses to test the question: “If we are wrong about our Performance Indicator analyses, would the decision be different?”

Coastal

The coastal performance indicators on Lake Ontario and the upper St. Lawrence River are critical to plan selection because it is so difficult to improve on the status quo and because there is an active south shore lobby to prevent further damages. Hence, very small changes in these results can change a plan’s acceptability.

Validation

The Plan Formulation and Evaluation Group identified critical flaws in the calculation of these coastal performance indicators. At the June 2004 workshop, several plans were presented with high lake levels causing large increases in hydropower and other benefits, with very little or no increase in Lake Ontario coastal damages. The analysis later revealed two errors: (1) The 101-year simulation was performed as one century-long experiment rather than a series of 101 one-year experiments. Using the one-century approach, a home that might be flooded five times in a century would only be flooded once (after which mitigation removed it from the pool of vulnerable homes), thus resulting in greatly underestimated damages. (2) Digital Elevation Model data for a few Lake Ontario and U.S. upper St. Lawrence River counties need to be updated. Calculations for some properties were at lower than actual elevations, resulting in the overestimation of damages for those counties. New surveys were taken and the results for the base plan were deemed credible.

Sensitivity Analysis

The susceptibility of shore protection to overtopping damages is partly influenced by the estimate of the design water level used in the calculation. In the Flood and Erosion Prediction System (FEPS) Model, the design water levels are attributed on a county basis and are estimated based on risk determined from a statistical analysis of the historical wave and surge conditions for a particular county (standard coastal engineering practice). A sensitivity analysis revealed that the choice of design water levels for a county can influence susceptibility to overtopping failures under a particular plan. The use of higher design water level estimates for areas along the south shore of Lake Ontario, where shore protection costs are greatest, tends to decrease overtopping failure. Applying higher design water levels can significantly reduce the differences among plans under the shore protection maintenance performance indicator. If, in fact, most existing shore protection structures exceed the Coastal work group estimates of height requirements for surge in U.S. counties, then the differences among plans are less than FEPS estimates. However, experience suggests that U.S. shore protection structures are sometimes under-designed and that many if not most of the structures have lower top elevations than estimated in the FEPS modeling, so the differences among plans are at least what FEPS estimates and possibly more. Further details of the validation and sensitivity analysis for FEPS are discussed in the Coastal TWG summary in Annex 2 of this report.

Environmental

Validation

Where possible, the Environmental Technical Work Group conducted verification of performance indicator results by developing detailed spreadsheet calculations that were intended to reproduce the Integrated Ecological Response Model (IERM) output for a given performance indicator. For some of the more complex sub-models, it was necessary to develop simplified spreadsheet calculations that could adequately reproduce the relative performance indicator response when two regulation plans were compared. Verification of the IERM sub-models was also achieved through an iterative process whereby the individual Environmental Technical Work Group researchers reviewed model results and provided feedback after each version of the IERM was released. Validation of the research on the individual environmental performance indicators is described in each of the performance indicator fact sheets.

Sensitivity Analysis

The Plan Formulation and Evaluation Group changed the overall environmental index and used a subset (the “priority performance indicators”) of the 32 performance indicators that measure the most significant sector changes rather than the overall basin impact, none of which changed plan rankings. Plan B^+ clearly outperforms the other plans based on the distinguishing performance indicators, while Plan D^+ is about the same as Plan 1958-DD and Plan A^+ is worse.

Recreational Boating

Validation

The Shared Vision Model was compared to an Excel model by means of stage damage curves and found accurate. The stage-damage relationships were verified for internal consistency (i.e., number of slips, depths of each, the draft of boats assigned to the slip, and the calculated elevation at which the slip could not accommodate the boat) for above-dam U.S. marina damages.

Sensitivity Analysis

The plans were evaluated with normal, doubled and halved willingness-to-pay estimates and it was found that only when plans were exceptionally close did plan rankings change. This demonstrated that plan selection was not sensitive to errors in user-day value estimates.

Hydropower

Validation

The economic experts were asked to advise on the true measure of public welfare and they agreed that marginal changes in energy production at estimated market prices should be used. A study was commissioned to determine what rates to use. The three power entities were asked to determine which other metrics they would use to rank plans. Adjustments were made to changes in Ontario generation for concurrent changes in Niagara generation (higher Lake Ontario elevations increase the head and energy produced at Moses-Saunders but reduce the head and energy produced at Niagara Falls).

Sensitivity Analysis

None. There were no challenges to the seasonal patterns of prices, which reflect the increased use of electricity to heat and cool. Plans that produce more hydropower benefits do so because they maintain slightly higher Lake Ontario elevations. There is no doubt that this creates a higher "head" at the Moses-Saunders power dam, which will lead to greater energy production.

Commercial Navigation

Validation

Cross-checks of performance indicators carried out between the navigation model and the other two evaluative models of the Study showed that calculations were being performed correctly - all three models returned consistent results. The navigation model used 1995-1999 shipping data, including ship cost estimates updated to 2005 levels, so the base case is defensible. Traffic is about the same now as it was from 1995-1999, but container traffic in Montreal is up dramatically and not reflected in the model. As a result, the estimates of shipping costs and benefits are probably too low for current and near-term future conditions.

Sensitivity Analysis

Plan differences are most dramatic in the area of delay costs, especially delays caused because the slope of the water surface in the upper St. Lawrence River is too steep to navigate safely. In one short segment, the limit for delays is a 0.25-meter (0.82-foot) drop, and most gradient delays occur because of problems in that reach.

Municipal and Industrial Water Uses

Validation

The surveys of water intake and outflow elevations were carefully reviewed by stakeholders and experts in and outside the Study. Findings on Montreal's water system were discussed with the mayors of the region and they agreed to address the vulnerability of that system to very rare low levels.

Sensitivity Analysis

None.

Further Modifications of Plans

Each of the candidate plans represents certain trade-offs among interests. Unfortunately, no plan can create positive benefits for all interests and regions at all times. Each plan makes the trade-offs a little differently, and every time a plan is adjusted or modified even slightly the results can change. The International Joint Commission may still wish to modify these balances. Near the end of the Study, one attempt at adjusting Plan B^+ was pursued to try to improve coastal benefits while maintaining environmental benefits. This modification began with Plan B^+ and applied a more conservative forecast in the fall, increasing outflows at that time of year, when levels were fairly high, to ensure that winter levels never rose excessively to threaten spring flooding. This plan, which was termed Plan G, showed some promise. It improved coastal performance without harming the environmental scores, but did increase recreational boating damages because of lower summer and fall levels. Modification of these plans remains an option for the International Joint Commission.

Unexpected Conditions and Plan Flow Deviations

The 1952 IJC Order of Approval as amended in 1956 permits deviations from or changes in plan flows under Criterion (k) in response to hydrologic conditions outside the range upon which the plan was developed and with specific Commission approval. In addition, through its approval of the Operational Guidelines for Plan 1958-A in 1959 and subsequent Operational Guidelines for Plan 1958-C (1962) and 1958-D (1963), the Commission recognized the need for deviations from the plan flows in response to varying ice conditions in the River and to emergency conditions.

By letter dated May 5, 1961, the Commission also gave the St. Lawrence River Board discretionary authority "to vary the outflow from Lake Ontario to provide beneficial effects or relief from adverse effects to any interest when this could be done without appreciable adverse effects to other interests, within the criteria and other requirements of the Order of Approval." When the Commission approved the adoption of Plan 1958-D in October 1963, it also renewed this discretionary authority vested in the Board of Control.

Discretionary deviations from plan flows are currently implemented by Control Board consensus and direction and are categorized as short term (having durations of a few hours to weeks) or long term (lasting for periods of weeks and months).

Short-term deviations can be defined as and considered for:

Emergencies: dam or dike failures, hydropower plant or system failures and declared emergencies such as occurred during the 1998 ice storm or the August 2003 blackout, oil spills near the dam, and operations to free a grounded ship near the dam, etc.;

Ice Condition Operations: within-the-week flow variations necessitated by and based on actual river ice conditions, consistent with the intent of the rules of the plan;

Forecast Adjustments: within-the-week flow variations if local inflows from the Ottawa River or other downstream tributaries change markedly from those forecasted when the weekly plan flows were established, and the effect of plan flows on river interests and processes changes significantly from the intent of plan rules.

"Immediate response" authority for short-term emergency and ice condition operations has been divested to and is currently exercised by the Control Board's Regulation Representatives.

The Study Board recommends that short-term discretionary deviations continue to be allowed to address emergency events. These deviations should be restricted to short-term actions to benefit one or more interest and, although the intent is to do so without adversely affecting others, it may be necessary under emergency circumstances to cause small harm to some in order to avoid larger harm to others. This is a judgment call reviewable by the Control Board and Commission.

The Study Board also recommends that flow adjustments within the week due to changing ice conditions or departures from forecasted inflows to the River downstream of the Moses-Saunders Dam should not be treated as deviations if they are applied in order to maintain the intent of the plan rules.

All the new plans have rules that take into account ice management, downstream flooding and, in some cases, low flows. However, the plan flow computed for the week based on initially forecasted conditions for the coming week may no longer conform to the intent of the rules of the plan if a significant and unpredicted change occurs in ice conditions or downstream inflows within the week. In such cases, the flow is adjusted within the week. Since these within-the-week changes are made to better conform to plan rules given the occurrence of marked changes within the week, they should not be considered deviations from the plan.

Short-term discretionary deviations can also be defined as and considered for:
Interest-Specific Deviations: within-the-week flow variations for several hours or a day or so, for example to:

- meet short-term peak hydropower capacity needs;
- allow an ocean-going ship to reach Montreal if levels are below forecasts provided during ship loading at its departure port;
- accommodate a recreational boat haul-out weekend;
- meet a short-term environmental need on the River, i.e. defer a reduction in river flow to maintain steady water levels during a fish spawning period; or
- maintain minimum draft conditions in the St. Lawrence Seaway upstream of Montreal.

Interest-specific short-term deviations have mixed support on the Study Board. Each of the above-mentioned examples of interest-specific deviations has been implemented by the Control Board in past years. These actions are open to varied interpretations, and the Control Board may not always be aware of other interests that might be harmed by these actions. The Study Board cannot reach a consensus view in support of or against short-term, interest-specific deviations or on the details concerning how such deviations might be applied. It is suggested that the Commission decide whether deviations for these purposes should proceed at all, or proceed only with Control Board assessment of effects and/or prior Commission approval.

In all potential short-term deviation cases, the intent of the regulation plan rules should be maintained. Consideration should also be given to balancing the effect of short-term deviations within the week.

To minimize the effect that short-term deviations might have on Lake Ontario, all interest-specific deviations if allowed, should be limited. For example, the Study Board suggests the following: (1) deviations should be limited to no more than 323 cubic metres per second (11,400 cfs) equivalent to 1 centimetre (0.4 inches) on a weekly basis on Lake Ontario levels; (2) the total of these accumulated deviations at any time should be limited to no more than +/- 5 cm (2 inches) over a calendar year on Lake Ontario; (3) no increase in the Lake Ontario level should be permitted if levels there are approaching the extreme high-water-level threshold listed in Table 11; and (4) conversely, no decrease should be permitted if Lake Ontario levels are approaching the extreme low-water-level thresholds as listed.

Long-term discretionary deviations from plan flows have been an increasingly frequent practice of the St. Lawrence River Board of Control in recognition of changing conditions and priorities in the system and as a means of meeting the criteria in the existing Orders of Approval when water supplies are outside the range for which Plan 1958-D was developed. An example of such a deviation is the “storing” of water on Lake Ontario in the springtime, during expected lower-than-average upstream water supply conditions, for the purpose of maintaining higher Lake Ontario levels into the fall and enabling additional late fall releases of water down the St. Lawrence River.

All of the proposed candidate plans have been designed in recognition of the current Lake Ontario-St. Lawrence River water level and flow interests. The plans have also been designed to respond to and accommodate a wide range of water supply conditions reflective of 50,000-years of stochastic hydrology as well as potential climate change conditions. Therefore, deviations from candidate plan flows when water levels on the Lake or River are high or low will act to nullify the benefits of the plans.

The Study Board is of the opinion that long-term discretionary deviations from plan flows are not generally justified because such actions change the performance of the plans as designed and the benefits that flow from them. This position is conditional on ensuring that performance indicators upon which the regulation plan is based are verified and updated in an adaptive management process.

During extreme low- or high-water level and flow conditions on Lake Ontario or the St. Lawrence River, consideration should be given, however, to implementing Criterion (k) type plan deviations after examination of the impact of plan flows on interests and processes in the Lake Ontario-St. Lawrence River system and with the express concurrence of the Commission.

The definition of extreme events at which point deviations from plan conditions should be considered can be viewed as somewhat arbitrary. These thresholds can be defined as extreme water level and flow occurrences approximating 1:100 year exceedance probability events, or by known physical limitations or response functions of the system, for example Lake Ontario and St. Lawrence River water level conditions at which significant shoreline damages occur, or levels beyond which environmental benefits may not continue to accrue depending on recent occurrences of high- or low-water level events. The Study Board suggests that in the event of a 50% probability that the thresholds listed in Table 15 will be exceeded, the International St. Lawrence River Board of Control evaluate the effects of deviating from plans flows and implement appropriate water management strategies, with the express concurrence of the Commission.

Table 15: Threshold Water Levels/Flow

Location	Threshold	Level/Flow	Threshold	Level
Lake Ontario				
	high still-water level	75.6 m (248.0 ft)	low still-water level	73.9 m (242.5 ft)
St. Lawrence River				
Outflow at Moses Saunders Dam	high flow	9,900 m^3/s (350,000 cfs)		
Lac St. Louis	high still-water level	22.50 m (73.8 ft)	low still-water level (66.3 ft)	20.2 m
Montreal Harbour	high still-water level	9.10 m (29.9 ft)	low still-water level (15.4 ft)	4.70 m

The Study Board cannot reach consensus on a position in support of or against this Criterion (k) type of deviation, nor can the Study Board agree on the magnitude and timing of the extreme event thresholds that could trigger such deviations. It is suggested that the Commission decide whether deviations for these purposes should proceed at all, or proceed only with Control Board assessment of effects and/or prior Commission approval.

A clear procedure to exit from “deviation conditions” should be established in new operational guidelines that are consistent with the conditions established to enter deviation operations.

Once a deviation action has been taken, successive plan flows should be computed based on actual water level conditions so that deviation credits or debits are not perpetuated in plan operations.

Status Quo Options

No Action

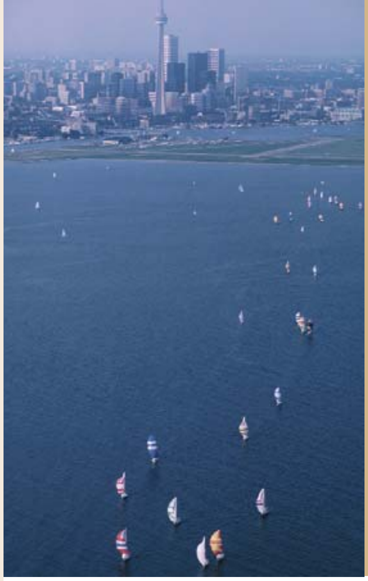
If the Commission decides not to implement any of the candidate plans developed by this Study (the null option), then Plan 1958-D remains the written plan under the existing 1956 Orders of Approval, and deviations would continue under the present authority. Presumably, deviations would be made in a manner similar to the way in which the Control Board currently deviates, and results/impacts similar to those modeled by the base case 1958-DD in this Sudy could be expected. However, history has shown that the Control Board will vary the way it deviates depending on its make-up and the conditions of the time; hence, some uncertainty surrounds the future impacts of such actions. Under the null option, the needs of the environment and recreational boaters would not be formally recognized in the Orders of Approval.

Change the Criteria and Deviation Authority

Under a second possible option, the Commission would not change the operating plan, but only change the criteria listed under Condition (i) in the Orders of Approval. Changes would be made to reflect the preferences of the environment and recreational boating and perhaps revised criteria for coastal interests. The Commission would also have to consider the issue of how the Control Board might be restructured to reflect the views of recreational boating and environmental interests. The Control Board would continue to deviate, but would use the revised criteria and new deviation guidance. This could be termed the "Unknown Plan" since there is no way of knowing how the Control Board would make their decisions, or how they would trade off the interests specified under the criteria. It is well known, through this Study and the plan formulation process, that certain trade-offs have to be made at certain times among interests and locations. Under this type of option, there is no way to anticipate what the impacts would be since this method of regulation would not proceed according to a defined plan, but would be dependent on the ad hoc decisions of the Control Board of the day.

Implement the Modeled Plan 1958-DD

Another possibility, which some argue is the closest to the present status quo that could be achieved, is to implement the modeled base case 1958-DD, taking advantage of the new knowledge developed during the Study. In order to establish a base case, a Plan1958-DD had to be developed that mimicked the decisions of the Control Board in its deviations as closely as possible. This took into consideration the ways in which the Control Board has deviated over the past 40 years, with special attention paid to the last decade. Implementation of this plan would mean that impacts could be modeled and predicted. Actual deviations by the Control Board would not be required (or at least not as regularly) because they have already been programmed into the plan. However, the benefits achieved by such a plan would be variable and are unpredictable at the present time.



Public Involvement

Public Information and Advisory Function

To emphasize the importance of public outreach, consultation, and participation during the Study, the International Joint Commission appointed a 20-member, bi-national Public Interest Advisory Group (PIAG). The Group received Terms of Reference from the International Joint Commission stating in brief:

The Public Interest Advisory Group is responsible for providing public involvement guidance, consultation and assistance to the International Lake Ontario-St. Lawrence River Study Board, and to periodically report to the International Joint Commission on its activities, findings and recommendations.

Over the five-year period of the Study, the Public Interest Advisory Group fully met and in many cases exceeded their responsibilities by:

- providing a public liaison function to the Study Board through the Public Interest Advisory Group co-chairs, who served as members of the Study Board, and the many valuable contributions to Board and Study discussions by other Group members;
- advising the Study Board on the responsiveness of the Study process to public concerns;
- advising the Study Board on public consultation, involvement and information exchange;
- serving as a conduit for public input to the study process and public dissemination of Study outcomes; and
- liaising with and participating in the activities of Technical Work Groups.

The Public Interest Advisory Group, in consultation with the Study Board, also worked with grass-roots organizations and interests throughout the Study area and conducted public participation activities at strategic points in the Study to:

- identify and utilize local expertise and information;
- consult with the public on critical or potentially controversial Study findings before related Study components were finalized by the Study Board;
- disseminate plain language information to enhance public understanding of the causes and problems related to fluctuating water levels and of the consequences of proposed solutions;
- identify and consider priorities and preferences of the public as alternatives were defined; and
- consult with the public on Study findings and recommendations prior to their adoption by the Study Board.

The Public Information and Advisory Group was fully integrated into the Study Board and Study Team. Members participated in all aspects of the Study, working to ensure effective communication between the Study Team and the public, and ensured that input from the public was considered. Individual members acted as liaisons to the various technical work groups of the Study. The Group helped to focus discussions in a practical way, giving the Board real world implications for decisions.

Through the advocacy of the PIAG, the Communications Plan was re-worked for greater targeting using a wider variety of tools. In developing options through technology for reaching interested parties by a wider variety of methods, the PIAG helped to ensure that new and hard-to-reach parties were involved. Group members coordinated the Study's communications process, which included publication of the Ripple Effects newsletter, creation of the website, stakeholder meetings, workshops, a speaker's bureau, roundtable meetings and public meetings. The Group published a glossary of terms and led the creation of Study banners and brochures.

Public Interest Advisory Group members suggested metrics in the Coastal, Environment and Recreational Boating technical work groups and played an integral role in providing input from the public into the Study's Performance Indicators. The Public Interest Advisory Group was instrumental in ensuring that advice received from the public was implemented, for example regarding the splitting of recreational boating reaches in the Ogdensburg, New York area and the screening and modification of plans. It provided advice on domestic, municipal and industrial water uses. The Group contributed to the formulation of the Study guidelines, including those pertaining to transparency, ensuring that plan selection was open to the public.

Prior to the Study, some members of the Public Interest Advisory Group were tough and active critics of the Board of Control's operations. After its formation, the Public Interest Advisory Group continually challenged the process and the Study Team to do better. The public, through PIAG members, had a rare and valuable opportunity to see the most positive work that occurred and the flaws in the process and outcomes. It took advantage of opportunities to be fully involved in all phases of the decision-making process and to hold those making decisions accountable to all stakeholders. Through this process, PIAG has now developed a cadre of lay-experts in public interest available to the International Joint Commission.

The Public Interest Advisory Group's principal objective was to ensure that Study results consider the interest and "natural knowledge" of the public. The PIAG accomplished this and all of its other objectives. The PIAG's mandated goals of creating an awareness of the Study, educating the public regarding the Lake Ontario-St. Lawrence River system, and engaging the public to stimulate interest in becoming involved in the Study were achieved. A summary of first-year activities can be found in the PIAG's Year One Report. Activities during years two and three of the Study were summarized in the PIAG's Year Two-Three Report. The PIAG's Final Report describes findings resulting from the highly productive public meetings of 2004 and 2005 and other key messages (PIAG, November 2005).

A list of the current membership, their location along the system, and their areas of affiliation is included at the end of this report and in the Public Interest Advisory Group Final Report.

One of the key messages throughout the Study has been that "we have to realize that we cannot satisfy the expectations of all of the interests all of the time." This is indeed the case as the Public Interest Advisory Group does not, as a whole, favor any one candidate plan over another.

Public, Agency and Organization Views on Candidate Plans

During the final year of the Study, 30 agency briefings and 15 public meetings were held throughout the system, primarily in May through July 2005. Feedback was garnered through comments at the meetings, correspondence directed to the Study, and a public opinion survey designed to capture stakeholder opinions regarding the Study's candidate plans as they stood in June of 2005. A report on the 2004 and 2005 public meetings and other outreach activities is contained in the PIAG's Final Report (PIAG, November 2005).

The following trends and patterns in public comment were observed:

- Depending on location and interest group, there was broad support for Plans B and D, but relatively less interest in Plan A, with the notable exception of Gananoque, where it had some support. In meetings on the south shore of Lake Ontario, there was large support for the status quo, that is Plan 1958-D with Deviations, because all of the candidate plans appeared to raise Lake Ontario levels.

- Concerns regarding shoreline erosion and flooding were noted at meetings in Oswego, North Rose, Greece, Olcott, Gananoque, Belleville, Jordan and Montreal.
- Even those who wanted much lower highs or higher lows also said that they wanted a more natural lake/river regime. When the debate is framed in terms of a natural or environmental plan versus any other kind of plan, meeting attendees from the River and similarly located survey respondents tend to favour plans characterized in those terms.
- Concerns about the short timeline for comment were expressed in Sorel, where some residents said they felt that they were not being fairly dealt with and their opinions were not truly valued. This concern was also expressed in Alexandria Bay. Once it was explained that the International Joint Commission would hold hearings next year, the audiences seemed to be satisfied that their voices would be heard.
- A vocal number of property owners expressed their opposition to the possibility that they might experience property losses to protect environmental, shipping, recreational boating or hydropower interests.
- Several attendees, especially those interested in environmental aspects of the system, commented on both the need for better communications and more education on water issues and were generally unaware of initiatives related to education about water in their areas.
- A strong wish was expressed by the public in several locations that the performance of the plans be monitored, with a review, for example, every five years, to assess the results.
- Some of the graphs exhibited during the presentation were received very well at the meetings where they were shown and helped people to understand the complexity of the Lake Ontario-St. Lawrence River system in a very direct way.
- Some urged that the Control Board be restructured to better reflect the interests in the system.
- Many people wanted to know what the upper limit/criterion would be under the various plans or whether deviations would be allowed. There was some skepticism and concern that, without deviations, a plan might result in serious negative outcomes such as flooding or increased erosion.
- At many of the meetings, elected officials spoke to express what many in the audience strongly supported. A large number of resolutions were passed by municipalities, mostly in New York State communities, confirming the views expressed.

In summary, the Public Interest Advisory Group expressed the hope that the new plan selected will help all to live in better harmony with the Lake Ontario-St. Lawrence River system and environment.

Public Interest Advisory Group Findings and Recommendations

Based on input from the public and observations from individual members, the Public Interest Advisory Group made the following recommendations regarding this and future studies:

1. The Public Interest Advisory Group has commented on the St. Lawrence River Board of Control's communication plan and appointed a member to be a liaison with that Board's Communication Committee. The PIAG found that the Control Board would benefit from continued correspondence with individuals and agreed to provide names and addresses of people who wish to stay informed.
2. Input from the public indicates a desire for a restructuring of the International St. Lawrence River Board of Control to better reflect the views of all interests.
3. The PIAG recommends that a body be given responsibility in the area of adaptive management, perhaps the next Board of Control, with input from members of the Plan Formulation and Evaluation Group.
4. It is recommended that a review of shoreline management practices and policies be undertaken by the responsible state, provincial and municipal authorities. The scope of this policy review needs to be defined but should include: environmental policy, coastal development policy (housing/development set backs, elevations, etc.), marina development and maintenance. The review should first gather together the policies that already exist at the various government levels and should include sections on lessons learned from the technical work of the Study. For example, basic information has been learned about erosion and flooding and it should help guide future government policy.

5. People living along Lake Ontario and the St. Lawrence River need to be educated and informed with respect to the basic hydrology of the Great Lakes System. Some type of education program needs to be established or misconceptions will continue to persist. A shoreline management (public safety, public use, and natural heritage) strategy should be developed for certain reaches of the shoreline utilizing the data and information gathered by the Technical Work Groups. This review would also help define options (i.e., acquisition, planning policy and guidelines and shoreline protection) for existing structures within the shoreline hazard zone or area.
6. A way should be sought to engage municipal governments, students and researchers and maintain interest and involvement as years go by.
7. The time dedicated to the Study by the Public Interest Advisory Group volunteer membership was much more than initially expected. It is suggested that the Commission establish some sort of stipend to offset financial losses associated with time away from jobs or make a donation to participants' favorite charities. The organizers of future studies should encourage prospective members to plan ahead of time and be prepared to devote time when joining an advisory group. However, the Commission must give prospective members a more realistic idea of the time commitment expected.
8. Public Interest Advisory Group members should be appointed on the basis of their expertise and ability to reach out to local interest groups and this appears to have worked well. It is very important for members to have networking capability as this promotes public participation. Active and dedicated liaison officers will help maintain continuous communications.
9. Also with regard to networking, it is important to reach out to the all of the interests, including First Nations, from the beginning.
10. At the beginning of a study, it is important to have a website running that is accessible by all study participants including the communication team. A website needs to be created to store and if possible maintain the information collected.
11. When deciding on scientific research, care must be taken as there is some tendency for scientists to focus on what they view as a topic of concern. A study must look at what Commission questions are asked before deciding on what science is needed. The study should drive the science.
12. Publication of the results of the research work should be encouraged and supported by the Commission and governments to the extent funding may be secured. Any publications resulting could be referenced on the Commission's website in order to broaden public awareness.
13. For transparency, all reports should be available as soon as possible, even if only initially in language of the person writing the report. Care must be taken to ensure that early and preliminary drafts are identified as such.
14. The turnout at some public meetings was very low, even though they were held in large cities. Efforts need to be made to get the word out. For example, make announcements on radio stations, local television stations, make follow-up telephone calls (this likely helps the most) to marina and riparian interests, send ready-to-post announcements and engage community shoreline interests and organizations.
15. On the St. Lawrence River, recreational boating is a water-related issue as are fishing and hunting on Lake St. Louis and Lake St. Pierre. Invite people who are experts in these areas to provide advice and ideas.
16. One observation based on experience with public meetings is that people may not understand the process being described at initial meetings, but their understanding evolves from year-to-year, as they go to additional public meetings. Conversely, those that attend later meetings do not always understand the process because they've missed earlier events. It is important therefore to effectively link participants throughout the Study process.

Transition to Implementation

Mitigation and Other Measures

Managing water levels and flows in the Lake Ontario and St. Lawrence River system in a way that maximizes the economic, environmental and ecological benefits to each individual user or interest group over all time periods and places is not possible. The three new candidate plans attempt to balance the resulting benefits among the different public and private interest and user groups over space and time in different ways. The result is that some interest and user groups may not be able to obtain the benefits they could obtain if a plan were designed purely to maximize their particular objectives. Furthermore, some plans may result in fewer benefits than those obtained by certain user or interest groups under the existing Orders of Approval and their implementation in the existing Plan 1958-DD.

For example, if Plan A^+ is chosen, the least bittern may be at risk, and downstream St. Lawrence River shore owners may experience increased damages from flooding. If Plan B^+ is chosen, muskrats in the lower river may be at risk and shoreline erosion on the shores of Lake Ontario and the lower St. Lawrence River may be increased.

If, under a new plan, any interest and/or user group suffers significant* losses in excess of those associated with the existing plan, the concept of mitigation provides that they could be compensated for, or measures could be taken to reduce those losses. The Study Board is not of one opinion as to the necessity for mitigation associated with any particular plan, but clearly mitigation measures can increase public support for any selected plan. The Study Board recommends that the IJC engage in discussions with appropriate agencies or organizations to explore the possibility of implementing mitigation measures if desired to offset any significant losses.

The IJC Study Directive requested that the Study Board provide information for any mitigation measures and actions that might be appropriate to implementation of a proposed plan. As part of its Study Guidelines, the Study Board addressed this complex issue in the form of principles and guidelines that were used to both direct the formulation of options, as well as their evaluation and acceptability to the Study Board. Guideline 4 stipulates that "[m]itigation alternatives *may be* identified to limit damages *when considered appropriate*." The Study Board expanded on this guideline by adding the following:

The Study Board will consider a range of plans that include:

a. Plans that maximize net benefits, but require mitigation to eliminate disproportionate loss (not to be implemented until the mitigation implementation measures are in place);
b. Plans that minimize losses and require little or no mitigation.

* Significant losses would be judged relative to the uncertainty and variability of the performance indicator. For environmental performance indicators, the Study Board determined that these losses would have to exceed 10%.

The Study Board considered mitigation requirements for each of the candidate Plans. There were mixed views on this, with a Study Board majority determining that there were no disproportionate losses and, hence, that no mitigation was necessary for implementation of any of the Plans. This view held that all the candidate Plans fulfilled the Study Board Guidelines and principles, with a net improvement in ecological and economic benefits. However, several Study Board members thought that some degree of mitigation was needed in one or more areas for each of the Plans because there were disproportionate losses in certain geographic segments of the system and/or for a number of individual interests.

There are many categories of measures that one could apply to mitigate the significant adverse effects of an otherwise favorable plan in order to make it acceptable to all parties. It is difficult to single out any one measure, since they are often applied as a complementary package of measures, the success of which is dependent on the implementation of prerequisite measures. It is noted that the IJC does not have the authority to impose or implement any of the mitigation measures that may be desired for a Plan. The responsibilities and authorities for most of the mitigation measures typically considered as complements to a well-functioning plan are distributed among numerous federal, provincial, state and county entities. The IJC should seek to facilitate and coordinate these various entities as part of its plan selection process.

Typical mitigation mechanisms that could be considered include:

1. **Structural measures:** shore protection, breakwaters, beach nourishment, habitat restoration/modifications, dredging channels, floating docks, etc.;
2. **Non-structural measures:** relocation, floodproofing, setbacks, public acquisition of hazard lands; easements, change of lake levels and operating rules;
3. **Regulatory actions:** floodplain and land use management, zoning, revision of existing provisions, change of design criteria;
4. **Technological changes:** design changes, construction materials, forecasting, models, etc.;
5. **Economic incentives:** tax abatement/rebate policies at the state and local levels, low interest loans for repair and maintenance of public and private infrastructure;
6. **Institutional changes:** legislative changes, organizational restructuring of Control Board, Orders of Approval, etc.;
7. **Transfer of benefits:** taxing beneficiaries to compensate interest adversely affected by an action;
8. **Direct indemnification for losses**: usually for government exercise of eminent domain – taking property for public purposes;
9. **Insurance:** National Flood Insurance Program, private insurance;
10. **Emergency management:** Corps of Engineers Advance Flood measures.

Adapting the New Rules over Time

Adaptive management has generally come to represent an approach to management (the combination of planning, design, operation and regulation of a resource) that relies on a continuing accumulation of knowledge and information through a monitoring and evaluation system, which is used to improve the suite of management decisions. An adaptive management plan must focus on those elements of the adopted operating plan that are most uncertain. Adaptive management essentially has two interrelated components or functions. One is to serve as a quality control and assurance mechanism to ensure that the predicted performance of a plan actually materializes. The other is to better deal with circumstances in which decisions are routinely made based on information associated with a high degree of uncertainty. In particular, the most uncertain, unpredictable data are the climate/hydrologic inflows into the Lake Ontario-St. Lawrence River system, and the impacts of lake level fluctuations on the ecology of the system. To a lesser extent, there is uncertainty in the economics of recreational boating and the flooding and erosion impacts of lake level and flow variability. There is also uncertainty associated with some environmental performance indicators.

The overall approach of this Study, which we term “Shared Vision Planning,” encompasses all of the goals typically associated with adaptive management (Walters, 1986) and provides a level of transparency and public feedback recommended by the U.S. National Research Council (2004):

1. bounding of management problems in terms of explicit and hidden objectives, practical constraints on action, and the breadth of factors considered in policy analysis;
2. representation of existing understanding of managed systems in terms of more explicit models of dynamic behavior, that spell out assumptions and predictions clearly enough so that errors can be detected and used as a basis for further learning;
3. representation of uncertainty and its propagation through time in relation to management actions;
4. design of balanced policies that provide for continuing resource production while simultaneously probing for better understanding.

In its report on “Adaptive Management for Water Resources Project Planning,” the U.S. National Research Council (NRC, 2004) notes that “adaptive management entails a spectrum of approaches. These range from ‘passive’ programs, which focus on monitoring and evaluating outcomes from a particular policy choice, to more formal and rigorous ‘active’ adaptive management, which designs management actions to test competing models of system behavior so that models can be improved for future decision making.” A form of passive adaptive management is reflected in the operational decisions of the International St. Lawrence River Board of Control, which routinely deals with a fairly significant amount of uncertain information. The NRC then goes on to recommend three necessary components of any adaptive management plan:

- post-project (plan, program) evaluations should be a standard for adaptive management;
- stakeholder collaboration should be an integral component of adaptive management;
- independent experts should be periodically enlisted to provide advice on adaptive management initiatives.

Within each optional plan, and its complementary operating plan, there are several key areas which are candidates for an ‘active’ adaptive management plan. The adopted operating plan and criteria would be periodically (no less than 10-year intervals) reviewed by the IJC and the Control Board, with the involvement of stakeholders and independent experts. In order to accommodate the new adaptive management functions associated with the implementation of a plan by the International Joint Commission, the Control Board would need to reorganize its technical support, currently provided by the Corps of Engineers and Environment Canada. This may include broadening U.S. and Canadian federal agency representation to include the National Oceanic and Atmospheric Administration, the U.S. Geological Survey and perhaps the U.S. Environmental Protection Agency, and their counterparts in Canada, in order to provide the added technical and financial support and ensure responsibility is taken for carrying out the key adaptive management plan actions. The basic components of a practically achievable adaptive management plan that addresses a review of the performance of an operating plan, can be described as follows:

- **Forecasting** technology, methods and models need to be constantly assessed, tested and periodically updated and incorporated into the water control operations of the Control Board. Climate and hydrologic forecasting is a key and critical element in effective water management and regulation, particularly in the tightly controlled circumstances within the Lake Ontario- St. Lawrence River system.
- **Mitigation measures** that are deemed necessary to plan implementation have been identified to potentially target erosion and flood damages, wetlands habitat losses, and several species, as well as one species at risk (Plan A^+), depending on the plan selected for implementation.
- **Reform and coordination of regulatory permit procedures** is an essential component of adaptive management that is required to update permit requirements to conform to the new flow and lake level design limits of each plan.

- **Ecohydrology** is the fundamental scientific basis for enhancing the ecological integrity of the Lake Ontario- St. Lawrence River system. The hypothesis that hydrologic variability is essential to improved wetland structure and function which, in turn, increases species diversity and abundance, needs to be validated, and the predictive models which are based on these premises need to be constantly updated as new information is collected and developed. Consideration should be given to establishing a permanent network of monitored wetland sites for the purpose of collecting and analyzing data as part of Integrated Ecological Response Model improvement. An equivalent monitoring of selected species at risk might also be considered.
- **Shoreline erosion rates** should be monitored, as well as recreational boating responses in terms of usage, benefits and costs.
- **Coordination**, evaluation and incorporation of the necessary actions cited above, including the integration of ongoing monitoring programs of numerous federal, provincial and state agencies, should be the responsibility of the Control Board and the IJC.

Conversion to Operational Form of the Plan Selected by the Commission

During the last two years, the Plan Formulation and Evaluation Group has been developing and refining plan options as alternatives to the present plan, Plan 1958-D. Once an option is selected by the Commission, an operational version of the option will be required for use by the International St. Lawrence River Board of Control for their weekly outflow decisions. The operational arms of the Control Board are presently the offices of the U.S. and Canadian Regulation Representatives at the U.S. Army Corps of Engineers, Buffalo District, and Environment Canada's Great Lakes-St. Lawrence River Regulation Office in Cornwall, Ontario, respectively. It is suggested that this role be retained by these offices and that they undertake the task of developing the operational tools for the Control Board.

Conversion of Quarter-month to Weekly Outflow Specification

Each of the plans were evaluated over an historical supply period from 1900 through 2000. In order to make use of existing historical data, to be consistent with previous plan evaluations, and to standardize all years eliminating leap years, each year was divided into 48 quarter-months. The same standardization was used in the evaluation of stochastic supplies considering the equivalent of 50,000 years. However, actual regulation is performed weekly. The present weekly outflow begins at 00:01 hours on Saturday. In order to convert the rules in the plans from those using quarter-monthly values to weekly values, procedures outlined in "Operational Guides for Plan 1958-D," dated December 12, 1963, will be used, but modified to pertain to the particular procedures used within each option.

Selection of Forecasting Options for Lake Ontario Water Supplies, Ottawa River and Tributary Flows

All operational plans rely on an estimate of future conditions. Each option has a component that looks at various forecast horizons to determine what the next outflow release should be. There are a suite of tools available to provide the Control Board with assistance in the area of forecasts, including:

- U.S. Upper Great Lakes water level forecasts
- U.S. Lake Ontario water level forecasts
- Canadian Great Lakes water level forecasts
- Great Lakes Advanced Hydrologic Prediction System
- NOAA Climate Outlooks
- Environment Canada Seasonal Climate Outlooks
- Ottawa River Basin Regulation Committee forecasts
- Canadian forecasts of downstream tributary flows

Reference is made to "Improving Hydrological Forecasts for IJC Lake Ontario-St. Lawrence River Study – Project 2: Forecasting Review" by the Hydrology and Hydraulics TWG.

Another tool for considering St. Lawrence River tributaries is the "Adirondack Mountain Watersheds Forecasting Model," developed by the Northeast River Forecast Center of NOAA.

The Regulation Representative offices should evaluate the suitability of using these forecasts and their application within the various operational procedures. Consultation may also be required with the Coordinating Committee for Great Lakes Hydrologic Data and other agencies that make hydrologic forecasts.

Defining the Rules for Invoking/Revoking Criterion (k)-Type Discretionary Deviations

Procedures will be defined for determining the likelihood of conditions resulting in the recommendation to the IJC by the Control Board of the invocation and eventual revocation of Criterion (k)-type deviations. These may be based on the risk of exceeding a certain stage-frequency or another trigger. The Regulation Representative Offices should use rules suggested by the Study Board and test other procedures used by these offices in the past as well as those used by others.

Coordination between Regulation Representative Offices after Consultation with IJC

The following steps are suggested for the development of operational tools:

- The staff of the Regulation Representative offices should meet to discuss the efforts that have already been made towards the development of operational models, and those that are still required.
- After the meeting, the next step will be to identify the roles involved in defining how the limitations, criteria, adjustments, etc. will be structured in the context of outflow decisions. A possible scenario would be for the Canadian Regulation Representative office to develop the operational plan for one option, and the U.S. Regulation Representative office to develop another.
- Development and evaluation of near-real time forecast methods will be carried out by the Regulation Representative offices. Forecast accuracy, availability and reliability of input data, repeatability, and other operational aspects will be considered.
- The Regulation Representatives and Control Board will meet to describe the operational models with proposals regarding tracking. Adaptive management may be considered based on discussion/recommendations by the Study Board. As in the past, it is suggested that the preferred option(s) be tracked along with Plan 58-DD and the pre-project case for three years. However, in a departure from the past tracking, consideration should be given by the IJC to the new option becoming the operational procedure for determining weekly outflows, with Plan 58-DD in the background.
- An operations manual will be developed by the Regulation Representative offices.

Institutional Issues

A workshop addressing institutional issues relating to water level and flow management on Lake Ontario and the St. Lawrence River was organized and hosted in Amherst, New York on November 30 and December 1, 2004, by the Study Board. In attendance were representatives of the International St. Lawrence River Board of Control, staff of the International Joint Commission, and members of the Study Board, its Plan Formulation and Evaluation Group, the Public Interest Advisory Group, and a consultant.

The purpose of the workshop was to engage representatives of these groups in a discussion of "institutional" and related issues and topics related to the transition of Study results to the International Joint Commission and the Control Board, and to provide a report on these matters to the Commission well in advance of the final Study Report.

Institutional issues discussed included those raised in a report commissioned by the Study Board and proposed by an Aboriginal member of the Board (Clinton Edmunds and Associates, Ltd., 2002), as follows:

- The Lake Ontario-St. Lawrence River Study decision making process;
- Consensus decision making;
- Roles, responsibilities, interrelationships and membership of the Control Board, the Operations Advisory Group and the Control Board's Regulation Representatives;
- Flexibility inherent in the Boundary Waters Treaty;
- Consideration of Aboriginal peoples' knowledge about water levels in relation to the system as a means of increasing understanding; and
- Input from lesser-represented users.

Other issues discussed were:

- The hydrology envelope within which existing control structures are valid,
- Timely-decision making,
- User-friendly descriptions of models,
- Communication,
- Funding of hydraulic and hydrologic research,
- Information management,
- Peer/independent review,
- Adaptive management,
- Mitigation, and
- Transition.

A workshop report summarizing these discussions was conveyed to the International Joint Commission on January 19, 2005.

The Study Board suggests that the International Joint Commission consider and act on the findings in the Study Board's January 2005 Institutional Issues Workshop report and communicate Commission decisions and actions to affected groups and communities. Many of the issues addressed in this report have been raised at the Study's public meetings and in other Study discussions. Many are also independent of the selection of a new plan and can be acted upon independently. Early and decisive action on these findings would be very positively received. To further its understanding of the system, the Commission should also continue the dialogue established with the Mohawk Council of Akwesasne, the St. Regis Mohawk Tribal Council, the environment departments and tribes throughout the region including the Akwesasne, Kahnawake and Tyendinaga.

At the conclusion of this $20 million U.S. Study, the Study Board will be transferring three candidate plans to the International Joint Commission, and a sizable amount of documents, software and knowledge that provide the basis for the plans. If one of these plans is selected and implemented, this will initiate a new set of requirements for the Board of Control. These requirements will include information management (including preserving the existing documents and data bases); greater communication and outreach; model running, maintenance and upgrading; and analysis of monitoring data. In this way, the Board of Control will be kept aware of plan impacts and will know when and to what extent adaptive changes in policy should be considered. Meeting these new requirements will necessitate additional resources and personnel. This transition provides a window of opportunity to change more than just the regulation plan. It provides an opportunity to change the way in which the plan is implemented and explained to the public, the way adaptive management can be considered, and the way in which the research and documents produced by the Study are kept available for scientists and the public.

The obvious question is, where will the additional resources come from, or will Environment Canada and the U.S. Army Corps of Engineers just take over these responsibilities? For long-term planning, the International Joint Commission might wish to explore the possibility of receiving tax revenues from water users, in a manner similar to the way in which water management districts are funded in Florida. After all, one could argue that the cost of implementing policies that increase both economic as well as environmental and ecological benefits to stakeholders should be reimbursed by taxing those stakeholders in some way. This could apply to the entire Great Lakes–St. Lawrence system, or indeed the entire waters over which the International Joint Commission has management responsibilities.

Agency Linkages

During the course of the Study, numerous advances in data collection occurred and several state-of-the-art models were developed. The vast amount of information collected and the tools created to use and analyze this information helped to define the Lake Ontario-St. Lawrence River system to an extent never before achieved. With the completion of the Study, the models and information can now be used to track the performance of the selected plan option. In addition to this tracking by the International Joint Commission and the International St. Lawrence River Board of Control using the operational plan, it will also be possible for others to benefit from this knowledge. Additional information about Study data and research is described in the previous section of this report entitled “New Information and Science.”

Coastal Data, the Flood and Erosion Prediction System and the St. Lawrence River Model

In the early stages of the Study, it was determined that mapping of the near-shore zone, both the land side (topographic mapping) and the underwater portion (bathymetric mapping), was critical to providing the information needed for technical groups evaluating flooding, erosion and low water level impacts, for assessing the impacts of water levels on wetland and environmental health and sustainability, and for assessing water level impacts on private and public shore properties, municipal water intakes and outflows, and recreational boating facilities.

Using airborne laser mapping systems, aerial photography and orthoimagery, and existing agency maps, a shoreline classification and digital elevation model were developed. Through the cooperation of municipal, state and provincial agencies, all U.S. property parcels and most Canadian parcels have been identified. Detailed information is available regarding the erosion and flooding potential by shoreline kilometre. The information is linked to a flood and erosion prediction system which contains water level and wind generated wave data that can be used to determine how each kilometer of shoreline will respond to various hydrologic conditions around Lake Ontario and the upper St. Lawrence River.

Information about the shoreline and parcel data is available on the Study website (www.losl.org). The flood and erosion prediction system will reside at the Buffalo District Office of the U.S. Army Corps of Engineers. The information and model could be used to assist that office with its issuance of general and individual permits, compliance inspections, and resolution of unauthorized activities. The information can also be used by other agencies associated with permit actions, such as the New York State Departments of State and Environmental Conservation.

The data and model have the potential to be used as an information and planning tool by other federal, provincial and state agencies regarding best shoreline management practices.

A model referred to as the St. Lawrence River Model calculates impacts of erosion and shore protection maintenance on the lower St. Lawrence River coastal interests and will also be available for future studies.

On the lower St. Lawrence River, a detailed shoreline digital elevation model and parcel database was compiled and has the potential for use in other applications. This is housed with Environment Canada in Quebec.

Environmental Data and the Integrated Ecological Response Model

In order to assess the impact of various water level regimes on environmental factors, thirty-two wetlands of four geomorphic types were identified around the Lake Ontario and upper St. Lawrence River shorelines, along with fourteen wetlands around the lower St. Lawrence shoreline. Detailed bathymetric and topographic data is available for the sites. Each site was photo-interpreted to identify vegetation communities and estimate how the wetlands have changed over time with varying water levels. In addition to this information on wetlands, extensive data was collected on birds, fish, amphibians, reptiles and mammals within the nearshore zone of Lake Ontario and the St. Lawrence River. Information about this extensive comprehensive database is located on the Study's website (www.losl.org). The information is stored in a meta-data format providing details regarding who collected it, what data was gathered and where and when it was collected.

An integrated ecological response model was developed to help determine the overall environmental conditions that result from a particular water level regime. The model provides an index which can be used as an indicator of how a particular species or factor changes relative to a base case. A version of the model will reside at the Institute for Water Resources of the U.S. Army Corps of Engineers in Fort Belvoir, Virginia. In cooperation with that office, future studies of Lake Ontario and the St. Lawrence can take place. Such future studies could be useful to universities investigating the health of the system or to agencies like the Ontario Ministry of Natural Resources, Fisheries and Oceans, Environment Canada, the U.S. Fish and Wildlife Service, The Nature Conservancy, U.S. Environmental Protection Agency, Environment Quebec and Faune Quebec.

Recreational Boating Surveys

The impact of water level changes on recreational boating and tourism was determined by developing an extensive inventory for the interest. Recreational boaters were surveyed to gather specific information about expenditures. Marina and yacht club owners were contacted to assess impacts on them and to obtain physical measurements of depths at slips and boat launching facilities. Charter boat and tour boat operators were contacted to access the impacts of fluctuating levels on their businesses. Information about this data can be accessed through the Study website (www.losl.org).

Commercial Navigation and the Impact Model

All commercial harbors were inventoried and the movement of commodities through all possible routes throughout the Great Lakes was modeled. A commercial navigation vessel movement database was developed. The Commercial Navigation Economic Impact Model can determine the impact of changing water levels, outflows and velocities affecting movement between ports. This model has potential for use in related studies regarding the movement of ships in the system and has applications for the Great Lakes/St. Lawrence Seaway Study being conducted by the U.S. Army Corps of Engineers, Transport Canada and other agencies.

Municipal, Industrial and Domestic Water Intakes

Details regarding all municipal, industrial and domestic water intakes and waste treatment outfalls are available as metadata on the Study website. This includes information about intake/outfall lengths and invert elevations, as well as capacities of facilities and the number of individuals served. Information regarding shore wells, which are for the most part located along the shores of the upper St. Lawrence River, is also available.

Agency Linkages

The Study Board recommends that the Commission sponsor a two-day conference for Great Lakes agencies to demonstrate the data and models generated during the Study with a view to creating linkages and partnerships among agencies.

Information Access

In past International Joint Commission studies, the final products have always comprised a set of final hardcopy documents and annexes. The supporting documentation, databases and models were left to those who created them, dispersed amongst agencies, organizations, and contractors, and generally not accessible for use beyond the Study. The development of an Information Management Strategy (IMS) was deemed important by this Study Board for long-term utilization of data assets compiled or created within the Study. The Information Management Strategy included a comprehensive assessment of available information resources, likely future additional resources, capabilities of partners and alternative approaches for integrated information management and data access constraints and limitations. The Information Management Strategy promoted improvements in data storage, discovery, evaluation and access, all of which were addressed by this Study.

The Information Management Strategy chosen for this Study focused on using the Internet for information discovery, evaluation and access. The components of the Information Management Strategy are depicted below in Figure 47.

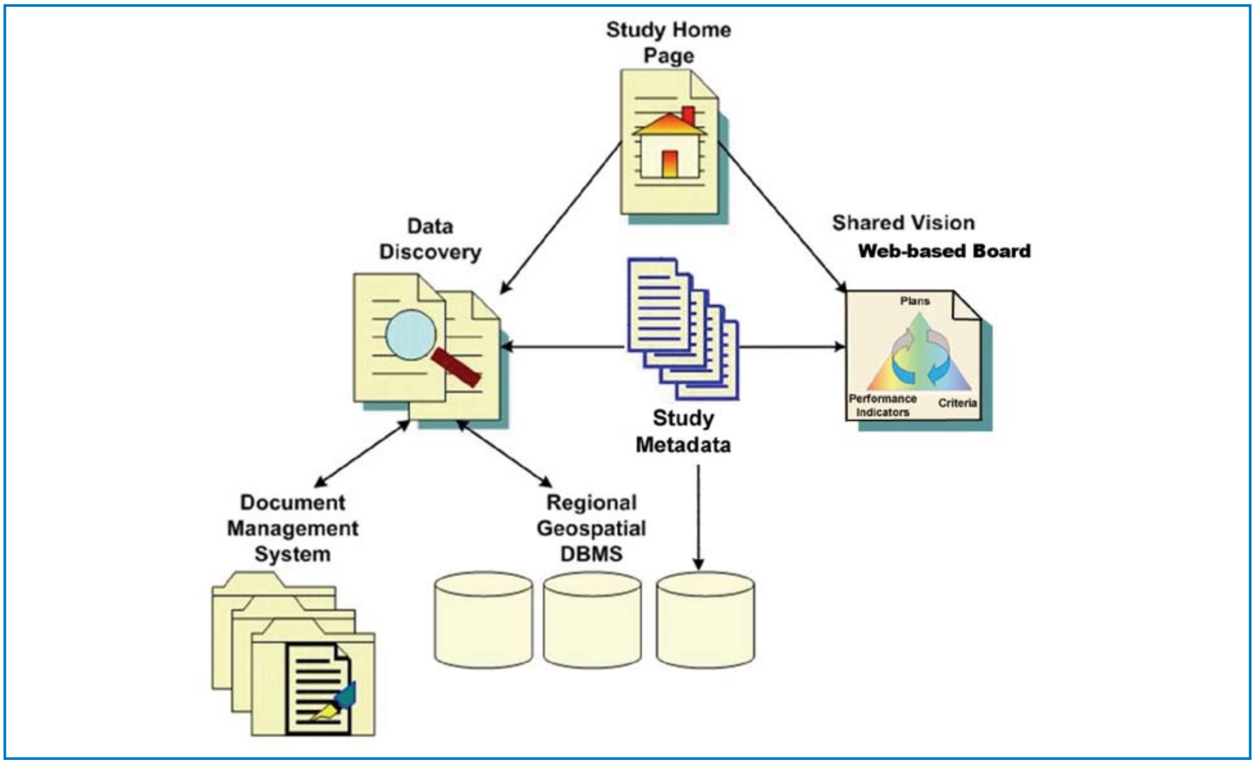


Figure 47: ***Schematic of the Information Management Strategy***

The point of access to all Study information is the Study website at **www.losl.org**. Through this website, a user can access all components of the Information Management System. The first of the System's two main components is data discovery. This links to a search engine for finding information. The first link is to the description of all documents, data, or models and is called metadata. Then, if available, the metadata links to the documents, data and models themselves. The second component is the Internet version of the Study results of candidate plan evaluations. This is a trimmed down version of the "Board Room" (the name given to the location on the website) used by the Study Board in evaluating plans. This version includes the key graphs and tables used in the evaluation process.

The members of the Study Board decided early on that they could not afford to have all information resources in bilingual form (English and French). Rather, the Study Board required that all metadata be bilingual to provide equal access for the discovery of Study information. Technical supporting documents and data were to be available in the language in which they were produced.

This is the first time an International Joint Commission study has built an information management system to allow for post-study access and retrieval of information sources. For more information on the Information Management Strategy and its various components, refer to Annex 2 – Technical Work Group Summaries.

Related Issues

Peaking and Ponding in the Upper St. Lawrence River

The owners and operators of the Moses-Saunders hydropower complex, i.e., the New York Power Authority and Ontario Power Generation, have approval from the IJC to perform peaking and ponding which allows within-week deviations from the approved outflow. The approval by the IJC is usually for sequential periods of five years, subject to review. A considerable economic benefit results when, while maintaining weekly average flow, daily flows are allowed to increase in the daytime and are reduced at night in phase with the electric power load demand, and similarly, weekday flows are increased and weekend flows correspondingly decreased. The daily flow variation about the mean is termed “peaking.” The weekly variation in which the average is increased for the five weekdays, and decreased for the two weekend days, is termed “ponding.” It is clear that no ponding operations are allowed during navigation season.

If peaking and ponding deviations are made, outflow deviations must be eliminated within the week, i.e., the sum of all daily outflows must equal the approved weekly outflow. The Operations Advisory Group of the International St. Lawrence River Board of Control requests and advises the Regulation Representatives of within-week flow adjustments for peaking and ponding operations by the power entities.

Peaking and ponding operations create rapid water level variations in the vicinity of the Moses-Saunders power dam, with these actions superimposed on the results of any regulation plan. Changes in the peaking and ponding procedures of the power entities are beyond the scope of this Study. However, concerns were expressed during public meetings held by the Study team in the Cornwall, Massena, and Akwesasne communities that local fisheries and shorelines can be highly sensitive and impacted by these short-term water level variations, depending upon the time of year, season and days when they happen. It is recognized that local weather conditions causing wave “set-up” can also be a source of these problems, with one cause often masking the effect of another.

The Study Board suggests that prior to the next renewal of the Commission’s peaking and ponding authorization, the International St. Lawrence River Board of Control analyze the physical extent of peaking and ponding operations over the previous couple of years, and then assess the impacts and sensitivities of these operations, with a view to possibly limiting them during sensitive times, i.e., fish spawning periods. The Akwesasne Native communities would be a place to start this assessment, but it should include non-native lands adjacent to the power dam on Lake St. Francis and Lake St. Lawrence.

Possible Changes in the St. Lawrence River Seaway Facilities

The Great Lakes/St. Lawrence Seaway Study is a joint effort between the United States and Canada. The Study partnership involves the following organizations:

- U.S. Army Corps of Engineers
- Transport Canada
- U.S. Department of Transportation
- St. Lawrence Seaway Management Corporation
- Saint Lawrence Seaway Development Corporation
- Environment Canada
- U.S. Fish and Wildlife Service

The Seaway Study was formally initiated in May 2003 after a Memorandum of Cooperation (MOC) was signed between Transport Canada and the U.S. Department of Transportation that facilitated a bi-national study partnership. This is a collaboration between both governments, and helps them to:

- Assess the economic, environmental and engineering factors associated with the current and future needs of the Great Lakes St. Lawrence Seaway commercial navigation system;
- Identify factors and trends affecting the domestic and international marine transportation industries serving the Great Lakes St. Lawrence Seaway, including evolving intermodal linkages and transportation technologies; and
- Evaluate the reliability and condition of the Great Lakes St. Lawrence Seaway, including the ongoing maintenance and capital requirements of sustaining and optimizing the existing marine transportation infrastructure on which it depends.

More information about the Seaway Study is available at the U.S. Army Corps of Engineers, Detroit District website, from which the above information was retrieved.

The Seaway Study is being conducted independently from the International Lake Ontario-St. Lawrence River Study. It is not anticipated that the findings of that Study will impact the options and operational plans recommended in this Final Report. However, once an option is selected, its performance will be assessed relative to future physical changes in the Seaway System in accordance with the adaptive management procedures discussed in a previous section of this report.

Additional Control Structures – Lower St. Lawrence and Ottawa Rivers

Consideration of new dams and structures, for example the construction of additional dams on the Ottawa River or on the St. Lawrence River downstream of Montreal, was beyond the scope of the Study mandate. Reference, however, is made to previous Canadian studies and reports on these topics: the *Ottawa River Regulation Planning Committee, Final Report*, and the *Projet Archipel; Feasibility Report*. These prior studies concluded that no feasible location or conditions for such structures have been found that would provide sufficient additional controls over levels and flows in the lower St. Lawrence River.

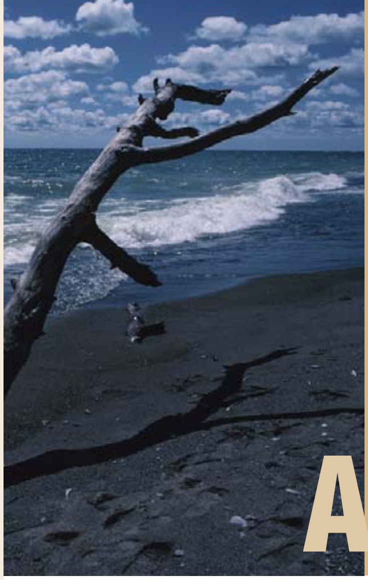
Water Diversions

There are presently five diversions on the Great Lakes: the Long Lac and Ogoki diversions into Lake Superior, amounting to 150 m^3/s (5,300 cfs), the Chicago Sanitary and Ship Canal diversion from Lake Michigan, amounting to 91 m^3/s (3,200 cfs), the Welland Canal passing on average 241 m^3/s (8,500 cfs) from Lake Erie into Lake Ontario, and the New York State Barge Canal passing on average 28 m^3/s (1,000 cfs) from the Niagara River to Lake Ontario. The Welland and New York State Barge canals do not divert water into or out of the Great Lakes, but rather provide navigation channels around Niagara Falls. Man-made diversions play a minor role in the balancing of Great Lakes water levels when compared with natural forces. The cumulative impacts of all five diversions have raised Lake Ontario levels by less than 0.4 cm (less than 1 inch).

New diversions of Great Lakes water are restricted by the *Canadian Boundary Waters Treaty Act*, the Great Lakes Charter (signed in 1985) and the supplementary implementing agreements of the Great Lakes Charter: Annex 2001 (signed December 14, 2005). Consideration of any new diversions and their impacts on the levels of Lake Ontario are beyond the scope of this Study.

Water Quality Concerns

Water quality is a major issue, but it was beyond the scope of this Study since it is only marginally affected by water levels. The depth of water in near-shore areas around Lake Ontario and in shallow areas within and along the St. Lawrence River has an impact on the growth of algae and concentration of toxins. But algae and toxins result from other factors that would prevail regardless of water levels. This is appropriately addressed by the Great Lakes Water Quality Agreement between Canada and the United States, which strives "to restore and maintain the chemical, physical and biological integrity of the water of the Great Lakes Basin Ecosystem."



Acknowledgements

Funding

Shortly after the Study began, it was determined that the Plan of Study document dated September 1999, did not include and/or underestimated the cost of some activities. In a memo to the Commission dated January 3, 2003, the Study Board requested a retooling of funding values for the following reasons:

- On initiation of the Study, the collection of topographic, bathymetric and other baseline data and the development of GIS became the responsibility of the Common Data Needs Group, increasing funds to that group while reducing funds for other technical working groups.
- A comprehensive information management program was required for the Study and to some extent for a post-Study period. The costs for this program were not included in the Plan of Study.
- In the Plan of Study, there was a line item for interrelations review. This was replaced by a broader Plan Formulation and Evaluation Group, which played a significant role in the Study process. The costs of this activity were significantly higher than that allocated for interrelations review. Also, in the final year of the Study, an independent review was undertaken of Study modeling at the request of the Commission. This review resulted in a funding reallocation in the final year of the Study.
- The Plan of Study called for individual technical work groups to receive alternative plan scenarios and evaluate them within their models. In the Study, these models were incorporated into a Shared Vision Model run by the Plan Formulation and Evaluation Group, resulting in individual group evaluations being substantially reduced or eliminated.
- In the Plan of Study, the administrative cost of transferring funds to agencies and developing contracts was not considered. Also, the cost of managing the Study and related Board activities was underestimated.
- Some technical work groups required less funding than estimated in the Plan of Study, and funds were reallocated for underestimated and unanticipated tasks and activities for other technical work groups.
- The Plan of Study identified substantial work and funding in years 4 and 5 that was reallocated to meet the overall Study mandate and agenda.

The actual amount spent for U.S. activities through September 2005 was $10.3 million U.S. The actual amount spent for Canadian activities through September 2005 was $12.7 million Canadian.

Since the Study's inception, individuals and agencies supporting Study activities have provided significant in-kind services over and above the direct expenditures identified above. In addition, the Public Interest Advisory Group has contributed hundreds of hours of volunteer time, participating in Study activities and preparing for and giving presentations at stakeholder meetings throughout the Study area.

People and Organizations

Over the five year Study period, about 180 people and dozens of organizations participated in the Study, providing the leadership, energy, information and technical expertise that led to the Study's completion and the recommendations contained herein.

The volunteer efforts of members of the Public Interest Advisory Group must be acknowledged as a significant, unique and invaluable part of this Study. Congratulations and thanks to each and every one of the PIAG members.

The following is a list of the people who directly participated in the Study with, where applicable, the organizations supporting them identified. Those who provided leadership for the various groups are also identified. Numerous technical assistants, students and researchers from agencies, First Nation communities and universities also worked behind the scenes to collect and compile information and assist with the administration of contracts and other functions. The contributions of organizations that provided staff and Study support are sincerely appreciated.

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Glossary of Terms

ABIOTIC – Non-living factors in the environment (air, water, sunlight, minerals, etc.).

ACCRETION – An increase by natural growth or addition, used in the Study in terms of increased beach area or wetland.

ACOUSTIC SOUNDINGS – Technique of determining bottom depth in a body of water by transmitting sound waves through the water and measuring the reflected signals.

ADVERSE CONSEQUENCES – Negative implication of fluctuating water levels for social, economic, environmental or political investments.

AGREEMENTS – Joint statements among two or more governmental units on (i) goals and purposes which should guide basin decision-making, (ii) processes of decision-making and (iii) authorities of governments to act. Agreements are an attempt to remedy a shared problem, and they serve to define the boundaries and constraints on choice of measures.

ALGAE – Microscopic organisms found in or near water, classified as plants and capable of photosynthesis but having no roots, flowers or seeds. These constitute the primary producers in lakes. Freshwater and marine algae are found in many forms and are therefore a diverse group of photosynthetic plant organisms that vary widely in size, shape and color. Algae form ranges from the substance on rocks that it attaches to, to the froth on the water surface, to the seaweed on the shore.

ALTERNATIVE DISPUTE RESOLUTION (ADR) – A process aimed at reaching a consensus agreement in order to end a dispute or reduce conflict among interest groups that have some stake in and can influence the outcome of decisions or actions related to the water level issue. The distinguishing characteristics of alternative dispute resolution are that: (1) interest groups are actively included in developing and assessing alternatives and making trade-offs between alternatives, and (2) issues are decided on their merits rather than on the interest's access to the decision-making process. Policy dialogues and negotiation are types of alternative dispute resolution processes.

ANTHROPOGENIC HABITAT LOSS – The loss of habitat due to human activities.

AQUIFER – Any subsurface material that holds a relatively large quantity of groundwater and is able to transmit that water readily.

AREA OF NATURAL AND SCIENTIFIC INTEREST (ANSI) – An area of land and water which, due to its natural landscapes or features, has been classified as having life science or earth science values related to protection, scientific study or education.

ARCHIPELAGOS – Expansive water with many scattered islands or a group of islands.

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

AVERAGE WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month. The period of record used in this Study commences January 1900. This term is used interchangeable with monthly-mean water level.

AWNED SEDGE – An endangered species in New York State that is known as Carex atherodes or sedge.

BARRIER BEACH – An offshore ridge of unconsolidated material (sand, pebbles, etc.) that runs parallel to a coastline, is formed in part by high tides and acts as a natural barrier.

BASIN – The rounded depression of a lake bed.

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

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

BATHYMETRY – The measurement and charting of water depths in large bodies of water; also information derived from such measurements.

BEACH – The zone of unconsolidated material that extends landward from the average annual low water level to either the place where there is marked change in material or physiographic form, the line of permanent vegetation, or the high water mark.

BENEFICIAL CONSEQUENCE – Positive implication of fluctuating water levels for social, economic, environmental or political investments.

BENTHOS – The plants and animals that live at the bottom of a body of water (ocean, river, lake, pond, etc.) either attached or unattached to substrate (sediment, rock, plant, etc.).

BIOTA – All plants and animals living in a given area.

BIRD GUILD – 1. A group of birds that have similar breeding habits. 2. A group of birds, not necessarily of the same species, that depend on the same environmental resources.

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

BOAT LAUNCHING RAMP – A sloping structure allowing small recreational water craft and trailers access to water.

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

BREAKWATER – A barrier built offshore to protect a harbor or a beach from the force of waves.

BUFFER ZONE – The minimum amount of land needed between a structure and an eroding shoreline before shoreline protection is needed.

CHART DATUM – The water level used to calculate the water depths that are shown on “navigation charts” and are a reference point for harbour and channel dredging.

CLIMATE – The prevalent weather conditions of a given region (temperature, precipitation, windspeed, atmospheric pressure, etc.) observed throughout the year and averaged over a number of years.

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.

COASTAL PROCESSES TECHNICAL WORK GROUP – A scientific and technical work group for the International Lake Ontario-St. Lawrence River Study that is investigating the impacts of water level fluctuations on shore property, with particular attention to erosion and flood processes.

COLONIAL BIRDS – Birds that nest in groups.

COMMERCIAL NAVIGATION TECHNICAL WORK GROUP – A scientific and technical work group for the Study that is investigating the impacts of water levels on cargo shipping, including tug and barge operations.

COMPUTER MODELLING – The use of computers to develop mathematical models of complex systems or processes.

CONNECTING CHANNELS – A natural or artificial waterway of perceptible extent, which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. The Detroit River, Lake St. Clair and the St. Clair River comprise the connecting channel between Lake Huron and Lake Erie. Between Lake Superior and Lake Huron, the connecting channel is the St. Marys River.

CONSERVATION – The planned management of a natural resource, with the goal of protecting and carefully preserving it from exploitation, destruction or neglect.

CONSUMPTIVE USE – The quantity of water withdrawn or withheld from the Great Lakes and assumed to be lost or otherwise not returned to them, due to evaporation during use, leakage, incorporation into manufactured products or otherwise consumed in various processes.

CONTROL WORKS – Hydraulic structures (channel improvements, locks powerhouses, or dams) built to control outflows and levels of a lake or lake system.

COSMOS MODEL – Name of the erosion prediction numerical model used in this Study for the Lake and upper river.

CRITERIA – A principle or standard by which a judgement or decision is made. Criteria are conceptual but must have operational (measurable in principle) components. Any single criterion can be used to compare the merit of measures or policies along the dimensions encompassed by the criterion. Criteria are used to assess measures and criteria are used to assess the decision-making process (for example, group access to the decision-making bodies).

CRITERIA, CORE – The broad principles upon which the overall value of any measure can be assessed relative to other measures. They include economic sustainability, environmental integrity, social desirability, uncertainty and risk, political acceptability and implementability, and equitability.

CRITERIA, OPERATIONAL – These criteria are subsets of the core criteria. These sub-criteria are quantified on the basis of the application of specific group rules to data or estimates of impacts of the measure. Impact assessments used to score sub-criteria are ultimately used to compare the profiles of measures.

CURRENT – The flowing of water in the lakes caused by the earth's rotation, inflows and outflows, and wind.

DESIGN RANGE – The range of factors (including expected water levels) taken into consideration when making an investment decision.

DIGITAL ELEVATION MODEL (DEM) – A digital image of geographical features consisting of a grid, in which the colour of each cell reflects an average elevation above or below sea level.

DIGITAL ORTHOIMAGERY – Computer-assisted cartography technique allowing representation of surface features with the positional accuracy of a map, through elimination of errors due to camera or sensor orientation and terrain relief.

DIGITAL ORTHOPHOTO – A computer-rendered image representing surface features, in which inaccuracies due to camera or sensor orientation and terrain relief have been removed. Such an image combines the positional accuracy of a map with the image quality of a photograph.

DIKE – A wall or earth mound built around a low lying area to prevent flooding.

DIVERSIONS – A transfer of water either into the Great Lakes watershed from an adjacent watershed, or vice versa, or from the watershed of one of the Great Lakes into that of another.

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

DROWNED RIVER MOUTHS (also known as estuaries) – The place where lake and river waters mix. They provide valuable habitat for spawning fish, nesting and migrating birds, and many rare or specialized plants. These wetlands typically have deep organic soils that have accumulated due to deposition of watershed-based silt loads and protection from coastal processes (waves, currents, seiche, etc.).

DUNE – a mound or ridge of sand formed by the action of wind or waves.

ECOLOGY – The science which relates living forms to their environment.

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

ECOSYSTEM INTEGRITY – A state of health, or wholesomeness of an ecosystem. It encompasses integrated, balanced and self-organizing interactions among its components, with no single component or group of components breaking the bounds of interdependency to singularly dominate the whole.

EMERGENTS – Plants rooted in soil under water but which emerge partially above the surface.

ENDANGERED SPECIES – A species threatened with extinction.

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.

ENVIRONMENTAL INTEGRITY – The sustenance of important biophysical processes which support plant and animal life and which must be allowed to continue without significant change. The objective is to assure the continued health of essential life support systems of nature, including air, water, and soil, by protecting the resilience, diversity, and purity of natural communities (ecosystems) within the environment.

ENVIRONMENTAL TECHNICAL WORK GROUP – A group of scientific and technical experts that is investigating impacts of water level variations on fish, birds, plants and other wildlife in the Lake Ontario-St. Lawrence River system, with particular attention to ecological effects on wetlands.

EQUITABILITY – The assessment of the fairness of a measure in its distribution of favorable or unfavorable impacts across the economic, environmental, social, and political interests that are affected.

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.

ESTUARIES – The place where lake and river waters mix. They provide valuable habitat for spawning fish, nesting and migrating birds, and many rare or specialized plants. These wetlands typically have deep organic soils that have accumulated due to deposition of watershed-based silt loads and protection from coastal processes (waves, currents, seiche, etc.).

EUTROPHIC – Waters high in nutrient content and productivity arising either naturally or from agricultural, municipal, or industrial sources; often accompanied by undesirable changes in aquatic species composition.

EVALUATION – The application of data, analytical procedures and assessment related to criteria to establish a judgment on the relative merit of a measure, policy or institution. Evaluation is a process which can be conducted both within formal studies and by separate interests, although different data, procedures and criteria may be employed in the evaluation by different interests.

EVALUATION FRAMEWORK – A systematic accounting of the criteria considered and methodologies applied in determining the impact of measures on lake levels, stakeholders, and stakeholder interests.

EVAPOTRANSPIRATION – Evaporation from water bodies and soil and transpiration from plant surface.

EXOTIC SPECIES – Non-native species found in a given area as a direct or indirect result of human activity.

FEEDBACK LOOP – Feedback loops are circular cause and effect relationships dominating some interaction of particular sets of system's key variables. Feedback loops belong generally to one of two types. "negative feedback loops" which act to maintain the value of a particular variable around a given level, and "positive feedback loops" which act to cause the value of a particular variable to increase or decrease in a self-amplifying manner; and, usually at a geometric rate.

FISH GUILD – 1. A group of fish that have share similar breeding habits. 2. A group of fish, not necessarily of the same species, that depend on the same environmental resources.

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.

FLOW – The rate of movement of a volume of water over time.

FLUCTUATION – A period of rise and succeeding period of decline of water level. Fluctuations occur seasonally with higher levels in late spring to mid-summer and lower levels in winter. Fluctuations occur over the years due to precipitation and climatic variability. As well, fluctuations can occur on a short-term basis due to the effects of periodic events such as storms, surges, ice jams, etc.

FLUVIAL – Related to or living in a stream produced by a river.

FRAZIL ICE – Stream ice with the consistency of slush, formed when small ice crystals develop in super-cooled 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.

FUNGIBILITY – Something that is exchangeable or substitutable. In this Study, fungibility refers to the degree to which performance indicators are measured in the same units and are comparable.

GABION – An open-ended, cylinder-shaped wire mesh container which is sunk into a bottom and filled with rocks to form a structure such as a dike used to prevent erosion.

GENERAL CIRCULATION MODEL (GCM) – A three-dimensional computer representation of climate and its various components, used to predict climat scenarios.

GEOGRAPHICAL INFORMATION SYSTEM (GIS) – An information system used to store and manipulate (sort, select, retrieve, calculate, analyze, model, etc.) geographical data.

GEOMORPHOLOGY – The field of earth science that studies the origin and distribution of landforms, with special emphasis on the nature of erosional processes.

GLOBAL POSITIONING SYSTEM (GPS) – A navigation system based on the transmission of signals from a network of satellites, which allows users anywhere on the planet to determine their exact location at all times.

GOVERNANCE SYSTEM – The complex, dynamic mosaic of governmental and non-governmental entities having some authority to manage, or the ability to influence the management of Basin resources.

GREENHOUSE EFFECT – The warming of the earth's atmosphere associated meteorological effects due to increased carbon dioxide and other trace gases in the atmosphere. This is expected to have implications for long-term climate change.

GROUNDWATER – Underground water occurring in soils and in pervious rocks.

GULLIES – Deep, V-shaped trenches carved by newly formed streams, or groundwater action, in rapid headward/forward growth during advanced stages of accelerated soil erosion.

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

HABITAT HETEROGENEITY – Habitat encompasses the diverse characteristics of the environment that define an area where specific biota live and is necessary for life functions.

HABITAT SUITABILITY INDEX (HSI) – A relative weighting (usually between 0 and 1) of the suitability of a particular environmental characteristic or combination of characteristics based on a particular biota's requirements.

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

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

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

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

HYDROELECTRIC POWER GENERATION TECHNICAL WORK GROUP – A group of technical experts for the Study that are evaluating how different regulation plans affect power generation.

HYDROLOGIC ATTRIBUTES – Statistics on water levels and stream flows.

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

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

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

HYDROLOGY AND HYDRAULICS MODELING TECHNICAL WORK GROUP – A scientific and technical work group for the Study that is developing models to predict water levels and flows in the Lake Ontario-St. Lawrence River system, based on various regulation plans and climate scenarios.

HYDROPERIOD – The length of time (and seasonality) that water is present over the surface of the wetland.

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

IMAGERY – Representation of objects as images through electronic and optical techniques.

IMPERIAL CONVERSION FOR FEET TO METERS – 1 foot = .305 meters.

IMPERIAL CONVERSION FOR INCHES TO CENTIMETERS – 1 inch - 2.54 centimeters.

IMPLEMENTABILITY – The ability to put into effect a measure considering factors of engineering, economic, environmental, social, political and institutional feasibility.

IMPLEMENTING AUTHORITY – Any governmental agency at any level having appropriate authority to authorize and execute the implementation of any particular action and the jurisdiction to enforce an action.

INFILTRATION – Movement of water through the soil surface and into the soil.

INFORMATION MANAGEMENT TECHNICAL WORK GROUP – A scientific and technical work group for the Study that is collecting and updating information on depths and elevations (bathymetric and topographic data) in critical areas of the Lake Ontario-St. Lawrence system and sharing findings with other work groups.

INSTITUTION – An organization of governmental units which have the authority and ability to facilitate and/or make decisions affecting the water levels issue.

INTEGRATED ECOLOGICAL RESPONSE MODEL (IERM) – Establishes the framework for evaluating, comparing, and integrating the responses for the environmental performance indicators.

INTERESTS – Any identifiable group, including specialized mission agencies of governments which (1) perceive that their constituents'/members' welfare is influenced by lake level fluctuation or policies and measures to address lake level fluctuation, and which (2) are willing and able to enter the decision-making process to protect the welfare of their constituents/members.

INTERNATIONAL JOINT COMMISSION (IJC) – An international federal government agency formed in 1909 by the United States and Canada as an application of the Boundary Waters Treaty to oversee the resolution and prevention of disputes with regard to all bodies of water shared by the two countries, and to provide recommendations on such water management issues as water quality and water levels.

INTERNATIONAL LAKE ONTARIO – ST. LAWRENCE RIVER STUDY – A study sponsored by the IJC 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 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.

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

INVESTMENT – Expenditure made by an interest to capture benefits. The investment decision reflects available information and understanding about the system, government responsibilities and risks.

JURISDICTION – The extent or territory over which authority may be legally exercised.

LAKEBED DOWNCUTTING – Progressive erosion or deepening of the water depths in front of riparian property.

LAKE OUTFLOW – The amount of water flowing out of a lake.

LEACHATE – Contaminated liquid resulting from the percolation of water through pervious rocks and soils at a waste site or landfill.

LIDAR – A remote-sensing system similar to radar, in which laser light pulses take the place of microwaves.

LITTORAL – Pertaining to or along the shore, particularly to describe currents, deposits and drift.

LITTORAL CELL – An area under the continuous influence of specific longshore currents.

LITTORAL CELLS – Closed sediment compartments that define the limits of all sand movements, both along the shore and onshore/offshore.

LITTORAL DRIFT – The movement of gravel, sand and other beach material along the coast, which is caused by waves and currents.

LITTORAL ZONE – The area extending from the outermost breaker or where wave characteristics significantly alter due to decreased depth of water to: either the place where there is marked change in material or physiographic form; the line of permanent vegetation (usually the effective limit of storm waves); or the limit of wave uprush at average annual high water level.

LOCATION BENEFIT – Positive effect on the welfare of an interest derived from shore location and water level situation.

LOCATION COST – Negative effect on the welfare of an interest derived from shore location and water level situation.

LOW WATER DATUM – An approximation of mean low water, used for harbour-dredging purposes.

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 Lac St. Francis, Lac St. Louis, Montreal Harbour, Lac St. Pierre and the portions of the River connecting these lakes as far downstream as Trois Rivieres.

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

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

MEASURE – Any action, initiated by a level(s) of government to address the issue of lake level fluctuations, including the decision to do nothing.

MEASURE, NON-STRUCTURAL – Any measure that does not require physical construction.

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

METADATA – Data (information) about the characteristics of data such as content, quality (condition, accuracy, etc.), date of capture, user access restrictions and ownership.

META-DATABASE – A database used to store information about data (metadata).

METEROLOGICAL – Pertaining to the atmosphere or atmospheric phenomena; of weather or climate.

METRIC CONVERSION FOR CENTIMETERS TO INCHES – 1 centimeter = 0.4 inch.

METRIC CONVERSION FOR METERS TO FEET – 1 meter = 3.28 feet.

MICRO-ORGANISM – An organism that is too small to be visible without the aid of a microscope.

MODEL – A model may be a mental conceptualization; a physical device; or a structured collection of mathematical, statistical, and/or empirical statements.

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

MODEL, HYDRAULIC – A small-scale reproduction of the prototype used in studies of spillways, stilling basins, control structures, riverbeds, etc.

MODEL, VISUAL SITUATION – A pictorial display linked to an automated information/geographic information system(s) which connects the problems associated with fluctuating water levels whith the stakeholders and their interests that are impacted by the problems, with an emphasis on overlapping or interacting relationships.

MONTHLY MEAN WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month. The period of record used in this Study commences January 1900. This term is used interchangeably with average water level.

NEGOTIATION – The process of seeking accommodation and agreement on measures and policies among two or more interests or agencies having initially conflicting positions by a “voluntary” or “non-legal” approach. This is often considered a part of an alternative dispute resolution process.

NET BASIN SUPPLY (NBS) – The net amount of water entering one of the Great Lakes, comprised as the precipitation onto the lake minus evaporation from the lake, plus groundwater and runoff from its local basin. The net basin supply does not include inflow from another Great Lake.

NO NET LOSS – A working principle by which a department or agency strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada’s fisheries or U.S. wetland resources due to habitat loss or damage may be prevented.

OPERATING PLAN – A list of procedures to be followed in making changes to the lake levels or their outflows for the specific purpose or to achieve certain objectives. Operation of regulatory facilities on the Great Lakes are carried out by their owners and operators under the supervision of the IJC and in accordance with Plan 1977 (Lake Superior) and Plan 1958-D (Lake Ontario).

OUTFALL – The place or structure where a sewer, drain, conduit or stream discharges into the surface water.

OUTFLOW – The quantity of water flowing out of a lake through surface rivers or streams, measured in time units at a given point.

OXIC – To expose to oxygen.

OZONATION – The application of a substance or compound with ozone as a possible remedy for the occasional taste and odor problems experienced in some municipal water supplies that withdraw water from the lower river.

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.

PHOTOSYNTHESIS – The process through which the cells of green plants and certain micro-organisms convert energy from sunlight into stored, usable chemical energy.

PHYSICAL IMPACT SURVEY – A characterization study of the impact of water level fluctuation on infrastructure use or constraints.

PHYSIOGRAPHY – A descriptive study of the earth and its natural phenomena, such as climate, surface etc.

PLAN 1958-D – A plan used by the International St. Lawrence River Board of Control since April 1963 that specifies outflows from Lake Ontario in order to satisfy the existing set of criteria established by the IJC and related to interests on Lake Ontario and the St. Lawrence River.

PLAN FORMULATION AND EVALUATION GROUP – A group established as part of the Study to develop alternative water level regulation plans, establish performance indicators for such plans, and to measure the effectiveness of such alternate criteria and operating plans.

PLAN FORMULATION METHOD – A method involving a multi-objective, multi-stakeholder evaluation procedure used to evaluate factors not previously considered in determining whether a revised operating plan performs better than an existing plan.

PLANIMETRIC CAPABILITIES – The capability of a system to measure areas.

POLICY – The position adopted by a government on an issue which is expected to structure and guide the decision-making process.

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.

POSITION OF INTERESTS – The perceptions, beliefs and preferences of interests regarding fluctuating water levels, implications of those levels, and acceptability of a measure or policy to an interest. Positions may be directly stated or may be inferred from supporting or opposing activities taken by the interest in the decision-making process.

PRIORITY CONSERVATION SPECIES – A species protected by federal, state, or provincial laws.

PUBLIC COMMUNICATIONS – Activities where the purpose, design, and plan intends for two-way communication for a defined period of time between Study personnel and the public or various publics.

PUBLIC INFORMATION – Activities where the purpose, design, and plan intends to deliver information to the public or various publics. Examples: press releases and articles in the Study Newsletter, Ripple Effects.

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

PUBLIC INVOLVEMENT – Activities where the purpose, design, and plan is such that members of the public or various publics are engaged in the Study on a continuing basis with other “expert” resources.

PUBLIC PARTICIPATION – Activities where purpose, design, and plan intends that members of the public have an opportunity to participate for a defined period of time in a Study activity.

QUARTER-MONTHLY MEAN WATER LEVEL – This is the average water level that would occur during a quarter-month period. A quarter-month is seven or eight days depending on the number of days in the month.

RAPIDS – A turbulent and swift-flowing section of a river.

REACH – A length of shore with fairly uniform onshore and offshore physiographic features and subject to the same wave dynamics.

REBOUND (CRUSTAL MOVEMENT) – The uplift or recovery of the earth’s crust in areas where a past continental glaciation had depressed the earth’s crust by the weight of the ice.

RECESSION – A landward retreat of the shoreline by removal of shore materials in a direction perpendicular or parallel to the shore.

RECREATIONAL BOATING AND TOURISM TECHNICAL WORK GROUP – A group of technical experts that will investigate the impacts of water levels on individual boaters, marinas, and boating-related tourism for the Study.

REGULATION – Artificial changes to the lake levels or their outflows for specific purpose or to achieve certain objectives.

REGULATIONS – Control of land and water use in accordance with rules designed to accomplish certain goals.

RELIABILITY – While ranking plans, it is the percentage of time that a criterion is met (i.e., 4,848 out of 4,848 quarter-months = 100%).

RESILIENCE – During plan ranking, it is the average amount of time it takes to get back in compliance (how long). It is calculated as the total number of quarter-months of failure divided by the number of failures.

RESILIENCY – The ability to readily recover from an unexpected event, either because costs were not significantly affected by changing levels, another source of income provided a cushion to levels induced costs, and/or a conscious effort was made on the part of the interest.

RESERVOIR – A place where water is collected and kept for use when wanted, as to supply a fountain, a canal, or a city by means of aqueducts, or to drive a mill wheel, or the like.

REVETMENT – A natural (grass, aquatic plants, etc.) or artificial (concrete, stone, asphalt, earth, sand bag, etc.) covering (facing) to protect an embankment (raised structure made of soil, rock or other material) or other structure (such as a cliff) from erosion.

RIPARIAN – Of, relating to or found along a shoreline.

RIPARIANS – Persons residing on the banks of a body of water.

RIVERINE – Of or relating to a river or a riverbank.

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

SCOURING – Erosion, generally in the form of downcutting in front of shore protection or other coastal structures that may be temporary or permanent.

SEDIMENT BUDGET – An accounting system for all of the sand and gravel within a defined study boundary (spatial extents).

SHARED VISION MODEL – A decision-making tool used to develop a collective representation (image or view) of the future a group aspires to create.

SHOALS (SCANNING HYDROGRAPHIC OPERATIONAL AIRBORNE LIDAR SYSTEM) – A LIDAR system that uses a green laser to profile underwater terrain and an infrared laser to detect water surfaces. The system is used to obtain bathymetric and topographic data.

SHORELINE – Intersection of a specified plane of water with the shore.

SILLS – Underwater obstructions placed to reduce a channel's flow capacity.

SOCIAL DESIRABILITY – The continued health and well-being of individuals and their organizations, businesses, and communities to be able to provide for the material, recreational, aesthetic, cultural, and other individual and collective needs that comprise a valued quality of life. The satisfaction of this objective includes a consideration of individual rights, community responsibilities and requirements, the distributional impacts of meeting these needs, and the determination of how these needs should be achieved (paid for) along with other competing requirements of society.

SOCIO-ECONOMIC SURVEY – A survey measuring the basic characteristics of a community, from which statistics can be compiled.

SPATIAL EVALUATION FRAMEWORK – The classification and delineation of terrestrial, wetland and aquatic environments in spatial units meaningful to an assessment of fluctuating levels and measures.

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.

STANDARDIZED HYDROLOGIC STATIONS (SHS) – Water level measurement stations operated by a governmental agency where water depth that was measured at specific geographical locations is translated into International Great Lakes Datum as updated in 1985 equivalent data.

STEADY STATE – No change over time.

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

STRATEGY – A general conceptual framework for guiding action based upon a particular purpose and selected means for achieving agreed upon ends.

SUBMERGED MACROPHYTES – Plant species that grow under water during their entire life cycle (not including algae).

SUBSTRATE COMPOSITION – Categorical assignments of the lake/river bottom from silt to bedrock size classes.

SURFACE WATER – Water open to the atmosphere including lakes, ponds, rivers, springs, wetlands, artificial channels and other collectors directly influenced by surface water.

SYSTEM DYNAMICS – A simulation modeling methodology developed at Massachusetts Institute of Technology for the study of the behavior of complex systems. System dynamics is based upon the identification of key system variables, the interactions between them and the study of the effects of these interactions over time.

SYSTEMS APPROACH – A method of inquiry which complements the classical analytical method of science by emphasizing the concept of "whole systems" and the irreducible properties of whole systems that result from the interactions among individual components.

TECHNICAL WORK GROUP (TWG) – A team of scientific and technical experts formed to study each of the following areas: the coastal processes, commercial navigation, common data needs, the environment, hydrology and hydraulics modeling, water uses, hydroelectric power generation, and recreational boating and tourism for the International Lake Ontario-St. Lawrence River Study.

TOPOGRAPHY – The representation on maps or charts of the surface features of a region in such a manner as to illustrate their relative positions and elevations.

TROPHIC – Of, or related to, nutrition.

UNCERTAINTY AND RISK – The evaluation of a proposed measure in terms of the unpredictability and magnitude of the consequence which may follow, the detectability of anticipated or unanticipated consequences, and the ability to reverse, adapt, or redirect the measure, depending on the effects.

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

URBANIZATION – The change of character of land, due to development, from rural or agricultural to urban.

VULNERABILITY – The average amount of failure when a plan does not meet criterion during ranking (how bad it performs). So if it goes over a criterion in two quarter-months, once by 10 cm (3.9 inches), the other by 20 cm (7.89 inches), the vulnerability is 15 cm (5.9 inches).

VUSILIENCE – How poorly a plan performs multiplied by how long it performs poorly (the product of vulnerability times resilience).

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. Several different types of water levels are used in the Study. In the case of Lake Ontario, the water level is assumed to be the calm water level without wind effects or waves included. In the erosion and flood analysis, these wind effects are added to the calm water level. Many of the analyses done in the Study use the quarter-monthly mean water level. This is the average water level that would occur during a quarter-month period (approximately a week).

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

WATER USES TECHNICAL WORK GROUP – A technical and scientific team of the Study that is investigating impacts of water level variations on industrial, municipal, and domestic water intakes and treatment facilities.

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

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

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.

WAVE DIRECTION – The direction from which a wave approaches.

WAVE PERIOD – The time for two successive wave crests to pass a fixed point.

WEATHER – The meteorological condition of the atmosphere defined by the measurement of the six main meteorological elements: air temperature, barometric pressure, wind velocity, humidity, clouds, and precipitation.

WEIGHTED SUITABLE AREA (WSA) – The aggregate sum of the areas within a region, or larger area, that have been weighted by habitat suitabilities (see Habitat Suitability Index).

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

WETLAND OBLIGATE BIRD SPECIES – Birds that require wetland habitats for breeding purposes (such as nesting and/or food sources).

WETLANDS – (marshes, swamps, bogs, and fens) – lands where the water table is at, near or above the land surface long enough each year to support the formation of hydric soils and to support the growth of hydrophytes, as long as other environmental variables are favorable.

WILLINGNESS TO PAY (WTP) – The maximum amount that a consumer will pay for a given item or service.

YACHT CLUB – A member-owned facility allowing access to docks or mooring to recreational boaters, and often offering complementary services.

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The Words Before All Else...
(The Haudenosaunee Thanksgiving Address)

Ohe'n:ton Karihwale'hkwen

Greetings to the Natural World

The Words Before All Else

Native Self-Sufficiency Centre

Six Nations Indian Museum

Tracking Project

Tree of Peace Society

These words of thanksgiving come to us from the Native people known as the Haudenosaunee (also Iroquois or Six Nations —Mohawk, Oneida, Cayuga, Onondaga, Seneca and Tuscarora) of upstate New York and Canada. The Thanksgiving Address has ancient roots, dating back over 1,000 years to the formation of the Great Law of Peace by a man called the Peacemaker, and perhaps before that. Today these words are still spoken at the opening and closing of all ceremonial and governmental gatherings held by the Six Nations.

A speaker is chosen to give the Thanksgiving Greetings on behalf of the people. They choose their own words, for we are all unique and have our own style, but the general form is traditional. It follows an order in which we can all relate to all of the Creation. The Address is based on the belief that the world cannot be taken for granted, that a spiritual communication of thankfulness and acknowledgement of all living things must be given to align the minds and hearts of the people with Nature. This forms a guiding principle of culture.

We believe that all people at one time in their history had similar words to acknowledge the works of the Creator. With this in mind, we offer these words in a written form as a way to re-acquaint ourselves with this shared vision. Our version of the Thanksgiving Address has been modified for a young, general audience—it has been shortened and many specific references to the cultures of the Six Nations have been generalized. We hope this will enhance the accessibility of the words for readers around the world.

It was Jake Swamp's original vision that this Address would go out to the children of the world, "so that later in life, when they go out and meet one another, they will find that they are all coming from the same place."

You are invited—encouraged—to share in these words, that our concentrated attention might help us rediscover our balance, respect, and oneness with Nature.

Now our minds are one.

Greetings to the Natural World

Salutations au monde de la nature

Ohên:ton Karihwatêhkwen

The People

Today we have gathered and we see that the cycles of life continue. We have been given the duty to live in balance and harmony with each other and all living things. So now, we bring our minds together as one as we give greetings and thanks to each other as People.

Now our minds are one.

Le Peuple

Aujourd'hui nous nous sommes rassemblés et nous voyons que les cycles de vie continuent. Le rôle qui nous est confié est de vivre en équilibre et en harmonie les uns avec les autres et avec tous les organismes vivants. Aussi maintenant, nous unissons nos esprits pour n'en faire qu'un alors que nous nous adressons les uns les autres des salutations et remerciements comme Peuple.

Maintenant nos esprits ne font qu'un.

Onkwehshôn:ʔa

Onwa wenhniserâ:te ionkwakiaʔtarô:ron ne iorihwâ:ke ne aitewąkaʔeniônnion tsiniiohtonhâ:kie tsinaʔtitewâtere ne onkwehshôn:ʔa tânonʔ tsinî:iot tsi rokwatâkwen ne ohontsiâ:ke. Ne ne â:ienreʔk akwê:kon skên:nen tsitewanonhtôn:nion ne tsiniionkwè:take kenhnôn:we iahitewaiaʔtaiê:ri onì tsi ionkwataʔkarî:te iah thahò:ten tekionkwakiaʔtônkion ne kanonhwaʔktênhtsheraʔ. Ne kati enhôn:we iorihwâ:ke tsi entewâtkaʔwe ne kanonhwaratônhtshera.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Earth Mother

We are all thankful to our Mother, the Earth, for she gives us all that we need for life. She supports our feet as we walk about upon her. It gives us joy that she continues to care for us as she has from the beginnings of time. To our Mother, we send greetings and thanks.

Now our minds are one.

Notre mère, la Terre

Nous sommes tous reconnaissants à notre mère la Terre, parce qu'elle nous donne tout ce que nous avons besoin pour vivre. Elle supporte nos pieds alors que nous allons et venons à sa surface. Cela nous remplit de joie de savoir qu'elle continue de prendre soin de nous comme elle l'a fait depuis le commencement du monde. À notre Mère, nous adressons nos salutations et remerciements.

Maintenant nos esprits ne font qu'un.

IethiʔnistênhaOhôntsia

Onen nôn:wa ehnôn:we nentsitewateʔnikonhraiê:raʔte IethiʔnistênhaOhôntsia tsi neʔe taiakohtkaʔwenhâ:kie tsinahoʔtenʔshôn ionkionhêhkwen. Iotshennôn:niaʔt tsi shê:kon teionkhihsniêkie tsinî:iot tsi shakohrienaiên:ni ne shahakwatâ:ko ne tsiionhontsiâ:te. Ne ionkhihawîhshon ne onkwehshôn:ʔa tânonʔ karioʔtaʔshôn:ʔa tsinikarî:wes ohontsiâ:ke teionkwatawên:rie. Ne kati ehnôn:we iorihwâ:ke tsi entewâtkaʔwe ne kanonhwaratônhtshera.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Waters

We give thanks to all the Waters of the world for quenching our thirst and providing us with strength. Water is life. We know its power in many forms — waterfalls and rain, mists and streams, rivers and oceans. With one mind, we send greetings and thanks to the spirit of Water.

Now our minds are one.

Les Eaux

Nous rendons grâce à toutes les Eaux du monde parce qu'elles nous désaltèrent et nous donnent la force. L'Eau est la vie. Sa puissance se manifeste à nos yeux sous de nombreuses formes — cascades et pluie, brouillards et cours d'eau, rivières et océans. Unis en un seul esprit, nous adressons nos salutations et remerciements à l'esprit de l'Eau.

Maintenant nos esprits ne font qu'un.

Ohneka?shôn:?a

Onen ehnôn:we ientsitewakiê:ra?te ne ohneka?shôn:?a tsi rawê:ren tsi enkahnekônionke ne tsiionhontsiâ:te. Ne ehnôn:we nitewêhtha ne aionkwaha?tanâ:wen nô:nen enionkwania?tâthen. Nia?teka?satstenhserâ:ke tewaientê:ri—tsi ieiohnekên:shon, tsi iokennô:res, tsi iaonhawî:nes tânon? tsi kaniatarahrôn:nion. Khênska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra ne iorihwâ:ke tsi entewâtka?we ne kanonhwaratônhtshera.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Fish

We turn our minds to all the Fish life in the water. They were instructed to cleanse and purify the water. They also give themselves to us as food. We are grateful that we can still find pure water. So, we turn now to the Fish and send our greetings and thanks.

Now our minds are one.

Les Poissons

Nos esprits se tournent vers la vie de tous les Poissons qui sont dans l'eau. Ils ont été chargés de nettoyer et de purifier l'eau. Ils s'offrent également à nous comme nourriture. Nous sommes reconnaissants de pouvoir trouver encore de l'eau pure. Aussi, nous nous tournons vers les Poissons et leur adressons nos salutations et remerciements.

Maintenant nos esprits ne font qu'un.

Kentsionshôn:?a

Tânon? kati ehnôn:we nikontî:teron ne khia?tekêntsiake tânon? otsi?nonwa?shôn:?a. Ne?e teshakô:wi ne takontohtâhrho tsi kahnekarôn:nion. Ne oni taionatka?wenhâkie ne onkwatennà:tshera ne ionkwaia?tahnirâ:tha. Ne ne iotshennôn:nia?t tsi shê:kon iorihwatô:ken ionkwatshenrionhâkie ne ne kahnekî:io. Ehnonkwâ:ti entewakiê:ra?te ne entewâtka?we ne kanonhwaratônhtshera.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Plants

Now we turn toward the vast fields of Plant life. As far as the eye can see, the Plants grow, working many wonders. They sustain many life forms. With our minds gathered together, we give thanks and look forward to seeing Plant life for many generations to come.

Now our minds are one.

Les Plantes

Maintenant nous nous tournons vers les vastes champs remplis de végétaux. Aussi loin que le regard peut porter, les Plantes se développent, créant une multitude de merveilles. Elles entretiennent de nombreuses formes de vie. Nos esprits étant réunis, nous adressons nos remerciements et nous espérons voir les Plantes se perpétuer pendant de nombreuses générations à venir.

Maintenant nos esprits ne font qu'un.

Tsi Shonkwaienthô:wi

Ne onen ehnôn:we nentsitewakiê:ra?te ne tsinî:iot tsi tekahentaiên:ton. Ia?teiotkahrôktha ohontsiakwê:kor taiohnio?onhâkie ne shonkwaienthô:wi ne niatekonti?satstenhserâ:ke ne ohonte?shôn:?a. Aiâ:wens kiôtkon aitewatkahthôhseke ne tsinî:iot tsi rowinentâ:?on. Enska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra tânon? tsi ia?teiotihtehrôn:ton entitewahawihtânion ne kanonhwaratônhtshera.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Food Plants

With one mind, we turn to honour and thank all the Food Plants we harvest from the garden. Since the beginning of time, the grains, vegetables, beans and berries have helped the people survive. Many other living things draw strength from them too. We gather all the Plant foods together as one and send them a greeting and thanks.

Now our minds are one.

Les Plantes alimentaires

Unis dans un même esprit, nous désirons maintenant honorer et remercier toutes les Plantes alimentaires que nous récoltons dans le jardin. Depuis le commencement du monde, les céréales, les légumes, les haricots et les baies ont aidé les gens à survivre. Un grand nombre d'autres organismes vivants en tirent également leur force. Nous réunissons toutes les Plantes servant de nourriture en un tout et nous leur adressons nos salutations et remerciements.

Maintenant nos esprits ne font qu'un.

Kaien?thôhshera

Enska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra tânon? ehnôn:we nentsitewakiê:ra?te ne ne onkwatennâ:tshera tsinî:iot tsi shonkwaienthô:wi. Ne teionkwahsniêkie ne kaienthôhsera tsinikarî:wes ohontsiâ:ke teionkwatawên:rie. Nia?teiotikiôhkwake ne kâ:nen, osahê:ta tânon? kahi?shôn:?a tewaienthôkwas ne ionkwaiatahnirâ:tha. Ne oni iononhêhkwen ne kwah tsinaho?tên:shon rôhshon ne ohontsiâ:ke. Ne tsinentewâ:iere ne kati enkiethihwe?nôn:ni ne kaienthohtshera?shôn:?a tsi wa?tiiethinonhwarâ:ton.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Medicine Herbs

Now we turn to all the Medicine Herbs of the World. From the beginning, they were instructed to take away sickness. They are always waiting and ready to heal us. We are happy there are still among us those special few who remember how to use these plants for healing. With one mind, we send greetings and thanks to the Medicines and to the keepers of the Medicines.

Now our minds are one.

Les Herbes médicinales

Nous nous tournons maintenant vers toutes les Herbes médicinales du monde. Depuis le commencement, elles ont eu pour mission d'éloigner la maladie. Elles sont toujours là prêtes à nous guérir. Nous sommes heureux qu'il y en ait encore quelques-uns parmi nous qui se rappellent comment se servir de ces plantes pour guérir. Unis dans un seul esprit, nous adressons nos salutations et remerciements aux plantes médicinales et à ceux qui en sont les gardiens.

Maintenant nos esprits ne font qu'un.

Ononhkwa?shôn:?a

Ne onen ehnôn:we nentsitewakiê:ra?te ne ononhkwa?shôn:?a iorihwâ:ke. Ne tsinihoiê:ren ohontsiakwê:kon tethohrâhthon ne ononhkwa?shôn:?a. Ne ionaterîhonte a?ê:ren kontihawîhtha ne kanonhwa?ktênhtshera. Kiôtkon iotiharêkies tânon? ionatatewinentâ:on aiakôtsien?te?. Iotshennônnia?t tsi shê:kon teiontonkwe?taiestâhshion ne ronnê:iahre tsiniiotiianerenh-shero?tên:shon ne ononhkwa?shôn:?a. Onen kati nen?ne tentsiethinonhwarâ:ton ne ononhkwa?shôn:?a tânon? tsiniionkwè:take ne?e tehotîhkwen tsi rontenonhkwâ:tsheranonhne.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Animals

We gather our minds together to send greetings and thanks to all the Animal life in the world. They have many things to teach us as people. We see them near our homes and in the deep forests. We are glad they are still here and we hope that it will always be so.

Now our minds are one.

Les Animaux

Nous unissons nos esprits pour adresser des salutations et remerciements à tous les Animaux des quatre coins du monde. Ils ont beaucoup de choses à nous apprendre comme peuple. Nous les apercevons près de nos demeures et dans les forêts profondes. Nous sommes heureux qu'ils soient encore ici et nous espérons qu'il en sera toujours ainsi.

Maintenant nos esprits ne font qu'un.

Kontîrio

Enska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra tânon? teniethinonhwarâ:ton ne kontî:rio ne ne ohontsiakwê:kon shakotkâ:wen. Ôkia?ke iethî:kens teionatawenriehâkies aktônkie tsiionkwataskwarônnion oni tsikaskawaiên:ton. Iotshennônnia?t ehnôn:we iorihwâ:ke tsi shê:kon iethî:kens ne kontî:rio oni aiâ:wens kiôtkon ehnaiohtônhake.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Trees

We now turn our thoughts to the trees. The Earth has many families of Trees who have their own instructions and uses. Some provide us with shelter and shade, others with fruit, beauty and other useful things. Many peoples of the world use a Tree as a symbol of peace and strength. With one mind, we greet and thank the Tree life.

Now our minds are one.

Les Arbres

Nous portons maintenant nos pensées sur les arbres. Il y a sur la Terre de nombreuses familles d'Arbres qui ont leurs propres fonctions et utilisations. Certains nous fournissent un abri et de l'ombrage, d'autres nous apportent des fruits, leur beauté et d'autres choses utiles. Beaucoup de peuples dans le monde utilisent un Arbre comme symbole de paix et de force. Unis en un seul esprit, nous saluons et remercions les Arbres.

Maintenant nos esprits ne font qu'un.

Okwireʔshôn:ʔa

Onen nôn:wa ehnôn:we nentsitewateʔnikonraiê:raʔte ne iorihwâ:ke ne okwireʔshôn:ʔa. Ohontsiakwê:kon kahwatsirakê:ron iotihniô:ton ne ne khiaʔtekakwî:rake. Ne ne tsinahoʔtên:shon ionaterihôn:te ne khiaʔtekaiên:take ôkiaʔkeʔ thonôn:we nitewaterahkwawehosthâkhwa tânonʔ ôkiaʔkeʔ ionienʔtôn:nion oni tsi ne iontenonhshatarihaʔtâhkhwa tânonʔ oni ne ionniâ:ton ne tsi ionkwataskwahrôn:nion. Iotkaʔtâtkie ronatkwirarâkwen ne onkwehshôn:ʔa ne ne ohontsiakwê:kon kahwatsirakê:ron tsi neʔe shonehiaʔrâhkhwen ne skenenʔkô:wa tânonʔ kaʔsatstênhsera. Enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tsi waʔkiethinonhwarâ:ton ne okwireʔshôn:ʔa.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Birds

We put our minds together as one and thanks all the Birds who move and fly about over our heads. The Creator gave them beautiful songs. Each day they remind us to enjoy and appreciate life. The Eagle was chosen to be their leaders. To all the Birds — from the smallest to the largest — we send our joyful greetings and thanks.

Now our minds are one.

Les Oiseaux

Nous unissons nos esprits pour n'en faire qu'un et remercions tous les Oiseaux qui se déplacent et voltigent au-dessus de nos têtes. Le Créateur les a pourvus de chants magnifiques. Chaque jour, ils nous rappellent de jouir de la vie et de l'apprécier. L'Aigle a été choisi pour être leur chef. À tous les oiseaux — du plus petit au plus gros — nous adressons nos joyeuses salutations et nos remerciements.

Maintenant nos esprits ne font qu'un.

OtsiʔtenʔokÔn:ʔa

Enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tânonʔ teniethinonhwarâ:ton ne otsiʔtenʔokôn:ʔa tsiionkwatenontsistatênion kontikienônkieʔs. Ne kati neʔe shakorennâ:wi ne akonterennô:ten ne ne skên:nen akaiên:take tsiionhontsiâ:te. Ôkiaʔke oni ne entewatekhwaiêstahkwe. Oni ne rorâkwen ne tsinikâ:ien entkonwatikowanenhâke ne ne â:kweks nihohshennô:ten. Iotshennônniaʔt tsi shê:kon iethî:kens akwê:kon ne otsiʔtenʔokôn:ʔa ne nihonnâ:sa oni ne raktikowâ:nens. Onen kati tentsiethinonhwarâ:ton ne otsiʔtenʔokôn:ʔa.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Four Winds

We are all thankful to the powers we know as the Four Winds. We hear their voices in the moving air as they refresh us and purify the air we breathe. They help to bring the change of seasons. From the four directions they come, bringing us messages and giving us strength. With one mind, we send our greetings and thanks to the Four Winds.

Now our minds are one.

Les Quatre Vents

Nous sommes tous reconnaissants aux puissances que nous connaissons sous le nom des Quatre Vents. Nous entendons leurs voix dans l'air en mouvement alors qu'ils nous rafraîchissent et purifient l'air que nous respirons. Ils participent au changement des saisons. Ils viennent des quatre directions, nous apportant des messages et nous donnant la force. Unis dans un seul esprit, nous adressons nos salutations et remerciements aux Quatre Vents.

Maintenant nos esprits ne font qu'un.

Oweraʔshôn:ʔa

Onen nôn:wa ehnôn:we nentsitewateʔnikonraiê:raʔte ne tsinî:iot tsi rokwatâ:kwen rawê:ren-enkaiên:take ne kaʔsatstenhseraʔshôn:ʔa ne ne kaiê:ri nikawerâ:ke. Ne iethiwennahrônkha ratiwerarâstha ne tsiionhontsiâ:te â:se shonnôn:ni ne tsinî:iot tsi tewatôn:rie oni tsi ne tehotitenionhâkie ne tsi niionkwakenhô:tens. Kaiê:ri niiokwên:rare tsinôn:we thatiienhthâkhwa tsi ionkhiʔsatstenhsherâ:wis. Ne tsi nentsitewâ:iere enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tânonʔ teniethinonhwarâ:ton ne ne kaiê:ri nikawerâ:ke.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Thunderers

Now we turn to the west where our Grandfathers, the Thunder Beings, live. With lightning and thundering voices, they bring with them the water that renews life. We bring our minds together as one to send greetings and thanks to our Grandfathers, the Thunderers.

Now our minds are one.

Les Créatures du tonnerre

Nous nous tournons maintenant vers l'ouest où vivent nos grands-pères, les Créatures du Tonnerre. Avec les éclairs et leurs voix tonitruantes, ils apportent avec eux l'eau qui renouvelle la vie. Nous unissons nos esprits pour n'en faire qu'un afin d'adresser nos salutations et remerciements à nos grands-pères, les Créatures du Tonnerre.

Maintenant nos esprits ne font qu'un.

Ratiwê:ras

Onen ehnôn:we ientsitewakiê:ra?te ne tsi ia?tewa?tshênthos nôn:we thatiienhthâkhwa ne ionkhisho?thokôn:?a ratiwê:ras. Tewahni?nakara?wânions nô:nen â:re tontaiaonharê:re tahatihnekenhâ:wi ne â:se enshonnôn:ni ne tsi ionhontsiâ:te. Ne tsi nentewâ:iere enska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra tânon? teniethinonhwarâ:ton ne ionkhisho?thokôn:?a ratiwê:ras.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

The Sun

We now send greetings and thanks to our eldest Brother, the sun. Each day without fail he travels the sky from east to west, bringing the light of a new day. He is the source of all the fires of life. With one mind, we send greetings and thanks to our Brother, the Sun.

Now our minds are one.

Le Soleil

Nous adressons maintenant nos salutations et remerciements à notre Frère aîné, le Soleil. Chaque jour, sans arrêt, il traverse le ciel d'est en ouest, apportant la lumière d'une nouvelle journée. Il est la source de tous les feux qui entretiennent la vie. Unis dans un seul esprit, nous envoyons nos salutations et remerciements à notre Frère, le Soleil.

Maintenant nos esprits ne font qu'un.

Kionhkehnêkha Karâhkwa

Onen nôn:wa ehnôn:we nentsitewáte?nikonraiê:ra?te ne tsikaronhiâ:te rorihwatô:ken êhtho tehaiahiâkhons ne tshionkwahtsî:?a kionhkehnêkha karâhkwa. Ne tehoswa?thê:ton tsiniaonkwenonhâkie tânon? ne ro?tariha?tonhâkie ne tsi ionhontsiâ:te ne ne skên:nen tsi akontonha?tên:ti ne tsinahô:ten shonkwaienthô:wi. Ne tsi nentsitewâ:iere enska tsi entewahwe?nôn:ni ne onkwa?nikôn:ra tânon? tentshitewanonhwarâ:ton ne tshionkwahtsî:?a kionhkehnêkha karâhkwa.

Êhtho niiohtônha?k ne onkwa?nikôn:ra.

Grandmother Moon

We put our minds together and give thanks to our oldest Grandmother, the Moon, who lights the night time sky. She is the leader of women all over the world, and she governs the movement of the ocean tides. By her changing face we measure time, and it is the Moon who watches over the arrival of children here on Earth. With one mind, we send greetings and thanks to our Grandmother, the Moon.

Now our minds are one.

Notre Grand-mère, la Lune

Nous unissons nos esprits et rendons grâce à notre Grand-mère aînée, la Lune, qui éclaire le ciel pendant la nuit. Elle est la leader des femmes dans le monde entier et elle règle le mouvement des marées. Grâce à son aspect changeant, nous mesurons le temps et c'est la Lune qui surveille l'arrivée des enfants ici sur Terre. Unis dans un seul esprit, nous adressons nos salutations et remerciements à notre Grand-mère, la Lune.

Maintenant nos esprits ne font qu'un.

Ahsonhthenhnêkha Karâhkwa

Ne tsi nentsitewâ:iere enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tânonʔ teniethinonhwarâ:ton ne ne ahsonhthenhnêhshonʔ êhnôn:we kiekonhsarâkies ne ne ionkhihsôtha karâhkwa. Ohontsiakwê:kon ne tekontatenenʔtshî:ne ne tsionaʔthonwî:sen. Oni tsinî:iot tsi watʔnekoriâ:nerens ohontsiakwê:kon akaônha ne ehnôn:we iakorihwaientâhkwen. Ahaônha iakoteʔnientensthonhâkie kaʔnikahâ:wi tsi tehotitaʔonhâkie ne ratikshaʔokôn:ʔa. Oni ne tewatenientenstâhkhwa tsinî:iot tsi teiakotenionhâkie tsi nikakotkonhsaierâ:ton neʔe onkwatenhniʔtaʔshetâhtshera. Onen kati enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tânonʔ teniethinonhwarâ:ton ne ionkhihsôtha karâhkwa.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Stars

We give thanks to the Stars who are spread across the sky like jewellery. We see them in the night, helping the Moon to light the darkness and bringing dew to the gardens and growing things. When we travel at night, they guide us home. With our minds gathered together as one, we send greetings and thanks to all the Stars.

Now our minds are one.

Les Étoiles

Nous rendons grâce aux Étoiles qui sont éparpillées dans le ciel et ressemblent à des joyaux. Nous les voyons s'illuminer dans la nuit, aidant la Lune à éclairer l'obscurité et apportant la rosée aux jardins et aux choses qui croissent. Lorsque nous voyageons la nuit, elles nous guident vers notre demeure. Nos esprits étant réunis pour n'en faire qu'un, nous adressons nos salutations et remerciements à toutes les Étoiles.

Maintenant nos esprits ne font qu'un.

Otsistanohkwaʔshôn:ʔa

Ê:neken nentsitewakiê:raʔte ne ne otsistanohkwaʔshôn:ʔa tentsiethinonhwarâ:ton. Ahsonthenhnêhshon iethî:kens shakotiienawâ:se ne ionkhihsôtha karâhkwa tehotihswathê:ton. Ona tsi neʔe ronʔaweiâstha ne ne skên:nen tsi akontonhaʔtên:ti ne tsinahô:ten shonkwaienthô:wi tânonʔ tsi ionkwaʔthehtakê:ron. Ne oni tewateʔnientensthâkhwa tsi iah thaitewakiaʔtâhton tsi niahonkwennonhâkie. Enska tsi entewahweʔnôn:ni ne onkwaʔnikôn:ra tânonʔ teniethinonhwarâ:ton ne otsistanohkwaʔshôn:ʔa.

Êhtho niiohtônhaʔk ne onkwaʔnikôn:ra.

The Enlightened Teachers

We gather our minds to greet and thanks the enlightened Teachers who have come to help throughout the ages. When we forget how to live in harmony, they remind us of the way we were instructed to live as people. With one mind, we send greetings and thanks to these caring Teachers.

Now our minds are one.

Les Sages

Nous unissons nos esprits pour saluer et remercier les Sages qui nous ont apporté leur aide à travers les âges. Lorsque nous oublions de quelle façon vivre en harmonie, ils nous rappellent comment on nous a enseigné de vivre comme peuple. Unis dans un seul esprit, nous adressons nos salutations et remerciements à ces maîtres bienveillants.

Maintenant nos esprits ne font qu'un.

Shonkwaia?tîson Raonkweta?shôn:?a

Enska tsi entewahwe?nón:ni ne onkwa?nikón:ra tânon? teniethinonhwarâ:ton ne tsi nikâ:ien ne ronateríhonte ne ahonten?nikón:raren ne tsi kahwatsirakê:ron ne tôhsa? thê:nen ne akierón̂tshera ahonataweiâ:ten. Ne tsionkhiiehiahrâhkhwa tsinî:iot tsi rawê:ren ne taiontawén:rie ne onkwehshón:?a. Entewahwe?nón:ni ne onkwa?nikón:ra tânon? teniethinonhwarâ:tor ne Shonkwaia?tîson Raonkweta?shón:?a.

Êhtho niiohtónha?k ne onkwa?nikôn:ra.

Closing Words

We have now arrived at the place where we end our words. Of all the things we have named, it was not our intention to leave anything out. If something was forgotten, we leave it to each individual to send such greetings and thanks in their own ways.

And now our minds are one.

Paroles de fermeture

Nous sommes maintenant arrivés à l'endroit où nous finissons notre message. Parmi toutes les choses auxquelles nous avons donné un nom, nous n'avions pas l'intention d'en omettre aucune. S'il y a eu un oubli, nous laissons à chacun le soin d'adresser des salutations et remerciements à leur manière.

Et maintenant nos esprits ne font qu'un.

Sakarihwahô:ton

Onen ehnón:we iahêtewawe ne ieiôhe onsaitewarihwahô:ton. Ne tsi naho?tén:shon wetewana?tónnion, iah ki teionkwanikonhrón:ni toka nahò:tenk saionkwa?nikónhrhen. Tsisewaiatâtshon ki ne onen wakwarihwaientâhkwen ne entisewatka?we kanonhwaratónhtshera.

Êhtho niiohtónha?k ne onkwa?nikôn:ra.