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Lake Reference Study, Great Lakes-St. Lawrence River Basin

International Joint Commission. Levels Reference Study Board

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LEVELS REFERENCE STUDY
GREAT LAKES-ST. LAWRENCE RIVER BASIN

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SUBMITTED TO
THE INTERNATIONAL JOINT COMMISSION
BY THE LEVELS REFERENCE STUDY BOARD
MARCH 31, 1993

LEVELS REFERENCE STUDY
Great Lakes-St. Lawrence River Basin

Submitted to the
International Joint Commission

By the
LEVELS REFERENCE STUDY BOARD
MARCH 31, 1993

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Levels Reference Study Board

International Joint Commission

March 31, 1993
Chicago, Illinois
Burlington, Ontario

International Joint Commission
Ottawa, Ontario
Washington, D.C.

Dear Commissioners:

The Levels Reference Study Board is pleased to submit its report on methods to alleviate the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River System, pursuant the Commission's Directive dated February 8, 1990 and revised April 20, 1990.

The Board recommends forty-two practical actions that governments can take in the following six key areas:

- Guiding principles for future management of water level issues.
- Measures to alleviate the adverse consequences of fluctuating Great Lakes-St. Lawrence River water levels.
- Emergency preparedness for high- or low-water level crises.
- Institutional arrangements to assist in implementing changes.
- Improvements in communications with the general public on water level issues.
- Management and operational improvements to facilitate future Great Lakes-St. Lawrence River management.

The Board would like to call the attention of the Commission to Chapter 5 which deals with emergency preparedness. There are a number of actions recommended that should be given early attention by the Commission.

The details of public involvement and details of the studies and investigations carried out by the Board are contained in six separately bound Annexes to the Final Report.

The Board wishes to acknowledge with thanks the assistance and guidance provided by the Commission and numerous other public and private agencies and individuals during the course of the Study.

Respectfully submitted,

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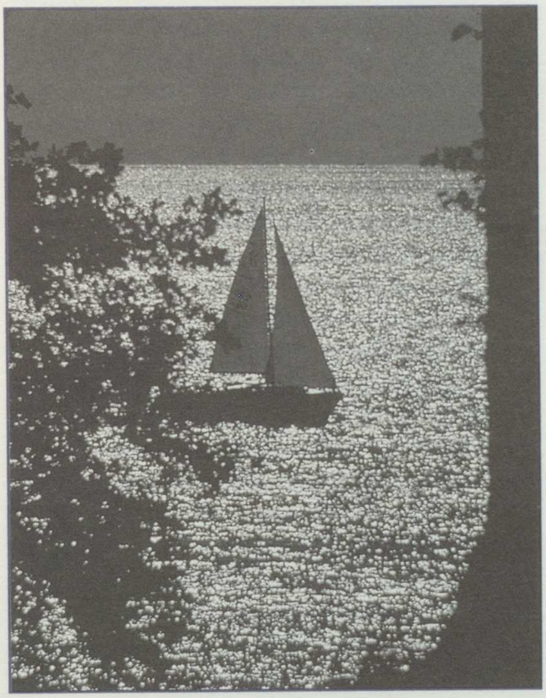
Executive Summary



In 1985 and 1986, after nearly two decades of above average precipitation and below average evaporation in the Great Lakes-St. Lawrence River Basin, all of the Great Lakes — with the exception of Lake Ontario —reached their highest levels of this century. Storm activity combined with these high levels to cause extensive flooding and erosion of lake shorelines and severe damage to lake shore properties. Millions of dollars in damage resulted. In response to widespread public concern, the governments of Canada and the United States requested the International Joint Commission to study methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River Basin.

This is the final report of the Levels Reference Study Board. It responds to the issues raised in the Reference from governments and the subsequent Directive from the Commission. This report recommends 42 practical actions that governments can take in six key areas: 1) guiding principles for future management of water level issues; 2) measures to alleviate the adverse consequences of fluctuating Great Lakes-St. Lawrence River water levels; 3) emergency preparedness planning for high or low water level crises; 4) institutional arrangements to assist in implementing changes; 5) improvements in communications with the general public on water level issues; and 6) management and operational improvements to facilitate future Great Lakes-St. Lawrence River water level management.

Central to the success of this study has been an intensive public involvement process, which included an 18-member Citizens

Advisory Committee and a full schedule of 17 public events throughout the Great Lakes-St. Lawrence River Basin during the study's final phase. Preparations leading up to this report and the recommendations contained herein have been subjected to review through public events, meetings with senior government officials in the United States and Canada, and the study's newsletter, *UPDATE/AU-COURANT*, with a mailing list that began at 1,200 and grew to more than 3,600.

Guiding Principles

Management of water level issues appears to be guided by no clear or consistent policies among the numerous agencies and government bodies responsible for various aspects of the issues. In order to ensure consistent and comprehensive recommendations the Study Board developed a set of guiding principles for the conduct of the study. These same principles which respect, not only the Great Lakes-St. Lawrence River Basin ecosystem but diverse interests of the people who use it, are recommended for adoption by all levels of government. The principles provide broad guidelines for future decisions and enhance coordinated, system-wide management. They improve the opportunity for wise use and management of the finite water resources of the Great Lakes-St. Lawrence River Basin.

Measures

A large portion of this study's effort was directed toward developing practical measures that Governments could take to alleviate the problems associated with fluctuating water levels. Three possible approaches could be used: preventive, remedial, or combinations of preventive and remedial.

The study found that no one measure will be the answer to all water level-related problems; nor can measures be applied in specific instances without regard for measures taken in other areas, or without regard to the varied interests affected. This study has also concluded that, regardless of lake level regulation, flooding and erosion caused by wind, wave and storm action will continue to occur along the shorelines of the Great Lakes and St. Lawrence River.

Lake Level Regulation Measures

The Study Board concluded that, although it would be engineeringly feasible to regulate all five of the Great lakes, the costs of such an undertaking would exceed the benefits produced, and it would have adverse environmental impacts. A number of possible plans for regulating three of the Great Lakes (Superior, Erie and Ontario) were examined. One of these plans was strongly supported by shoreline property owners of the middle lakes. Through dredging and installation of a structure in the Niagara River, this plan would have provided benefits to shoreline property owners on Lakes Michigan-Huron and Erie by reducing the range and frequency of water level fluctuations. Water level and flow ranges on Lakes Superior and Ontario and in the St. Lawrence River would increase. Mitigation works in the St. Lawrence River would be required. This plan would adversely affect the wetlands of the middle three lakes by reducing the range of water level fluctuations.

This plan had the highest economic efficiency of any of the three-lake plans considered. While debate continues with shoreline property owners of the middle lakes as to the calculation of this plan's benefits and costs, the study determined that this plan could achieve a benefit-cost ratio of 0.08; much less than the ratio of 1.0 that is required if a project's benefits are to equal its costs. Because of strong representations from shoreline property owners, the study also considered the maximum plausible benefits that could result from this plan. Even these benefits produced a benefit-cost ratio of only 0.15.

Approximately $322 million annually would be needed to dredge, construct, operate and maintain the control works on the Niagara River, together with the mitigation works in the St. Lawrence River that would be needed for this plan to be implemented. Further costs of approximately $3.3 million annually to the United States commercial shipping industry, and $14.7 million annually to hydropower production would be incurred. The Board concluded that, although the plan is engineeringly feasible and would reduce flooding and erosion damage on the middle three lakes, the potential economic and environmental costs were too high to justify the project.

This study finds that preparation and implementation of an emergency operations plan before the next water level crisis is essential. However, manipulation of the Long Lac-Ogoki and Chicago Diversions, are controversial and would have impacts outside the Basin. In addition, the potential side effects of hydraulic measures would have to be considered. Preparation of such a plan would require cooperation by the two federal governments, the provincial, state and local governments, in consultation with other affected parties.

Institutional Arrangements

A multitude of individuals, groups and agencies, both within and outside the basin, benefit from the Great Lakes and St. Lawrence River. This study reviewed the range of jurisdictions involved in activities related to water levels and flows and examined the ways in which they currently fulfill their responsibilities. These investigations led to proposals for changes to institutional structures that could improve coordination and effectiveness of the decision-making process.

The Board recommends that a Great Lakes-St. Lawrence River System Advisory Board be established with membership from the existing Boards of Control, the states and provinces, and interest groups. This board should provide advice to the Commission on Great Lakes-St. Lawrence River water level issues, including lake level regulation and land use and shoreline management activities. It should also review and monitor the activities of a recommended water level communications clearinghouse.

The Study Board further recommends expansion of the Lake Superior and St. Lawrence River Boards of Control to allow additional citizen membership, as well as addition of state and provincial membership to the Lake Superior Board. The Study Board also recommends that the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data be formalized under the auspices of the Commission.

Communications Programs

Regardless of the measures implemented as a result of this study, the foundation for their success will be laid only through effective two-way communication between Governments and the users of the Great Lakes-St. Lawrence River System. This study considered several options for establishing a communications clearinghouse that would act as the central coordinating point for all government information efforts regarding Great Lakes-St. Lawrence River water levels.

The Board recommends that a Great Lakes water level communications clearinghouse be established as a bi-national effort by the United States and Canadian Governments. The clearinghouse should be established as part of major federal agencies such as Environment Canada and the United States Army Corps of Engineers and have linkage with larger organizational units that can provide staff support in water level crisis periods. The clearinghouse should have direct access to governments' corporate memories with regard to Great Lakes-St. Lawrence River water level issues, and direct access to current expert knowledge.

Management and Operational Improvements

The development and distribution of information on management of the Great Lakes-St. Lawrence River System and on reducing the risks of exposure to high or low water levels needs to be continually reviewed. While this study has succeeded in making a comprehensive examination of the engineering, economic, environmental and social issues implicit in Great Lakes-St. Lawrence River management, it has also identified areas in which data gathering efforts, information storage, interpretation and communication could be improved.

The Board recommends a number of actions to update hydrologic and hydraulic models, improve data collection, improve forecasting and statistical methodologies and improve communication of water level and flow information.

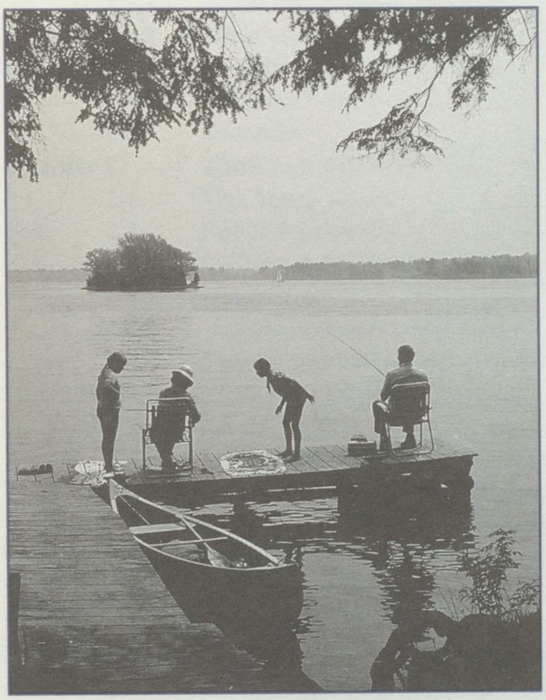
Summary

This report represents the culmination of six years of intense effort by government and non-government agencies, interest groups, private citizens, academics and consulting professionals. The result is a distillation of the best available knowledge about many aspects of the Great Lakes-St. Lawrence River Basin, and a set of recommendations that reflects the collective wisdom of the study team and the interested public. The recommendations not only outline practical actions for the near- and long-term, they show Governments how to ensure continued success in their application by improving the mechanisms for implementation.

The Study Board recommends several emergency preparedness actions that should be taken as soon as possible. These include increasing the flow capacity of the Black Rock Lock in the Niagara River, installation of an ice boom at the head of the St. Clair River, and examination of the potential effects of changing the flows through the four major Great Lakes-St. Lawrence River diversions during high or low water level crises. The Board further recommends that comprehensive emergency preparedness planning by all levels of government begin immediately.

In addition, the Board recommends comprehensive and coordinated land use and shoreline management measures, as well as improvements to operational capabilities, that should be undertaken over the long term. Further recommendations for changes to institutional structures and public communications practices are also put forward as means to achieve long-term improvements in the way Governments, together with citizens and interest groups, address water level issues in the Great Lakes-St. Lawrence River Basin.

Acknowledgment



This report is the product of the dedicated efforts of more than 140 individuals from citizens groups, interest groups, federal, provincial, state and local government agencies and universities. The Study Board recognizes the perseverance and commitment of each of these participants that helped produce a final report on time and within budget. The Board extends special thanks to the Citizens Advisory Committee members who gave considerable amounts of their own time over the past three years to attend meetings and review documents. Their contribution to the Study has been invaluable, both in terms of the expertise and personal experience each committee member brought to the work, and in terms of setting the tone for citizen involvement in future Great Lakes-St. Lawrence River resource issues. The Board would also like to thank the hundreds of other individuals throughout the Great Lakes-St. Lawrence River Basin who took the time to learn about and comment upon the Study through the newsletter, *UPDATE/AU COURANT,* through documents distributed for review, and through public meetings. Finally, the work of the Study was made easier with the cooperation of many state, provincial and local agencies who were not direct participants in the Study, but who assisted in many ways with research and public outreach efforts.

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Annex 6. Crisis Condition Responses - Final Report.

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Guiding Principles

1. The Board recommends that federal, state and provincial governments adopt the eleven Guiding Principles and that these principles be used as guidelines for the management of issues related to water levels and flows within the Great Lakes-St. Lawrence River System 27

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2. The Board recommends that Governments give no further consideration to five-lake regulation.......... 39
3. The Board recommends that Governments give no further consideration to three-lake regulation.......... 46
4. The Board recommends that the regulation plans of Lakes Superior and Ontario be modified to achieve water levels and flows similar to those described in Measure 1.21. 52
5. The Board recommends that the Orders of Approval for the Regulation of Lake Superior be reviewed to determine if the current criteria are consistent with the current uses and needs of the users and interests of the System.......... 52
6. The Board recommends that the International Lake Superior Board of Control be authorized to use its discretion in regulating the outflows from Lake Superior subject to conditions similar to those which authorize discretionary action by the International St. Lawrence River Board of Control.......... 52
7. The Board recommends that the criteria of 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 particular, the Board recommends that Criterion (d) of these orders be amended as follows:.......... 52

   Criterion (d): The regulated outflow from Lake Ontario during the annual flood discharge from the Ottawa River shall not be greater than would have occurred assuming supplies from the past as adjusted. *When Lake Ontario levels and supply allow, consideration should be given to reducing outflows from Lake Ontario during the annual flood discharge from the Ottawa River.*
8. The Board recommends that the Orders of Approval for the Regulation of Lake Ontario be modified by adding the following criterion:.......... 52

   Criterion ( ): Consistent with other requirements, the outflows of Lake Ontario shall be regulated to minimize the occurrence of low water levels on Lake Ontario and the St. Lawrence River downstream as far as Trois Rivières during the recreational boating season.

   Criteria should be added that consider the environmental interest on Lake Ontario and the St. Lawrence River downstream as far as Trois Rivières.
9. The Board recommends initiating negotiations for the purpose of removing fills upstream of the International Railway Bridge on the Niagara River and lowering the mean level of Lake Erie by 0.03 to 0.06 metre (0.1 to 0.2 foot).......... 53
10. The Board further recommends that Nicholl's Marine be the first priority for fill removal 53

Measures - Land Use

11. The Board recommends that any comprehensive approach to managing adverse impacts of fluctuating water levels be multi-objective in focus and coordinated in application. 55

12. The Board recommends that consideration be given to establishing multi-level government funding of $10 to $20 million per year for planning and implementing land use and shoreline management projects. A possible funding cost-sharing formula might be 1/3 federal, 1/3 provincial/state, and 1/3 local 55
13. The Board recommends that areas requiring land use and shoreline management measures be prioritized through a comprehensive shoreline management program in developed and undeveloped areas. 55
14. The Board recommends that consideration be given to implementing remedial measures when appropriate to the local conditions. The following measures are recommended for implementation, as appropriate: 58
    - Relocation of structures from hazard areas.
    - Flood proofing of existing structures.
    - Non-structural shore protection.
    - Structural shore protection, where other alternatives are not appropriate, only if well-designed and engineered, and only if impacts are not shifted to adjacent areas.
15. The Board recommends that the following preventive land use and shoreline management measures be implemented and applied consistently and uniformly around the Great Lakes and St. Lawrence River: 61
    - Erosion setbacks that include minimum requirements for a 30 year erosion zone for movable structures and a 60 to 100 year erosion zone for permanent structures plus an adequate distance to assure a stable slope. A provision for variance should be included for areas where the slope has been, or is proposed to be, stabilized by a well-engineered structure.
    - Flood setbacks and elevation requirements that include minimum requirements for a 1% flood risk line plus allowance for wave uprush and freeboard.
    - Shoreline alteration requirements established in the context of a comprehensive plan. The environmental, updrift and downdrift impacts of shoreline alterations must be considered, along with hydraulic impacts on the connecting channels.
    - Regulations in Canada to control fills and other obstructions in connecting channels. The most effective means of achieving this would be through amendment of the International Rivers Improvement Act.
    - Real estate disclosure requirements where the seller should be required to disclose to prospective buyers that the property is within a mapped or known flood or erosion hazard area. The buyer should sign an acknowledgment that he or she has been informed of the risk.
16. The Board recommends that acquisition of undeveloped and developed land and habitat protection areas be considered in areas where it is appropriate. 63
17. The Board recommends that where hazard insurance exists or is implemented in the future that the following elements be included. 63
    - A hazard insurance program should use historic shoreline change methods coupled with recession rate studies to identify and map long-term erosion hazards on flood insurance rate maps.
    - A hazard insurance program should encourage community-based erosion management by establishing setbacks for new construction.
    - The program should deny subsidized flood insurance for new or substantially improved construction within the erosion hazard zone and should require that any structure substantially damaged during a storm be reconstructed landward of the hazard zone. The program should also deny subsidized insurance for recurring claims.
    - A hazard insurance program should provide eligibility for mitigation assistance when the aggregate of damage claims exceed 50% of the fair market value of the insured property and provide mitigation assistance for structures imminently threatened by erosion with an emphasis on relocation of structures out of the hazard area, not demolition.

Emergency Preparedness

18. The Board recommends that the two federal governments, in cooperation with provincial and state governments, begin preparation of a joint and cooperative Emergency Operations Plan for the Great Lakes-St. Lawrence River as soon as possible. 74
19. The Board recommends as a priority that investigations continue into methods of alleviating high or low water crises on the lower St. Lawrence River and that investigations continue into avoiding increased damage as a result of crisis actions taken upstream. 74
20. The Board further recommends that the following be implemented in the near future: 74
- The authority necessary for deviation from the Lake Superior Regulation Plan during an emergency, similar to the authority to deviate that exists for Lake Ontario.
- The installation of an ice boom at the head of the St. Clair River to reduce the risk of ice jams and flooding.
- An increase in the flow capacity of the Black Rock Lock, so the flow through the lock may be increased in emergency situations by an additional 340 cms (12,000 cfs).
- The manipulation of the four major Great Lakes diversions; Long Lac, Ogoki, Lake Michigan at Chicago, and the Welland Canal during crisis situations when conditions permit.

21. The Board recommends that, prior to implementing the manipulations of diversions, the potential impacts within and outside the Great Lakes-St. Lawrence River System of changes to the Long Lac, Ogoki and Lake Michigan at Chicago diversions be determined. 74
22. The Board recommends that post-crises action reports be done to evaluate the effectiveness of emergency preparedness plans and to recommend areas for improvement. 74
23. The Board recommends that comprehensive emergency preparedness planning be undertaken immediately at the provincial, state and local government levels. The preparations should include public information programs, stockpiling emergency materials, active monitoring of water levels and flows, and identifing areas where community-based shore protection can be implemented immediately. 74

Institutions

24. The Board recommends that the membership of the Lake Superior Board of Control be expanded to include representation from citizens, states and provinces. 82
25. The Board recommends that the membership of the International St. Lawrence River Board of Control be expanded to include citizen representation from Lake Ontario, the upper St. Lawrence River and the lower St. Lawrence River. 82
26. The Board recommends that the functions of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data be formalized and that the Committee report to the Commission. 82
27. The Board recommends that a Great Lakes-St. Lawrence River Advisory Board be created to coordinate, review, and provide assistance to the Commission on issues relating to the water levels and flows of the Great Lakes and St. Lawrence River. 82

Communications

28. The Board recommends that a Great Lakes-St. Lawrence Water Level Communications Clearinghouse be established as a bi-national effort by the United States and Canadian

Governments, with the responsibility to communicate with the public, to facilitate communication between the public and governments, and to facilitate coordination of agency communication activities related to the water levels and flows of the Great Lakes and St. Lawrence River. 84

29. The Board recommends that the Clearinghouse be established under major federal agencies such as Environment Canada and the United States Army Corps of Engineers, which already have significant responsibilities in this area, and that it be linked to larger units within these agencies to act as information resources and provide staff support in water level crisis periods 85
30. The Board recommends that the Clearinghouse establish and coordinate a network of agencies and groups that communicate about water level issues 85

Management and Operational Improvements

31. The Board recommends that action be taken to improve the information base used to manage the Great Lakes-St. Lawrence River resource in the following ways: 91
    - That the identified deficiencies in the precipitation and snowpack network be remedied.
    - That a risk analysis model be developed that takes into account uncertainties of water supply to Lake Ontario, storm surge on Lake Ontario, variations of tributary inflows to the St. Lawrence River downstream of Cornwall and updated stage-damage data in the Lake Ontario-St. Lawrence River system to assist in equitably managing outflows during high- and low-water supply periods. If discretionary authority is provided to the Lake Superior Board of Control, as recommended elsewhere in this report, this model should be implemented for Lake Superior, as well.
    - That efforts be made to improve long-range precipitation and temperature forecasts.
    - That new technologies such as satellite, airborne and ground-based radar be developed for use in the monitoring of lake evaporation, overlake precipitation and basin-wide snow conditions.
    - That work continue on upgrading models used for simulation, forecasting and regulation to formulate a comprehensive water supply and routing model that includes the whole basin through Trois Rivières, Québec.
    - That efforts to improve forecasting and statistical information be continued, so that all users throughout the system can make better decisions and that this be coupled with an upgraded system-wide supply and routing model.
    - That the suggestions referenced in Chapter 8 to improve communication be implemented.
32. The Board recommends that efforts be initiated to standardize hazard mapping methodologies across the Great Lakes-St. Lawrence River region and that efforts continue to identify and map all flood and erosion hazard areas in the system 92
33. The Board further recommends that procedures be developed for allowing broad access to such maps for general use. 92
34. The Board recommends that long-term monitoring of shoreline erosion and bluff recession be undertaken and that future erosion damage assessments consider, or be based on, information and methodologies developed under this study to improve these approaches. 93
35. The Board recommends that the United States and Canadian land use mapping systems be updated on a periodic basis and that they be designed and developed cooperatively to promote uniformity. 93
36. The Board recommends that a potential damage sample survey be undertaken in the future to improve flood damage estimates 94
37. The Board further recommends that the first priority for the potential damage sample survey be Lake Ontario and the St. Lawrence River. 94

38. The Board recommends that a comprehensive wetlands inventory be completed and that long-term assessments of the effects on wetlands of variations in levels and flows be continued. ... 94
39. The Board recommends that refinement of Global Climate Models be continued to improve their predictive capability and use as a planning tool. ... 95
40. The Board further recommends that efforts continue to develop a bi-national assessment of the potential impacts of climate change on the Great Lakes-St. Lawrence River Basin System and to coordinate a response to the expected climate changes. ... 95
41. The Board recommends that the following data elements be incorporated into Geographic Information System databases: ... 96
• All land use information for the entire shoreline.
• All hazard areas along the Great Lakes-St. Lawrence River.
• All coastal wetlands.
42. The Board further recommends that cooperative bi-national coordination and planning of Geographic Information System development and use be considered to increase the usability of the information stored in Geographic Information Systems relating to the Great Lakes St. Lawrence River System, and that national and international standards for data transfer be established. ... 96

began at the turn of the century. Lake Superior's levels peaked at approximately 0.3 meter (one foot) above the long-term average, while Lakes Michigan, Huron and Erie rose as high as one meter (three feet) above their averages. Storm activity combined with these high levels to cause extensive flooding, erosion of lake shorelines, and severe damage to lake shore properties. Millions of dollars in damage resulted.

This marked the sixth occurrence this century of water level extremes. The first period of extremely high water levels was in 1929. This was followed by extreme lows in the dry years of the early 1930's. By 1952, lake levels had reached highs that matched those of 1929, but by the early 1960's they had dropped again to record lows. In 1973, lake levels had again reached highs equal to those of 1929 and 1952. The highs of the 1980's set new records for the century.

In response to the heavy damage and widespread public concern, the Governments of Canada and the United States requested on August 1, 1986 that the International Joint Commission examine methods that could alleviate the problems associated with fluctuating water levels. The word "fluctuating" recognized that both high and low water levels can result in problems for some Great Lakes-St. Lawrence River System users. The subsequent drop in water levels from their 1986 record highs to near average levels by 1987 illustrated the changeable nature of the system as a result of changing weather patterns and variations in climate.

The Reference from governments to "examine and report on measures to alleviate the adverse consequences of fluctuating water levels" was a broad one. The Commission identified five major areas of inquiry in its Directive for the final phase of the study.

1. Propose a plan for responding to high and low water crises;
2. Examine land use management practices along Great Lakes-St. Lawrence River shorelines;
3. Determine socio-economic costs and benefits of land use and management practices, and compare these with revised costs and benefits of lake regulation schemes;
4. Investigate ways to improve the outflow capacities of the connecting channels and St. Lawrence River; and,
5. Develop an information program on water levels for governments.

A detailed account of the study's response to the components of the Directive is contained in Appendix C.

1.2. INITIAL REPORT TO GOVERNMENTS

Environment Canada and the United States Army Corps of Engineers were assigned lead federal roles in the water levels study. Approximately $6 million (US) was spent during the final phase of the study through the Commission and the two federal agencies. In addition to this funding, provincial and state governments, citizens, and other federal agencies have contributed staff time and resources.

The Commission's initial report[7] to governments in late 1986 listed actions it had already taken in response to the high water levels. These actions included ordering retention of emergency water storage on Lake Superior that began in 1985, ordering increased discharges from Lake Ontario and alerting responsible agencies to possible flood and erosion hazards for shoreline dredge and waste disposal sites.

The report also proposed additional technically feasible actions governments could take immediately to help lower water levels, which included shutting down the Ogoki and Long Lac diversions into Lake Superior, increasing flows through the Lake Michigan Diversion at Chicago, increasing flows through the Welland Canal, and timely closure of the navigation season to allow maximized outflows through the St. Lawrence River.

[7]International Joint Commission, Letters to Governments, (November 14 and December 10, 1986).

1.3. INTERIM REPORT ON EMERGENCY RESPONSES

Subsequently, a Commission task force examined measures that could be implemented within a year to reduce high water levels. A report[8] containing this group's findings and the Commission's recommendations was submitted to governments in October 1988. While the report concluded that a combination of relatively low capital cost measures using existing facilities, such as existing diversions and regulation structures, could be implemented within a one-year time frame to respond to future high water level crises, it also found that implementation of an emergency high or low water management plan would require agreements between the governments of both countries, and coordination among the entities with responsibility for operating these facilities.

One of the Commission's recommendations was that governments immediately begin discussing their uses of Great Lakes water with a view to achieving agreement upon issues that bear upon resolution of water level problems. For example, the Commission noted that governments of both countries may have differing policies regarding the use of Great Lakes-St. Lawrence River water, that divisions of authority and cost sharing with regard to management of the resource differ between the United States and Canada, and that distribution of benefits and disbenefits of possible measures could be viewed differently by each of the parties involved; the various interest groups, federal, provincial, state and local governments.

The 1988 report recommended coordinated emergency management plans for both high and low water conditions, actions to discourage construction in hazard areas, actions to discourage land filling that could reduce flows in connecting channels, together with continued dissemination of information about high water levels and how to avoid damage.

1.4. THE 1989 PROGRESS REPORT

The first part of the reference study culminated in a progress report[9] that identified some of the major issues that would need to be addressed in order to adequately respond to the Reference from governments. Among other things, the progress report emphasized the need for a broad planning approach to managing water level issues over the long term, which it said should have the following components:

- Development of bi-national agreement on principles that would provide broad guidelines for future decisions on water levels issues;
- Development of an overall strategy for deploying measures[10] that would encompass the needs of the entire basin as well as the circumstances of specific locales; and
- Development of a framework for an effective governance system, including considerations for the role of interests and the public.

A portion of the work summarized in this final report has been directed toward addressing these points. The remainder of the work has concentrated on scientific studies and other research into developing practical measures to deal with fluctuating water levels and their associated problems.

1.5. TOWARDS A PRACTICAL RESPONSE

This final report responds to the issues raised in the Directive[11] from the Commission, the Reference from governments, and in the progress report, by identifying practical actions that governments in Canada and the United

[8] International Joint Commission, *Interim Report on 1985-86 High Water Levels in the Great Lakes-St. Lawrence River Basin,* (October 1988).

[9] Project Management Team, *Living with the Lakes: Challenges and Opportunities,* (July 1989).

[10] For the purposes of this study, a measure is any action that could be taken to alleviate the adverse consequences of fluctuating Great Lakes-St. Lawrence River water levels.

[11] A request from the Governments of Canada and the United States to the International Joint Commission for a study similar to this one is called a "Reference". The Reference will typically contain specific instructions for areas of investigation. The Commission, in responding to this Reference, prepared instructions for the Board that it appointed to study issues raised in the Reference. These instructions are called a "Directive". Consequently, this report responds, not only to the Reference from Governments, but to the Directive from the International Joint Commission.

States can take to alleviate problems associated with fluctuating water levels. These problems have persisted through numerous high and low water periods and have become increasingly diverse as the basin has continued to develop.

This report presents recommendations based upon six key areas of investigation:

1. Guiding principles for management of water levels and flows issues;
2. Measures that could alleviate the adverse effects of fluctuating Great Lakes-St. Lawrence River water levels;
3. Emergency Preparedness Planning to deal with high and low water level crises conditions;
4. Changes to institutions relating to water levels issues;
5. A communications program that Governments can use to improve public awareness of the impacts of, and responses to, changing water levels; and,
6. Management and operational improvements.

1.6. A COMPREHENSIVE STUDY

The changing water levels of the Great Lakes and St. Lawrence River System have been studied often. This is the fourth study by the International Joint Commission since 1964 and it is one of more than 30 that have examined regulation of water levels and flows since monitoring of Great Lakes levels began at the turn of the century.[12]

While previous studies have concentrated principally upon measures to regulate water levels and flows, this study has endeavored to be more comprehensive by examining a full range of potential solutions to water level problems. These include land-based measures, such as modifications to the way the lakes and their shorelines are used, lake regulation measures that would modify the regime of lake level fluctuations, and potential changes in government policies and institutions that deal with water level issues. In addition, a significant effort has been directed to providing human and environmental, as well as economic and engineering, perspectives on possible solutions and to placing them in a system-wide context.

The final phase of the study has involved the general public of the Great Lakes-St. Lawrence River Basin to an extent unprecedented in earlier Reference studies. The Board and working committees have traveled the length and breadth of the basin to meet people in their own communities and to see and hear about their experiences. Working committees included citizens from many walks of life, as well as professionals from government and other institutions. An 18-member Citizens Advisory Committee[13] composed of individuals from diverse backgrounds has participated fully in the final phase of the study, from planning of and completion of the work to preparing the recommendations presented in this report.

1.6.1. Bringing the Interests Together

Users of the water resource are as diverse as the system is vast, but they all have one thing in common: major changes in lake levels can have major impacts on them. Extremely high lake levels can cause shoreline property damage, flood municipal infrastructure and docks, and cause hazardous currents in shipping channels. Extremely low levels can expose navigation hazards, hinder municipal water intakes and power production, and render docks inaccessible. Meanwhile, wetlands depend upon periodic highs and lows to sustain a healthy diversity of plant and animal species. This study has attempted to bring all of the affected interests together in a collective search for solutions to individual problems.

Ten interest groups and categories were identified as being directly affected by changes in

[12]Reports by the International Joint Commission dealing with this subject since 1964 include:
- *Great Lakes Diversions and Consumptive Uses,* International Joint Commission, (1985)
- *Lake Erie Water Level Study,* International Lake Erie Regulation Study Board, (1981).
- *Regulation of Great Lakes Water Levels: Report to the International Joint Commission,* International Great Lakes Levels Board, (1973).

[13]See Annex 5 for details of the activities of the Citizens Advisory Committee, and for the Committee's recommendations to the Study Board.

Great Lakes-St. Lawrence River water levels, and the Citizens Advisory Committee was designed to roughly reflect these groups. Effort was also made to include as wide a range of interest representation as possible on the committees conducting the work of the study. The interests are listed here in alphabetical order:

- Agriculture
- Commercial Fisheries
- Commercial Navigation
- Fish, Wildlife and Other Environmental Considerations
- Hydropower
- Industrial and Commercial Facilities
- Municipal Infrastructure (such as water intakes and sewage outfalls)
- Native North Americans
- Recreation and Tourism (including Recreational Boating)
- Residential Shore Property (Riparian)

These participants, even while coming together to solve common problems, recognize that no single proposed measure to alleviate water level problems can fully satisfy them all. However, an underlying principle of this study is that no measure will be recommended that causes new or additional undue hardship for any particular interest. Additionally, implementation of the study's recommendations should be to the overall benefit of the people and resources of the Great Lakes-St. Lawrence River Basin.

1.7. THE GREAT LAKES

The rich agricultural lands, plentiful water supply and extensive navigation routes that first attracted people to the Great Lakes-St. Lawrence River region eventually led to its establishment as the industrial heartland of the North American continent. More than 35 million people live in the Great Lakes-St. Lawrence River Basin. Major cities have been established on the shorelines with thriving ports and industries; huge amounts of electricity are generated from the water that flows through the system; millions of tons of cargo are shipped annually; a variety of agricultural uses has continued; a number of Native North American communities dot the shorelines, and recreationists flock to the lakes to boat, swim, fish or simply enjoy the scenery and abundance of plant and animal life. Still others have chosen to make the lake shores their homes for at least part of the year on more than 100,000 privately owned residential properties[14] lining the United States and Canadian shorelines.

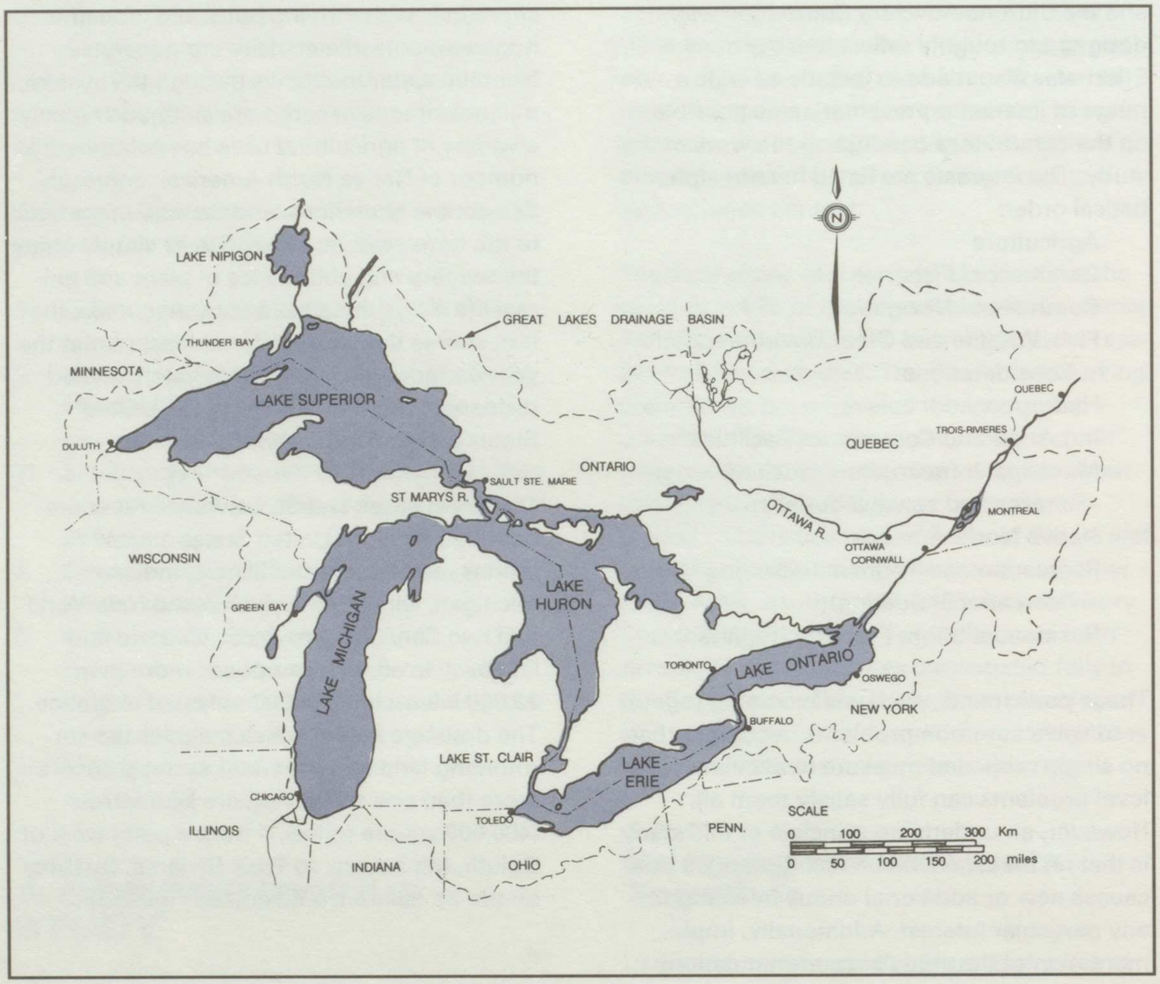
The Great Lakes and St. Lawrence River are bounded by eight United States states (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York) and two Canadian provinces (Ontario and Québec). In all, this comprises more than 23,000 kilometres (14,000 miles) of shoreline. The drainage basin (which includes the surrounding land and the water surface) covers more than one million square kilometres (400,000 square miles),[15] from a point west of Duluth, Minnesota, to Trois Rivières, Québec, on the St. Lawrence River (see Figure 1).

1.7.1. The Natural System

The Great Lakes were formed 10,000 years ago at the end of the last ice age. With the final retreat of the last ice cap, deposits of debris and altered preglacial valleys formed the basins of what are now the Great Lakes. As the glacier receded, melt water pooled in these basins, and the lakes, somewhat different in shape and size than they appear today, were formed. As the ice mass shrank, the earth's surface began to rebound from the weight. This gradual and uneven process, referred to as crustal movement or isostatic

[14]From census data gathered for the U.S. and Canadian Riparian Surveys. See Annex 2.
[15]This figure includes both the land drainage area (approximately 865,000 square kilometres - 334,000 square miles), and the water surface area (approximately 246,000 square kilometres - 95,000 square miles).

Figure 1. Great Lakes-St. Lawrence River Basin.



rebound, continues to slowly change the surface of the basin and affect the measurement of water levels.[16]

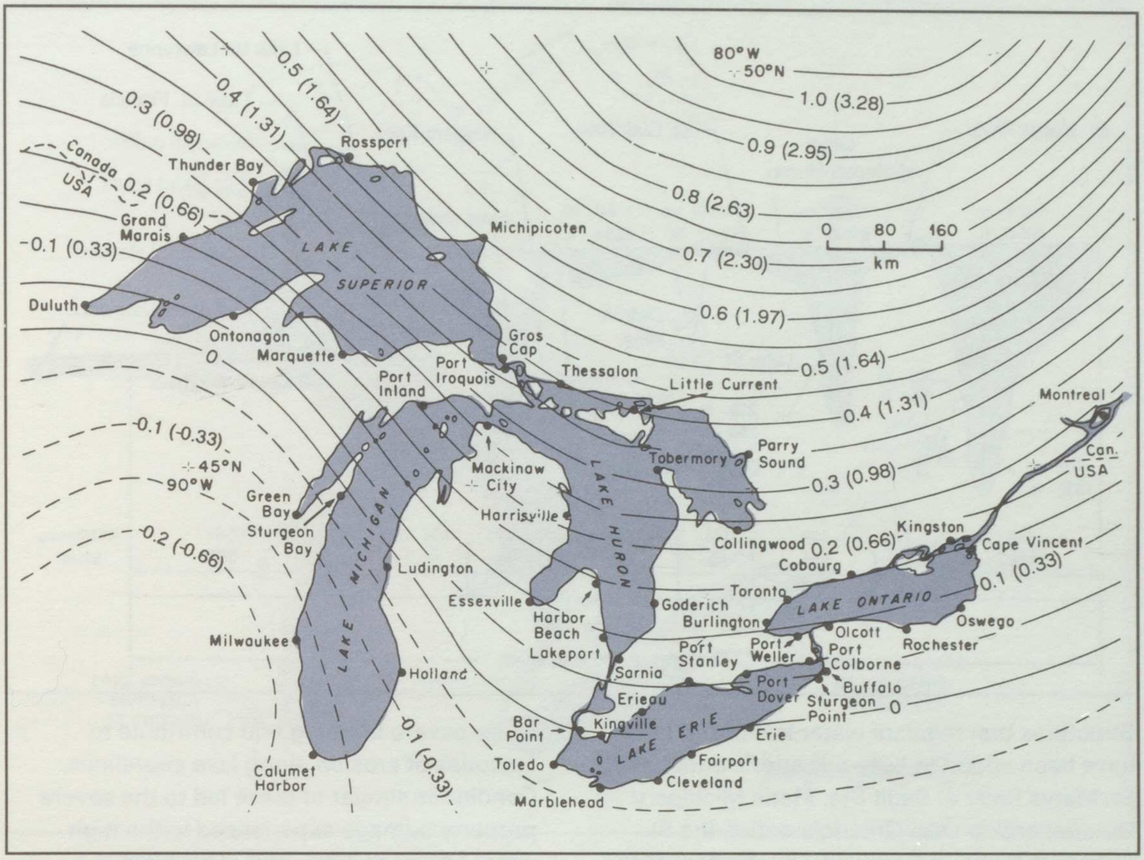
An example of the effects of crustal movement is the rising of Michipicoten, Ontario, relative to Duluth, Minnesota, at a rate of approximately 0.521 metres (1.71 feet) per 100 years.[17] On Lake Superior, this gradual tilt has meant that while water levels appear to be receding on the north shore, they appear to be rising on the south shore. Figure 2 illustrates the way isostatic rebound affects the Great Lakes-St. Lawrence River Basin. The bands across the map show the amounts by which the earth's crust is rising at specific latitudes. The figures give the estimated rate of uplift in metres and feet per century.

The Great Lakes and St. Lawrence River are referred to as a "system" because they are interconnected, and because a major change in the water level or flow in one part of the system can affect levels or flows both

[16]Isostatic rebound of the Great Lakes-St. Lawrence River Basin has necessitated the continued updating of the system by which water levels are measured. The International Great Lakes Datum (IGLD) was changed in 1992 to reflect movements that have taken place in the earth's surface since this system of measurement was introduced. This system consists of benchmarks at various locations on the lakes and St. Lawrence River, which are referenced to a point near the mouth of the St. Lawrence River that roughly coincides with sea level. All water levels are measured in metres or feet above this reference point. The first IGLD was based upon measurements and benchmarks that centered on the year 1955, and it was called IGLD (1955). Calculations for the new datum are centered on 1985; hence, its new name, IGLD (1985). Although the new measurements have not changed the quantity of water in the lakes and St. Lawrence River, the updated benchmarks have been assigned higher elevations, which means that water level measurements are also given in higher units than under IGLD (1955). More detailed information about IGLD (1985) is contained in a brochure entitled IGLD 1985: *Brochure on the International Great Lakes Datum* (January 1992), published by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. Since this study began before institution of the new IGLD, all calculations have been carried out in IGLD (1955). In cases where such calculations will require practical application in recommended actions, measurements will be converted to IGLD (1985) using a simple conversion formula.

[17]Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, *Apparent Vertical Movement over the Great Lakes* (July, 1977).

Figure 2.[18] Rate of Isostatic Rebound in metres and (feet) per century.



upstream and downstream. The only exception to this is Lake Ontario, which is affected by upstream water supplies even though its level does not affect the system upstream, due to the steep drop at Niagara Falls.

Lake Superior is at the upper end of this system. This lake, which contains the largest volume of water (equal to more than all of the other lakes combined), drains through the St. Marys River into Lakes Michigan and Huron. Because these two lakes are connected by the wide and deep Straits of Mackinac, they respond to precipitation and changes in levels and flows as if they were one lake. Lakes Michigan-Huron drain through the St. Clair River, Lake St. Clair (which is not one of the five Great Lakes but is still part of the system), and the Detroit River into Lake Erie. The shallowest of all the Great Lakes, Lake Erie, drains through the Niagara River (and Welland Canal) over Niagara Falls and into Lake Ontario. The last and lowest lake in the system, Lake Ontario, empties through the St. Lawrence River to the Gulf of St. Lawrence and into the Atlantic Ocean.

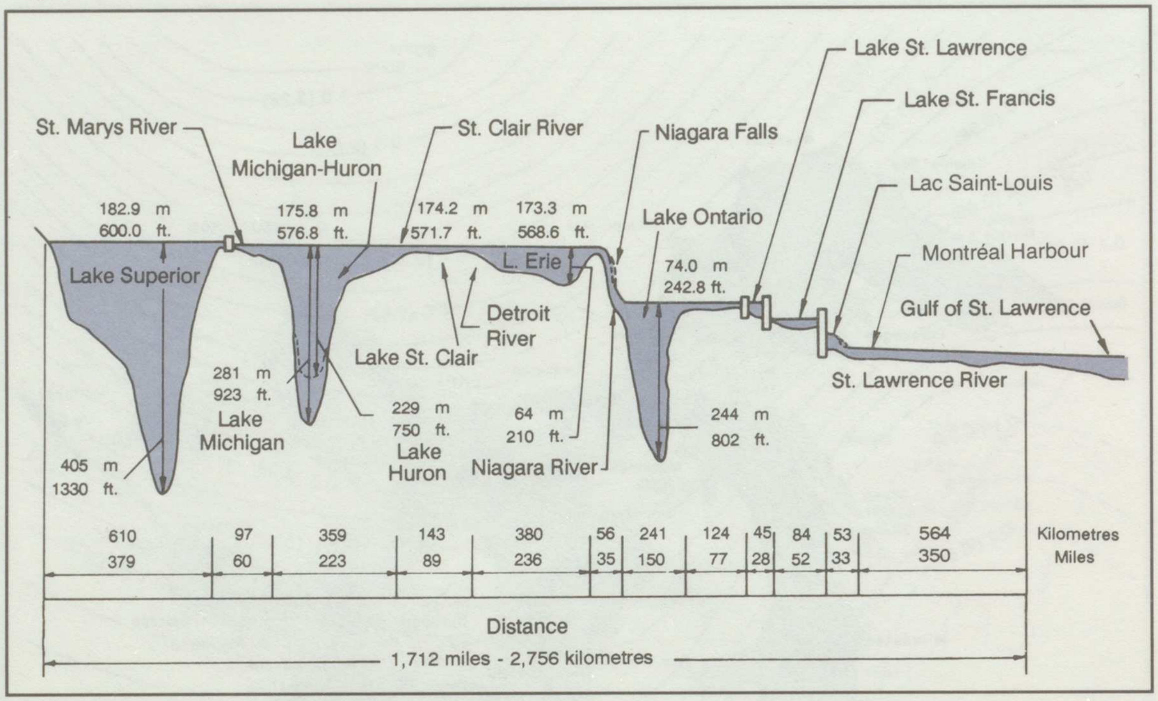
Figure 3 shows a profile of the Great Lakes and St. Lawrence River. Elevations are given in metres and feet referenced to International Great Lakes Datum (1955). These are the elevations of chart (low water) datum, the reference level used for navigation. The mean levels of the lakes are usually higher than these figures. This profile is for illustration purposes only, and its dimensions are not to scale.

With the exception of the Lake Michigan Diversion at Chicago and the Welland Canal between Lakes Erie and Ontario, the only outlets for the lakes are their narrow connecting channels.[19] These small and relatively shallow channels, together with the large storage capacity of the lakes, mean that major changes in lake levels have limited effects on the flows in the outlet channels.

[18]Used with permission and adapted from: Tushingham, A.M., *Postglacial Uplift Predictions and Historical Water Levels of the Great Lakes*, International Journal of Great Lakes Research, Vol. 18, No. 3 (1992).

[19]Other, smaller diversions such as the New York State Barge Canal at Tonawanda, New York, remove water from one part of the system and return it to another. The location of the diversion and the small quantity of water diverted result in no impact on levels of the lakes.

Figure 3. Profile of the Great Lakes and St. Lawrence River.



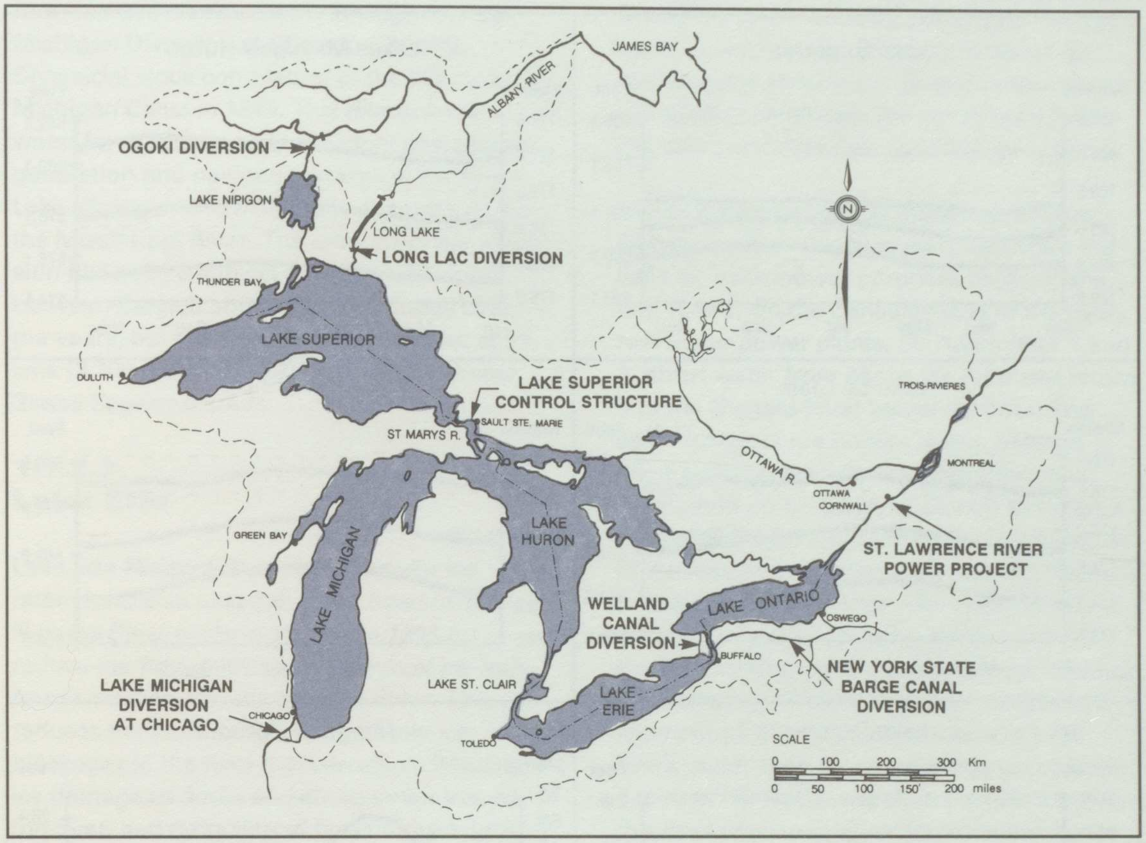
Structures that regulate water levels and flows have been added to Lake Superior's outlet, the St. Marys River at Sault Ste. Marie Michigan/Ontario; and to Lake Ontario's outlet, the St. Lawrence River, at Cornwall, Ontario/Massena, New York. These structures, together with other modifications to the natural system, are explained in more detail in the next section (see Figure 4).

Water levels and flows in the system depend upon the balance between the amount of water going into the lakes (inflows, precipitation on the lake surface, runoff from the drainage area, diversions and condensation) and the amount going out (evaporation, outflow, diversions and consumption). If more water goes into a lake than goes out, levels will rise; if more water goes out than the lake receives in supplies, the level will fall. This balance changes from year to year and season to season. In addition, strong and sustained winds, as well as changes in barometric pressure, can cause changes in the surface of the lakes. For example, a strong wind blowing from one direction for several hours can move water in the downwind direction and tilt the lake's surface, a phenomenon known as wind set-up. High lake levels, in combination with wind set-up and storm-generated waves can cause severe flooding and contribute to episodes of erosion along lake shorelines. Conditions similar to these led to the severe property damage experienced in the high water period of 1985-1986. This tilt in the lake's surface also results in wind set-down at the opposite end of the lake. For the duration of such an event, levels can be extremely low and can cause problems for water intakes, shipping and boating.

Despite the sometimes dramatic response to storms and changes in air pressure, the size of the lakes makes them relatively slow to respond to major changes in supplies. Their large storage capacities mean that variations in water supplies are absorbed and modulated to some extent. Outflows from the lakes show little fluctuation in comparison to the ranges of flows observed in large rivers of the world. For example, the maximum flows of the lakes' outlet channels are two to three times their minimum flows. In comparison, the maximum flows of the Mississippi River are about 30 times its minimum, and the maximum flows of the Saskatchewan River are nearly 60 times the minimum.[20] The modulating effect of the connecting channels means that any change in water supplies to the upper part of the system remains within the system for some time

[20]International Lake Erie Regulation Study Board, International Joint Commission, *Lake Erie Water Level Study: Main Report* (July, 1981).

Figure 4. Diversions and Regulation Structures.



— as much as 15 years — before its full effect is felt on the downstream lakes.

Figure 5 shows the historic ranges of levels for the five Great Lakes, Lake St. Clair and Montréal Harbour in metres and feet. The upper line indicates the maximum monthly levels, the lower line indicates the minimum monthly levels, and the middle line indicates the mean monthly levels. The numbers on the left are in metres and the numbers on the right are in feet (IGLD 1955).

1.7.2. Modifications to the Natural System

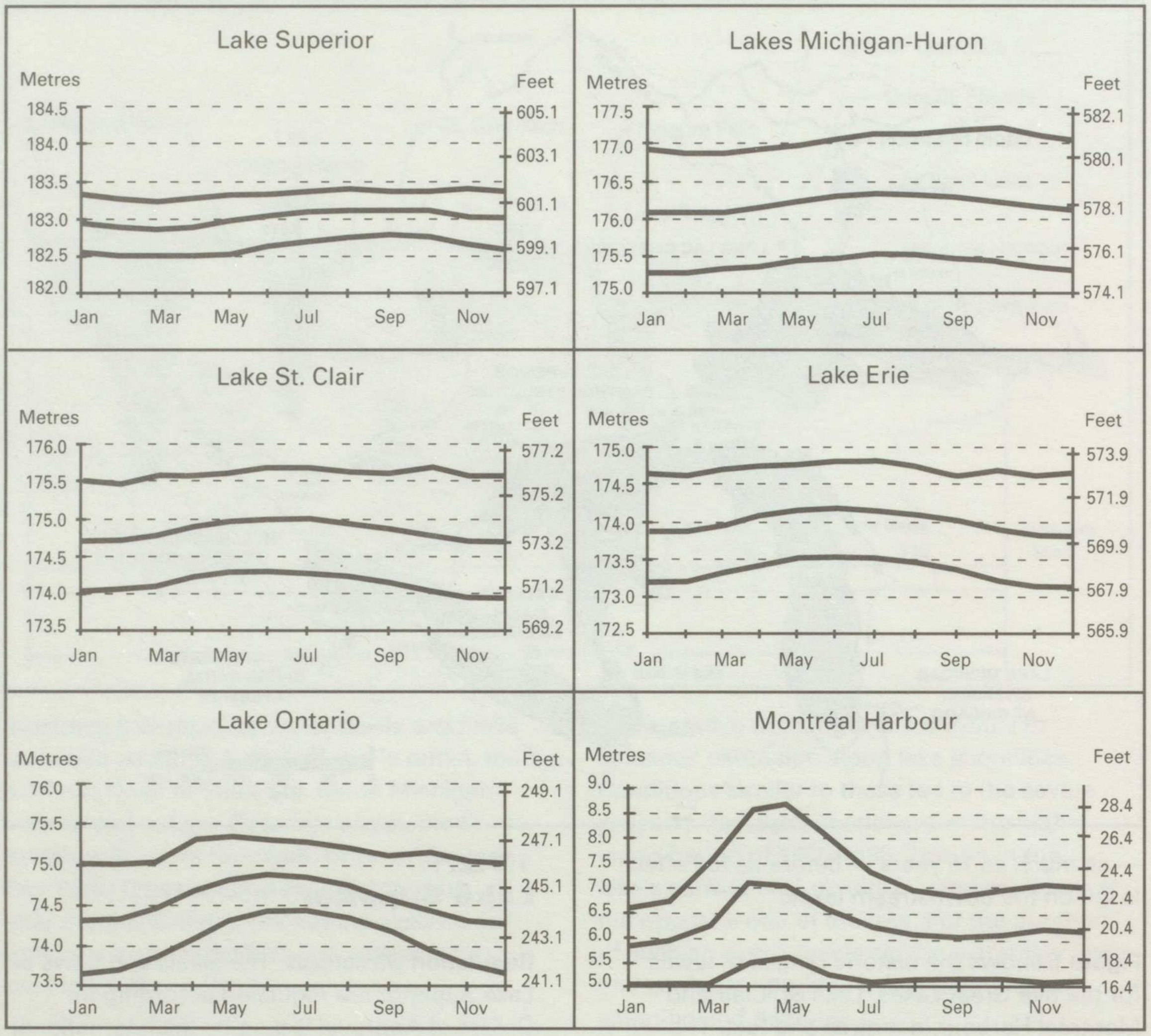
While the Great Lakes and St. Lawrence River have their own natural checks and balances, human interventions have changed this system to a certain extent. Some of these modifications have been small and their effects minor; others have involved major engineering projects that have altered levels and flows of the entire Great Lakes-St. Lawrence River System.

1.7.2.1. Lake Superior

Regulation Structures. The levels and flows of Lake Superior are regulated according to Orders of Approval issued by the International Joint Commission in 1914 and modified in 1979. Regulation of the lake began as a result of hydropower and navigation developments in the St. Marys River. The hydropower plants, navigation structures and compensating works, which help offset the effects of the other structures, are operated according to a regulation plan.[21] The Lake Superior plan, which has been revised several times since it was first instituted, attempts to maintain the lake's levels between 182.4 and 183.5 metres (598.4 and 602 feet) above sea level. It also attempts to balance the level of Lake Superior with that of Lakes Michigan-Huron. The object of the plan is to keep the lake's level within a range of 1.10 metres (3.6 feet). The actual effects of Lake Superior regulation have been to increase the range of lake levels from 1.16 metres (3.8 feet) to 1.19 metres (3.9 feet), a difference of 0.03 metres (0.1 foot).

[21]Regulation Plan: A system of procedures established by the International Joint Commission that governs the operation of structures that control the outflow from a lake.

Figure 5. Historic Water Level Fluctuations in metres and feet.



Water Diversions. In addition to the regulation structures, the Long Lac and Ogoki Diversions have channeled additional water into Lake Superior since the early 1940's. These diversions bring water into Lake Superior that originally drained north to James Bay via the Albany River. They were developed to generate hydropower and, in the case of the Long Lac Diversion, to transport pulp logs southward. Roughly 153 cms (5,400 cfs)[22] flows into the lake through these two diversions. The actual amount of the diversions varies frequently.

1.7.2.2. Lakes Michigan, Huron and St. Clair

Dredging of St. Clair and Detroit Rivers. The St. Clair River between Lakes Huron and St. Clair, and the Detroit River between Lake St. Clair and Lake Erie, have been dredged several times in this century in order to improve navigation channels. This dredging has lowered Lakes Michigan and Huron by approximately 0.40 metres (1.3 feet).

[22]Flow rates in the Great Lakes-St. Lawrence River System are measured in cms (cubic metres per second) and cfs (cubic feet per second).

Water Diversion. Water has been diverted from the Great Lakes Basin through the Lake Michigan Diversion at Chicago (Chicago Diversion) since completion of the Illinois and Michigan Canal in 1848. This diversion of water for domestic and municipal use, power generation and navigation, takes water from Lake Michigan and eventually channels it into the Mississippi River. The amount of the diversion has been a subject of diplomatic notes between Canada and the United States over the years, but the current flow rate is set at 91 cms (3,200 cfs) by a 1980 order of the United States Supreme Court.

1.7.2.3. Lake Erie

Lake Erie-Niagara River Ice Boom. An ice boom has been installed at the head of the Niagara River every winter since 1964 to reduce the frequency and duration of ice runs from Lake Erie into the Niagara River. This reduces the probability of large scale ice blockages in the river that can cause flooding, ice damage to docks and shore structures on the river, and reduction of flows to hydropower plant intakes. Placement of the boom hastens the formation of, and lends stability to, the natural ice arch that forms near the head of the river nearly every winter. The boom is removed every spring.

Construction in the Niagara River. Lake Erie's level has been affected by obstructions in the Niagara River since the 1820's. These obstructions include recent fills for parks and marinas, the Bird Island Pier, and the Peace and International Railway Bridges between Fort Erie, Ontario and Buffalo, New York. The cumulative effect of these obstructions has been to raise the lake's level between 0.12 and 0.16 metres (0.40 and 0.53 foot).

Welland Canal. Originally built in 1829, the present Welland Canal takes water from Lake Erie at Port Colborne, Ontario, and diverts it across the Niagara Peninsula to Lake Ontario at Port Weller. The canal has been modified several times since it was first constructed and has been an integral part of the St. Lawrence Seaway since 1959. In its current configuration, the average diversion is about 244 cms (8,600 cfs), and the estimated annual capacity is approximately 260 cms (9,200 cfs) without causing serious erosion or navigation problems. The canal provides a deep draft navigational waterway and water conveyance for hydropower generation, as well as for municipal and industrial use. The canal has a lowering effect on Lakes Erie and Michigan-Huron.

Power Developments in the Niagara River. Diversions from the Niagara River above the Falls for hydropower purposes began in the late 1880's. On the Canadian side of the river, two major power plants, Sir Adam Beck 1 and 2, divert water from above the Falls and return it to the Niagara River below the Falls. The same is true of the Robert Moses Niagara Plant on the United States side of the river. A structure immediately upstream of Niagara Falls extends from the Canadian shoreline part of the way to Goat Island. It is used to maintain prescribed flows over the Falls while allowing diversion of water for the power plants. The area behind this structure is called the Chippawa-Grass Island Pool. Located 26 kilometres (16 miles) downstream of Lake Erie's outlet at an elevation of approximately 3 metres (10 feet) lower than the lake's outlet, this pool produces no measurable backwater effect on Lake Erie.

Black Rock Lock. The Black Rock Lock and Black Rock Canal near Buffalo, New York, where Lake Erie drains into the Niagara River, provide a protected waterway for vessels around the reefs, rapids and fast currents of the upper Niagara River. The canal extends from Buffalo Harbor to a point above Strawberry Island and is separated from the river by a series of stone and concrete walls and by Squaw Island. While this canal is primarily intended as an aid to navigation, it does have some capacity to increase flows from Lake Erie to the extent that Lake Erie's level can be affected.

New York State Barge Canal. The Barge Canal links the Niagara River near Tonawanda, New York, to the Hudson River near Albany, New York. Near Syracuse, an extension runs northward into Lake Ontario at Oswego. All of the water withdrawn from the Niagara River via this canal is returned to Lake Ontario. As with the Chippawa-Grass Island Pool, this canal is located at an elevation far enough below the outlet of Lake Erie, and the flow is small enough — on average approximately 20 cms gas concentrations in the atmosphere (the "greenhouse effect"), there is scientific consensus that global warming is underway and can be expected to continue. The World Meteorological Organization has stated that "no matter how drastic the actions taken to control the emission of greenhouse gases in the atmosphere, the global warming to which we are already committed will be realized in the next fifty to one hundred years."[24]

Global Circulation Models have added significantly to understanding how climates are likely to change; however, knowledge remains far from complete. The results of most studies to date agree that the average warming of the earth's surface due to a doubling of carbon dioxide will be between 1.5 and 4.5 degrees Celsius (2.7 - 8.1degrees Farenheit), a warming unprecedented in human history. Average global evaporation and precipitation rates will increase, and there is a significant probability that summer soil moisture conditions in the middle latitudes of the northern hemisphere will be drier. This will occur while generally moister conditions will prevail in winter over the polar regions.[25]

Given the strong body of scientific opinion in support of the theory that climate change is contributing to global warming, this study examined the hypothetical effects of potential global warming upon the levels and flows of the Great Lakes-St. Lawrence River System. The most advanced computer models currently predict that water supplies to the Great Lakes and St. Lawrence River will be dramatically reduced over the next century — possibly to the extent that Lake Superior's level could drop by one third of a meter (one foot), and the other lakes could be reduced between 1.2 and 1.5 metres (four and five feet). St. Lawrence River flows at Montréal could be reduced by as much as 40%. The effects of the reduced water supply are more dramatic farther downstream in the system, because they accumulate as the effects of reduced water supplies are carried through the system.

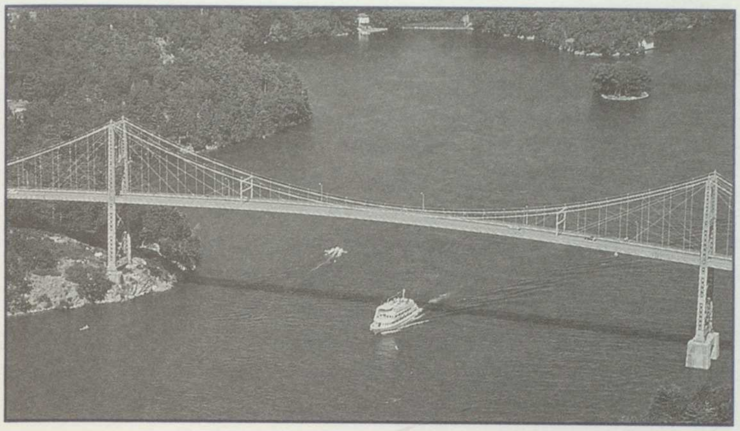
However, modeling results are simulations of plausible future conditions that may be experienced under a warmer global climate. They cannot be considered precise predictions. Further details about the implications of climate change upon management of the Great Lakes-St. Lawrence River System are discussed later in this report.

1.8. SUMMARY

This chapter has provided background information about the Levels Reference Study, about the Great Lakes-St. Lawrence River System, and about the context in which this study was undertaken. The next chapter will explain the various components of the study and the process used to achieve the final results. Chapters 3 through 8 will present the findings, conclusions and recommendations for each of the study's major components.

[24]World Meteorological Organization, *Global Climate Change: A scientific review presented by the World Climate Research Programme,* World Meteorological Organization, Geneva, (1990).

[25]Hengeveld, H., *Understanding Atmospheric Change: A survey of the background science and implications of climate change and ozone depletion: A State of the Environment Report,* ISBN 0843-6193: SOE Report No. 91-2, Atmospheric Environment Service, Environment Canada (1991).



Chapter 2

The Study Process

This chapter outlines the process by which the study was undertaken. The results of numerous investigations, and the recommendations following from them, will be presented in the chapters that follow. In addition, six annexes to this report contain the details of activities carried out by each of the four working committees and the Citizens Advisory Committee. The work detailed in these annexes and referenced in this document forms the basis for this report.

2.1. THE STUDY TEAM

The study's final phase was managed by an eleven-member Study Board established by the International Joint Commission. The Board appointed an eighteen-member Citizens Advisory Committee, four members of which were also Board members. The Study Board was assisted by the Committee in developing a Plan of Study that was approved by the Commission on August 15, 1990. This Plan outlined the work to be done and established working committees to conduct technical and scientific investigations. These investigations form the basis of the Study Board's response to the Reference and Directive.

Each of the four working committees had membership from the Citizens Advisory Committee, as well as two members from the Study Board. Figure 6 shows the study organization. Each committee's membership was balanced between Canada and the United States, and each committee had co-chairs from both countries.[26]

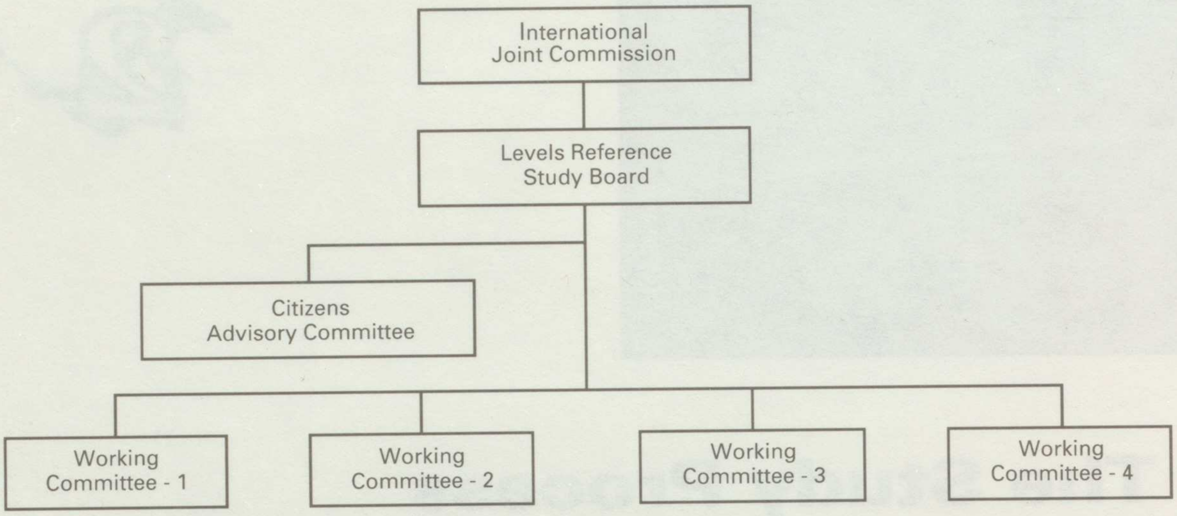
This report is a compilation of the efforts of many people. The study brought together professionals from Canada and the United States in a wide range of fields and teamed their work with the practical knowledge and personal experience of interested citizens of the basin. The result is a distillation of the best available knowledge about many aspects of the Great Lakes-St. Lawrence River Basin, and a set of recommendations that reflects the collective wisdom of the study team and the interested public.

2.2. PUBLIC PARTICIPATION

Underlying the final phase of this study has been the principle that the people of the Great Lakes-St. Lawrence River Basin need to be involved in a process for developing actions that will directly or indirectly affect them.

[26]Appendix F has a complete list of Board and Committee membership.

Figure 6. Study Organization Chart.



Working Committee 1 - Public Participation and Information
Working Committee 2 - Land Use and Management
Working Committee 3 - Existing Regulation, System-Wide Regulation and Crises Conditions
Working Committee 4 - Principles, Measures Evaluation, Integration and Implementation

2.2.1. Citizens Advisory Committee

Although previous water level studies have included public participation components, one aspect of this study that sets it apart from others is the intensive degree to which the Board and working committees endeavored to involve citizens. The Citizens Advisory Committee participated in the entire study process. With membership on the Board and on each of the working committees, this group had significant influence upon the direction of the study. Members of the committee participated actively in the study process. They also assisted, through their own local contacts, with other public involvement efforts. The Citizens Advisory Committee report, with recommendations, is contained in Annex 5.

2.2.2. Newsletter

Eight issues of the study's newsletter, *UPDATE/AU COURANT*, were mailed to interested citizens[27] in Canada and the United States, together with periodic summaries of work in progress. Comments were invited and passed on to the relevant working committees and the Board. In addition, study members worked with the International Joint Commission to provide articles for a special section in the Commission's newsletter, Focus.

2.2.3. Public Outreach and Review

The study also conducted a three-phase public outreach and review program in which study members visited 17 Great Lakes communities to discuss their work and learn first-hand about local issues. The first six meetings, held in Windsor, Ontario, Alexandria Bay, New York, Cleveland, Ohio, Port Rowan, Ontario, Duluth, Minnesota, and Traverse City, Michigan, allowed members of the Board to introduce the study to these communities and to receive suggestions on study activities. The next three meetings, in Baraga, Michigan, Toledo, Ohio, and Burlington, Ontario presented progress of various investigations and

[27] In the early stages of the study's final phase, questionnaires were distributed to more than 3,000 Canadian and U.S. residents of the Great Lakes-St. Lawrence River Basin. Approximately 1,200 of these indicated an interest in being included on a study mailing list. Since that time, the list has grown to more than 3,600. This includes basin media, federal, state, provincial and local officials, as well as citizens who have attended public events hosted by the study.

gathered citizens' comments on the work completed to that point. A set of four public forums followed in Thunder Bay, Ontario, Milwaukee, Wisconsin, Sarnia, Ontario, and Watertown, New York. These meetings presented the findings, together with a preliminary examination of the options for action, and solicited discussion about what the final recommendations might be. The last set of public forums, held in Sault Ste. Marie, Ontario, Chicago, Illinois, Buffalo, New York, and Dorval, Québec discussed the draft recommendations of this study. All of these locations are shown on the map in Figure 7. The recommendations contained in this report reflect the discussions at all of these meetings. A summary of the discussions at the last set of public forums is provided in Appendix D, and a summary of some of the most commonly asked questions, together with the Study Board's responses, is provided in Appendix E.

2.3. THE HUMAN IMPLICATIONS OF CHANGING WATER LEVELS

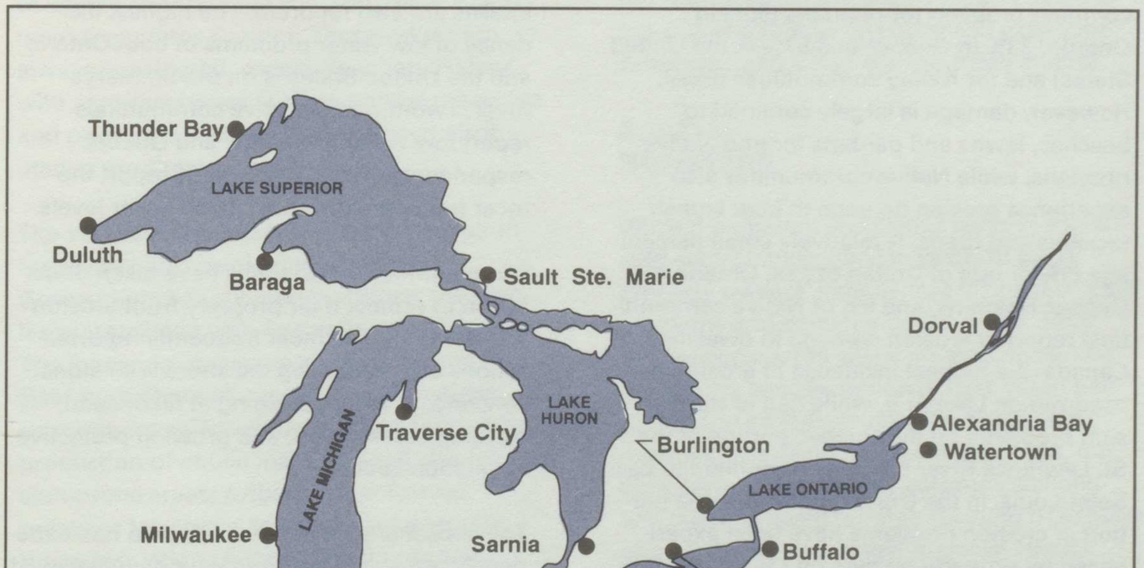
As noted earlier, this study considered the human, as well as the environmental, economic and engineering implications of fluctuating Great Lakes-St. Lawrence River water levels. In the course of this study, surveys and qualitative assessments were carried out to gain a better understanding of the effects that changing water levels have upon shoreline property interests, including residential property owners, farmers, industrial and commercial facilities, public infrastructure and commercial fisheries.

2.3.1. Riparian and Native Surveys

Shoreline property owners (also referred to as riparians for the purposes of this study) have been the most vocal of the interests affected by changing water levels of the Great Lakes and St. Lawrence River. Some argue that the major impetus for this study arose from concerns expressed by groups speaking on behalf of shoreline property owners. They played a major role in prompting the 1986 Reference to the International Joint Commission.

Slightly more than 100,000 (66,000 United States and 45,000 Canadian) residential properties, and 40 Native North American commu-

Figure 7. Locations of Public Events.



nities[28] line the shores of the Great Lakes and St. Lawrence River. In order to better understand the experiences of these people, comprehensive surveys were conducted along the full length of the United States and Canadian shorelines between 1989 and 1991. Riparians in the Great Lakes States, Ontario and the Québec section of the St. Lawrence River, together with representatives of Native North American communities, were questioned in four separate but similar surveys.

The survey findings indicate that shoreline property owners are a predominantly mature group, with more than half over the age of 51. Many are long-time shore residents, with over 25% having owned their properties for more than 25 years. In the United States, 59% of the properties are used as year-round residences and 39% are occupied seasonally. In Ontario, the reverse is true, with 53% of the properties used as seasonal residences and 37% occupied year-round.[29] In Québec, 80% of the properties surveyed are used as year-round residences and 15% are used as cottages. Although Native communities have a mix of commercial, residential and traditional land uses and structures on their shorelines, their shoreline areas are used primarily for fishing (93.8%)and recreation (81.3%).

The surveys indicate that erosion is the most common problem for riparians (60% in Ontario, 33% in Québec and 57% in the United States) and for Native communities (66%). However, damage is largely confined to beaches, lawns and gardens for non-Native riparians, while Native communities also experience erosion damage to boat launch facilities and roads. A relatively small percentage (5% or less of United States, Ontario and Québec riparians, and 9% of Native communities) reported erosion damage to dwellings. In Canada, the highest incidence of erosion has occurred on Lake Erie, while half of the erosion problems on the Québec portion of the St. Lawrence River have been confined to Lac Saint-Louis. In the United States, a large portion of erosion problems have been experienced by property owners on Lake Michigan.

Of four categories of water level-related problems (erosion, flooding, high water levels and low water levels), flooding is the least common, according to the survey respondents. Of the United States, Ontario and Québec respondents, 20%, 27% and 24% respectively report experiences with flooding. Most of this has been confined to yards and, in the case of Québec respondents, basements. Four per cent or less of non-Native respondents have had water on the first floor of a residence. Forty-four per cent of Native communities report experiences with flooding. In addition to water in yards, water on roads is a common flooding problem, followed by flooding of wetlands.

Experiences with high water levels were assigned a separate category, since many riparians report high water problems other than flooding (i.e., damage to docks, damage to boat houses, decreased beach area, loss of beach access and septic system problems). In the United States, 76% of respondents report experiences with high water levels. Similar experiences are reported by 53% of Ontario riparians, 55% of Québec riparians, and 75% of Native communities.

The most commonly reported impact of low water is an increase in beach area. Difficulties with boat launch facilities, docks, and water intakes are also reported. The highest incidence of low water problems in both Ontario and the United States is on the St. Marys River. Two-thirds of Native communities report low water problems, and Québec respondents on Lac Saint-Louis report the most frequent incidence of low water levels.

Large numbers of riparians have taken direct action to protect their property from erosion and flooding. The most frequently reported actions are reinforcing the shore with stone, concrete, or wood; bringing in fill or sand; building breakwaters; and growing protective vegetation cover.

The subset of property owners who had experienced erosion was asked what they believed

[28]The populations of these communities vary greatly, but the majority have 2,000 or fewer residents. Twenty of the native communities are located on Lake Huron, 13 are located on Lake Superior and the St. Mary's River, two are on the St. Clair River, and three are on the St. Lawrence River. The remaining two are on Lake Michigan and Lake Erie. Thirty-one of the communities are in Canada and nine are in the United States.

[29]These particular survey statistics do not apply to Natives, because questionnaires were completed by representatives of Native communities, rather than by individuals.

to be the main cause. In the United States and Ontario, responses were similar: storm-driven waves only, United States 5%, Ontaro 10%; high water levels only, United States 18%, Ontario 23%; and, both storms and high water levels, United States 67%, Ontario 57%. In Québec, 31% attributed erosion to high water levels, and 27% attributed it to ships' wakes. Native communities held a different view: 31% believed that storm driven waves were the main cause of erosion, and 25% stated that neither storms nor high water levels caused erosion.

The riparians who had experienced flooding were also asked what they perceived to be the causes. Again, responses were similar in the United States and Ontario: storm-driven waves only, United States 6%, Ontario 7%; high water levels only, United States 26%, Ontario 17%; and, both storms and high water levels, United States 54%, Ontario 71%. In Québec, 65% of those with flooding problems felt that high water levels were the cause. Among Native communities with flooding problems, 59% believed storm-driven waves to be the cause of flooding.

Although Native people who live in communities along the shoreline are in many ways similar to other riparians, the survey indicated that Native people have unique uses of the shoreline and traditional values that are centered around the Creator. These values are always considered, especially when dealing with sensitive issues such as natural resources and processes that have always been attributed to the Creator's will.

The surveys also measured levels of support for several proposed measures that Governments might take to address the problems associated with fluctuating water levels. The following measures were supported by a clear majority of all riparians in all surveys: government construction of shore protection; production of public maps of flood and erosion-prone areas; setback requirements; grants or tax credits to property owners for the construction of shore protection; and emergency forecasts of winds and water levels. Construction of dams and channels to regulate water levels received the following levels of support: United States 40%, Ontario 52%, Québec 48%, and Native Communities 13%. Regulation was not well supported by Natives, who view actions to control nature as contrary to their traditional beliefs and culture.

Approximately half of the non-Native respondents in both the United States and Canada who experienced erosion damage were not aware of the erosion risk when they purchased their property. Similarly, between 60% and 70% of those who experienced flooding were unaware of that risk when they purchased their property. These results indicate that large numbers of riparians have inadvertently taken on the risks of living by the water and that erosion and flooding have taken them by surprise.

More details of these surveys are contained in Annex 2.[30]

2.3.2. Other Social Studies

During the first part of the study, qualitative investigations were conducted into how fluctuating water levels affect public infrastructure, industrial and commercial facilities, agriculture, commercial fisheries and riparians. In the final phase of this study, reports of these investigations were reviewed and expanded. Annexes 2 and 4 also discuss these studies.

2.3.2.1. Riparians

While the riparian and Native surveys considered social implications in terms of shore property owners' experiences with water level problems and opinions on solutions, other studies considered social impacts, including the trauma and disruption of lives when people are forced to evacuate, the time spent repairing and cleaning up after damage, the time spent in emergency accommodations and the time spent fighting flooding or erosion along with the associated financial strains. Naturally, the level of anxiety is increased if

[30] Also see Social Impacts Task Group, Working Committee 2, *Final Report* (April, 1993); Sudar, Anne and Nelson, Gary, *Survey of Great Lakes-St. Lawrence River Riparian Property Owners in the United States* (March 1993); and, Ecologistics Limited, *Hypothesis Testing of Riparian Surveys: Ontario, Québec and Native North Americans*, for the Social Impacts Task Group, Working Committee 2 (May 25, 1992).

financial losses are significant and no insurance coverage or assistance is available. Decline in property values is also a major concern for shoreline residents.

Negative impacts of low water levels are generally confined to such things as exposure of unsightly shore features or loss of boat docking. However, increased beach area brought about by low water levels is often considered a benefit.

2.3.2.2. Commercial Fisheries

Although commercial fisheries appear to be in a continuing decline, the size of the industry is still significant, with reported late 1980's values in the tens of millions of dollars for both Canada and the United States.

However, the commercial fishing industry is generally less concerned with high water levels than it is with low water levels. Low levels can interfere with docking and unloading of catches, and with the moving of boats. Changing levels also have an impact on fish stocks, which can, in turn, result in losses in income.

2.3.2.3. Public Infrastructure

Government agencies report that fluctuating water levels affect transportation, water and sewage, public buildings and parks, together with shore protection structures. Concerns exist with respect to the need for new facilities and associated protection, changes required to existing facilities to accommodate fluctuating lake levels, and repair or maintenance to damaged facilities.

The greatest concern to those responsible for maintaining infrastructure is erosion. A 1986 survey by the University of Michigan[31] indicated that, among public agencies along the United States and Canadian shoreline, with the exception of Lake Ontario shoreline, all of the respondents were of the opinion that high lake levels are a problem. The concerns appeared to be most acute at the local level. Although the survey focused on high water levels, shoreline erosion was the greatest concern.

2.3.2.4. Industrial and Commercial Facilities

A wide variety of commercial and industrial facilities make use of the Great Lakes-St. Lawrence River System shorelines. They range from grain elevators and steel plants to resorts and marinas. Because of their diversity, there is little consensus in this group on the nature of the impacts of changing water levels. However, some commonly-cited problems are discussed here.

For commercial businesses that depend upon beachfront recreation, high water levels and associated loss of beach area are negative impacts. Meanwhile, for marina operators, tour boat companies and other commercial businesses that rely on near-shore or harbor navigation, low water levels and associated docking and channel problems bring the greatest adverse impact. Industries that rely on shipping benefit from the potential for increased loads during periods of high water levels and suffer problems with dock facilities during low water level periods.

Information from earlier reports indicates that commercial and industrial facilities have a degree of tolerance for changing water levels, within a boundary zone of 0.3 or 0.6 metre (one or two feet) of the long-term monthly average. With the exception of businesses that depend upon beachfront recreation, commercial and industrial concerns appear to benefit from slightly higher than average lake levels. However, once levels rise above a certain point, flood damage to structures is believed to outweigh the benefits.

2.3.2.5. Agriculture

Although agricultural uses of land are not as directly linked with the shoreline as the above categories of use, a significant number of agricultural lands are located along the shoreline, predominantly on the lower lakes and St. Lawrence River.

[31]Marans, Robert W., et al, *Trends and Emerging Environmental Issues in the Great Lakes: Perceptions and Assessments*, Institute for Social Research and School of Natural Resources, University of Michigan, Michigan Sea Grant College Program, Report No. MICHU-SG-89-201.

The greatest concern expressed by agricultural representatives is related to high water levels. Specific impacts include flooding of low-lying crops and potential crop loss, overtopping of dikes, and reduction in crop yield associated with high water tables near the shoreline. Previous reports indicate that existing diking can provide effective protection from high water to specific levels. Once water levels exceed this, damage can be significant. Damage does not increase proportionally with increasing levels but is significant once shore protection is breached.

2.4. THE DEVELOPMENT AND EVALUATION OF MEASURES

The largest portion of this study's effort was directed toward practical measures to alleviate problems associated with fluctuating water levels. Such measures included land use and shoreline management, and lake level regulation measures. Making decisions about the measures to be recommended in this report included not only examination of numerous potential actions, but evaluation of how these actions might affect the interests involved. Chapter 4 presents the recommended measures and explains why they were selected.

Every measure has potential advantages and disadvantages. For example, a measure that changes the levels and outflows of a lake will affect the many life forms in the lake, as well as the processes acting on the shoreline, the public's enjoyment of the shoreline and possibly their willingness to spend money in a particular location. This could have spin-off benefits or disbenefits for recreational industries as well as for the economies of local communities. Meanwhile, alterations to a lake's outflow may also affect the amount of water available for production of hydropower or the depth that determines how much cargo ships can carry. In addition, some land use and shoreline management measures can have implications for property values and shoreline uses. Some of these measures carry large financial costs for implementation, while others are relatively cost-free. All of these effects have broad impacts on the general economic and social life of a particular area and of the basin in general.

During the first part of the Levels Reference Study, a list of more than 120 possible measures was developed. The final phase used a multi-stage process to narrow this list down to the ones that are contained in Chapter 4.

2.4.1. Study Planning Objectives

In order for this study to produce strong recommendations for action, it needed a process that would ensure that the choices for measures responded to interests' needs, as well as to the specific requests set out in the Reference from the Governments of both countries. To assist each of the working committees in fulfilling that goal, a set of 41 study planning objectives[32] was prepared. These objectives were aimed at reducing or avoiding adverse effects of changing water levels and flows upon the ten interests, or water use categories, listed in Chapter 1. Most of the objectives involved reducing financial, social or environmental losses due to erosion, flooding or low water levels.

The study planning objectives were used as indicators for the working committees' assessments of individual measures. Each committee described how well each measure would meet the study planning objectives in its areas of investigation. Since the objectives were based upon the desires of the ten interests, some were contradictory; for example, an objective to reduce or eliminate flooding for shoreline residents might preclude desirable levels for recreational boating. Conflicts such as these were dealt with in the measures evaluation process, described next.

2.4.2. Multi-Objective Multi-Criteria Measures Evaluation Process

Once the measures were described according to their abilities to meet the objectives, it was possible to begin making judgments about their desirability, based upon a set of evalua-

[32]Working Committee 4, *Inventory of Study Planning Objectives*, (September 30, 1991).

tion criteria.[33] These criteria formed the standard of comparison for all of the measures. The closer a measure was to meeting all of the criteria, the more likely it was to find its way into the recommendations of this report. This procedure was called a "multi-objective multi-criteria measures evaluation process." Four "core criteria" were developed, and each criteria had two or more "sub-criteria":

Economic Impact. Each measure was evaluated for its overall effect on the basin's economy. To be recommended for implementation, a measure would be required, as a minimum, to allow the existing economic performance in the basin to be maintained. Positive economic impacts were preferable. Two sub-criteria, "benefit-cost analysis" and "other economic and social impacts," were used to determine whether the measures met the economic and social impact standard.

Environmental Impact. This criterion rated measures based upon the extent to which they would change the basin's environment, either positively or negatively. These assessments were qualitative; that is, they relied on descriptive information that could not be measured in numbers rather than on quantitative information (economic or physical measurements). Two sub-criteria, "ecological productivity" and "environmental purity," were used.

Distribution of Impacts. The dispersion of impacts across the spectrum of interests and regions was also assessed. The objective was to ensure that no one region or interest group would be subjected to undue hardship as a result of a measure. In order to assess this distribution, the evaluation process looked at the relative magnitude of the impact and whether it was positive or negative.

Feasibility. To meet this criterion, measures were required to be technically and operationally feasible, which means that they would need to respond to changing conditions, have predictable outcomes once put into effect, and be reliable under extreme conditions. Under this criterion, measures would also need to be feasible from a legal and public policy perspective. This required assessing whether the measures could be implemented within existing legal frameworks, and whether they fit within current public policy or would likely require amendments to current policy. Public acceptability was also a factor.

The measures recommended in this report were chosen by consensus. The first step toward this consensus was taken in the fall of 1991, when study participants were asked to reduce the list of more than 120 measures to a more manageable number. In August and September of 1992, a detailed survey and study-wide workshop[34] led to the further screening of 33 remaining measures. This second screening was accomplished through a questionnaire that asked study participants to rate the measures based upon their review of information contained in a 250-page compendium[35] of information on each measure.

From this workshop a document[36] was prepared that listed the measures favored by most study participants as the most likely possibilities for governments to pursue. These possibilities were reviewed by senior government representatives at policy forums at Indianapolis, Indiana, in October 1992 and in Hull, Québec and Washington, D.C. in November 1992. Simultaneously, the key points of the document were summarized in the Board's newsletter and distributed to the study's mailing list. Later, from November 30 to December 3, 1992, four public forums were held to discuss the options for action. Subsequently, these options were refined still further and presented as draft recommendations in the study newsletter and at four additional public forums from February 22 to 25, 1993. Once the review process was complete, the recommendations were finalized by the Study Board.

[33]Working Committee 4, *Evaluation Criteria* (June 22, 1992).
[34]This workshop was held September 28-30, 1992. It was attended by approximately 70 stake holder and agency representatives from Duluth to Québec City. The majority of participants were members of the study, but citizens at large and interest group representatives also attended.
[35]Working Committee 4, *Impacts of Measures for Evaluation - Summary* (September 8, 1992, revised March 1993).
[36]Levels Reference Study Board, *Options Document: Including Key Results of Technical Studies, Guiding Principles for Governments, Measures to Reduce Impacts of Fluctuating Water Levels, Emergency Actions in Response to Crises Conditions, Institutional Arrangements, Communications Practices* (October 23, 1992).

2.5. GUIDING PRINCIPLES

The social and environmental well-being, conomic development and international competitiveness of both Canada and the United States demand the strategically wise use and management of the finite water resources of the Great Lakes-St. Lawrence System. One of this study's tasks was the development of guiding principles that would facilitate such management.

These broad principles are based upon the principles that guided the study process and were directed to ensuring the ecosystem integrity of the Great Lakes and St. Lawrence River, as well as to ensuring the environmental and economic sustainability of measures that deal with changing water levels and flows. Recommendations on guiding principles for governments are presented in Chapter 3.

2.6. THE APPROACH TO IMPACT ASSESSMENTS

2.6.1. Economic Impacts

In order for any measure to be considered implementable, the economic benefits it could provide would have to outweigh the financial costs. Benefits included prevention of further damage, increases in revenue, or avoidance of future costs. Potential benefits and costs were calculated for shoreline property owners, the commercial shipping industry, the recreational boating industry and hydropower utilities. The economic evaluations for the principal measures considered are described in Chapter 4 and in Annexes 2 and 3.

2.6.2. Environmental Impacts

Because this study considered the entire Great Lakes-St. Lawrence River ecosystem, investigations were also conducted into the possible effects that measures to regulate lake levels and flows could have on the natural environment. Wetlands were selected as indicators of the overall health of the basin's aquatic environment. Site studies of the potential effects of water level regulation on fish habitat were also conducted. Results of the evaluations are provided in Chapter 4. Further details are provided in Annex 2 and its supporting documentation.

2.7. EMERGENCY PREPAREDNESS PLANNING

The Commission's interim report of October 1988 recommended short-term use of existing regulatory structures and diversions to alleviate high or low water crises. Later investigations built upon this earlier report.

Emergency preparedness measures fit under two categories: hydraulic and land-based. The hydraulic measures include such activities as modifying diversions into, within, or out of the system, or adjusting existing lake regulation plans. Land-based measures included such activities as water level forecasting, emergency floodproofing and disaster assistance.

Chapter 5 outlines a combination of measures to reduce the effects of a high or low water crisis.[37]

2.8. EXAMINATION OF INSTITUTIONS

A multitude of individuals, groups, firms and agencies, both within and outside the basin, benefit from the Great Lakes and St. Lawrence River. These interests' demands have combined to make the basin one of the continent's most important economic centers. Eight United States states and two Canadian provinces surround the system. More than a dozen federal agencies in both countries have responsibilities for management of the system's resources. Each state and province also has obligations in this regard. Additionally, the many municipalities and townships, counties and districts, regional and local agencies along the shorelines of the system have jurisdiction in matters directly related to water level and flow issues.

[37]See Annexes 3 and 6 for details about how the emergency preparedness measures were developed.

Chapter 3

Guiding Principles

In order to clarify various interests expectations of the study, a set of study evaluation principles was adopted early in the study process. These principles reflected fundamental values that were considered critical in deciding whether proposed policies or actions in the management of water levels and flows are in the public interest and viewed as acceptable. These principles were a key component in developing of the criteria used to evaluate the measures recommended in this report.

Future management of problems associated with fluctuating water levels and flows in the Great Lakes-St. Lawrence River System would benefit from a similar set of guiding principles[41] agreed to by federal, state and provincial governments. The intention of these guiding principles is to establish a policy framework and to provide a common focus under which all current and future programs could be pursued.

3.1. GUIDING PRINCIPLES

The following text consists of a proposed preamble and set of guiding principles that, if adopted by governments,[42] would improve decisions related to water levels and flows in the Great Lakes-St. Lawrence River System, as well as the understanding of these decisions.

[41]For more information on development of the Guiding Principles see Annex 4.
[42]The term"governments" refers to the two federal, the eight state and two provincial governments.

GUIDING PRINCIPLES FOR MANAGEMENT OF THE GREAT LAKES-ST. LAWRENCE RIVER SYSTEM

Preamble

With almost 20% of the world's supply of fresh surface water, a drainage basin that embraces the industrial heartland of the North American continent, and a surrounding population of more than 35 million people, the significance of Great Lakes and St. Lawrence River is considerable.

Many people benefit in many ways from this vast water resource, which has a value that extends well beyond the boundaries of its drainage basin. The Great Lakes-St. Lawrence ecosystem is extremely diverse and dynamic. The shores of the Great Lakes are physically rich, bearing evidence of geological events that occurred hundreds of millions of years ago. Physical processes are continuously changing the shoreline and have done so over the last 10,000 years, even up to the last few hours.

Millions rely on the lakes for their drinking water, for transportation of goods and community sanitation, for their industrial jobs, for electricity in their homes and at work, for food and traditional lifestyles, and for their leisure time enjoyment. Hundreds of plant and animal species rely on the lake system, as well, from common backyard varieties to the Carolinian forests and the bald eagle which are examples of the many rare, threatened and endangered species that depend on this resource.

Water quality is related to water quantity. Increases or decreases in the quantity of water affect the availability and the quality of the water. Proper management of the resources of the system requires close coordination of water quality and quantity concerns and recognition of their interdependence.

The geography of the basin has facilitated the close social and economic ties that exist between Canada and the United States. This has contributed to the movement of goods and services between the two countries, making the Great Lakes-St. Lawrence River Basin an important center in terms of economics, transportation and natural resources.

The region's relative prosperity can be expected to continue well into the foreseeable future, but it cannot continue without due consideration for the complex ecosystem that supports the diversity of economic and social development. Nor can this prosperity continue without regard for the diversity of interests directly and indirectly affected by changes in management of the system. Not only are these interests diverse, they are often in conflict. Farsighted management of the Great Lakes and St. Lawrence River also calls for resolution of conflicts in ways that are, at best, to the overall benefit of the system and its inhabitants, and at least, not to the undue detriment of any one interest.

The future pattern of economic activity in the Great Lakes-St. Lawrence River Basin is uncertain, but it is possible that the ways in which the lakes and channels are used may change dramatically in response to technological, social, economic and environmental pressures. Recent findings related to global climate change indicate that the system could see dramatic decreases in its water supplies that could markedly affect both the uses to which it is put and its availability for those uses. These factors combine to confound a decision-making process that is already complicated by the numbers of federal, provincial, state, and local authorities with jurisdiction in water level-related issues; by the sheer size of the basin, which includes eight states and two provinces; and by the fact that the Great Lakes-St. Lawrence River System is an increasingly valued resource that is shared by two countries.

Despite the huge volumes of water stored in the lakes and moving through the system every day, the Great Lakes and St. Lawrence River are not inexhaustible resources. The system depends primarily on precipitation and runoff from the drainage basin for its water supplies. This often over-

looked fact underlines the need for wise planning today of a finite water resource that must serve generations to come at least as well as it has served to the present day.

The following principles are broad guidelines to enhance coordinated, system-wide management in future water levels and flows issues. Such management calls for the full involvement of all levels of government, including Native communities, and the general public. These principles provide a common focus under which all current and future programs can be pursued. These principles will be considered in dealing with issues related the water levels and flows of the Great Lakes-St. Lawrence River System.

Principles

1. *Existing and future beneficial uses will be considered, and the fundamental character of the Great Lakes-St. Lawrence River System will not be adversely affected.*

2. *Actions approved or taken will be environmentally sustainable and respect the integrity of the Great Lakes-St. Lawrence River System ecosystem.*

3. *Actions approved or taken will be beneficial to the Great Lakes-St. Lawrence River System and not result in undue hardship to any particular group.*

4. *Coordinated management of the system needs to respect and accommodate the dynamic nature of the entire Great Lakes-St. Lawrence River System.*

5. *Reduction of damage to existing development from fluctuating water levels in the Great Lakes-St. Lawrence River System will be based on the use of both non-structural and structural measures*[43] *at various locations throughout the basin.*

6. *Prevention of damage to future development from fluctuating water levels in the Great Lakes-St. Lawrence River System will include the implementation of land use measures to discourage construction in areas subject to damage from fluctuating water levels and storms.*

7. *Management of the Great Lakes-St. Lawrence River System will be done in full awareness of the potential for reduced water supply as a result of climate change.*

8. *Decision-making with respect to the management of the Great Lakes-St. Lawrence River System will be open, respecting the full range of interests affected by any decisions and facilitating wide participation in the policy process.*

9. *Management of the Great Lakes-St. Lawrence River System will be based on coordination of actions relating to levels and flows.*

10. *Management of the Great Lakes-St. Lawrence River System will be based on continued improvement in the collection of data and the understanding of the processes and impacts of fluctuating water levels and flows.*

11. *Management of the Great Lakes-St. Lawrence River System requires ongoing communications and public awareness.*

[43]In the sense that the term is used here, structural measures do not include new regulation structures that would affect the levels and flows of the Great Lakes and St. Lawrence River. The structural measures referred to in this context include existing regulation structures as well as those that would be taken on land, such as shore protection works. Non-structural measures include beach nourishment, landfilling, bluff drainage, bluff stabilization and similar practices. Structural measures include shore protection works, including seawalls, breakwaters, groins, revetments, artificial headlands, artificial islands, dikes and similar practices.

3.2. RECOMMENDATION

The Board recommends that federal, state and provincial governments adopt the Guiding Principles listed above, and that these principles be used as guidelines for the management of issues related to water levels and flows within the Great Lakes-St. Lawrence River System.

The Board is not recommending changes in the Boundary Waters Treaty of 1909 but is suggesting that the International Joint Commission use these guiding principles within the limits of the Treaty.

Chapter 4

Measures to Alleviate the Adverse Consequences of Fluctuating Water Levels

This chapter summarizes the results of investigations into measures that could alleviate the adverse consequences of fluctuating water levels. Presented here are the principal measures that were evaluated, together with some of the key findings from the assessments of their potential impacts. On the basis of these findings, recommendations are made for actions that could be taken by governments.

Two types of measure were evaluated: 1) lake regulation measures that would alter the levels and flows of one or more of the Great Lakes; and, 2) land use and shoreline management measures that would use various methods to adapt shoreline areas and their uses to changing water levels. In this study, lake level regulation measures were considered to be remedial since they would reduce damage to property and structures that already exist, or they would reduce other negative water level impacts. Land use and shoreline management measures could be considered either remedial or preventive, depending upon whether they help protect existing development, or whether they keep development from occurring in areas vulnerable to future damage. Additional details on these measures are provided in Annexes 2 and 3.

4.1. IMPACT ASSESSMENTS

Quantitative and qualitative assessments were carried out on the potential economic and environmental impacts of the measures presented in this chapter. The economic impacts of regulation measures were assessed for riparian property, commercial navigation, recreational boating, and hydropower. Wetlands were studied as indicators of the environmental effects of changes in water level regimes, while erosion studies determined possible changes in shore recession rates under reduced ranges of water level fluctuation. Other interests such as agriculture, commercial fishing, public infrastructure and Native North American communities were not evaluated quantitatively, but qualitative assessments were undertaken which focused primarily on characterizing the interests and their responses to fluctuating water levels. Land use and shoreline management measures were assessed by reviewing existing examples and conducting case studies. The following sections detail how these assessments were accomplished.

4.1.1. Qualitative Assessments

Qualitative assessments of the impacts of changing water levels on riparian property, Native communities, commercial fisheries, public infrastructure, commercial and industrial facilities, and agricultural interests were discussed in Chapter 2. While economic assessments were also conducted into how lake level regulation could affect shoreline property, commercial shipping, recreational boating and hydropower generation, similar quantitative assessments were not possible for the other interests listed above. However, the qualitative information assisted study participants in weighing the suitability of measures during the evaluation process.

4.1.2. Economic Impacts

4.1.2.1. Potential Damage to Shoreline Property

An important issue raised in the Reference is whether additional regulation of water levels and flows in the Great Lakes and St. Lawrence River could reduce the amount of erosion and flooding damage sustained by shoreline property. To answer this question, researchers estimated the potential changes in dollar values of flood and erosion damage to residential, commercial, industrial and public property, and public infrastructure. The difference between the estimated damage under existing conditions (the basis of comparison[44]) and damage under new water level regulation schemes indicated the potential benefits or costs of each regulation measure. Stage-damage curves[45] and detailed site studies[46] were used to prepare these estimates.

The Great Lakes-St. Lawrence River shoreline above Cornwall, Ontario, was divided into 78 sections, called reaches. The St. Lawrence River below Cornwall, Ontario (the Montréal area), was divided into five additional reaches.

Stage-Damage Curves

The stage-damage curves for flooding and erosion were based on curves developed from damage surveys and damage payments made during the 1970's. The curves were updated to 1991 values to take into account inflation, new development, moving or removal of structures, and construction of shoreline protection. In addition, the curves for flood damage incorporated a risk analysis approach[47] that defined upper and lower thresholds for flood damage. This gave a range of water levels within which researchers could be confident flood damage would occur. This range was developed by closely examining the water levels at which flood damage occured in the past and applying updated dollar figures to them.

Detailed Site Studies

As requested in the Directive from the International Joint Commission, detailed site studies were used to help verify the damage estimated from the stage-damage curves. These studies were also used to gather insight into the specific nature of damage, and attempts were made to apply this information to the entire system. Thirteen detailed site studies were carried out. Information was collected at varying levels of detail on damage caused in the past by fluctuating water levels, and on the damage that could be expected under various lake level regulation schemes. Information from these sites provided a substantial increase in the understanding of specific problems for specific interests. Three of

[44]For the purposes of this study, "existing" water level and flow conditions were based upon a set of levels and flows called the basis of comparison (BOC), which is used as a reference for assessing the impacts of various measures. The BOC is calculated for the 90-year period from 1900-1989, and it gives the water levels and flows that would have occurred each month of that period if all current regulation plans, current channel conditions and existing diversions had been in effect over the entire period.

[45]A Stage-damage curve is a graph developed by plotting the amount of dollar damages anticipated for a range of flood water elevations (or stages) caused by high lake levels. Stage-damage curves were also used to predict erosion damage. Stage-damage curves that were developed for the St. Lawrence River differed from those prepared for the lakes, because the stage part of the curve was based upon river flows, rather than water levels. Stage-damage curves for the United States included flooding and erosion damage for agriculture, commercial-industrial property, public infrastructure and residential property. The Canadian curves included flooding and erosion damage for agricultural, residential property and vacant land.

[46]A detailed site study involved the investigation of selected locations to gather information on flooding, erosion and low water impacts caused by either natural conditions or a given lake level regulation scenario.

[47]An analysis that evaluated the probability of flood damage occurring at differing elevations along the shoreline and assessing the probability of damage levels being exceeded.

the site studies provided information that could be compared and contrasted with damage estimates that used the existing stage-damage curves for erosion. Generally speaking, the stage-damage curves allowed system-wide estimates of potential flood and erosion damage, while the detailed site studies determined localized damage and increased the understanding of the impacts of changing water level regimes. These approaches gave researchers improved understanding of the potential impacts of various water level regulation scenarios.

Avoided Costs of Shore Protection

One of the benefits of additional regulation of levels and flows is avoidance of future shore protection costs for some shoreline property owners. It is generally assumed that the cost of building shore protection is less if the high water levels are lowered as a result of regulation. The cost avoided is the difference between the cost of building and maintaining shore protection under the current water level regime and the cost of building and maintaining shore protection under a specified water level scenario. For example, a well-engineered structure built today that would withstand a 1-in-25-year event under the current water level regime might cost $10,000. Under a three-lake water level regulation scenario, that 1-in-25 year event may be at a lower water level elevation, allowing the shore protection structure to be built at a lower height and requiring fewer materials. Perhaps the structure could be built for $8,000 if additional water level regulation were implemented. The avoided cost would, therefore, be $2,000. In addition, high levels with additional regulation might be less frequent. As a result, maintenance costs for the structure could decrease. This, too, would be a cost savings, or an avoided cost.

These avoided costs were calculated for a number of water level regulation scenarios. The analysis estimated the replacement cost of all existing residential shore protection,[48] assuming the replacement was well engineered, and including the maintenance and replacement costs for 50 years. This estimate was compared with the reduction (or increase) in the maintenance and replacement costs that would occur for the same degree of protection under new water level regulation conditions. In both cases, it was assumed that replacement of all existing protection would occur at a uniform rate over the next 25 years.

Shore protection costs for future development were also considered. Development forecasts were used to estimate the amount of new development along the shore that could be expected over the next 50 years. It was assumed that the level of shore protection for new development would be the same as for existing development and that all new protection would be well engineered. A comparison was made between expected construction and maintenance costs under existing water level conditions (the basis of comparison), and costs that could be expected with new water level regulation scenarios. Estimates were calculated for both developed areas where no protection currently exists, and for areas that could be developed in the future. The difference between costs of shoreline protection under existing conditions (the basis of comparison) and projected future conditions was converted to an average annual cost, using an interest rate of 8%. These estimates of avoided costs were included in the economic analysis.

At least some of the avoided costs for shore protection would be offset by a reduction in the amount of flood and erosion damage that could be expected to occur if well-engineered and extensive shore protection were in place without new regulation plans. The amount of this possible damage reduction was not estimated, and some double counting of benefits occurred. The potential benefits of further lake level regulation due to estimated avoided costs of shore protection were added to the potential benefits of reductions in estimated flood and erosion damage. However, flood and erosion damage would be reduced if the assumed level of shore protection used to calculate the avoided costs were actually in place.

No lake level regulation plan was found capable of eliminating all flood damage, because flood damages on the Great Lakes are most

[48]The methodology and mix of various types of shore protection is contained in Annex 2, which gives more detailed information on how the avoided costs were calculated.

often caused when storm winds cause stillwater levels[49] to rise in a phenomenon known as wind set-up. While the regulation of a lake's outflow can lower the monthly average level of the lake, this lowering usually cannot compensate for the amount by which the water level may rise due to wind set-up. Similarly, no lake level regulation plan was able to completely eliminate erosion, since many types of shoreline continue to erode (albeit at reduced rates in some locations) regardless of reductions in water level ranges. These erosion processes are explained in the following section.

In addition, all the lake level regulation plans considered in this study redistributed the impacts of fluctuating levels and flows. In other words, plans that decreased damage in one location often resulted in increased damage (not necessarily of the same magnitude) in another location.

4.1.2.2. Effects of Water Level Changes on Various Shore Types

The relationship between fluctuating lake levels and erosion of Great Lakes-St. Lawrence River shorelines was evaluated. Preliminary findings of earlier studies[50] suggested that changing water levels have little or no influence on erosion rates for many shore types. In this study, the relationship between lake levels and erosion was studied in greater detail. Annex 2 and its supporting documentation provide more information on these studies.

In Canada, all of the Great Lakes have a diversity of shore types. Almost half (47%) of the Canadian shoreline of the Great Lakes and St. Lawrence River is classified as resistant bedrock, which does not erode. The majority of this type is found on the upper Great Lakes, where resistant bedrock accounts for 60% of Lake Superior's shoreline, 35% of the St. Marys River, 77% of northern Lake Huron and 58% of southern Lake Huron. The majority of the remainder is found on the Niagara River, Lake Ontario and the St. Lawrence River.

The remainder of Lake Superior's shoreline is composed largely of coarse beach (19%), sand beach or dunes (10%), and open shore wetland. The majority of the portion of Lake Huron's shoreline that is not resistant bedrock is composed of sand beaches and dunes (12% of northern Huron and 25% of southern Huron).

Wetlands predominate on the Canadian shorelines of the St. Marys River (40%), the St. Clair River (31%), Lake St. Clair (61%) and the Detroit River (46%). The largest portion of the remainder of Lake St. Clair's shoreline is sand or silt banks (21%). The Canadian shoreline of Lake Erie is fairly evenly distributed between bluff (43%) and sandy beach (37%) shorelines, with a predominance in the high bluff category (28%).

Of the five Great Lakes, Lake Ontario is by far the most diverse geomorphically, with percentages of its shoreline falling into all of the 16 main categories of shore type that were classified. This lake also has the highest percentage (11%) of artificial shoreline (excluding the connecting channels), due to the intense residential and industrial development at its western end.

In the United States, Lake Superior is also dominated by resistant bedrock shoreline, although this type of shoreline accounts for less than 30% of the Great Lakes-St. Lawrence River total. Lake Michigan is dominated by sandy shores (63%).

The United States shorelines of Lakes Huron and Erie are the most diverse. Sandy shores (17%), course beaches (17%) and wetlands (25%) dominate Lake Huron's shores, while Lake Erie's shoreline is evenly distributed among bedrock, cohesive bluff, sandy shore, wetland and artificial shoreline, with each category accounting for approximately 20%. Lake Ontario's shoreline tends to be either bedrock (42%) or cohesive till bluffs (35%).

The United States sides of the connecting channels tend to be either bedrock (St. Lawrence River, 60%), wetlands (St. Marys

[49]Stillwater level: The level of water measured without the influence of storms or waves.
[50]Project Management Team, *Living With The Lakes; Challenges and Opportunities, Annex B, Environmental Features, Processes and Impacts: An Ecosystem perspective on the Great Lakes-St. Lawrence River System*, p. B-166, (June 1989).

River, 49%; Lake St. Clair, 58%), or artificial (St. Clair River, 81%; Detroit River, 60%). The Niagara River shoreline is mostly low sandy banks (53%) and artificial (13%) in the upper reaches, but predominantly bedrock (26%) throughout its lower course.

Erosion Processes

There are two basic categories of shore types for which erosion processes are fundamentally different. The first of these are sandy shores, which are continually changing and may either erode or accrete, depending upon the balance between the amount of sand being supplied to the beach by waves and currents and the amount being taken away. The second type is cohesive shores, which are typically composed of some type of clay or till. Unlike a sandy shore, once cohesive material is eroded by wave action, it cannot reconstitute itself; its cohesive form is lost forever. Furthermore, any beach sand that may be a by-product of the erosion of the cohesive sediment usually moves quickly away.

Researchers used case studies involving field data, laboratory data, and numerical model tests for both sandy and cohesive shore examples to develop a better understanding of the influence of lake level fluctuations on erosion rates for different shore types. Sandy and cohesive shorelines were used in the evaluations, because they covered the largest number of shore types classified, and they produced the best and most readily available data.

The evaluations were based upon a hypothetical 50% reduction in the range of stillwater levels, which was considered a "best case" scenario. A reduction of this magnitude was achieved by only one of the five-lake regulation plans discussed later in this chapter. Nevertheless, studies of the relationship between shoreline erosion and a 50% reduction[51] in the range of water levels serve as a useful indicator of how water level changes affect Great Lakes-St. Lawrence River shorelines.

Using the shore classification data presented above, along with the results of the numerical modeling tests, researchers developed an erosion sensitivity index and prepared a series of erosion sensitivity maps[52] to predict changes in the recession rates of various shoreline types as a result of a reduction in the water level range. Results indicate that in Canada, excluding the connecting channels and St. Lawrence River, approximately 32% of the shoreline would experience reductions in erosion as a result of a 50% reduction in lake level range. The majority of this reduction would occur on Lakes Erie, St. Clair and Ontario, where 70%, 67% and 43%, respectively of their shorelines, would benefit. Maps indicate that approximately 29% of the United States Great Lakes shoreline would experience a reduction in erosion as a result of a 50% reduction in lake level range. The majority of this reduction would occur on Lakes Erie, Ontario, and Michigan. In both countries, changes in erosion rates would range primarily from 5% to 50%, with a small percentage of shoreline (2.6% in the United States and 0.7% in Canada) undergoing complete elimination (100%) of recession .

4.1.2.3. Potential Losses or Gains to Commercial Shipping

Shipping companies experience losses or gains due to changes in the regime of levels and flows in the Great Lakes-St. Lawrence River System. Low water levels mean that many vessels must carry lighter loads than they are capable of carrying, while high water levels allow larger vessels to carry more cargo. Changes in transportation costs were estimated for each regulation scenario and the crisis management plan. Impacts on overseas traffic to and from the Port of Montréal were also evaluated.[53]

Losses or gains to commercial navigation as a result of level and flow changes differ between the United States and Canada due to differences in vessels, commodities and harbor characteristics. The majority of United States

[51] A 50% reduction is equivalent to a reduction in monthly mean stillwater range of from 1.9 metres to 1.0 metres (6.5 feet to 3.2 feet) on Lakes Michigan-Huron and from 1.7 metres to 0.9 metres (5.6 feet to 2.8 feet) on Lake Erie.
[52] See Annex 2 and supporting documents.
[53] Some incoming international shipments could not be accounted for, as unloading of shipments occurred at other harbors east of Montreal due to weather and other circumstances.

traffic is large bulk carriers carrying coal, iron ore, grain and limestone between upper lake ports. Much of this traffic is handled by 1,000-foot vessels capable of utilizing more than the 27-foot seaway draft. These vessels are very sensitive to reductions of water levels on the upper lakes.

Canadian traffic can be categorized into three groups:

1. Traffic in coal, iron ore and grain carried on standard lakers (740 feet in length, 27 feet draft) between ports that meet or exceed seaway depths. This traffic is not very sensitive to level fluctuations unless levels are very low.
2. Traffic in pulpwood, petroleum products, and salt from or through facilities with depth limitations. This traffic is very sensitive to reductions in levels on the St. Clair River and Welland Canal.
3. Container traffic from overseas to St. Lawrence River ports including Montréal. These vessels can utilize additional draft and will divert their destinations away from Montréal if water level conditions are too low.

4.1.2.4. Potential Losses or Gains to Recreational Boating

Recreational boating is a thriving industry throughout the Great Lakes-St. Lawrence River System. Water levels that are too high or too low could prevent boats from using particular marinas, which would result in lost revenue for marina owners and lost enjoyment for boaters. Studies were conducted to determine the effects of various regulation plans on boater use. Because of the large area covered in this study, and the sheer numbers of recreational boaters, studies of specific sites on each lake were conducted. Nine sites were selected, extending from Duluth on Lake Superior to Lac Saint-Louis in the St. Lawrence River. These investigations were reinforced by representative surveys of boaters and marinas in the United States and Canada.

An economic evaluation of the impacts of regulation measures was completed for recreational boating sites in the United States. In Canada, impacts were assessed on the basis of the number of times that the operating range for boating activities would be exceeded at specific sites for each lake during the boating season. These were compared to the number of such incidents under basis of comparison water levels, and effects were evaluated in terms of frequency of adverse conditions.

4.1.2.5. Potential Losses or Gains in Hydropower

Further regulation of the Great Lakes and St. Lawrence River would affect hydropower plants in the St. Marys, Niagara and St. Lawrence Rivers, and the Welland Canal. Generally, hydropower plants benefit from uniform flows. If a particular regulation scenario were to cause extremely high flows, some water may have to be spilled (allowed to bypass the power plants) without producing electricity; if a scenario allowed extremely low flows, power production would be reduced. A plan to deal with high or low water crises, which will be discussed later in this report, would affect power production at the Long Lac and Ogoki diversions north of Lake Superior, at the Lake Michigan Diversion at Chicago and at the Welland Canal, in addition to power generating stations on the lakes' connecting channels.

The timing and magnitude of losses or gains in power production were determined for each of the proposed water level regulation scenarios and for the crisis management plan. This information was used in the economic analysis.

4.1.3. Effects on the Environment

The Great Lakes-St. Lawrence System is an extremely diverse and important environmental resource. The economic health of the Great Lakes-St. Lawrence River System directly correlates to the environmental health of the basin. Changes in water levels and flows have impacts on the environmental health of the system, which supports numerous plant and animal species and a diversity of land, wetland, and aquatic habitats. Over 200 species and subspecies of fish inhabit the lakes and channels, and productive coastal wetlands support many of those fish and provide habitat for international migrations of many waterfowl species.

Wetlands were used as the primary indicators of the overall health of the system's aquatic environment. The impacts upon wetlands of lake level regulation plans were assessed. Research was oriented toward two goals:

1. To better understand the response of wetland communities to fluctuations in water levels; and,
2. To apply this knowledge generally and speculate on the response of wetland plant communities to proposed water level regulation schemes.

In the United States, field studies were conducted at 35 randomly selected locations on Lakes Superior and Ontario. In Canada, aerial photos were examined to determine changes in vegetation at seven sites (six on the Great Lakes and one on the St. Lawrence River) in order to determine the relationship between changes in vegetation and changes in water levels. Two site specific studies of fish habitat were also undertaken.[54]

These studies determined that plant communities at elevations that are flooded periodically each ten to twenty years and dewatered for two or more consecutive years between floods had the greatest diversity of wetland vegetation. These plant communities contained the most wetland species and the greatest diversity of plant types. Seasonal fluctuations and the timing of peak water levels were also found to be important to wetland health.

While the economic impacts of water level changes were evaluated using quantitative means, the environmental effects were evaluated based on qualitative assessments; that is, descriptive rather than numerical data were used to rate impacts as either positive, neutral or negative. A conceptual model[55] of changes to wetland area in response to water level changes found that fluctuations are important to maintain the extent of coastal marshes on the Great Lakes and St. Lawrence River. The smaller the fluctuation in water levels, the smaller the extent of wetlands.

The wetland studies compared conditions on Lake Ontario under its currently regulated outflows with conditions that would have occurred without regulation. The studies determined that a reduction in the range of Lake Ontario's level brought about by regulation of its outflows[56] has had a significantly adverse effect on the extent, diversity, and integrity of its wetlands. The structures used to control the lake's outflow and operation of the regulation scheme have also caused flooding and erosion losses to flood plain forests in Lac Saint-Louis on the St. Lawrence River.

4.1.4. Potential Impacts of Climate Change

Investigations were also conducted into the possible impacts of global climate change upon water supplies to the Great Lakes and St. Lawrence River. Use of global circulation models in concert with other modeling techniques that predict water supplies to the system has demonstrated that higher temperatures due to climate change will lead to higher evapotranspiration[57] over land, increased evaporation from the surfaces of the lakes, and reduced runoff into the lakes. Although uncertainty remains, the best current projection is that these factors could combine to significantly reduce water supplies to the lakes. This would result in a reduction in the mean outflow of Lake Superior by 13%, of Lakes Michigan-Huron by 33%, of Lake Erie by 40%, of Lake Ontario by 39%, and of the St. Lawrence River by approximately 40%.

These reduced supplies could have the following impacts on water levels:

- Lake Superior's mean level reduced by 0.23 metres (0.75 feet).

[54]Details of this work are provided in Annex 2.

[55]A conceptual model is derived from expert judgment about various impacts, and is used as a means for qualitatively assessing the impacts of water levels in a consistent manner.

[56]These assessments were based on Lake Ontario's current regulation plan, called Regulation Plan 1958-D, and they took into account discretionary deviations from the plan, which often occur in times of above or below average supply.

[57]Evapotranspiration is the combined effect of evaporation of water from land and the transfer of moisture from vegetation into the air.

- Lakes Michigan-Huron mean level reduced by 1.6 metres (5.6 feet).
- Lake Erie's mean level reduced by 1.4 metres (4.5 feet), with the maximum level 1.70 metre (5.05 foot) above the current minimum level.
- Lake Ontario's mean level reduced by 1.3 metres (4.25 feet).[58]
- St. Lawrence River's mean level at Montréal reduced by 1.3 metres (4.27 feet).

These are the best estimates of possible future conditions based upon information that is currently available. They should not be considered as firm predictions. There remains a considerable amount of uncertainty in the scientific community over the potential magnitude of specific hydrologic impacts of climate change; however, there is a general consensus that climate change is taking place and that the potential impacts of global warming should be considered in decisions relating to the Great Lakes-St. Lawrence River System. Thus, the possibility of extremely low water supplies to the Great Lakes and St. Lawrence River should be considered in future regulation plan design and policy development. Existing regulation plans should be reviewed and modified as necessary to ensure their responsiveness to low water supply conditions.

4.2. LAKE LEVEL REGULATION MEASURES

The question of whether to further regulate the levels and flows of the Great Lakes and St. Lawrence River was examined. For the purposes of this study, such regulation is considered a remedial measure, since its primary objective is to reduce the risk of damage to existing structures, although it can also be said to provide some benefits to undeveloped land and to future development.

Currently Lakes Superior and Ontario are the two of the five Great Lakes that have structures at their outlets to regulate their outflows. These structures are operated according to regulation plans[59] approved by the International Joint Commission. While not strictly controlling lake levels (factors such as precipitation, runoff, evaporation, diversions and consumption also affect the levels of the lakes), these structures are usually able to keep the lakes' levels within specified target ranges. A large portion of this study's effort was devoted to determining whether similar structures could achieve water level ranges for some or all of the other lakes that would be beneficial to the interests involved. Among measures examined were possible regulation of all five Great Lakes, possible regulation of three of the lakes (Superior, Erie and Ontario), and possible modification of existing regulation plans to make them more responsive to interests' needs, both upstream and downstream of the regulation structures. Complete details of all these plans are provided in Annex 3.

Five-Lake Regulation (SMHEO).[60] Consideration was given to whether all five of the Great Lakes could be regulated in a manner that would treat the entire system as a unit. Depending upon the specific goals of any particular five-lake regulation plan, this type of regulation would require some or all of the following: dredging and construction of regulation structures in the St. Clair and Detroit Rivers at the outlet of Lakes Michigan-Huron; dredging and construction of regulation structures in the Niagara River at the outlet of Lake Erie; additional protective and mitigation works in the St. Lawrence River at the outlet of Lake Ontario upstream of current regulation structures around Cornwall, Ontario and Massena, New York; and, further dredging and structural works for the St. Lawrence River and Lac Saint-Louis downstream of Cornwall.

Three-Lake Regulation (SEO). Investigations were conducted into various methods for regulating three of the lakes: Superior, Erie and Ontario. These types of plans would call for the addition of structures in the Niagara River

[58]The existing Lake Ontario regulation Plan 1958-D does not function realistically with the substantially reduced water supplies resulting from global warming. This level reduction was calculated assuming that the Lake Ontario outflow would be determined using the pre-regulation Lake Ontario stage-discharge relationship. Because Lake Ontario outflows are completely regulated, its average level could be kept higher with a different regulation scheme, but its average outflows would have to be reduced by 38%.

[59]A regulation plan is a system of procedures that governs the operation of structures that control the outflow from a lake.

[60]This acronym derives from the first letter in the name of each of the five Great Lakes: Superior, Michigan, Huron, Erie, Ontario. Three-lake regulation plans were referred to as SEO, while two-lake plans were called SO..

to reduce outflows from Lake Erie, and dredging of the river bottom to allow for increased flows. A three-lake plan would also call for additional structures and dredging in the St. Lawrence River to allow for changes in Lake Ontario's supplies brought about by regulation of Lake Erie. Under three-lake scenarios,[61] Lake Superior's regulation plan might also be modified to change the balance of water between that lake and Lakes Michigan-Huron, which would in turn cause changes in water supplies to Lakes St. Clair and Erie. Depending upon specific modifications and additions, such plans — although referred to as three-lake regulation — would affect the levels of all the lakes.

Two-Lake Regulation (SO). This manner of regulation would call for changes to the existing regulation plans for Lakes Superior and Ontario to allow them to operate outside some of their current restrictions. The plans would be operated with a system-wide view to more effectively respond to the needs of affected interest groups.

Regulation Plan 1958-D[62] Modified. Possible modifications to Lake Ontario's regulation plan were considered. Each of these was aimed at achieving a more desirable balance among the interests upstream and downstream of the regulation structure at Cornwall, Ontario/Massena, New York.

Regulation Plan 1977-A[63] Modified. In a way similar to the modified plan for Lake Ontario, Lake Superior's current regulation plan was examined for ways to improve its responsiveness to interests both upstream and downstream of the regulation structure at Sault Ste. Marie, Michigan/Ontario.

Variations for each of these plans were examined. These examinations included investigations of how some of the plans would respond to extremely high or extremely low water supplies. These scenarios were tested using the preferred levels of various interests, including riparians, recreational boaters, commercial shippers, hydropower utilities, and the environment. In all, 44 five-lake regulation plans, 65 three-lake plans, and 62 two-lake regulation plans were developed and examined. These examinations narrowed down further consideration of possible regulation plans in the study's multi-objective multi-criteria evaluation process (described in Chapter 2). Of all the plans developed, twenty-one were evaluated using this process.

Four of the possible plans (two for five-lake regulation, one for three-lake regulation, and one for Lake Ontario regulation) were tested in a computer model that attempted to optimize their benefits. This model treated the Great Lakes-St. Lawrence River System as a unit and attempted to minimize a regulation plan's adverse effects throughout the system. Its goal was to meet the preferences of interests to the maximum extent possible. This computer model assumed perfect foreknowledge of water supplies and made corrections to the plans based upon this knowledge.

In preparation for the detailed evaluation, the potential economic costs and benefits of these regulation plans were calculated. In addition, five scenarios underwent detailed assessments to determine their potential impacts upon shoreline flooding and erosion, and upon wetlands and fish habitat. These assessments helped study participants determine which of these measures should be carried forward for recommendation.

4.2.1. Five-Lake Regulation

Seven of the 44 five-lake regulation plans were evaluated using the multi-objective multi-criteria evaluation process. Of these, three focused on the concerns of middle lake riparians (Lakes Michigan-Huron and Erie). These three plans reduced the maximum stillwater fluctuations on the middle three lakes (Michigan-Huron and Erie) to 0.30, 0.50 and 0.61 metre (1, 1.5 and 2 feet) around the long-term monthly mean. In addition, three five-lake

[61]For the purposes of this study, the term "lake level regulation scenario" refers to a hypothetical set of conditions that could be expected to occur if a particular lake level regulation plan were implemented. The "regulation scenarios", which told researchers the lake level and flow conditions that could be expected under various lake regulation plans, allowed evaluations of their economic, social and environmental costs and benefits.

[62]Regulation Plan 1958-D is the plan currently in effect for Lake Ontario.

[63]Regulation Plan 1977-A is the plan currently in effect for Lake Superior.

plans that maximized benefits to the environment, commercial navigation and recreational boating were reviewed. The seventh plan attempted to optimize[64] water levels and flows according to the preferences of all six interests (riparian, commercial navigation, the environment, recreational boating, and hydropower).

4.2.2.
Evaluation of Five-Lake Regulation

4.2.2.1.
Distribution of Impacts

The evaluations found that the economic impacts of five-lake regulation could not be evenly distributed among regions, nor among interests. While shoreline property owners on Lakes Michigan-Huron and Erie would benefit from reduced water level ranges, those on Lake Ontario and the St. Lawrence River would see increased damage as a result of increased supplies from the upper lakes. Meanwhile, even though commercial navigation would benefit from decreased water level ranges on the middle three lakes, hydropower production would be decreased due to increased fluctuations of flows in the St. Marys, Niagara and St. Lawrence Rivers. The effects on recreational boating would be minimal in all locations, with the exception of Lac Saint-Louis, where the effects would be more severe. Wetlands, and possibly fish habitat, on the middle lakes would sustain adverse impacts as a result of five-lake regulation.

4.2.2.2.
Economic Impacts

The implementation costs of the five-lake regulation plans varied from $5.3 billion for the moderate impact riparian plan (± 0.6 metre or 2 feet around the long term monthly mean on Lakes Michigan-Huron and Erie) to a maximum of $10.3 billion for the plan that provided maximum benefits to riparians on Lakes Michigan-Huron and Erie. These plans resulted in projected costs[65] between $482 million and $907 million per year.

The lake regulation measure that provided the greatest compression in the range of levels on Lakes Michigan-Huron and Erie was a five-lake regulation plan that reduced fluctuations to 0.30 metre (1 foot) above and below the monthly mean stillwater level. This plan would result in a net reduction in average annual flood and erosion damage in the order of $1 million. The costs of shore protection that might be avoided due to this decreased range (see discussion on avoided costs earlier in this chapter) could total $26 million. The $1 million reduction in flood and erosion damage would result from a decrease in annual damage on Lakes Michigan-Huron and Erie of $11 million, or 25% of the amount of damage currently sustained. However, this regulation plan would increase flood and erosion damage on Lake Ontario and the St. Lawrence River by $10 million, or 45% of the current annual amount.

This plan would reduce the value of annual hydropower production by almost $50 million, resulting in a loss to hydropower utilities. On the other hand, the plan would result in decreased costs to United States commercial navigation in the order of $45,000, and it would provide some benefits to recreational boating.[66]

Implementation of this plan would require new control structures and dredging in the St. Clair, Detroit and Niagara Rivers, together with additional dredging and new structures in the St. Lawrence River, to compensate for increased outflows from the Great Lakes during periods of high water supplies. The dredging and disposal of contaminated sediments in the St. Clair, Detroit and St. Lawrence Rivers added significantly to the estimated first costs of this plan. Implementation costs were estimated at $10.3 billion. This, together with operating expenses, translated to an annual cost of approximately $907 million.

The economic evaluation of this plan demonstrated that its dollar costs would far exceed any potential benefits it may have provided.

[64]The plan attempted to achieve the preference levels and flows of each interest with the minimum negative impact on other interests.
[65]The annual costs of these plans were calculated by amortizing their initial capital costs using an interest rate of 8% and by projecting their annual operation and maintenance expenses. These costs are expressed in 1991 U.S. dollars.
[66]U.S. system-wide impacts based on 5 U.S. sites investigated.

4.2.2.3. Environmental Impacts

Assessments of the potential environmental impacts of five-lake regulation determined that a reduction of this magnitude in the range of water levels on the middle three lakes would adversely affect the integrity and diversity of wetland plant communities. This would affect the waterfowl, mammals and other species that depend on these wetlands for habitat and sustenance. The effect on fish spawning areas is difficult to predict based on current knowledge, but limited investigations carried out in this study indicate that there would be potential for adverse effects to nearshore fish habitat as a result of a reduction in water level ranges. The environmental evaluation of the change in lake level regimes as a result of this regulation plan found that the environmental impacts on Lakes Michigan-Huron and Erie and the St. Lawrence River were highly negative, and on Lake Ontario, they were negative.[67]

4.2.2.4. Feasibility

Even though regulation of all five of the Great Lakes is engineeringly feasible (in other words, the necessary works could be designed and put into place), the economic assessment indicates that the financial costs of such a plan far exceed the benefits it could provide. Implementation of a five-lake plan would cause a redistribution of the impacts of fluctuating water levels and flows, such that new benefits to some users of the Great Lakes-St. Lawrence River System would come at the expense of disbenefits (not necessarily of equal magnitude) to others. Implementation of a five-lake regulation plan would require major reassignments in the budgetary priorities of the governments of both Canada and the United States. Current federal policies would also make it necessary for further, more detailed, assessments of the potential environmental impacts of such a plan before final approval. Any project that would alter the levels and flows of the system would also require review and approval by the International Joint Commission.

The evaluations of the five-lake regulation plans, and the subsequent multi-objective, multi-criteria evaluation process, led the Study Board to conclude that, although five-lake regulation is engineeringly feasible, it is neither economically efficient nor environmentally acceptable. Consequently, it is unlikely such a plan would be considered feasible from a government or public policy perspective.

4.2.3. Recommendation

The Board recommends that Governments give no further consideration to five-lake regulation.

4.2.4. Three-Lake Regulation

Four of the 65 three-lake regulation plans[68] were evaluated using the multi-objective multi-criteria evaluation process. Of these, two plans optimized[69] flows for power production and one plan attempted to balance the levels and flows around the preferences of individual interests. The fourth plan provided benefits to riparians on Lakes Michigan-Huron and Erie by compressing the range of Lake Erie levels and storing water on Lake Superior. Of all the three-lake plans considered, this plan provided the greatest compression in the range of levels of Lakes Michigan-Huron and Erie, while it caused some expansion in the ranges on Lakes Superior and Ontario and on the St. Lawrence River.

Implementation costs of the three-lake plans varied from a minimum of $352 million for one of the plans favoring the hydropower interest to a maximum of $3.2 billion for the plan that balanced the preferences of all five interests.[70] These plans resulted in annual

[67] In the environmental impact assessments, degrees of impacts were assigned as follows: Highly Negative = any wetland loss greater than 30%, Moderately Negative = any wetland loss between 20%-30%, Negative = any wetland loss between 10%-19%, No Net Impact = positive or negative impact of less than 10%, Positive = any wetland gain between 10%-19%, Moderately Positive = any wetland gain between 20%-30%, Highly Positive = any wetland gain greater than 30%.

[68] For more information on the three-lake regulation plans given detailed consideration, see Annex 3.

[69] The plans attempted to maximize hydropower production without major adverse impacts on other interests.

[70] The five interests considered in the assessment of five and three-lake regulation are: riparians, recreational boating, commercial navigation, hydropower generation, and the environment.

costs (including operation and maintenance and amortization at 8%) between $32 million and $301 million per year.

4.2.5. Measure 1.18 — Three Lake Extended Regulation

Riparians from the middle three lakes who participated in the study, attended the public forums, or corresponded with the Board, expressed support for the three-lake regulation plan that compressed the range of levels on the middle lakes. Of all the three-lake plans reviewed, this plan (known for study purposes as Measure 1.18 SEO—Three-lake Extended[71]) provided the maximum reduction in the range and frequency of fluctuations on Lakes Michigan-Huron and Erie and achieved the highest level of economic efficiency. While this plan produced negative economic impacts for riparians on Lakes Superior, Ontario and the St. Lawrence River, these negative impacts were the lowest of those produced by any

Three Lake Regulation — Level and Flow Impacts (Metric Units) Table 2a[72]

Levels in IGLD (1955) metres Flows in cms	Basis of Comparison		Measure 1.18 SEO Three Lake Extended		Change from BOC		
	Level	**Flow**	**Level**	**Flow**	**Level**	**Flow**	
Mean	183.03	2,209	183.00	2,209	−0.03	0	**Superior**
Maximum	183.45	3,852	183.51	3,965	+0.06	+113	
Minimum	182.48	1,405	182.56	1,416	+0.08	+11	
No. above (183.34 m or 3,680 cms)	38	2	42	36	+4	+34	
No. below (182.88 m or 1,560 cms)	218	8	282	462	+64	+454	
Mean	176.25	5,296	176.21	5,296	−0.04	0	**Michigan/Huron**
Maximum	177.27	6,797	176.94	6,740	−0.33	−57	
Minimum	175.30	3,738	175.42	3,483	+0.12	−255	
No. above (186.48 m or 6,230 cms)	288	42	193	76	−95	+34	
No. below (175.81 m or 4,250 cms)	127	28	72	47	−55	+19	
Mean	174.87	5,409	174.78	5,437	−0.09	+28	**St. Clair**
Maximum	175.74	7,108	175.19	7,052	−0.55	−57	
Minimum	173.99	3,880	174.40	3,512	+0.41	−368	
No. above (175.26 m or 6,230 cms)	126	70	0	119	−126	+49	
No. below (174.25 m or 4,250 cms)	33	13	0	32	−33	+19	
Mean	174.00	5,976	173.86	5,976	−0.14	0	**Erie**
Maximum	174.84	7,873	174.41	7,788	−0.44	−85	
Minimum	173.13	4,333	173.37	3,653	+0.24	−680	
No. above (174.35 m or 6,790 cms)	155	124	1	323	−154	+199	
No. below (173.31 m or 4,810 cms)	16	32	0	217	−16	+185	
Mean	74.58	6,995	74.64	6,995	+0.06	0	**Ontario**
Maximum	75.38	9,912	75.47	9,346	+0.09	−566	
Minimum	73.66	4,990	73.54	5,324	−0.12	+334	
No. above (75.22 m or 8,780 cms)	19	30	14	101	−5	+71	
No. below (74.00 m or 5,320 cms)	13	8	10	0	−3	−8	
Mean	21.14	8,156	21.15	8,184	+0.01	+28	**St. Lawrence River at Pte. Claire**
Maximum	22.46	12,801	22.63	12,857	+0.17	+57	
Minimum	20.19	5,862	20.19	5,607	+0.00	−255	
No. above (22.25 m or 11,330 cms)	3	26	8	52	+5	+26	
No. below (20.27 m or 7,080 cms)	3	275	12	337	+9	+62	
Mean	6.29		6.29		+0.00		**St. Lawrence River at Montréal**
Maximum	8.69		8.85		+0.16		
Minimum	5.08		4.95		−0.13		
No. above (7.62 m)	19		29		+10		
No. below (5.49 m)	30		84		+54		

71 The concept for this plan was initially developed and recommended to the Board by the International Great Lakes Coalition.
72 Flows at Montreal Harbour are not provided since inflows from downstream tributaries and tides affect the level and prevent the calculation of realistic flows. (That is, there is no unique stage-discharge relationship for Montreal Harbour.)

Table 2b[73] Three Lake Regulation — Level and Flow Impacts (English Units)

	Levels in IGLD (1955) metres Flows in 1,000 cfs	Basis of Comparison		Measure 1.18 SEO Three Lake Extended		Change from BOC	
		Level	Flow	Level	Flow	Level	Flow
Superior	Mean	600.49	78	600.39	78	−0.10	0
	Maximum	601.86	136	602.06	140	+0.20	+4
	Minimum	598.68	50	598.95	50	+0.27	0
	No. above (601.50 ft or 130 tcfs)	38	2	42	36	+4	+34
	No. below (600.00 ft or 55 tcfs)	218	8	282	462	+64	+454
Michigan/Huron	Mean	578.26	187	578.12	187	−0.14	0
	Maximum	581.59	240	580.51	238	−1.08	−2
	Minimum	575.13	132	575.51	123	+0.38	−9
	No. above (579.00 ft or 220 tcfs)	288	42	193	76	−95	+34
	No. below (576.80 ft or 150 tcfs)	127	28	72	47	−55	+19
St. Clair	Mean	573.72	191	573.43	192	−0.29	+1
	Maximum	576.56	251	574.77	249	−1.79	−2
	Minimum	570.84	137	572.19	124	+1.35	−13
	No. above (575.00 ft or 220 tcfs)	126	70	0	119	−126	+49
	No. below (571.70 ft or 150 tcfs)	33	13	0	32	−33	+19
Erie	Mean	570.86	211	570.41	211	−0.45	0
	Maximum	573.63	278	572.20	275	−1.43	−3
	Minimum	568.02	153	568.81	129	+0.79	−24
	No. above (572.00 ft or 240 tcfs)	155	124	1	323	−154	+199
	No. below (568.60 ft or 170 tcfs)	16	32	0	217	−16	+185
Ontario	Mean	244.67	247	244.87	247	+0.20	0
	Maximum	247.32	350	247.60	330	+0.28	−20
	Minimum	241.66	176	241.26	188	−0.40	+12
	No. above (246.77 ft or 310 tcfs)	19	30	14	101	−5	+71
	No. below (242.77 ft or 188 tcfs)	13	8	10	0	−3	−8
St. Lawrence River at Pte. Claire	Mean	69.37	288	69.39	289	+0.02	+1
	Maximum	73.69	452	74.25	454	+0.56	+2
	Minimum	66.24	207	66.24	198	0.00	−9
	No. above (73.00 ft or 400 tcfs)	3	26	8	52	+5	+26
	No. below (66.50 ft or 250 tcfs)	3	275	12	337	+9	+62
St. Lawrence River at Montréal	Mean	20.65		20.65		0.00	
	Maximum	28.51		29.04		+0.53	
	Minimum	16.67		16.24		−0.43	
	No. above (25.00 ft)	19		29		+10	
	No. below (18.00 ft)	30		84		+54	

three-lake plan. The environmental impacts of this plan were negative throughout the system, except on Lake Superior.

Measure 1.18 would extend current regulation of Lakes Superior and Ontario to Lake Erie by adding a control structure[74] in the Niagara River to retard flows during periods of low water supply, or during periods when the water supply to Lake Ontario would have to be reduced. The Niagara River would also be dredged to increase its capacity to handle higher flows in periods when outflows from Lake Erie were increased. This plan would require mitigation on the lower St. Lawrence River to compensate for increased discharges from Lake Ontario, due to increased discharges from Lake Erie during periods of high water supplies. This could include land acquisition, shore protection works, dredging and additional works to regulate flows.

[73] See footnote 72.

[74] A control structure is a gated structure (similar to a dam) placed in the river to allow adjustable retardation of flow from the upstream lake.

Measure 1.18 was tested using historic supplies from 1900-1989 on the Great Lakes and supplies from 1950-1989 on the St. Lawrence River (the basis of comparison). Implementation of this plan would result in the changes in monthly mean levels and flows shown in Tables 2a and 2b. In these tables, all levels are referenced to International Great Lakes Datum (IGLD) 1955. Measurements are given in metric units in Table 2a and in English units in Table 2b. Flows for the connecting channels and St. Lawrence River are given in cubic metres per second (cms) and thousands of cubic feet per second (tcfs). The right-hand columns give the levels and flows according to the basis of comparison (BOC), then give levels and flows under Measure 1.18, and finally indicate the increase or decrease from

Distribution of Impacts for Three Lake Regulation **Table 3**[75]

Location	Average Annual Property Damage ($1,000's US) Basis of Comparison	Measure 1.18	Difference	% Change	Environmental Impact
Superior					No net impact
Flooding	1,022	884	138	14%	
Erosion	3,491	3,368	123	4%	
Shore Protection	3,582	3,771	– 189	– 5%	
Michigan					Moderately negative
Flooding	2,086	1,407	679	33%	
Erosion	13,973	12,388	1,405	10%	
Shore Protection	34,785	27,604	7,181	21%	
Huron					Moderately negative
Flooding	1,791	889	902	50%	
Erosion	6,782	6,050	732	11%	
Shore Protection	18,126	14,264	3,862	21%	
St. Clair					Highly negative
Flooding	2,129	8	2,121	100%	
Erosion	3,723	2,550	1,173	32%	
Shore Protection	9,350	5,163	4,187	45%	
Erie					Highly negative
Flooding	4,780	1,901	2,879	60%	
Erosion	9,489	6,805	2,684	28%	
Shore Protection	39,462	28,126	11,336	29%	
Niagara River					Highly negative
Ontario					Highly negative
Flooding	723	769	– 46	– 6%	
Erosion	14,270	14,921	– 651	– 5%	
Shore Protection	18,308	17,592	716	4%	
St. Lawrence River below Cornwall					Moderately negative
Flooding	7,858	10,117	– 2,259	– 29%	
Erosion	Not Available				
Shore Protection	Not Available				
Totals					
Flooding	**20,389**	**15,975**	**4,414**	**22%**	
Erosion	**51,548**	**46,082**	**5,466**	**11%**	
Shore Protection	**123,613**	**96,520**	**27,093**	**22%**	
Total	**195,550**	**158,577**	**36,973**	**19%**	

[75]The economic figures in this table are based on historic stage-damage curves for flooding and erosion and the avoided cost of shore protection for the lakes. Outlet rivers are included with upstream lake. Flooding, erosion and shore protection impacts are not additive. Erosion and shore protection impacts for the lower St. Lawrence were not evaluated. The highly negative environmental impact on the Niagara River is based on the impacts of construction. Wetlands were used as the indicator of environmental impacts. Wetland impacts correlate to percent losses as follows: Highly Negative = any wetland loss greater than 30%, Moderately Negative = any wetland loss between 20%-30%, Negative = any wetland loss between 10%-19%, No Net Impact = positive or negative impact of less than 10%, Positive = any wetland gain between 10%-19%, Moderately Positive = any wetland gain between 20%-30%, Highly Positive = any wetland gain greater than 30%.

the BOC in levels and flows that the new measure would provide. In the left-hand column, the notation, "No. above," refers to the number of months that levels would be above or below the 90-year maximum or minimum (1900-1989). For the lower St. Lawrence River, this notation refers to the 40-year period of 1950-1989.

Implementation of this plan would decrease the maximum stillwater levels on Lakes Michigan-Huron and Erie. On Lakes Superior and Ontario, the maximum level would increase. On the St. Lawrence River at Montréal, the maximum level would increase and the number of occurrences below the 40-year low water level would increase by 176%.

4.2.6. Evaluation of Three-Lake Regulation

4.2.6.1. Distribution of Impacts

Table 3 shows how the impacts on property damage and the environment of this regulation plan would be distributed throughout the system. Impacts on property damage are shown separately for flooding and erosion. The impacts for the St. Marys, St. Clair and Detroit Rivers are included in the figures for their upstream lakes. Damage figures are presented in thousands of dollars. The middle four columns show annual damage under present conditions (the BOC), under Measure 1.18, the differences between those figures, and the percentage of change between the two conditions. Positive numbers indicate reductions in damage (benefits) and negative numbers indicate increases in damage (costs).

Table 3 illustrates that the three-lake extended regulation plan would provide benefits to riparians on Lakes Michigan-Huron and Erie. It would also decrease flooding and erosion damage on Lake Superior. However, it would increase flooding and erosion damage on Lake Ontario and the St. Lawrence River. The reduction in range and frequency of fluctuations on the middle three lakes would negatively affect the wetlands on these lakes.

Table 4 shows the potential distribution of Measure 1.18's impacts on hydropower production. The difference between the costs incurred with the measure and those incurred under the basis of comparison represents the replacement cost of energy due to reductions in production as a result of changes in levels and flows. The costs shown under the Capacity column represent losses incurred, because power plants would not be able to produce to their full capacity. The average annual impact on hydropower value is the total obtained by adding the energy replacement costs and the costs of lost capacity. Negative numbers indicate costs.

The table indicates that hydropower production would suffer negative impacts throughout the Great Lakes-St. Lawrence River System, if Measure 1.18 were implemented.

4.2.6.2. Economic Impacts

The system-wide economic impacts of this plan were calculated. The figures in Table 3 and the best estimate of benefits in Table 5 are based on the estimated change in average annual damage for flooding and erosion using the historic stage-damage curves discussed

Table 4 Distribution of Hydropower Impacts for Three Lake Regulation

Measure 1.18	Average Annual Hydropower Impact ($1,000's US)					
	Energy Value					
	Basis of Comparison	Measure	Difference	% Change	Capacity Costs	Total
St. Marys River	23,309	21,321	– 1,988	– 9%	– 1,134	– $3,122
Niagara River	718,158	715,103	– 3,054	0%	– 4,493	– $7,548
St. Lawrence River above Cornwall	336,272	334,770	– 1,502	0%	93	– $1,409
below Cornwall	308,944	304,992	– 3,952	– 1%	1,365	– $2,587
Total	1,386,683	1,376,187	– 10,496	– 1%	– 4,169	– $14,665

earlier in this chapter.[76] The costs of shore protection that could be avoided were also calculated, based upon the procedure described earlier in this chapter, assuming that uniform replacement of existing shore protection was done over a 25-year period.[77]

The estimated benefits attributed to the avoided costs of shore protection overlap with the benefits from reduced flooding and erosion. It was not possible to estimate the amount of overlap. The Board recognizes that the addition of these benefit categories results in some double counting of benefits, but this addition was done in order to display a benefit-cost ratio. The sum results in a benefit-cost ratio that is higher than would have resulted if the overlap could have been estimated and taken into account.

While the Board has confidence in the best estimate of the benefit-cost ratio, there is a possibility that benefits may be either under or over stated. The possibility that benefits from reduced flooding and erosion may be understated was given further consideration. The maximum plausible benefit shown in Table 5 displays the highest benefit it is reasonable to assume might occur using current data. The maximum plausible benefit due to reduced flood damage was calculated using an alternative approach that incorporated a risk assessment analysis. A site study for one county in the United States[78] indicated that the benefits from reduced erosion could be up to three times higher than the benefit determined through the stage-damage curve for that location. Therefore, the most likely benefit due to decreased erosion damage that is shown in Table 5 incorporates a tripling of all erosion benefits to establish a figure that reflects the highest possible benefit.

Two columns of costs are shown: The Best Estimate column gives the estimate of the most likely benefits, based upon the available

Benefit Cost Analysis of Three Lake Regulation **Table 5**

Benefit Cost Analysis	Best Estimate	Maximum Plausible
Benefits (average annual at 8%)		
Property Damage		
Reduction of Flooding	$6,673,000	$18,493,000
Reduction of Erosion	$5,466,000	$16,398,000
Avoided Cost of Shore Protection	$27,093,000	$27,093,000
Losses in Hydropower	– $14,665,000	– $14,665,000
Gains to Commercial Navigation[79]	$494,000	$494,000
Losses to Recreation Boating[80]	– $106,000	– $106,000
Total	$24,955,000	$47,707,000
Construction Costs		
Niagara River	$527,874,000	$527,874,000
St. Lawrence River Mitigation	$2,854,000,000	$2,854,000,000
Total	$3,381,874,000	$3,381,874,000
Average Annual Costs (at 8%)		
Niagara River	$46,250,000	$46,250,000
St. Lawrence River Mitigation	$275,294,000	$275,294,000
Total	$321,544,000	$321,544,000
Benefit Cost Ratio	0.08	0.15

[76]An increase in flooding on the St. Lawrence River is not reflected in Table 5, because the plan assessed in the table assumes installation of mitigation works.

[77]For additional information on these methodologies see Annex 2.

[78]Potential Damages Task Group, Working Committee 2, *Detailed Site Study Report - Berrien County, Michigan* (1993).

[79]U.S. impact is a loss of $3,348,000. Canadian impact is a gain of $3,842,000. The net impact is shown.

[80]U.S. impact for five 5 U.S. sites investigated extrapolated to system-wide.

information. The Maximum Plausible column gives the highest possible benefits it is reasonable to assume might occur, based upon available information. In the upper section of the table, average annual benefits are indicated by positive numbers, and costs (or disbenefits/ losses) are indicated by negative numbers. In the middle section, costs are indicated by positive numbers. The bottom of the table gives the estimated range of the benefit-cost ratio calculated by dividing average annual benefits by average annual costs.

The table indicates that the most likely reduction in property damage due to flooding and erosion would be $12,139,000, and that the maximum plausible reduction would be $34,891,000. The possible benefits due to avoided costs of well-engineered shore protection would be $27,093,000 in both cases.

Assessments of the potential impacts on other interests of this plan found that the value of hydropower production would be decreased by $14,665,000. The net gain to commercial navigation would be $494,000, although there would be a loss of $3,348,000 in the United States. Meanwhile, costs to recreational boating in the United States would rise by approximately $106,000.

Implementation of this measure would require dredging and construction of control works in the Niagara River. It would also require construction of mitigation works to compensate for increased and decreased flows along the St. Lawrence River downstream of Cornwall. In all, the components of this regulation plan would result in an average annual cost of $321,544,000. It may be possible to modify the operating plan for Measure 1.18 to somewhat reduce the impact of high and low flows on the St. Lawrence River. This could reduce the cost of mitigation works on the lower St. Lawrence, but it would also reduce the amount by which property damage could be decreased on Lakes Michigan-Huron and Erie.

The most likely benefit cost ratio is 0.08 and the maximum likely benefit cost ratio is 0.15. These numbers are considerably less than a benefit cost ratio of 1.0 which is needed for the benefits of the project to equal the costs.

A comparison of the economic positives and negatives of the plan follows:

Positives	
Lakes Superior, Michigan, Huron, St. Clair and Erie	
Flooding and Erosion Reduction	$12,836,000
Lakes Michigan, Huron, St. Clair, Erie and Ontario	
Avoided Cost of Shore Protection	$27,282,000
Canadian Commercial Navigation Gains	$3,842,000
Negatives	
Lake Ontario and St. Lawrence River	
Flooding and Erosion Increase[81]	$2,956,000
Lake Superior	
Increased Cost of Shore Protection	$189,000
Hydropower Losses	$14,665,000
U.S. Commercial Navigation Losses[82]	$3,348,000
U.S. Recreation Boating Losses[83]	$106,000
Annual Cost of Implementation and Maintenance	
Niagara River	$46,250,000
St. Lawrence River Mitigation	$275,294,000

These evaluations led the Study Board to conclude that, from an economic standpoint, the reduction of damage sustained by riparian properties on the middle three lakes would not be adequate to support the total costs of the part of this plan that calls for control works and dredging in the Niagara River. Consequently, even if such a plan could be operated so that there were no adverse impacts to the lower St. Lawrence River, its costs would still exceed its benefits.

4.2.6.3. Environmental Impacts

As with the assessment of the environmental impacts of five-lake regulation, examination of the potential impacts that Measure 1.18 would have upon wetlands and fish habitat in Lakes Michigan-Huron, Erie and Ontario determined that these environmental indicators would be adversely affected. These adverse effects would result from changes in the timing and

[81] The installation of the St. Lawrence River mitigation works referred to in Table 5 at a construction cost of $2,854,000,000 reduces this figure to $697,000.

[82] There would also be adverse impacts to the port of Montréal. These could not be fully quantified as traffic would be diverted to other ports in cases of low water levels.

[83] There would also be losses to Canadian recreational boating throughout the Great Lakes. These losses were not quantified in dollars.

magnitude of high and low water levels, increases in the variability of flows in the connecting channels, and increases in flooding of forests in flood plains along the St. Lawrence River. These assessments concluded that the overall environmental impact of this measure would be negative.

4.2.6.4. Feasibility

The three-lake extended regulation plan would redistribute impacts and have costs that exceed its benefits. The plan would decrease flooding and erosion damage on the middle three lakes. It was the most feasible and the most economically efficient of the regulation plans reviewed with the primary objective to reduce flooding and erosion damage on the middle three lakes. It would have a significant negative environmental impact.

As with five-lake regulation, this three-lake regulation plan is engineeringly feasible. Because it would require fewer structures and less dredging than a five-lake plan, this measure could also be implemented more quickly, and at less cost, than five-lake regulation. However, its economic costs would still be high; design and construction would take several years, and detailed environmental assessments would be required. Such assessments might call for mitigation of major environmental impacts. At a capital cost of $3.38 billion this plan would also require significant funding commitments from federal, state and provincial governments. Finally, the regulation plan would have to be reviewed and approved by the International Joint Commission.

4.2.7. Recommendation

Under the present economic evaluation, this plan has a negative economic efficiency. The environmental impact of the measure is negative in all areas except Lake Superior.

The Board recommends that Governments give no further consideration to three-lake regulation.

4.2.8. Two-Lake Regulation

Outflows from Lakes Superior and Ontario are currently regulated by separate plans designed to meet criteria[84] established by the International Joint Commission when it approved regulation of each of the lakes. In this study, two-lake regulation refers to potential modifications to these two plans.

Lake Superior Regulation Plan 1977-A regulates Lake Superior's outflows through the St. Marys River. The plan uses a technique that attempts to balance the levels of Lakes Superior and Michigan-Huron about their mean levels, giving consideration to their natural ranges. A 16-gate control structure and hydropower plants in the St. Marys River between Sault Ste. Marie, Ontario, and Sault Ste. Marie, Michigan, are the works used to regulate Lake Superior's water levels and flows.

Lake Ontario Regulation Plan 1958-D is used to regulate the outflows from Lake Ontario through the St. Lawrence River, according to criteria set by the Commission. The objective of this plan is to maintain lake Ontario's levels within a fixed range, while providing safeguards against extremely high or low levels and flows upstream and downstream of the regulation structure. The main structure for regulating the outflows is the Saunders-Moses power dam located in the St. Lawrence River between Cornwall, Ontario and Massena, new York. The nearby Long Sault Dam acts as a spillway when outflows from Lake Ontario are higher than the capacity of the power dam. Another dam near Iroquois, Ontario, together with ice booms, is used to aid in the formation of stable ice cover in the winter in order to avoid ice jams. This dam can also be used to regulate flows.

The study reviewed more than 62 possible modifications to the existing regulation plans and settled upon ten modifications to be subjected to the multi-objective, multi-criteria evaluation process. From these, one two-lake plan was selected as the most promising. For study purposes, it is known as Measure 1.21.

[84]When the International Joint Commission approves an application for regulation of lake levels and flows, its consent (called orders of approval) may include conditions and criteria governing the construction and operation of regulation facilities. In the cases of Lakes Superior and Ontario, a number of these criteria are set out specifically in the regulation plans.

This measure would modify the outflow forecasts used in Lake Superior Plan 1977-A, increase the maximum winter outflow limit, modify the balancing relationship for Lakes Superior and Michigan-Huron, and revise the minimum flow limit during periods of low levels on Lake Superior.

The same measure would revise Lake Ontario Plan 1958-D by increasing the maximum flow limits to better reflect actual practice; by modifying the seasonal outflows to better balance the needs of upstream recreational boating (Lake Ontario and St. Lawrence River to Cornwall) with downstream commercial navigation and recreational boating (St. Lawrence River below Cornwall); by incorporating a limited amount of discretionary[85] outflows in winter to discharge more water in times of high supply when ice conditions permit; and by

Table 6a[86] Two Lake Regulation — Level and Flow Impacts (Metric Units)

	Levels in IGLD (1955) metres Flows in cms	Basis of Comparison		Measure 1.21 SO Two Lake Plan		Change from BOC	
		Level	**Flow**	**Level**	**Flow**	**Level**	**Flow**
Superior	Mean	183.03	2,209	183.00	2,209	−0.03	0
	Maximum	183.45	3,852	183.52	3,370	+0.08	+481
	Minimum	182.48	1,405	182.43	1,558	−0.05	+153
	No. above (183.34 m or 3,680 cms)	38	2	40	0	+2	−2
	No. below (182.88 m or 1,569 cms)	218	8	303	0	+85	−8
Michigan/Huron	Mean	176.25	5,296	176.25	5,296	0.00	0
	Maximum	177.27	6,797	177.22	6,712	−0.05	−85
	Minimum	175.30	3,738	175.38	3,852	+0.08	+113
	No. above (186.48 m or 6,230 cms)	288	42	281	39	−7	−3
	No. below (175.81 m or 4,250 cms)	127	28	121	24	−6	−4
St. Clair	Mean	174.87	5,409	174.87	5,409	0.00	0
	Maximum	175.74	7,109	175.71	7,023	−0.02	−85
	Minimum	173.99	3,880	174.05	3,965	+0.06	+85
	No. above (175.26 m or 6,230 cms)	126	70	121	65	−5	−5
	No. below (174.25 m or 4,250 cms)	33	13	25	12	−8	−1
Erie	Mean	174.00	5,976	174.00	5,976	0.00	0
	Maximum	174.84	7,873	174.83	7,845	−0.01	−28
	Minimum	173.13	4,333	173.18	4,390	+0.05	+57
	No. above (174.35 m or 6.790 cms)	155	124	152	120	−3	−4
	No. below (173.31 m or 4.810 cms)	16	32	13	28	−3	−4
Ontario	Mean	74.58	6,995	74.58	6,995	+0.01	0
	Maximum	75.38	9,912	75.54	9,912	+0.16	0
	Minimum	73.66	4,990	73.79	5,098	+0.13	+108
	No. above (75.22 m or 8,780 cms)	19	30	9	41	−10	+11
	No. below (74.00 m or 5,320 cms)	13	8	8	3	−5	−5
St. Lawrence River at Pte. Claire	Mean	21.14	8,156	21.15	8,156	0.00	0
	Maximum	22.46	12,801	22.39	12,489	−0.07	−312
	Minimum	20.19	5,862	20.20	5,834	+0.01	−28
	No. above (22.25 m or 11,330 cms)	3	26	3	20	+0	−6
	No. below (20.27 m or 7,080 cms)	3	275	3	261	+0	−14
St. Lawrence River at Montréal	Mean	6.29		6.29		0.00	
	Maximum	8.69		8.62		−0.07	
	Minimum	5.08		5.08		0.00	
	No. above (7.62 m)	19		17		−2	
	No. below (5.49 m)	30		28		−2	

85Lake Ontario's regulation plan allows the International St. Lawrence River Board of Control to use its discretion in setting outflows at times when strict adherence to the prescribed flows could result in extremely high or low water levels or flows. The use of this discretionary authority is referred to as a "deviation" from the regulation plan. The Lake Superior Board of Control does not have this discretionary authority.

86Flows at Montréal Harbour are not provided since inflows from downstream tributaries and tides affect the level and prevent the calculation of realistic flows. (That is, there is no unique stage-discharge relationship for Montréal Harbour.)

Two Lake Regulation — Level and Flow Impacts (English Units) Table 6b[87]

Levels in IGLD (1955) metres Flows in 1,000 cfs	Basis of Comparison		Measure 1.21 SO Two Lake Plan		Change from BOC		
	Level	Flow	Level	Flow	Level	Flow	
Mean	600.49	78	600.39	78	−0.10	0	**Superior**
Maximum	601.86	136	602.11	119	+0.25	−17	
Minimum	598.68	50	598.52	55	−0.16	+5	
No. above (601.50 ft or 130 tcfs)	38	2	40	0	+2	−2	
No. below (600.00 ft or 55 tcfs)	218	8	303	0	+85	−8	
Mean	578.26	187	578.26	187	0.00	0	**Michigan/Huron**
Maximum	581.59	240	581.42	237	−0.17	−3	
Minimum	575.13	132	575.39	136	+0.26	+4	
No. above (579.00 ft or 220 tcfs)	288	42	281	39	−7	−3	
No. below (576.80 ft or 150 tcfs)	127	28	121	24	−6	−4	
Mean	573.72	191	573.73	191	+0.01	0	**St. Clair**
Maximum	576.56	251	576.49	248	−0.07	−3	
Minimum	570.84	137	571.03	140	+0.19	+3	
No. above (575.00 ft or 220 tcfs)	126	70	121	65	−5	−5	
No. below (571.70 ft or 150 tcfs)	33	13	25	12	−8	−1	
Mean	570.86	211	570.87	211	+0.01	0	**Erie**
Maximum	573.63	278	573.59	277	−0.04	−1	
Minimum	568.02	153	568.17	155	+0.15	+2	
No. above (572.00 ft or 240 tcfs)	155	124	152	120	−3	−4	
No. below (568.60 ft or 170 tcfs)	16	32	13	28	−3	−4	
Mean	244.67	247	244.69	247	+0.02	0	**Ontario**
Maximum	247.32	350	247.83	350	+0.51	0	
Minimum	241.66	176	242.09	180	+0.43	+4	
No. above (246.77 ft or 310 tcfs)	19	30	9	41	−10	+11	
No. below (242.77 ft or 188 tcfs)	13	8	8	3	−5	−5	
Mean	69.37	288	69.38	288	+0.01	0	**St. Lawrence River at Pte. Claire**
Maximum	73.69	452	73.46	441	−0.23	−11	
Minimum	66.24	207	66.27	206	+0.03	−1	
No. above (73.00 ft or 400 tcfs)	3	26	3	20	0	−6	
No. below (66.50 ft or 250 tcfs)	3	275	3	261	0	−14	
Mean	20.65		20.65		0.00		**St. Lawrence River at Montréal**
Maximum	28.51		28.28		−0.23		
Minimum	16.67		16.67		0.00		
No. above (25.00 ft)	19		17		−2		
No. below (18.00 ft)	30		28		−2		

coordinating spring outflows from Lake Ontario with those from the Ottawa River to reduce the incidence of spring flooding in the Montréal area when Lake Ontario is below flood stage .

Implementation of Measure 1.21 would result in the changes in monthly mean lake levels and flows that are shown in Tables 6a and 6b. In these tables, all levels are referenced to International Great Lakes Datum (IGLD) 1955. Flows for the connecting channels and St. Lawrence River are given in cubic metres per second (cms) in Table 6a and in thousands of cubic feet per second (tcfs) in Table 6b. The right-hand columns give the levels and flows according to the basis of comparison (BOC), then give levels and flows under Measure 1.21, and finally indicate the increase or decrease from the BOC in levels and flows that the new measure would provide. In the left-hand column, the notation, "No. above," refers to the number of months that levels would be above or below the 90-year maximum or minimum (1900-1989). For the lower St. Lawrence River, this notation refers to the 40-year period between 1950-1989.

[87] See footnote 86.

Implementation of this plan would increase the maximum stillwater levels on Lake Superior and lower its long-term mean. On Lakes Michigan-Huron, St. Clair and Erie, the maximum elevations would be reduced. On Lake Ontario, maximum and minimum lake levels would increase over their current elevations. The maximum level would be decreased on the St. Lawrence River at Pointe Claire and Montréal.

4.2.9. Evaluation of Two-Lake Regulation

4.2.9.1. Distribution of Impacts

The distribution of high and low levels throughout the seasons is important for wetlands, recreational boating, and commercial navigation on Lake Ontario and the St. Lawrence River. On average, Measure 1.21 would decrease Lake Ontario levels from January through April, and it would increase levels in May through November. This increase could provide benefits to recreational boaters and commercial navigation. The current average for levels would be maintained in December. On the St. Lawrence River at Montréal, implementation of this plan would increase average levels from January through March, decrease levels from April through August, and keep levels essentially the same in September. Slight increases would be seen in October and November, with a slightly greater increase in December.

Table 7 shows the distribution of property damage and environmental impacts among regions. Property damage for flooding and erosion are shown separately. Impacts on the St. Marys, St. Clair and Detroit Rivers are included in the figures for their upstream lakes.

Table 7[88] Distribution of Impacts for Two Lake Regulation

		Average Annual Property Damage ($1,000's US)				
		Basis of Comparison	Measure 1.21	Difference	% Change	Environmental Impact
Superior						No net impact
	Flooding	1,022	928	94	9%	
	Erosion	3,491	3,393	98	3%	
Michigan						No net impact
	Flooding	2,086	2,037	49	2%	
	Erosion	13,793	13,733	60	0%	
Huron						No net impact
	Flooding	1,791	1,698	93	5%	
	Erosion	6,782	6,780	2	0%	
St. Clair						No net impact
	Flooding	2,129	1,931	198	9%	
	Erosion	3,723	3,668	55	1%	
Erie						No net impact
	Flooding	4,780	4,684	96	2%	
	Erosion	9,489	9,283	206	2%	
Ontario						Negative
	Flooding	723	689	34	5%	
	Erosion	14,270	14,165	105	1%	
St. Lawrence River below Cornwall						
	Flooding	7,858	7,856	2	0%	
	Erosion	Not Available				
Totals						
	Flooding	**20,389**	**19,823**	**566**	**3%**	
	Erosion	**51,548**	**51,022**	**526**	**1%**	
	Total	**71,937**	**70,845**	**1,092**	**2%**	

88 The economic figures in this table are based on historic stage-damage curves for flooding and erosion. Outlet rivers are included with upstream lake.

Table 8 — Measure 1.21

Distribution of Hydropower Impacts for Two Lake Regulation

Average Annual Hydropower Impact ($1,000's US)

	Energy Value: Basis of Comparison	Energy Value: Measure	Energy Value: Difference	% Change	Capacity Costs	Total
St. Marys River	23,309	23,282	–27	0%	–72	–$99
Niagara River	718,158	718,744	586	0%	103	$690
St. Lawrence River above Cornwall	336,272	336,263	–9	0%	68	$59
below Cornwall	308,944	309,243	299	0%	393	$692
Total	1,386,683	1,387,532	849	0%	492	$1,341

Damage figures are presented in thousands of dollars. The middle four columns show annual damage under present conditions (the BOC), under Measure 1.21, the differences between those figures, and the percentage of change between the two conditions. Positive numbers indicate reductions in damage (benefits) and negative numbers indicate increases in damage (costs).

Implementation of this measure would decrease flood and erosion damage throughout the system. It would have no impact on the wetlands of Lakes Superior, Michigan-Huron, St. Clair and Erie. However, Lake Ontario wetlands would sustain negative impacts due to changes in the frequency and timing of water level fluctuations.

Table 8 shows the distribution by region of hydropower production impacts as a result of Measure 1.21. The difference between the Measure column and the Basis of Comparison column represents the replacement cost of energy from reduced energy production as a result of changes in levels and flows. The cost shown under the Capacity column represents losses due to the inability of plants to run at their full capacity. The average annual impact of Measure 1.21 on hydropower value is the sum of energy replacement costs and costs due to loss in capacity. Positive numbers indicate benefits, and negative numbers indicate disbenefits.

4.2.9.2. Economic Impacts

The system-wide benefits and costs of Measure 1.21 are shown in Table 9. In the upper section of the table, average annual benefits are indicated by positive numbers. Because the works used to regulate the levels of Lakes Superior and Ontario are already in place, as are the boards of control that oversee the operation of the plans, revisions to these plans could be instituted at no additional capital costs. There would be no additional annual costs over and above those that already exist. Consequently, the Costs section of Table 9 shows that the average annual costs of Measure 1.21 would be zero.

Table 9

Benefits and Costs of Two Lake Regulation

Benefits and Costs	
Benefits (average annual)	
Property Damage	
Reduction in Flooding	$566,000
Reduction in Erosion	$526,000
Gain to Hydropower	$1,341,000
Gain to Commercial Navigation	$4,125,000
Gain to Recreation Boating[89]	$325,000
Total	$6,883,000
Costs (average annual @ 8%)	$0

Implementation of this measure would reduce average annual flooding and erosion damage by $1,092,000. The value of average annual hydropower production would be increased by $1,341,000. Meanwhile, transportation costs for commercial navigation would be reduced by an average of $4,125,000 per year. This includes domestic and international shipments. The impacts of Measure 1.21 on recreational boating on Lake Ontario would be low.

4.2.9.3. Environmental Impacts

Investigations during this study indicate that the extent, diversity and integrity of wetlands surrounding Lake Ontario have already been adversely affected by decreased ranges in

[89] Impact for five 5 U.S. sites investigated extrapolated to system-wide.

water levels brought about by regulation of the lake's levels and outflows. Flood plain forests located along the St. Lawrence River have also sustained flooding and erosion as a result of regulation. The overall impact on the environment of Measure 1.21 would be incremental on Lake Ontario. However, a change in the timing of water level peaks would have a further negative effect. While Lake Superior regulation has affected wetlands and fish habitat of that lake to some extent, the implementation of Measure 1.21 would have no additional effect on these environmental indicators for Lakes Superior, Michigan-Huron, St. Clair and Erie.

4.2.9.4. Feasibility

Since Measure 1.21 could be implemented at no additional capital cost, and since it would require only revisions to current regulation plans, it is both technically feasible and likely to have characteristics that fit within current policies of the Governments of Canada and the United States. This measure has the highest economic efficiency and the minimum environmental impact of any of the lake regulation measures reviewed. Nevertheless, the environmental impacts would be negative.

4.2.10. Review of Current Regulation Criteria

Changes to the levels and outflows of Lakes Superior and Ontario would not, by themselves, form a complete response to the changing needs of Great Lakes-St. Lawrence System users. The original criteria for Lake Superior's regulation plan were written in 1914 and modified in 1979. The criteria for Lake Ontario's regulation plan were written in 1952 and supplemented in 1956. Review of the existing regulation plans found that the needs of users have changed since these criteria were prepared.

Since the implementation of regulation of lake Ontario, recreational boating has become an important and significant use of Lake Ontario and the entire St. Lawrence River. Recent studies have found that reduced ranges on Lake Ontario as a result of regulation have adversely affected wetlands and flood plain forests of Lake Ontario and the St. Lawrence River.

The current criteria for regulation of Lake Ontario reflect needs for domestic water supply, commercial navigation, hydropower and riparians, as those needs existed in the 1950's. There are no criteria specifically related to the needs of recreational boating or the environment. Criteria should be added to reflect the needs of these two interests. A review of the current criteria for the regulation plans of Lakes Ontario and Superior identified specific opportunities for improvements. However, these potential modifications should be reviewed understanding that any modification to the current distribution of water within the system would also modify the distribution of positive and negative impacts.

Criterion (d) of the Orders of Approval for regulation of Lake Ontario provides that "The regulated outflow from Lake Ontario during the annual flood discharge from the Ottawa River shall not be greater than would have occurred assuming supplies of the past as adjusted." The purpose of this criterion is to prevent an increase in damage downstream of the Ottawa River mouth over and above those that would have occurred without regulation. When Lake Ontario levels allow, deviations from the plan are used to reduce lake outflows and provide additional relief to the downstream interests during the Ottawa River freshet that normally occurs in April, May or June. Including a specific reference to this practice in the regulation plan's criteria would ensure that it continues.

The regulation plan for Lake Ontario gives discretionary authority to the St. Lawrence Board of Control to deviate from the plan. This allows a degree of flexibility in day-to-day operations. Similar authority for the Lake Superior board would allow more efficient adjustment to developing conditions, improving the regulation plan's ability to achieve a balance between upstream and downstream requirements.

Further opportunities for modification of Lake Superior's regulation plan were also identified in the course of this study. They are described in detail in Annex 3.

4.2.11. Recommendations

The Board recommends that the regulation plans of Lakes Superior and Ontario be modified to achieve water levels and flows similar to those described in Measure 1.21.

The Board recommends that the Orders of Approval for the Regulation of Lake Superior be reviewed to determine if the current criteria are consistent with the current uses and needs of the users and interests of the system.

The Board recommends that the International lake Superior board of control be authorized to use its discretion in regulating the outflows from Lake Superior subject to conditions similar to those which authorize discretionary action by the International St. Lawrence River Board of Control.

The Board recommends that the criteria of 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 particular, the Board recommends that Criterion (d) of these orders be amended as follows:

> **Criterion (d): The regulated outflow from Lake Ontario during the annual flood discharge from the Ottawa River shall not be greater than would have occurred assuming supplies from the past as adjusted. *When Lake Ontario levels and supply allow, consideration should be given to reducing outflows from Lake Ontario during the annual flood discharge from the Ottawa River.***

The Board recommends that the Orders of Approval for the Regulation of Lake Ontario be modified by adding the following criteria:

> **Criterion ( ): Consistent with other requirements, the outflows of lake Ontario shall be regulated to minimize the occurrence of low water levels on Lake Ontario and the St. Lawrence River downstream as far as Trois Rivières during the recreational boating season.**

Criteria should be added that consider the environmental interest on Lake Ontario and the St. Lawrence River downstream as far as Trois Rivières.

4.3. CHANNEL CHANGES IN THE NIAGARA RIVER

The outflow capacity of Lake Erie has been affected by changes to the Niagara River and the diversion of water through the Welland Canal. The river's capacity has not been affected by dredging, but it has been affected by fill in the river, which in turn has affected the levels of Lake Erie. The Special International Niagara Board of 1928 reported three major changes in the level regime of the upper Niagara River in the period before 1926: construction of the piers for the International Bridge at Squaw Island in 1872; dumping of rock and earth above the first cascade during the 1918-1921 period; and construction of piers for the Peace Bridge in 1925. Since that report, additional obstructions have been placed in the river, which have affected its ability to pass water out of Lake Erie. These further obstructions are: construction of the Bird Island Pier, which separates the Black Rock Lock and canal from the river; the placement of fill at Mather Park at Fort Erie; the placement of fills at Nicholl's Marine; the Buffalo water intake, the fill at Squaw Island, and other fills immediately downstream of the International Railway Bridge.

The cumulative impact of these fills and obstructions has been to raise Lake Erie's level by between 0.12 metre (0.4 foot) and 0.16 metre (0.53 foot).[90] The combined impact of channel obstructions on the Niagara River and the increase in outflow through the Welland

[90] These figures are different from those presented in Table 1, page 12, because a different method was used to calculate the impacts. See Annex 3 for more information.

Canal (which, by itself, has a lowering effect on the lake) has been a net increase to Lake Erie's level of about 0.04 metre (0.14 foot).

A 1987 Task Force Report[91] to the Commission determined the potential impact of the removal of specific fills in the Niagara River. Of particular interest were two recent fills on the Canadian shoreline upstream of the International Railway Bridge. The 1987 report indicated that removal of the fills and some streamlining of the shoreline at Mather Park, Nicholl's Marine and removal of the fills at, and adjacent to, an area then known as the Utvich property would lower the levels of Lake Erie between 0.03 and 0.06 metre (0.1 and 0.2 foot). The report also indicated that the major portion of this lowering could be affected by removal of the fills at Mather Park and Nicholl's Marine.

The Mather Park fill is in a shallow area of the river with little flow conveyance. Removal of the fill in this area would have negligible impact on Lake Erie levels unless additional material were excavated. In effect, this would constitute a channel improvement as well as a fill removal.

The cost of fill removal at the Nicholl's Marine site, and the removal of all fills to align the shoreline with the upstream and downstream approaches, is estimated at $271,000. The estimated cost for removal of fills adjacent to the Utvich property is $187,000. The estimated cost for removal of fills at Mather Park is $1,164,000. The estimated total cost for removal of fills, including removal, improvement and streamlining of shoreline at Mather Park, is $1,622,000. These estimates do not include the cost of acquisition of land rights. The removal of the Nicholl's Marine fill and possibly part of the other fills would restore the Lake Erie outflows to the conditions existing prior to their installation.

The removal of these obstructions would require care to avoid worsening possible future low water conditions. Measures to remove fills in the Niagara River should be part of a larger strategy that involves shoreline and land use management measures to prevent future obstructions in connecting channels, as discussed in the Land Use and Shoreline Management Measures portion of this chapter. Currently, the federal government in Canada does not have a means to prevent such fills, but the International Rivers Improvement Act could be amended to provide this authority.

4.3.1. Recommendations

The Board recommends initiating negotiations for the purpose of removing fills upstream of the International Railway Bridge on the Niagara River and lowering the mean level of Lake Erie by 0.03 to 0.06 metre (0.1 to 0.2 foot).

The Board further recommends that Nicholl's Marine be the first priority for fill removal.

4.4. LAND USE AND SHORELINE MANAGEMENT MEASURES

Regardless of whether a shoreline property is located on a regulated lake or an unregulated lake, risks of flooding and erosion are always present to varying degrees. Storms will continue to cause short-term high water level events that lead to flooding and erosion; and erosion of some types of shoreline will continue independently of changes in water levels. In addition, extremes in long-term water level fluctuations can be expected in the future, just as they have occurred in the past. This study investigated land use and shoreline management measures that are currently in use around the Great Lakes-St. Lawrence River Basin. The study developed recommendations for improving and expanding the application of those most effective in alleviating the adverse consequences of fluctuating water levels. While even these measures cannot completely eliminate all shoreline damage, they can often provide practical and effective solutions to specific shoreline problems, if undertaken in concert and harmony with conditions unique to each site or locale.

[91] International Joint Commission, *Interim Report on 1985-86 High Water Levels in the Great Lakes-St. Lawrence River Basin*, Appendix A - Summary, Great Lakes Levels Task Force (October 1988).

The recommendations in this section are made independently of considerations about whether to further regulate the Great Lakes and St. Lawrence River. Regardless of whether lake levels and outflows are artificially kept within prescribed ranges, land use and shoreline management practices are required to reduce the still-present risks to shoreline property. The measures detailed in the following section are recommended for consideration along the entire Great Lakes-St. Lawrence River System, which includes the currently regulated Lakes Superior and Ontario, as well as the unregulated Lakes Michigan-Huron, St. Clair and Erie. Nevertheless, because of the variable nature of the system's shorelines, and the consequent variations in the nature of local shoreline problems, measures may be applicable in some areas and not in others. It is likely, however, that every location with water level-related problems on its shorelines can apply at least one of the land use and shoreline management measures discussed here. All of the measures recommended here would be undertaken on a community-wide scale, with regional coordination and with funding from all levels of government.

4.4.0.1. Multi-Objective Planning

To be truly responsive to local situations, such land use and shoreline management measures would have to incorporate multi-objective planning. This is a local or regional approach to coordinated planning. The approach uses objectives that are important to the region. They may be related to water quality, water quantity, natural habitat, open space, public access, and greenways. Multi-objective planning emphasizes "bottom-up" planning and the inclusion of all interested citizens, private and public interest groups, and various levels of government.

Multi-objective planning involves more than finding the most "economically efficient" answer to a particular problem. It allows the integration of diverse and sometimes conflicting objectives and values, and it establishes a framework for finding broadly-supported solutions. This approach to comprehensive and coordinated land use and management measures can ensure both appropriateness and public acceptance of local practices.

4.4.0.2. Permit Requirements and Monitoring

In order to implement land use and shoreline management measures on the comprehensive scale suggested in this chapter, effective monitoring and permitting programs would be required. Permitting of construction would allow local control of development in hazard areas, and it would facilitate the monitoring of development to ensure that it conforms to locally-enacted and comprehensively-planned zoning objectives. Monitoring of development would also assist in determining the effectiveness and appropriateness of particular measures.

4.4.1. Funding Options

Funding for land use and shoreline management measures is often difficult to acquire and maintain. Often, programs are planned with the best intentions, yet funding is not made available for implementation. This limits the effectiveness of land use and shoreline management measures to prevent or reduce flood and erosion damage. Some of the measures described here are capital intensive, such as large-scale shore protection or land acquisition. These types of measures may also be long-term in nature and require long-term funding and policy commitments. Since most matters of zoning and municipal planning are within the jurisdiction of municipal governments, these governments often are expected to carry the brunt of the financial burden; yet, they have the smallest treasury from which to draw. These factors can inhibit the effectiveness, if not prevent implementation, of comprehensive land use and shoreline management plans.

These obstacles could be overcome by a funding program shared among federal, provincial and local governments. Such funding could be used to plan and implement large-scale activities, or to capitalize loan programs as incentives for implementation of projects.

tally-friendly alternative for shore protection. However, the shoreline characteristics must be amenable to, and appropriate for, this approach. At Long Point Provincial Park, Ontario, vegetation planting was used in sand dune stabilization research projects in 1978.[96] Costs to implement bio-stabilization projects vary considerably due, primarily, to the types of plants used and the size of the area to be protected.

4.4.4.4. Structural Shore Protection

For the purposes of this study, structural shore protection refers to any community-wide construction along the shoreline to reduce the impacts of flooding and/or erosion. Dikes and levees are common forms of flood protection, while revetments, seawalls, breakwaters, groynes and headland embayment structures are more commonly used to reduce erosion damage.

Structural shore protection may be the only appropriate alternative for some areas. A major city or any intensively developed shoreline area, where there is little likelihood of land acquisition or relocation of structures, may be an appropriate location for well-engineered shore protection.

Structural shore protection has been used extensively along the Great Lakes-St. Lawrence shoreline to prevent flooding and erosion damage to public property. One example is the Presque Isle Peninsula along central Lake Erie. In 1954, a cooperative beach erosion control project between the United States Government and the Commonwealth of Pennsylvania was initiated. This included construction of a seawall, bulkhead and a groyne system along the neck of the peninsula, and restoration of beaches on the lakeward perimeter of the peninsula by placement of sandfill (beach nourishment). The entire project cost about $33 million initially, with annual maintenance costs of $445,000.[97] In Ontario, the Essex Region Conservation Authority and the City of Windsor implemented a project to protect 817 metres of eroding shoreline on the south shore of the Detroit River. This project cost $7 million.[98]

The cost of implementing this type of shore protection will vary dramatically by type, size and location. Typical costs for revetments, seawalls/bulkheads, dikes, groynes and other types of structural protection are provided in Annex 2.

4.4.5. Evaluation of Remedial Measures

4.4.5.1. Distribution of Impacts

Because remedial land use and shoreline management measures would be applied based on their applicability to local situations, the distribution of their impacts among interests and regions is favorable. It is assumed that only those measures that were found acceptable in the community's multi-objective planning process would be implemented. Even though all measures may still not be acceptable or advantageous to all interests, the multi-objective process would help ensure the broadest possible distribution of benefits at the least possible expense to other interests.

4.4.5.2. Economic Impacts

Examples of the potential costs of remedial measures have been discussed above. Although measures such as government-funded relocation of dwellings and major shore protection projects can be costly, case studies show that, when properly applied, such measures can have benefits that outweigh their costs. As noted earlier, the success of remedial programs could depend to a large degree on the levels of funding committed by all levels of government, since local governments may not have the financial resources to undertake large capital projects alone.

[96]Ecologistics Ltd., *Evaluation of Shoreline Management Practices - Canadian Shoreline.* For the Land Use and Shoreline Management Task Group, Working Committee 2 (1992a).
[97]Ecologistics Ltd. (1992b).
[98]Ecologistics Ltd. (1992a).

4.4.5.3.
Environmental Impacts

Most of the remedial measures were environmentally acceptable. The exception was structural shore protection, which can have negative environmental impacts by interfering with natural beach processes and sometimes creating new problems updrift or downdrift of the structure, or by affecting plant and animal life in the immediate area. Large structures along the shoreline can also be unsightly. As a result, this study viewed structural shore protection as a measure for situations in which no other remedial actions would be effective in protecting against flooding or erosion.

4.4.5.4.
Feasibility

The remedial land use and shoreline management measures rated well in the evaluation of their feasibility. While some situations might require changes to current laws and public policy, these changes would likely be insufficient to block implementation of these projects, particularly if they were developed in response to local needs and under the umbrella of a comprehensive, basin or lake-wide approach. These types of actions are currently in use to varying degrees throughout the Great Lakes-St. Lawrence River Basin.

4.4.6.
Recommendations

The Board recommends that consideration be given to implementing remedial measures when appropriate to the local conditions. The decision should be made as part of a regional multi-objective planning process, and it should be consistent with federal, state and provincial guidelines, taking into account local concerns. The following measures are recommended for implementation, as appropriate, taking into account the above discussion:

- **Relocation of structures from hazard areas.**
- **Flood proofing of existing structures.**
- **Non-structural shore protection.**
- **Structural shore protection, where other alternatives are not appropriate, only if well-designed and engineered, and only if impacts are not shifted to adjacent areas.**

4.4.7.
Preventive Measures

The trend in the basin over the last several decades has been toward a general and often rapid increase in shoreline development (primarily residential) in areas previously classified as natural areas (mainly forest and wetland). There has been some loss of agricultural land to residential shoreline development. Examination of land use trends leads researchers to project a significant increase in residential and recreational land uses along the shoreline throughout the 1990's. Continued development in hazard areas without appropriate planning controls can result in increased property damage due to flooding and erosion. This study examined measures to prevent future damage resulting from new development in flooding and erosion-prone areas. These measures would allow planners to apply knowledge gained from previous damage experiences. They could be implemented, either uniformly to undeveloped areas throughout the basin, or on site-specific bases, as is the case with the remedial measures.

4.4.7.1.
Erosion/Recession Setback Requirements

Setback requirements consist of regulations specifying that new development (both public and private) along the Great Lakes-St. Lawrence River shoreline take place landward of a specified erosion line. Setbacks can be divided into two general categories, fixed and floating. Fixed setbacks are established prior to a permit application. Floating setbacks are determined at the time the permit is requested and are based upon the specific site conditions.

Presently there is little uniformity among states and provinces throughout the basin on erosion setback policies, either in how setbacks are determined or in how they are enforced. There is no common method of calculating recession lines. In some cases, the recession rate is based on aerial photography of the shoreline, while in other cases it is based on shoreline monitoring. Setbacks can vary anywhere from 10-to 100-year recession limits.

In Ontario, 38 of 74 municipalities along the Great Lakes shorelines have setback designations. These designations range from 7.6 metres (25 feet) to the 1% risk line (100-year erosion/recession line). Michigan has a 30-year setback for areas with average long-term recession rates greater than one foot per year. New York has a 40-year setback for recession rates greater than one foot per year. Pennsylvania has a 50-foot minimum, or 50-year, setback for residential structures. Wisconsin and Minnesota have setback requirements of 75 feet from the normal high water mark. Illinois and Indiana have no specified setback requirements.[99]

Agencies administering erosion/recession setbacks will encounter significant costs implementing and maintaining this type of measure. Costs include determining setback limits, mapping erosion hazard areas, monitoring compliance, and related enforcement actions. Widespread implementation of this measure could increase costs for prospective developers within, or adjacent to, hazard areas by requiring additional land surveys, together with application and recording fees.

4.4.7.2. Flood Elevation and Protection Requirements

Flood elevation requirements ensure that any new structures built in a hazard area are constructed above a specified elevation, either by using fill in low-lying areas or by raising foundations with posts, piles, piers or walls. Requirements may be instituted that all buildings be above the flood elevation or behind the flood line. The objective of this type of requirement is to prevent construction of structures at risk of incurring flood damage. In some cases, it may be necessary for certain water dependent structures to be built in flood hazard areas. In these cases, the buildings may be permitted if they are dry or wet floodproofed,[100] depending on their use.

In Ontario, flood elevations are specified in planning guidelines established by Conservation Authorities. The majority of Conservation Authorities use the 1% risk level with a wave uprush limit, a standard derived from the Canada-Ontario Flood Damage Reduction Program.

The National Flood Insurance Program (NFIP) includes a wave run-up provision and specifies flood elevation criteria with which participating municipalities must comply.[101]

As with erosion/recession setback requirements, implementation and maintenance of this measure could require administering agencies to assume significant costs for determining and mapping flood hazard limits, monitoring compliance, and related enforcement actions. Estimates of actual costs for a comprehensive program of this nature were not compiled by this study.

4.4.7.3. Shoreline Alteration Requirements

This measure involves the regulation of changes to the shoreline that might have the potential to interfere with the natural environment, neighboring properties, or with water levels and flows. One type of shoreline alteration requirement applies to privately or publicly constructed shore protection and structures that aid navigation. Regulations would require obtaining construction permits and would place limitations on the types of protection. Such regulations would also carry penalties for violations or require removal of non-permitted construction. Shoreline alteration requirements also apply to the extraction of nearshore deposits and any other alteration of the natural shoreline, such as removal of vegetation or infilling. They might also require evaluation of impacts of proposed structures prior to issuance of a permit.

99 Ecologistics Ltd. (1992a) and (1992b).
100 Dry floodproofing is designed to keep water out of a structure in a structurally safe manner. Wet floodproofing is designed to allow the flooding of portions of the structure where there are no materials that could be damaged.
101 Ecologistics Ltd. (1992b).

These requirements could also apply to land fills in connecting channels that alter water levels and flows. In the United States, fills and channel alterations are adequately controlled through permitting requirements. In Canada, current federal legislation is not adequate to achieve effective control over boundary water fills and alterations. In some cases, the environmental assessment requirements of the Navigable Waters Protection Act have been used to achieve this control, but amendments to the International Rivers Improvement Act would be the most effective means of controlling infilling in Canadian waters.

Shoreline alternation requirements are most effective within comprehensive plans which take into account entire sections or reaches of shoreline and the potential impacts of specific alterations. In Ontario, Conservation Authorities have jurisdiction to apply regulations to control fill, construction and alterations to waterways under Section 28 of the Conservation Authorities Act. As of 1991, six Conservation Authorities have implemented shoreline development regulations. In the United States, the United States Army Corps of Engineers and individual state agencies have jurisdiction to apply regulations to control fill, construction, and alteration of waterways.

The costs of implementing this type of measure vary depending upon the types of permits required. Major federal, state and provincial programs currently exist to implement this type of measure.

4.4.7.4. Real Estate Disclosure Requirements

Buyers of shorefront property are often unaware of the natural hazards associated with their purchases. The purpose of a real estate disclosure requirement is to notify prospective shoreline buyers of the potential for flooding or erosion in areas of known or mapped hazards, and to give buyers recourse if such notice is not given. The disclosure would be contained in the offer to buy, attached to the deed, or both. Sellers or their agents would also be required to disclose any past damage or repair costs associated with flooding or erosion of the property.

There is currently little use of this type of mechanism in Ontario, although it has been applied in isolated instances by four Conservation Authorities.[102] Real estate disclosures have been more widely applied in the United States. Several states require, or have recently proposed, deed restrictions and disclosures in their real estate transactions. For example, legislation in the state of Ohio requires:

> Any person who has received written notice under this section or notice through a recorded instrument that a parcel or any portion of a parcel of real property that he/she owns has been included in the Lake Erie erosion hazard area identified under this section shall not sell or transfer any interest in that real property unless he/she first provides written notice to the purchaser or grantee that the real property is included in the Lake Erie erosion hazard area. A contract or sale entered into in violation of this section may be voided by the purchaser or grantee.[103]

The costs to implement this type of measure would be nominal, since title and transfer fees for real estate transactions would carry most of the cost burden. However, development of consistent and uniformly-applied disclosure statements would result in some administrative costs to agencies.

4.4.8. Evaluation of Preventive Measures

4.4.8.1. Distribution of Impacts

Preventive land use and shoreline management measures were ranked favorably under the multi-criteria evaluation. Preventive measures tend to be applicable to all shoreline areas and are capable of being adapted on site-specific bases. They, therefore, result in generally favorable distributions of impacts.

[102] Triton Engineering and Ecologistics Ltd. *Inventory and Assessment of Land Uses and Shoreline Management Practices - Canadian Shoreline*. For the IJC Levels Reference Study, Working Committee 2. (May 1992).
[103] Ohio Revised Code, Sec. 1506.6 Cited by Ecologistics Ltd. (1992b).

However, in cases where preventive measures are applied in developed areas (i.e., setbacks in populated areas), some property owners could be negatively affected. The same is possible for real estate disclosure requirements, although the negative implications for the property owner could translate to positive ones for the potential buyer.

4.4.8.2. Economic Impacts

Many of these measures, such as setbacks and flood elevation requirements, can be applied with little capital expenditure and can be effective measures in preventing future damage, thereby achieving economic efficiency. This is especially true for undeveloped areas where planners are able to anticipate future problems and avoid future costs that could result from damage.

4.4.8.3. Environmental Impacts

Preventive measures are environmentally acceptable, and in some cases beneficial to the environment, where they prevent construction of structures or alteration of shoreline that could have negative impacts on shore processes or natural habitat.

4.4.8.4. Feasibility

Preventive measures are relatively neutral with respect to feasibility. All are feasible from a technical point of view, but some, such as real estate disclosure statements, may require changes to existing legal or policy structure. In addition, determining erosion setback lines for communities would have to be addressed.

4.4.9. Recommendations

The Board recommends that the following preventive land use and shoreline management measures be implemented and applied in a consistent and coordinated manner around the Great Lakes and St. Lawrence River:

- **Erosion setbacks that include minimum requirements for a 30-year erosion zone for movable structures and a 60-to 100-year erosion zone for permanent structures plus an adequate distance to assure a stable slope. A provision for variance should be included for areas where the slope has been, or is proposed to be, stabilized by a well-engineered structure.**
- **Flood setbacks and elevation requirements that include minimum requirements for a 1% flood risk line plus allowance for wave uprush and freeboard.**
- **Shoreline alteration requirements established in the context of a comprehensive plan. The environmental, updrift and downdrift impacts of shoreline alterations must be considered, along with hydraulic impacts on the connecting channels.**
- **Regulations in Canada to control fills and other obstructions in connecting channels. The most effective means of achieving this would be through amendment of the International Rivers Improvement Act.**
- **Real estate disclosure requirements where the seller should be required to disclose to prospective buyers that the property is within a mapped or known flood or erosion hazard area. The buyer should sign an acknowledgment that he or she has been informed of the risk.**

4.4.10. Other Measures

Two land use and shoreline management measures examined by this study fall into either the remedial or the preventive measure categories, depending upon how they are applied.

Land acquisition is a remedial measure when it involves the acquisition of developed land to keep existing damage levels from increasing; it is preventive when it involves the acquisition of undeveloped land to stop future development that could be vulnerable to flooding and erosion. Hazard insurance is remedial in the sense that it addresses damage to existing development, yet it is also preventive, because it limits reconstruction or future development that does not comply with hazard area management guidelines.

4.4.10.1. Acquisition of Undeveloped Land, Developed Land, and Habitat Areas

This type of measure prevents, or reduces, future damage and losses in hazard areas by encouraging government and non-government agencies to purchase properties, either developed or undeveloped, located in hazard areas. The purchasing body may designate the land for use as a park, allowing for public recreation and access or it may choose to leave the area in its natural state for the benefit of plant and animal life in the area. This measure could include government or community acquisition of barrier beaches, dunes and wetlands to preserve these coastal habitats in their natural states. In cases where such areas are already under community ownership, money might be spent to restore them to their natural states. The same might be true in cases of acquisition of developed areas. Such habitat protection could also extend to implementing regulations to protect sensitive coastal habitats in hazard areas that are currently located on private land.

Currently developed areas that have experienced repeated damage due to flooding or erosion are candidates for dedicated land acquisition programs under willing buyer/willing seller relationships wherever possible. The resulting open space with public access could be an asset to shoreline communities and could attract other inland development to add to the local tax base. However, some tax base would be lost through public acquisition of previously private property.

Land acquisition is capital intensive. Costs vary depending upon the magnitude of the purchase and the value of the property purchased. Coordinated funding would assist greatly in this type of measure, but it would also require a long-term, multi-objective approach, with cooperation at all levels of government. Local participation would be important in the purchasing and managing of the acquired land. Due to potentially strong resistance on the part of some hazard land owners, this type of measure would also require intensive citizen involvement throughout the planning, acquisition and land use conversion stages.

In Ontario, notable land acquisition programs include Frenchman's Bay in Pickering, Hamilton Beach and Burlington Beach. The Burlington Beach Acquisition Program undertaken by the Halton Region Conservation Authority and the City of Burlington since 1976 has cost $2.2 million, which includes the acquisition of 71 properties at an average price of $24,647.[104]

4.4.10.2. Hazard Insurance

Hazard insurance is used to compensate for flood and erosion damage as well as to encourage informed use of the coastal area. The United States National Flood Insurance Program was established in 1968 and has been effective in reducing flood damage. Because of program limitations, however, it has not been effective in preventing erosion damage, although some types of erosion damage are covered by the insurance. Flood damage insurance is not used in Ontario, because the provincial government has traditionally had an aggressive land use planning process, in which development controls and policies have been applied to effect the same kind of floodplain management objectives as a hazard insurance program.

The United States flood insurance program requires local governments to regulate floodplain land use in order to reduce exposure of the property to flood damage and resulting insurance losses. The premise of the program is that if communities act to limit future flood

[104]Ecologistics Ltd. (1992a).

of the hazard zone. The program should also deny subsidized insurance for recurring claims.

- **A hazard insurance program should provide eligibility for mitigation assistance when the aggregate of damage claims exceed 50% of the fair market value of the insured property and provide mitigation assistance for structures imminently threatened by erosion with an emphasis on relocation of structures out of the hazard area, not demolition.**

4.5. SUMMARY

The Study Board does not recommend the installation of new structures to further regulate the levels and flows of the Great Lakes and St. Lawrence River, because its investigations demonstrate that the costs of such measures would outweigh their economic benefits, and that these measures would produce negative environmental effects. However, recognizing that the levels of two of the Great Lakes (Superior and Ontario) are currently regulated, the Board further recommends improvement of these regulation plans to make them more responsive to the current needs of the interests affected by such regulation. Further, in recognition that various engineering and construction projects have changed the level and flow regimes of the Great Lakes and St. Lawrence River — particularly those of Lake Erie and the Niagara River — the Board recommends removal of some fill in the Niagara River to help restore Lake Erie's outflows nearer to pre-project conditions. To help ensure that future infilling of the connecting channels does not interfere with future levels and flows, the Board recommends steps to prevent similar activities in the future.

The Study Board also concluded that, regardless of whether lake levels and flows are regulated, damage to shoreline properties, public infrastructure and water dependent businesses will continue. In consideration of this, the Board recommends that the Governments of Canada and the United States, together with the states, provinces and local governments, take steps to institute comprehensive and coordinated land use and shoreline management programs. Such programs could include a range of measures, from community-based shore protection projects to acquisition of hazard land in order to prevent future damage-prone development. All of these programs would have to be instituted at the local level, using multi-objective processes that take into account a wide range of affected interests. While the Board recognizes that it may be impossible to implement such programs on a uniform basis throughout the basin, given the diversity of local needs and shoreline characteristics, the intent of its recommendations is that governments aim at uniformity to the maximum extent possible, in order to ensure consistency in the application of these measures along the full length of the Great Lakes-St. Lawrence River shoreline. Specific levels of funding have been recommended to help ensure implementation of the recommended measures.

The measures outlined in this chapter have partly addressed the Reference request to "examine and report on methods of alleviating the adverse consequences of fluctuating water levels." The next chapter outlines measures that could be taken to alleviate high or low water level crises. These measures are described as components of an example emergency preparedness plan.

Chapter 5

Emergency Preparedness

Water levels and flows of the Great Lakes and St. Lawrence River are constantly changing, largely in response to changing patterns of precipitation. While weather patterns are for the most part unpredictable, it is possible to say with a reasonable degree of certainty that extremely high and low water levels will occur in the future, as they have in the past. It is also safe to say the ranges of high and low levels that have been experienced in the past will probably be exceeded sometime in the future.

While water levels have reached extremes a number of times this century, three such occurrences in the last 30 years have been classified as crises. These were the extreme lows of 1964-65, the extreme highs of 1973-74 and the century record highs of 1985-87.

It is widely recognized that mechanisms for all levels of government to take action during crises must be in place prior to the crises. Therefore, emergency plans should be coordinated among agencies and levels of government so that, when a crisis arrives, roles are clear and actions can be implemented quickly. If pre-planned and coordinated action had been taken sooner during past crises, the impacts of the extreme water levels on some interests could have been partially mitigated in parts of the system. A review of actions taken during past crises, together with examination of a number of emergency operating plans currently in existence at various levels of government, indicates that significantly more could be done to prepare for the next high or low water crisis on the Great Lakes-St. Lawrence River System.

A wide variety of short-term actions was reviewed for possible incorporation into an emergency preparedness plan. These measures include hydraulic measures, which moderate water levels, and land side measures to help mitigate the adverse impacts of extreme levels. This study considered actions that could be implemented quickly to have maximum effect during a crisis and be discontinued once the crisis was over. An example emergency preparedness plan is presented in this chapter and explained in further detail in Annexes 3 and 6. This example plan illustrates the range of actions that could be taken in response to high or low water level crises.

Although equity in treatment of interests and regions was a principle in the development of this plan, the crisis actions described here would not necessarily be acceptable to all interests. This may be especially the case for the hydraulic measures which, to moderate extreme levels, re-distribute water within, and outside of, the Great Lakes-St. Lawrence River System. As a result, the benefits and impacts are also redistributed.

A limited economic evaluation was conducted of the combined hydraulic measures. The site specific nature of many of the land-side measures precluded their detailed economic evaluation within the time frame and resources of the study. The contribution of each of the individual hydraulic measures to the total economic benefit was not evaluated. It may be that some of the individual measures included in the combination of hydraulic measures would reduce the total economic effectiveness of the example plan and could have negative effects if implemented as individual measures.

5.1. HYDRAULIC MEASURES

A total of 29 hydraulic measures were reviewed. These included modifications to the existing regulation plans during extreme high or low water level conditions, manipulations of the diversions into, out of, and between lakes in the system, increases and decreases in the capacity of the connecting channels, weather modification, regulation of consumptive use, and a diversion from Lake Huron to the Ottawa River system. Of these potential measures, a group of more promising measures was selected for detailed review. These latter measures were evaluated and a subset was selected for consideration in an emergency preparedness plan.

Five of the 29 measures were related to increasing the outlet capacities of Lakes Michigan-Huron, Erie, and Ontario through dredging or removal of obstructions in the connecting channels. Two measures dealt with dredging in the St. Clair-Lake St. Clair-Detroit River system to lower high levels on Lakes Michigan-Huron or to maintain navigation depths in this part of the system during periods of low water supply. One measure proposed removal of the compensating works that have been placed in the Detroit River to offset the impact of prior navigation improvements. This would lower levels on Lakes Michigan-Huron. Another measure considered removal of land fills on the Canadian and United States sides of the Niagara River (see discussion and recommendation in Chapter 4) as well as dredging of the River to reduce high Lake Erie levels. A further possible measure involved increasing the channel capacity of the St. Lawrence River to reduce high levels on Lake Ontario and at Montréal Harbour. Each of these measures required that the system be restored to the regime that existed prior to the emergency condition. The measures were found to be costly and require a great deal of time to implement. To satisfy the requirement to restore the system to a pre-emergency condition, some type of moveable structure would best meet the needs of the measure. This matter was a part of the lake level regulation portion of the Levels Reference Study and was found impractical as a crisis management alternative.

The following hydraulic measures were considered the most effective in alleviating high or low water crises. Taken together, they represent the maximum effect that could reasonably be obtained through such actions.

- A series of controlled changes in the flows allowed by the regulation plans for Lakes Superior and Ontario that would respond to extremely high or low levels.
- Manipulation of the four major Great Lakes diversions:
  - Decrease the Long Lac and Ogoki diversions into Lake Superior during periods of high water levels.
  - Increase the Lake Michigan Diversion at Chicago out of Lake Michigan in periods of high water levels.
  - Vary the Welland Canal flows from Lake Erie in periods of high or low water levels.
- Place an ice boom at the head of the St. Clair River to help prevent ice jams and flooding along the river.
- Modify the Black Rock Lock to increase the total discharge through the Niagara River by 340 cms (12,000 cfs) during periods of high water levels.[105]

With the exception of the ice boom at the head of the St. Clair River and the capacity increase for the Black Rock Lock, the changes in flows suggested in this example emergency plan would be accomplished within the present

[105] The Black Rock Lock and Black Rock Canal near Buffalo, New York, where Lake Erie drains into the Niagara River, provide a protected waterway for vessels around the reefs, rapids and fast currents in the upper Niagara River.

capacities of existing works and channels. The ice boom would leave a gap across the navigation channel to allow ships to continue moving in the winter. It would be installed only during times when the level of Lakes Michigan-Huron was above average (176.22 metres/578.14 feet) in November.

The increases and decreases in flows for the emergency preparedness plan were calculated from a series of water level triggers (see Table 10), which would call for incremental flow changes starting at initial action levels. All hydraulic actions upstream of Lake Ontario, except for increased flow through the Black Rock Lock, would be triggered by the levels of Lakes Superior and Michigan-Huron. However, selection of these actions was based on the degree of hydraulic benefits they could provide to the entire Great Lakes-St. Lawrence River System. Increased flows through the Black Rock Lock were triggered by the levels of Lake Erie only, due to limitations with the model used in development of the plan.[106] The flows through the Lock would be increased when the level of Lake Erie exceeded 174.30 metres (571.9 feet). In actual practice, levels of Lake Ontario and the St. Lawrence River would also be used to determine whether flows through the Black Rock Lock could be increased. For Lake Ontario's regulation plan (Plan 1958-D), outflows would be increased if the lake were more than one standard deviation (between 0.16 and 0.26 metres/0.52 and 0.85 foot) above its seasonal average level. Decreases in Lake Ontario outflows would be based upon inflows to Lac Saint-Louis during the spring freshet. The table demonstrates that, as the crisis continued, the magnitude of the hydraulic actions would be increased. As water levels returned to normal, the deviations would be stopped to allow the system to return to its original state.

5.2. EVALUATION OF EMERGENCY MEASURES

5.2.1. Distribution of Impacts

The hydraulic measures were tested using the same historic supplies that were used for the testing of the regulation plans discussed in Chapter 4. Implementation of all the hydraulic elements of this example plan would result in the changes in monthly mean levels and flows shown in Tables 11a and 11b on the next pages. The potential effects of the ice boom at the head of the St. Clair River are not included in the table. "No. above," refers to the number of months that levels and flows would be above or below historic supplies (the basis of comparison). Flows for the connecting channels and St. Lawrence River are given in cubic metres per second (cms) in Table 11a and in thousands of cubic feet per second (tcfs) in Table 11b. The right-hand columns give the levels and flows according to the basis of comparison (BOC), then give levels and flows under the crisis management plan, and finally indicate the increase or decrease from the BOC in levels and flows that the new measures would provide. In the left-hand column, the notation, "No. above" refers to the number of months that levels would be above or below the 90-year maximum or minimum (1900-1989). For the lower St. Lawrence River, this notation refers to the 40-year period between 1950-1989.

Table 10 Emergency Preparedness Plan - Alert Levels

IGLD 1955 Metres (Feet)	For High Levels: Action Level Inital	For High Levels: High Threshold	For Low Levels: Action Level Inital	For Low Levels: Low Threshold
Superior	183.28 (601.30)	183.34 (601.50)	182.82 (599.80)	182.58 (599.00)
Michigan/Huron	176.78 (580.00)	176.94 (580.50)	176.02 (577.50)	175.81 (576.80)
St. Clair		175.63 (576.20)		174.53 (572.60)
Erie	174.32 (571.90)	174.50 (572.50)		173.43 (569.00)
Ontario		75.22 (246.77)		74.00 (242.77)
St. Lawrence at Cardinal		75.22 (246.77)		73.24 (240.30)
at Pte. Claire		22.25 (73.00)		20.27 (66.50)
at Montréal		8.50 (27.90)		5.49 (18.00)

[106]Efforts need to continue to fully integrate the hydraulic model used for the lakes with the model used for the lower St. Lawrence River.

As shown in Tables 11a and 11b, the combined effects of the hydraulic measures included in the example plan would reduce the maximum monthly mean levels of Lakes Superior, Michigan-Huron, St. Clair and Erie compared to the basis of comparison. Extremely high levels would occur less often as a result of the example measures. However, the maximum level of Lake Ontario and the St. Lawrence River in the Montréal region would increase. These measures would also raise the minimum levels of all of the lakes but would not raise the Montréal Harbour minimum level. The number of times extremely low levels would occur would be reduced on Lake Erie and the system upstream, but low levels would occur more often on Lake Ontario and at Montréal Harbour.

The Black Rock Lock measure was tested without using downstream conditions as criteria to determine whether flows could be increased from Lake Erie. As a result, extremely high water level conditions on Lake Ontario and the

Emergency Preparedness Plan – Level and Flow Impacts (Metric Units) **Table 11a**[107]

Levels in IGLD (1955) metres Flows in cms	Basis of Comparison		Crises Management Plan		Change from BOC		
	Level	**Flow**	**Level**	**Flow**	**Level**	**Flow**	
Mean	183.03	2,209	183.03	2,209	0.00	0	**Superior**
Maximum	183.45	3,852	183.42	3,880	−0.03	+28	
Minimum	182.48	1,405	182.50	1,416	+0.02	+11	
No. above (183.34 m or 3,680 cms)	38	2	24	13	−14	+11	
No. below (182.88 m or 1,560 cms)	218	8	207	114	−11	+106	
Mean	176.25	5,296	176.24	5,296	−0.01	0	**Michigan/Huron**
Maximum	177.27	6,797	177.18	6,740	−0.09	−57	
Minimum	175.30	3,738	175.35	3,795	+0.05	+57	
No. above (186.48 m or 6,230 cms)	288	42	278	41	−10	−1	
No. below (175.81 m or 4,250 cms)	127	28	123	31	−4	+3	
Mean	174.87	5,409	174.86	5,409	−0.01	0	**St. Clair**
Maximum	175.74	7,108	175.62	7,052	−0.12	−57	
Minimum	173.99	3,880	174.05	3,908	+0.06	+28	
No. above (175.26 m or 6,230 cms)	126	70	103	74	−23	+4	
No. below (174.25 m or 4,250 cms)	33	13	22	15	−11	+2	
Mean	174.00	5,976	173.99	5,976	−0.01	0	**Erie**
Maximum	174.84	7,873	174.70	7,873	−0.14	0	
Minimum	173.13	4,333	173.20	4,361	+0.07	+28	
No. above (174.35 m or 6,790 cms)	155	124	122	133	−33	+9	
No. below (173.31 m or 4,810 cms)	16	32	10	34	−6	+2	
Mean	74.58	6,995	74.57	6,995	−0.01	0	**Ontario**
Maximum	75.38	9,912	75.58	9,912	+0.19	0	
Minimum	73.66	4,990	73.78	5,098	+0.12	+108	
No. above (75.22 m or 8,780 cms)	19	30	15	43	−4	+13	
No. below (74.00 m or 5,320 cms)	13	8	16	40	+3	+32	
Mean	21.14	8,156	21.14	8,156	0.00	0	**St. Lawrence River at Pte. Claire**
Maximum	22.46	12,801	22.57	13,112	+0.11	+312	
Minimum	20.19	5,862	20.20	5,834	+0.01	−28	
No. above (22.25 m or 11,330 cms)	3	26	4	25	+1	−1	
No. below (20.27 m or 7,080 cms)	3	275	4	280	+1	+5	
Mean	6.29		6.29		0.00		**St. Lawrence River at Montréal**
Maximum	8.69		8.81		+0.12		
Minimum	5.08		5.08		0.00		
No. above (7.62 m)	19		18		−1		
No. below (5.49 m)	30		32		+2		

[107] Flows at Montréal Harbour are not provided since inflows from downstream tributaries and tides affect the level and prevent the calculation of realistic flows. (That is, there is no unique stage-discharge relationship for Montréal Harbour.)

Table 11b[108] **Emergency Preparedness Plan – Level and Flow Impacts (English Units)**

	Levels in IGLD (1955) metres Flows in 1,000 cfs	Basis of Comparison		Crises Management Plan		Change from BOC	
		Level	**Flow**	**Level**	**Flow**	**Level**	**Flow**
Superior	Mean	600.49	78	600.48	78	−0.01	0
	Maximum	601.86	136	601.76	137	−0.10	+1
	Minimum	598.68	50	598.75	50	+0.07	0
	No. above (601.50 ft or 130 tcfs)	38	2	24	13	−14	+11
	No. below (600.00 ft or 55 tcfs)	218	8	207	114	−11	+106
Michigan/Huron	Mean	578.26	187	578.23	187	−0.03	0
	Maximum	581.59	240	581.31	238	−0.28	−2
	Minimum	575.13	132	575.29	134	+0.16	+2
	No. above (579.00 ft or 220 tcfs)	288	42	278	41	−10	−1
	No. below (576.80 ft or 150 tcfs)	127	28	123	31	−4	+3
St. Clair	Mean	573.72	191	573.70	191	−0.02	0
	Maximum	576.56	251	576.18	249	−0.38	−2
	Minimum	570.84	137	571.03	138	+0.19	+1
	No. above (575.00 ft or 220 tcfs)	126	70	103	74	−23	+4
	No. below (571.70 ft or 150 tcfs)	33	13	22	15	−11	+2
Erie	Mean	570.86	211	570.83	211	−0.03	0
	Maximum	573.63	278	573.17	278	−0.46	0
	Minimum	568.02	153	568.24	154	+0.22	+1
	No. above (572.00 ft or 240 tcfs)	155	124	122	133	−33	+9
	No. below (568.60 ft or 170 tcfs)	16	32	10	34	−6	+2
Ontario	Mean	244.67	247	244.65	247	−0.02	0
	Maximum	247.32	350	247.95	350	+0.63	0
	Minimum	241.66	176	242.06	180	+0.40	+4
	No. above (246.77 ft or 310 tcfs)	19	30	15	43	−4	+13
	No. below (242.77 ft or 188 tcfs)	13	8	16	40	+3	+32
St. Lawrence River at Pte. Claire	Mean	69.37	288	69.36	288	−0.01	+0
	Maximum	73.69	452	74.05	463	+0.36	+11
	Minimum	66.24	207	66.27	206	+0.03	−1
	No. above (73.00 ft or 400 tcfs)	3	26	4	25	+1	−1
	No. below (66.50 ft or 250 tcfs)	3	275	4	280	+1	+5
St. Lawrence River at Montréal	Mean	20.65		20.64		−0.01	
	Maximum	28.51		28.90		+0.39	
	Minimum	16.67		16.67		0.00	
	No. above (25.00 ft)	19		18		−1	
	No. below (18.00 ft)	30		32		+2	

St. Lawrence River would be worsened in the example. In actual practice, flows through the Black Rock Lock would not be increased if Lake Ontario and St. Lawrence River levels or flows were too high.

Ice jams in the St. Clair River have caused flooding of shoreline properties along the river. The resulting restriction of outflows from Lake Huron has also affected the levels of the upstream and downstream lakes. By reducing the likelihood of ice jams and retardation of flows, the ice boom would, in effect, lower the maximum and minimum levels of Lakes Michigan-Huron and Superior. On the downstream lakes, slightly increased maximum levels could be expected, due to increased efficiency in discharge through the St. Clair River. The ice boom would have some adverse effects during low water periods. Consequently, its installation would not be recommended when the levels of Lakes Michigan-Huron were below normal. However, ice jams could still occur during low water periods and cause localized flooding on the St. Clair River. Installation of an ice boom

[108]See footnote 107.

would produce the most benefit for riparians on the St Clair River, and it would further facilitate navigation on the river during the winter months.

The impact of all these hydraulic measures upon commercial navigation would be positive on the five Great Lakes and negative on the St. Lawrence River at Montréal. Increased flows through the Black Rock Lock would have negative effects on recreational boating and commercial navigation, since the increased flows would necessitate restrictions on vessel traffic through the Lock.

5.2.2. Economic Impacts

Table 12 shows the distribution by region of the impacts that the hydraulic crisis measures would have on property damage. The column labeled "Difference" is the impact of these measures. A positive number is a benefit, a negative number is a loss. The effects of installation of an ice boom at the head of the St. Clair River are not included in the table.

The table shows that implementation of these actions would decrease damage on Lakes Superior, Michigan-Huron, St. Clair, Erie and Ontario, but it would increase damage on the St. Lawrence River due to increased flows through the Black Rock Lock. In actual practice, however, flows through the Black Rock Lock would not be increased if Lake Ontario and St. Lawrence levels or flows were high.

Table13 on the next page shows the distribution by region of the impacts these emergency actions would have upon hydropower generation. The table illustrates the change in the annual value of hydropower production that would result from these measures. The differences are shown in both dollar and percentage terms, and they are shown for each location in the Great Lakes-St. Lawrence River System where hydropower is produced.

Reduction of the flows into Lake Superior from the Long Lac and Ogoki diversions would reduce hydropower production and could spill water north to James Bay. This could affect communities along the Albany River.

Increases in the Lake Michigan Diversion at Chicago could increase hydropower production along the Illinois Waterway and provide benefits to commercial navigation. Damage could be increased for agriculture and residential property along the Illinois river, however.[110]

The system-wide benefits and costs are shown in Table 14.

5.2.3. Environmental Impacts

Although an assessment of environmental impacts was not carried out, these impacts would be minimal on Lakes Superior, Michigan-Huron, St. Clair, Erie and Ontario. The potential environmental impacts on the St. Lawrence River are not known. Environmental impacts could be expected on the Albany River system as a result of a reduction

Distribution of Property Damage Impacts for Crises Plan — **Table 12**[109]

Average Annual Property Damage ($1,000's US)				
Basis of Comparison	**Crises Plan**	**Difference**	**% Change**	
4,513	4,448	65	1%	**Superior**
15,879	15,544	335	2%	**Michigan**
8,573	8,278	295	3%	**Huron**
5,852	4,892	960	16%	**St. Clair**
14,269	13,603	666	5%	**Erie**
14,993	14,905	88	1%	**Ontario**
7,858	8,105	−247	−3%	**St. Lawrence River below Cornwall**
71,937	**69,775**	**2,162**	**3%**	**Total**

[109]The economic figures in this table are based on historic stage-damage curves for flooding and erosion. Outlet rivers are included with upstream lake. There are no shore protection costs or benefits included in this table.

[110]A U.S. Army Corps of Engineers study for the State of Illinois found benefits of $845,000 and increased damages of $917,000 for a plan to reduce high Lake Michigan levels by increasing flows. The impacts were based on a flow increase of 26 cms (940 cfs) for a wet year, 115 cms (4,030 cfs) for an average year and 190 cms (6,700 cfs) for a dry year.

Table 13 Distribution of Hydropower Impacts for Crises Plan

Crises Conditions	Average Annual Hydropower Impact ($1,000's US)					
	Energy Value					
	Basis of Comparison	Measure	Difference	% Change	Capacity Costs	Total
Long Lac & Ogoki			−48		−21	−$69
St. Marys River	23,309	23,095	−214	−1%	−28	−$242
Niagara River	744,530	743,378	−1,153	0%	−117	−$1,270
St. Lawrence River						
above Cornwall	336,272	335,491	−782	0%	−47	−$829
below Cornwall	308,944	308,685	−259	0%	+86	−$173
Total	**1,413,056**	**1,410,649**	**−2,407**	**0%**	**−106**	**−$2,513**

in flows to Lake Superior through the Long Lac and Ogoki diversions. Environmental impacts could also be expected on the Illinois River as a result of an increase in the Lake Michigan Diversion at Chicago. More detailed environmental assessments would be required in the development of an emergency preparedness plan.

Table 14 Benefit and Cost Analysis of Crises Management Plan

Benefits and Costs	
Benefits (average annual)	
Reduction in Property Damage	$2,162,000
Loss to Hydropower	−$2,513,000
Implementation Costs	
St. Clair Ice Boom	
Construction	$2,300,000
Operation and Maintenance[111]	$200,000
Black Rock Lock	
Construction	$3,400,000
Operation and Maintenance[112]	$150,000
Total (average annual @ 8%)[113]	$466,000

5.2.4. Feasibility

All of the hydraulic measures described above are technically feasible in times of water level crisis. They could also be reversed once the crisis had passed. However, measures to increase or decrease the major diversions into and out of the Great Lakes could face significant barriers in terms of approval from all of the parties involved. These potential difficulties are discussed in more detail in the section later in this chapter entitled "Institutional Considerations." In addition, some of these measures might require detailed environmental impact assessments prior to their implementation. The ability to quickly implement the measures described in the sections above would, therefore, depend upon the degree to which preparations had been made prior to a water level crisis.

5.3. LAND BASED MEASURES

A number of land-based measures could be implemented during high or low water crises. They include: land-based emergency preparedness plans; storm and water level forecasting and warning networks; emergency sandbagging and shore protection alternatives; and temporary land and water use restrictions. Such actions can be implemented at the federal, state, provincial, or local government levels. Many Great Lakes-St. Lawrence River communities currently practice some of these measures.

The most critical land-based crisis response is development of emergency preparedness plans. Depending upon local conditions, these plans can incorporate a number of land-side measures to alleviate some of the effects of crisis high or low water levels. Such plans should identify specific steps and procedures

[111] Only applicable during years that ice boom is installed.
[112] Only applicable during years that flow increase is utilized.
[113] This cost would increase to $816,000 during years that the ice boom was installed and additional flows passed through the Black Rock Canal.

to deal with either high water (flooding) or severe low water events. these should include specific steps taken at alert levels, action levels, and in the post-crisis period (i.e., cleanup and damage surveys).

To ensure consistency and incentive for implementation, initial development of the data necessary for such plans should begin at the state or provincial level with coordination at the local level. Plans should be consistent across counties and municipalities. Clear lines of communications among states, provinces, counties and municipalities should be established. Necessary supplies and equipment to respond to the crisis should be identified and located in areas where they can be quickly mobilized. These plans should be periodically tested and updated according to changing local conditions

A key element of land-side emergency preparedness planning is the continued monitoring of storm and water level conditions. Governments at the federal level should continue to provide resources for programs of this nature with additional resources available during crisis conditions. As part of the preparation of localized plans, additional efforts should be made to identify or update critical high and low water elevations to trigger successive levels of emergency action.

Emergency preparedness plans should also provide for distributing water level information and increasing hazard awareness of shoreline communities and their citizens. These programs could be incorporated into ongoing efforts to inform the public about the reasons for changing water levels, their effects, and the potential for crisis high and low water levels.

Extremely high water levels often lead to increased efforts to construct shore protection. In the past, much of this protection was hastily placed and inadequately designed. Consequently, property owners who had gone to considerable expense to protect their properties saw their protection fail within a short period of time. To avoid such problems in the future, long-term strategies should identify areas where community-based shore protection projects could be successfully implemented prior to a crisis. This would assure uniform protection along critical reaches of shoreline and would alleviate problems during crisis periods. See Chapter 4 for further discussion of shoreline protection measures.

Shore protection measures for flooding and erosion crisis situations include sandbagging and emergency beach nourishment. These measures should be included in emergency preparedness plans. Sandbagging has served as an effective response to flooding situations and should be utilized where appropriate and as necessary. Responsible agencies should ensure that all necessary supplies and equipment for the rapid construction of sandbag dikes are reasonably accessible and that those key areas where dikes may be needed are identified. Sandbags should also be readily available to private property owners who wish to undertake emergency protection of their own property. Consideration should be given during crisis high water conditions to utilizing emergency beach fill to protect areas subject to severe erosion. Such material can be quickly placed on beach and shoreline areas in order to create artificial berms that would protect backshore areas from erosion.

Construction of shore protection during crisis conditions could also be considered. This would require quick mobilization of contractors and equipment. Early consideration of acceptable designs would allow construction to take place once the alert level had been reached. This type of well-designed shore protection would remain effective after the crisis had abated.

During low water conditions, the most common problem is access for ships and boats to harbors, marinas, and docks. In many cases, these problems stem from a lack of maintenance dredging when water levels were higher. Consideration should be given to developing comprehensive emergency dredging procedures for commercial and public harbors. Sites for the disposal of dredge material should be identified in advance, as should areas where dredging would be prohibited due to severely contaminated sediments. Regulations should be considered to ensure that all new moorings utilize floating, as opposed to fixed, docks in order to adapt to continually fluctuating water levels.

In some areas of the Great Lakes-St. Lawrence River System, water supplies to shoreline communities could be affected during low water periods. These are usually small communities that rely on shore wells or small intake structures for water supply. For the long term, these communities should be identified and recommendations should be made to extend to their intakes. If this is not possible, contingency planning should be made to provide emergency water supplies when crisis low levels are reached.

In addition to periodic testing and updating, these plans should be subjected to post-crisis evaluations to ensure their continued improvement and applicability.

5.3.1. Impacts of Land-Based Measures

Land-based emergency measures primarily affect shoreline properties and communities. These measures would provide varying degrees of benefit to the shoreline property owners and public infrastructure, depending upon the extent to which they were used and the appropriateness of particular actions for specific areas. Shore protection alternatives, which would often be site specific, could also reduce damage to property and structures. However, these measures could have negative impacts on natural resources in the area of the construction. The potential impacts of public awareness programs, storm and water level forecasting, and emergency preparedness plans are harder to quantify, although positive impacts could be expected. As with the hydraulic measures in times of crisis, the feasibility of these actions would depend to a large degree upon the extent of pre-crisis planning.

5.4. INSTITUTIONAL CONSIDERATIONS

Emergency preparedness planning brings to light a number of institutional considerations. As noted in the previous discussion, some actions would require considerable pre-crisis preparation, including purchasing and stockpiling materials; preparing environmental impact statements; permit applications and authorizations; financing; the waiving of institutional constraints[114] and possibly even treaty requirements. Implementation of emergency preparedness planning on the scale suggested here could be facilitated by a central, coordinating board, such the board recommended in Chapter 6.

Availability of information and continuous communication during crises are essential to the implementation of any emergency preparedness plan.[115] Currently, the two federal governments have the primary responsibilities to monitor hydrologic conditions and forecast water level conditions on the Great Lakes and St. Lawrence River. The level of monitoring and frequency of making predictions would need to be intensified in a crisis.

The hydraulic measures described in the emergency operations plan presented here would require, during water level crises, the temporary relaxation of the International Joint Commission's orders of approval for the regulation of Lakes Superior and Ontario. The increase in the capacity of the Black Rock Lock and the installation of the ice boom at the head of the St. Clair River are not expected to have serious institutional constraints.

The reduction of inflows to Lake Superior from the Long Lac and Ogoki diversions would require approval from the Province of Ontario, in consultation with Ontario Hydro, and it would require considering the impacts of redirecting the diversions' flows northward. Additional river gauges and the development of operating guidance would be needed to minimize flooding, environmental and other impacts along the Albany River. An increase of flows through the Lake Michigan Diversion at Chicago would require United States Supreme Court consent, as well as approval of the Great Lakes Governors, or United States legislative authorization. Consultation with the Canadian Government, together with the Provinces of Québec and Ontario, would also be required.

[114]The range of possible institutional constraints includes any non-physical barriers to implementing emergency measures. Such barriers could include everything from local policy and funding limitations to International Joint Commission orders of approval and questions of jurisdiction. Further discussion of the institutional considerations that apply to Great Lakes-St. Lawrence River water levels issues is contained in Chapter 6.

[115]Additional recommendations to improve communications and information availability are contained in Chapters 7 and 8.

Further, an increase in Chicago Diversion flows might coincide with high supplies to the Illinois Waterway. Therefore, the timing of releases from Lake Michigan would be critical and would require the cooperation of the State of Illinois together with communities along the Illinois River. The use of the Long Lac and Ogoki diversions and Lake Michigan Diversion at Chicago to alleviate high water level crises could also necessitate environmental impact assessments.

The majority of deviations in Welland Canal flows that have been considered in the example emergency preparedness plan would be reductions rather than increases. Consequently, these flow changes would be absorbed in the flow apportioned for hydropower. The cooperation of the St. Lawrence Seaway Authority, Ontario Hydro and other users of canal waters would be required.

Many of the land-based measures discussed here have been, or are being, implemented to varying degrees at various levels of government. Government experiences can be helpful to develop and implement more comprehensive emergency preparedness plans. Measures such as storm and water level forecasting, developing preparedness plans, and ensuring public information and awareness need to be continued and adapted to crisis events. Shore protection alternatives require lead time for proper design and construction. Many of the above measures may require the use of loans, grants, or tax incentives to make their implementation easier and more widespread.

5.5. RECOMMENDATIONS

The Board recommends that the two federal governments, in cooperation with provincial and state governments, begin preparation of a joint and cooperative Emergency Operations Plan for the Great Lakes-St. Lawrence River as soon as possible.

The Board recommends as a priority that investigations continue into methods of alleviating high or low water crises on the lower St. Lawrence River and that investigations continue into avoiding increased damage as a result of crisis actions taken upstream.

The Board further recommends that the following be implemented in the near future:

- **The authority necessary for deviation from the Lake Superior Regulation Plan during an emergency, similar to the authority to deviate that exists for Lake Ontario.**
- **The installation of an ice boom at the head of the St. Clair River to reduce the risk of ice jams and flooding.**
- **An increase in the flow capacity of the Black Rock Lock, so the flow through the Lock may be increased in emergency situations by an additional 340 cms (12,000 cfs).**
- **The manipulation of the four major Great Lakes diversions; Long Lac, Ogoki, Lake Michigan at Chicago, and the Welland Canal during crisis situations when conditions permit.**

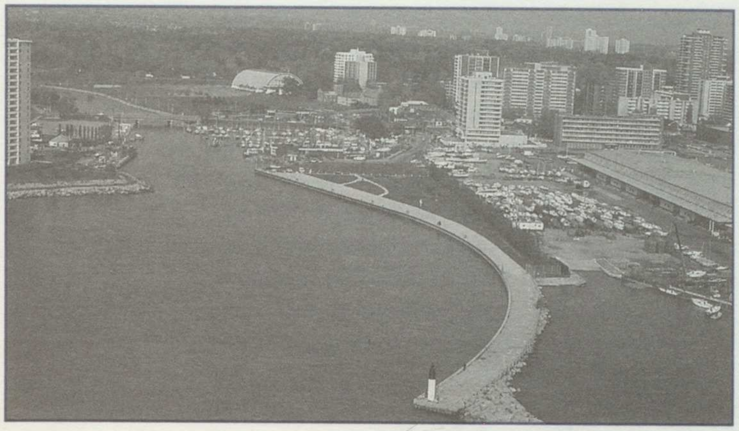
The Board recommends that, prior to implementing the manipulations of diversions, the potential impacts within and outside the Great Lakes-St. Lawrence River System of changes to the Long Lac, Ogoki and Lake Michigan at Chicago diversions be determined.

The Board recommends that post-crises action reports be done to evaluate the effectiveness of emergency preparedness plans and to recommend areas for improvement.

The Board recommends that comprehensive emergency preparedness planning be undertaken immediately at the provincial, state and local government levels. The preparations should include public information programs, stockpiling emergency materials, active monitoring of water levels and flows, and identifing areas where community-based shore protection can be implemented immediately.

5.6. SUMMARY

The key to successful emergency preparedness is planning well in advance of the crisis. The elements of an example plan for emergency preparedness are outlined in this chapter. Details of individual elements of the plan are in Annex 6. Two of the elements, manipulation of the Long Lac and Ogoki diversions into Lake Superior and an increase in the Lake Michigan Diversion at Chicago, have impacts outside the Great Lakes-St. Lawrence River System and would require examination in further detail prior to any decision whether they should be included in emergency preparedness plans. Investigations should continue into how to alleviate crises on the lower St. Lawrence River and how to avoid increased damage due to crisis actions taken upstream. After any emergency, a post-action report should be completed to evaluate the effectiveness of the emergency preparedness plans and to recommend areas for improvement. Preparation of comprehensive emergency plans will require cooperation and consultation among federal, provincial, state and local governments.



Chapter 6

Institutions

The ultimate success of the Lake Levels Reference Study will depend upon the extent to which institutions involved in resource management in the Great Lakes-St. Lawrence River Basin, and the arrangements through which they function, can embrace and advance study recommendations. Institutional arrangements include public agencies and associated laws, agreements, mandates and policies that bear directly on the development, interpretation and administration of public policy. Included within this framework are non-governmental organizations comprised of an array of interest groups (such as riparians, maritime industry and water-based recreation) with stewardship responsibility for the use, protection and management of the resource.

The framework for resource management in the Great Lakes-St. Lawrence River Basin is complex. Its institutional arrangements are among the most extensive in North America. As a multi-jurisdictional, multi-purpose resource characterized by both its expansiveness and intensity of use, the Great Lakes-St. Lawrence River System is subject to multiple layers of governance from the bi-national to the local level. Eight states and two Canadian provinces share the basin; each has a governmental structure in place to manage its particular interest in the basin's resources. Over a dozen federal agencies — United States and Canadian — have direct resource management responsibilities and a similar number have at least a peripheral role. At the state and provincial level, over 69 agencies in the ten jurisdictions have direct responsibilities, and an equal number provide some level of management. Hundreds of other governmental entities are charged with some resource management responsibility, including municipalities, county health boards and conservation authorities, among many others. A number of regional institutes, citizen groups, business and labor organizations, policy centers, foundations and special interest coalitions have flourished as well, using the various access points to governmental institutions to influence the nature and direction of resource management. All of these institutions exist in an equally complex framework of bi-national and domestic treaties, laws, mandates and policies.

Overlaying this variety of basin interests (both governmental and non-governmental) are regional, multi-jurisdictional institutions that are designed to be more capable of approaching resource management on an ecosystem basis. Such entities include, the International Joint Commission, the Great Lakes Fishery Commission, the Great Lakes Commission, and the Council of Great Lakes Governors. As coordinators of basin interests, and as catalysts for policy development and implementation, regional institutions have long played a role in advancing resource management by hydrologic as well as political boundaries.

One component of the complex institutional framework that oversees issues in the Great Lakes-St. Lawrence River Basin is the management of issues related to the changing water levels and flows of the system. Effective management of the adverse impacts of fluctuating water levels and flows requires coordination of both water-side and land-side actions.

The following sections describe the key existing arrangements related to the management of water levels and flows in the system and outline possible changes to improve communications, coordination and public participation in the management process.

6.1. INTERNATIONAL JOINT COMMISSION

The International Joint Commission was formed as a result of the *Treaty Between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada* that was signed by the two parties in 1909. The Commission consists of six commissioners, three from the United States and three from Canada. It has responsibilities in matters concerning the quantity and quality of boundary waters along the length of the United States-Canadian border. This chapter deals with the Commission's responsibilities in the area of water quantity in the Great Lakes-St. Lawrence River System. The principal Boards of the Commission relating Great Lakes-St. Lawrence River Basin water levels and flows are shown in Figure 8.

Figure 8.[116] International Joint Commission.

[116] In this chart and those that follow, the number in the bottom left corner of each box is the number of U.S. members; the number in the bottom right, Canadian members.

The Boards of Control generally meet at least twice annually in addition to their semi-annual appearances before the Commission, and they hold public meetings once a year. The Commission appoints equal numbers of members from Canada and the United States. Matters upon which the Boards are unable to agree are referred to the Commission for decision. Commission appointees to Boards serve in their personal and professional capacities and not as representatives of their agencies.

6.1.1. International Lake Superior Board of Control

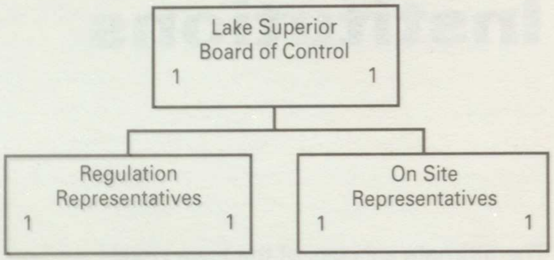


Figure 9. Lake Superior Board of Control.

The International Lake Superior Board of Control was established by the Commission in 1914 to formulate rules under which the compensating works, power canals and head gates relating to the levels and flows of Lake Superior and the St. Marys River are operated. The Board currently operates under a *Supplementary Order of Approval of the Commission* dated October 3, 1979 that formally established the International Lake Superior Board of Control and adopted Plan 1977 for regulation of Lake Superior.

The Board's organization is shown in Figure 9. The membership of the Board currently consists of one member from Canada and one from the United States. The Canadian member is a senior official of Environment Canada and the United States member is a senior official of the United States Army Corps of Engineers.

6.1.2. International Niagara Board of Control and International Niagara Committee

The International Niagara Board of Control was established by the Commission in 1953 to review and approve the installation of remedial works in the Niagara River and to exercise control over the maintenance and operation of the remedial works. The Board collaborates with the International Niagara Committee. The Board consists of two Canadian members and two United States members appointed by the Commission. The Board has responsibilities relating to the regulation of levels in the Chippawa-Grass Island Pool for Niagara Falls treaty flow requirements and diversions for power production. These works do not control the levels of Lake Erie; its levels are controlled by the outlet capacity of the lake.

The International Niagara Committee was established in 1950 by the *Treaty between the United States of America and Canada Concerning Uses of the Waters of the Niagara River.* The United States and Canada each designate a representative to the Committee. These representatives jointly ascertain and determine the amounts of water available for the purposes of the Treaty. The representatives report directly to their respective governments. The International Niagara Committee cooperates with the International Niagara Board of Control, which reports to the Commission.

The Board's organization is shown in Figure 10. The membership of the Niagara Board currently consists of two Canadian and two United States members. The Canadian chair is a senior official of Environment Canada and the Canadian member is a senior official of the Ontario Ministry of Natural Resources. The

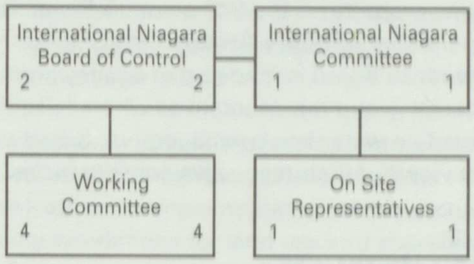


Figure 10. Niagara Board of Control and Niagara Committee.

United States chair is a senior official of the United States Army Corps of Engineers and the United States member is a senior official of the Federal Energy Regulatory Commission. The government representatives on the International Niagara Committee are currently the co-chairs of the Niagara Board of Control.

6.1.3. International St. Lawrence River Board of Control

The International St. Lawrence River Board of Control was established by the Commission in 1952 as part of *An Order of Approval of the Construction of Certain Works for the Development of Power in the International Rapids Section of the St. Lawrence River* to ensure compliance with the provisions of the order for the discharge of water from Lake Ontario and the flow of water through the International Rapids.

The Board's organization is shown in Figure 11. The Canadian section of the Board consists of members from Transport Canada (co-chair), Environment Canada, Environnement Québec and Ontario Hydro. The United States section of the Board consists of members from the United States Army Corps of Engineers (co-chair), New York Department of Environmental Conservation, the Power Authority of the State of New York and a citizen member who

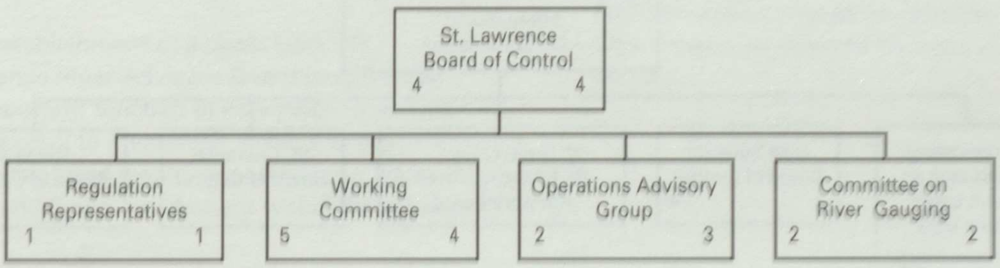


Figure 11. St. Lawrence River Board of Control.

owns property on the St. Lawrence River. The Operations Advisory Group to the St. Lawrence Board is made up of agency and interest group representatives who advise the Board on water level management, based on the views of their respective constituencies.

6.2. REVIEW OF INSTITUTIONAL ARRANGEMENTS

A number of options for organization of the Boards of Control under the Commission, and for other kinds of institutional arrangements to improve management of problems and issues related to adverse impacts of extreme water level conditions, were reviewed. Items considered in reviewing organizational options included:

a) The increasing importance of managing water levels and flows on an integrated, system-wide basis within the entire Great Lakes-St. Lawrence River Basin;

b) The need to coordinate actions throughout the system to respond to crisis conditions at times of extremely high or extremely low water levels;

c) The need to directly involve citizens, as well as state and provincial representatives, in the management of water levels and flows within the basin to increase understanding and acceptance of factors considered in making management decisions; and,

d) The need to comprehensively consider all dimensions of the problems associated with extreme water levels, from managing water levels and flows to land use and shoreline management.

Coordination among the existing Boards of Control is accomplished to some extent by overlapping membership among the lead agencies and individuals who provide support, but there is no formal mechanism for such coordination. The Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data works to ensure consistent development and use of data regarding water levels and flows in the basin, but it has never been formally recognized. In 1979, a Levels Advisory Board was created by the Commission to provide professional and citizen interests with an opportunity to contribute views on water level management, but its operation was discontinued. However, the Commission formalized interest group representation with membership of the St. Lawrence Board of Control.

While these initiatives have contributed in some measure to the coordination of data and the participation of interest groups in the decision-making process, the view has been repeatedly expressed during the Levels Reference Study that improved institutional arrangements to manage water levels and flows in the basin is required. Using the existing organizational framework as a starting point, a number of options to improve responsiveness and coordination of decision-making were examined.

Proposed Modifications

The modifications presented for consideration include changing the Lake Superior and St. Lawrence River Boards of Control, formalizing and expanding the responsibilities of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, and creating of a Great Lakes-St. Lawrence River Advisory Board.

The first modification expands the Lake Superior Board of Control to add state, provin-

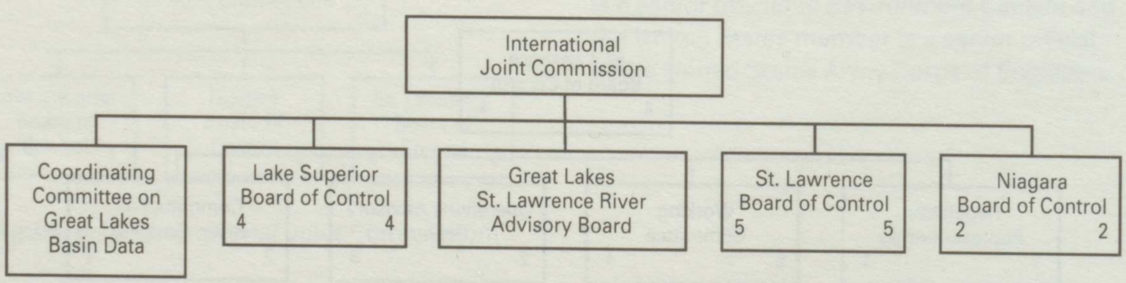


Figure 12. Great Lakes-St. Lawrence River Advisory Board.

cial and citizen participation. The second modification expands the St. Lawrence River Board of Control with additional citizen participation. Currently, the single citizen member is located on the upper St. Lawrence River. There are no citizen members from Lake Ontario or the lower St. Lawrence, even though interests in these areas are also affected by decisions of the Board. Not only would these two changes improve the level of participation by all affected interests, including governments, they would also increase the general understanding of the limitations and capabilities of lake level regulation plans.

The third suggested modification formally constitutes the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data so it would report to the Commission. Currently, the Committee serves an important function in coordinating the bi-national collection and use of water level and flow data. For example, this Committee was responsible for establishing and updating International Great Lakes Datum, the uniform system by which Great Lakes-St. Lawrence River water levels have been measured since the late 1950's. This Committee's functions are becoming even more important as data collection systems are improved and become more automated and computer-based, with expanding use of geographic information systems.

The fourth modification to existing institutional structures would be to establish a new Great Lakes-St. Lawrence River Advisory Board. The Board would report to the Commission and be linked to the Lake Superior and St. Lawrence River Boards of Control. The Board members would have fixed terms and there would be rotating membership from the three Boards of Control, the states and provinces, and interest groups.

Figure 12 illustrates how these four suggested changes could be implemented.

The establishment of a Great Lakes-St. Lawrence River Advisory Board would serve an important function of coordinating actions in response to fluctuating levels and flows. Its responsibilities would extend beyond water level and flow management within the system. This Board would also review and discuss policy issues as deemed necessary by the Commission or the Board.

In addition to its contribution to existing control boards, this advisory board would be involved in the implementation of this report's recommendations for land use and shoreline management measures. The Board could assist in developing strategies for coordinating and implementing more effective land use and shoreline management actions in cooperation with state, provincial and local governments. It could also take advantage of existing agency support and expertise to ensure implementation of measures recommended in this report.

The Great Lakes-St. Lawrence River Advisory Board would have specific responsibilities to:

a. Plan for, coordinate, and respond to problems caused by water level extremes (crisis conditions), including implementing emergency preparedness measures recommended in this report;
b. Assist in the coordination of actions between the upstream and downstream lakes affecting their levels and flows;
c. Develop and recommend improvements, as deemed necessary, to water level management practices;
d. Develop and recommend appropriate guidelines for managing water levels in the system, reflective of expanded citizen, state and provincial participation in the management process;
e. Develop and recommend standards for, and seek implementation of, agreed-upon land use and shoreline management practices, in cooperation with all levels of government;
f. Review and monitor activities related to the proposed Great Lakes-St. Lawrence River Communications Clearinghouse recommended in Chapter 7; and,
g. Perform other duties as assigned by the Commission, or deemed necessary by the Board.

6.3. RECOMMENDATIONS

The Board recommends that membership of the Lake Superior Board of Control be expanded to include representation from citizens, states and provinces.

The Board recommends that the membership of the International St. Lawrence River Board of Control be expanded to include citizen representation from Lake Ontario, the upper St. Lawrence River and the lower St. Lawrence River.

The Board recommends that the functions of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data be formalized and that the Committee report to the Commission.

The Board recommends that a Great Lakes-St. Lawrence River Advisory Board be created to coordinate, review, and provide assistance to the Commission on issues relating to the water levels and flows of the Great Lakes and St. Lawrence River.

Chapter 7

Communicating about Water Level Issues

Underlying the previous discussion of institutional arrangements is the assumption that, to be effective, these institutions must be responsive to the public they serve. A central premise to this study has been that actions can be more responsive to the public if the public is involved in the problem-solving process. In a sense, the Levels Reference Study has been an exercise in cooperative problem-solving by the institutions responsible for, and the citizens affected by, Great Lakes-St. Lawrence water levels issues. Such cooperation has been achieved by a process grounded firmly in two-way communication.

This study's strong commitment to openness and citizen involvement grew out of the public's demand for a major role in the decision-making process. The Reference for this study was issued in a climate of extreme mistrust of governments and their efforts to deal with problems accompanying high water levels of the Great Lakes and St. Lawrence River. This public perception was partly attributable to inconsistency in information, and to a decision-making process perceived as closed and oriented to the benefit of a few small, but powerful interests. The first steps toward dispelling this mistrust were taken by opening this study to full public scrutiny and inviting citizen input throughout the process.

This has led to the conclusions and recommendations for action presented in this document. The utility of an open communication process will not end with presentation of the study's final recommendations. If this study has laid the communication ground work successfully, it will have helped to build consensus among the affected interests on the most desirable solutions to water level problems, and it will have established at least a limited amount of trust in the institutions responsible for implementing recommendations. That trust will be maintained only if citizens continue to be involved in implementing of the study's recommendations.

Whatever measures governments implement as a result of this study, the foundation for their success will be laid only through an effective process of continuing two-way communication with the users of the Great Lakes-St. Lawrence River System. The recommendations presented in this chapter reflect the institutional considerations discussed in the previous chapter and respond to day-to-day needs of system users.

Besides providing information and receiving feedback on the implementation of measures, communications efforts must improve public knowledge of the Great Lakes-St. Lawrence

System. Regardless of measures arising from this study, water levels and flows in the Great Lakes and St. Lawrence River will continue to fluctuate. It is impossible to predict when or whether the extreme highs and lows of this century will be repeated or exceeded. However, the more the affected interests know about water levels, the reasons for their fluctuations, the actions governments are taking, and the risks involved in using a system that is subject to daily, seasonal and long-term fluctuations, the better they will be able to cope with these changes.

The Governments of the United States and Canada recognized this in their 1986 Reference.[117] In addition to their charge to "examine and report on measures . . .," the Governments requested the Commission to "develop an information program which could be carried out by responsible government agencies to better inform the public on lake level fluctuations."

The first steps toward such a program were taken by a communications task group which consisted of communications practitioners from government agencies involved in water levels issues and representatives of some of the interests that would be on the receiving end of communications efforts. This group produced a report that recommended a binational communications clearinghouse to deal with water levels issues. This report was examined and expanded upon in the final phase of this study.[118]

In addition to developing a broad framework for a coordinated communications program, this study surveyed 65 users of water level information to determine how best to meet their needs.[119] An assessment of the responses revealed that certain user groups (coastal engineers, government emergency workers, recreational boaters, marina operators and shoreline property owners) find deficiencies in the information services they currently receive.

The results of this survey suggest a strategy for improving the quality and communication of water level information involves: 1) developing better extreme level statistical decision-making tools; 2) proposing to relevant agencies that subtle changes be made to water level bulletins currently distributed in Canada and the United States to make them more understandable; and, 3) tailoring the wealth of existing information to users' needs.[120]

The communications recommendations presented here aim to achieve a coordinated communications effort in both countries to provide a framework for responding to, among others, the needs uncovered in the user survey.

7.1. WATER LEVEL COMMUNICATIONS CLEARINGHOUSE

In order to be effective, a clearinghouse would need unencumbered access to various experts involved in water levels issues. This would be true particularly in times of high or low water crises when the clearinghouse would be called upon to supply real-time information on water level events.

Currently, this expertise resides with the two federal agencies mainly responsible for communicating with the public on Great Lakes-St. Lawrence water level issues. An effective clearinghouse would also require continuous funding, which could best be guaranteed if it were an arm of existing agencies.

For these reasons, the Board concluded that such a facility could best be implemented by the federal governments of both countries through government agencies currently responsible for dealing with water level issues.

117 Letters of Reference (August 1, 1986).
118 Working Committee 1, *Recommendations on a Communications Program for Governments* (June 12, 1992).
119 Task Group 2, Working Committee 3, "Improved Communication of Water Level Information", *Climate, Climate Change, Water Level Forecasting and Frequency Analysis,* Supporting Documents, Vol. 3 (February 15, 1993).
120 See Chapter 8 for detailed recommendations as a result of this survey.

7.2.
RECOMMENDATIONS

The Board recommends that a Great Lakes-St. Lawrence Water Level Communications Clearinghouse be established as a bi-national effort by the United States and Canadian Governments, with the responsibility to communicate with the public, to facilitate communication between the public and governments, and to facilitate coordination of agency communication activities related to the water levels and flows of the Great Lakes and St. Lawrence River.

The Board recommends that the Clearinghouse be established under major federal agencies such as Environment Canada and the United States Army Corps of Engineers, which already have significant responsibilities in this area, and that it be linked to larger units within these agencies to act as information resources and provide staff support in water level crisis periods.

The Board recommends that the Clearinghouse establish and co-ordinate a network of agencies and groups that communicate about water level issues.

Chapter 8

Management and Operational Improvements

The discussion and recommendations of the previous chapters have indicated the difficulties inherent in managing a natural resource as vast in size and as widely used as the Great Lakes and St. Lawrence River. Many of the preceding recommendations aim at improving coordination and consistency of decision-making processes for uses of the water in the system and the land that surrounds it. However, issues management and decision-making require good data. While this study has succeeded in making a comprehensive examination of the engineering, economic, environmental and social issues implicit in Great Lakes-St. Lawrence River management, it has also identified areas in which data-gathering efforts, information storage, interpretation and communication could be improved. This chapter describes areas for potential improvement and makes recommendations accordingly.

8.1. WATER LEVEL MANAGEMENT

This study reviewed the current procedures for calculating, forecasting and regulating levels and flows of the Great Lakes and St. Lawrence River. Several areas for improvement were identified. These improvements, described in the following sections, could be incorporated into current procedures as they become available.

8.1.1. Lake-Wide Monitoring and Gauging Network

A 1979 assessment[121] of data collection networks and programs for gathering basin-wide precipitation, evaporation, inflow, and outflow information indicated that existing methods do not adequately define the complex climatology, hydrology and hydraulics of the Great Lakes and St. Lawrence River.

Deficiencies exist in the precipitation monitoring networks—especially in the Lake Superior basin—and in snow collection programs—particularly in the United States' portions of the basin. Some key locations for measuring inflows from tributaries are inadequately gauged in the Lakes Superior, Michigan, and Huron watersheds. Timely data transmission from the water level and hydrometeorologic station networks is not adequate during some critical periods.

[121] International Great Lakes Technical Information Network Board, Great lakes Hydrometeorologic and Hydraulic Data Needs, Report to the International Joint Commission, (December 1984).

Estimates of precipitation over the lakes are still crude; but these estimates could be quickly improved with next-generation radar observations. Revisions to lake evaporation estimates have begun only recently, based upon satellite and airborne-derived surface temperature observations.

Improvements in gathering and use of comprehensive basin-wide water supply data would allow better understanding of the system and improved water level management. Upgrades in computer models to simulate hydrologic conditions, forecast future water supplies, and calculate lake outflows would benefit from these improvements.

8.1.2. System Modeling

Development of adequate Great Lakes water level statistics is hampered by the lack of a comprehensive, coherent and unified strategy for modeling Great Lakes-St. Lawrence River hydrology and hydrodynamics. At the heart of a strategy to improve statistics should be a comprehensive water supply and routing computer model for the entire Great Lakes-St. Lawrence River system that allows for input of observed hydrometeorology and water levels. The model would simulate existing conditions and compare these estimates with historic conditions as well as forecast water supplies into the near future and route these supplies through the system. Such capability would provide timely assessments of the impacts from changing water levels and flows. Key features of such a model should include:

1. Comprehensive treatment of over-land and over-lake hydrologic inputs, and robustness in both simulation and forecasting of water supplies and water levels;
2. Continuous and automated daily accounting of the hydrologic parameters affecting water levels;
3. Links between deterministic and stochastic elements in the forecasting routines;
4. Validity over a wide range of temporal and spatial scales; and,
5. Availability to a wide user community.

This model has been largely developed, although additional improvements are required to take advantage of the emerging availability of over-lake observations acquired from radar, airborne and satellite systems. The predictive nature of the comprehensive model could assist in determining if deviations from current operational water level regulation plans are warranted.

8.1.3. Uncertainty Analysis

The St. Lawrence Board of Control has discretionary authority to deviate temporarily from Plan 1958-D. This can be done when a deviation would provide either benefits or relief from problems. However, such deviations are only permitted when they can be accomplished without appreciably adverse effects to any other interests concerned with Lake Ontario regulation. Similar authority should be provided to the Lake Superior Board of Control.

The St. Lawrence Board of Control uses its discretionary authority to manage outflows from Lake Ontario to minimize damage and hardship in times of high and low water supply on Lake Ontario and the St. Lawrence River. In periods of crisis, under the direction of the Commission, it does so in accordance with Criterion (k) of the orders of approval for the Regulation of Lake Ontario. This criterion specifies that: in times of extremely high supplies, lake outflows be managed to provide all possible relief to shoreline property owners upstream and downstream, and in times of extremely low supplies, the outflows be managed to provide all possible relief to navigation and power interests.

In these periods, the Board of Control must decide the flow from Lake Ontario almost daily. The Board of Control would benefit from increased and more accurate information relating to: the stillwater level of Lake Ontario, the risk of damage around the Lake, the flow from the Lake, and the risk of damage on the St. Lawrence River in the Montréal area and downstream. For example, if both Lake Ontario and the St. Lawrence River are above their flood stage, the Board of Control must decide how the outflow can be modified to equitably balance adverse impacts. Complicating factors are such weather-driven uncertainties as storm surge on Lake Ontario and the short-term outflow variations in the

Ottawa River and other downstream tributaries.

Other sections of this chapter state that models used for simulating, forecasting and regulating levels and flows should be upgraded, that forecasting and statistical information should be improved, and that Lake Ontario and the St. Lawrence River should be assigned first priority in a recommended survey of potential shoreline damage. This information could be used with uncertainty analysis to evaluate the combined uncertainty of water supply, weather, Ottawa River and other St. Lawrence River tributaries, to provide significantly improved understanding of the range of factors that must be considered in discretionary decisions by the St. Lawrence River Board of Control and other decision-makers.

8.1.4. Forecasting and Statistics

With the development of improved models, better statistics could be furnished to users. These statistics would:

1. Be conditioned on present levels and existing climate regimes, and incorporate the concept of planning horizon;
2. Correctly compute the joint probability of the combined effects of mean levels, surges, and waves; and,
3. Correct for physical trends such as crustal movement.

Water levels and supply forecasts that provide only a single forecast time series have limitations. Present Great Lakes-St. Lawrence water level forecasts (i.e., monthly water level bulletins) perform the same as, or only marginally better than, a simple reference forecast based on average changes in levels superimposed on beginning water levels.

Without significant improvements in long-range precipitation and temperature forecasts, substantive improvements in the accuracy of water supply forecasts are not possible. The net basin supply techniques do not perform significantly better than the forecasts based on long-term climatology. However, the Great Lakes Forecast Package[122] performs marginally better, with few exceptions. Some improvement in the net basin supply forecasting for all models could be achieved with advancements in modeling, data collection, and weather forecasting.

Water level forecasts that indicate the range of future probabilities should be used in the water level bulletins issued by both federal governments. Graphic forecasts indicating the highest or lowest that levels might be expected to go can allow users to exercise their own judgment about possible future levels. Currently, the Canadian bulletin illustrates the range of future water levels based on extremely high and extremely low water supplies.

8.1.5. Communications

It is impossible to predict when the extreme highs and lows of this century will be repeated or exceeded. It is, however, probable, based on historic conditions, that they will be exceeded. The more affected interests know about water levels, the reasons for their fluctuations, the actions governments are taking, and the risks involved in using a system that is subject to daily, seasonal and long term fluctuations, the better they will be able to cope with these changes.

The results of a user survey[123] suggest ways to improve the quality and communication of water level information:

a. **Tailor forecasts and other statistical information to the needs of specific user groups.**
Those with the clearest needs for this information are: engineers, government emergency workers, recreational boaters and shoreline property owners. Their needs range from additional technical information to explanations in simple terms of forecast information.

[122] The Great Lakes Forecast Package is a set of computer models and a data retrieval system that is used to forecast the water supplies to the lakes though a detailed hydrological accounting of recent and anticipated precipitation, evaporation and runoff.

[123] See Chapter 7 and Annex 3 for more discussion of the user survey.

b. **Make changes to the water level bulletins.**
In both the United States and Canada, the bulletins are the best known and most used tools for communicating lake levels and forecasts. However, a number of regular bulletin users do not fully understand this valuable tool; nor are the forecasts given in the two bulletins consistent.

c. **Increase access to historic/real-time water level data.**
While some of the survey respondents expressed a need for access to water level data, only a small percentage know how to obtain it. While some users need to perform their own statistical analyses on the data, others (marina owners, riparians, emergency officials) could benefit from access to real-time information at local gauges, particularly during periods of extreme levels.

d. **Statistical forecast graphics should be available on request.**
Some users would like more probabilistic information included in the water level bulletins.

e. **Scientists need to develop a credible methodology for combining the effects of high water levels, storm surges and waves.**
Areas not currently covered by storm surge forecasts need to be included. Where surge forecasts exist, efforts to improve their accuracy and distribution should be continued. Local government agency staff should be encouraged to provide forecasters with feedback.

f. **Periodic workshops should be held for scientists and users of water level information.**
If progress is to be made in the areas mentioned in paragraph "e," workshops for users (local government staff, engineers, and others who serve in an advisory or communication capacity) will be essential.

g. **Public awareness of existing products should be improved.**
Much useful information about the fluctuating levels of the Great Lakes and St. Lawrence River is not used, because people who could use it are not aware of it. The agencies involved in generating lake level forecasts and statistics need to take more active roles in effectively disseminating their information, perhaps through a Water Levels Clearing-house such as the one recommended in Chapter 7.

h. **Continue to publish and further coordinate the Monthly Water Levels Bulletin.**
The Monthly Water Levels Bulletin should continue to be published and further coordinated, so that the water level measurements and forecasts issued by each country agree.

i. **Conduct public awareness activities during non-crisis periods.**
Governments should continue to take advantage of non-crisis periods to educate the general public about the risks associated with changing Great Lakes-St. Lawrence River water levels, and to strengthen their communications capabilities.

j. **Enhance capabilities of communicating during watches and warnings.**
Governments should take steps to maintain and enhance their capabilities to communicate with the public during high water level/flood and erosion watches and warnings.

k. **Aim material at specific audiences.**
Information material should be focused toward specific audiences, such as riparians and recreational boaters.

l. **Participate in public awareness activities.**
Governments should participate in public awareness activities in school curricula and with the public in general.

These actions would require the initiative and support of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data referred to in Chapter 6. In addition, the water levels communications clearinghouse might take an active role in some of these activities. Both the Clearinghouse and the Coordinating Committee should be responsible for reviewing these recommendations and determining the best way to implement them.

It is estimated that Governments would need to commit approximately $500,000 per year, per country to support the above activities.

8.1.6. Recommendations

The Board recommends that action be taken to improve the information base used to manage the Great Lakes-St. Lawrence River resource in the following ways:

1. **That the identified deficiencies in the precipitation and snowpack network be remedied.**
2. **That a risk analysis model be developed that takes into account uncertainties of water supply to Lake Ontario, storm surge on Lake Ontario, variations of tributary inflows to the St. Lawrence River downstream of Cornwall and updated stage-damage data in the Lake Ontario-St. Lawrence River system to assist in equitably managing outflows during high- and low-water supply periods. If discretionary authority is provided to the Lake Superior Board of Control, as recommended elsewhere in this report, this model should be implemented for Lake Superior, as well.**
3. **That efforts be made to improve long-range precipitation and temperature forecasts.**
4. **That new technologies such as satellite, airborne and ground-based radar be developed for use in the monitoring of lake evaporation, overlake precipitation and basin-wide snow conditions.**
5. **That work continue on upgrading models used for simulation, forecasting and regulation to formulate a comprehensive water supply and routing model that includes the whole basin through Trois Rivières, Québec.**
6. **That efforts to improve forecasting and statistical information be continued, so that all users throughout the system can make better decisions and that this be coupled with an upgraded system-wide supply and routing model.**
7. **That the suggestions referenced in this chapter to improve communication be implemented.**

8.2. HAZARD AREA IDENTIFICATION

This report has repeatedly stressed the need for coordinated, and integrated management of both the water and land components of the Great Lakes-St. Lawrence River System. Decision-makers need good geographic information on which to base decisions regarding the use of hazard land areas and to communicate with the public during the decision-making process.

8.2.1. Mapping of Hazard Areas

Hazard mapping programs focus on determining the susceptibility of land to flooding and erosion. The need for mapping areas particularly susceptible to these natural hazards has long been recognized as the basis for many other land and water management strategies. Hazard maps could be produced for the entire Great Lakes-St. Lawrence shoreline in accordance with still-undeveloped standard and consistent methodologies. Maps of hazard areas should be updated periodically and made available to the public, particularly to those who live within mapped hazard areas.

8.2.2. Flood Hazard Areas

Flood hazard areas have been partially identified through the National Flood Insurance Program in the United States. Rough estimates indicate that the magnitude of efforts and costs required to adequately map United States areas within the 1% risk line to 0.3 metre (1 foot) contour detail would cost approximately $3.5 million. Standardized procedures for such a comprehensive flood hazard mapping program are not available at present. The Federal Emergency Management Agency, the United States Army Corps of Engineers, and the eight Great Lakes States would need to agree on such a standard before this type of effort could be initiated.

In Canada, flood areas along the Great Lakes-St. Lawrence River shoreline are being defined through the Canada-Ontario Flood Damage Reduction Program. Originally instituted to map riverine flood hazard areas, the program was expanded in the late 1980's to include parts of the Great Lakes. This project, which maps the 1% risk line to 1 metre contours, has cost the provincial and federal governments about $3.5 million to date and is scheduled to be completed in 1993. By that time, shoreline mapping will have been completed for parts of Lakes Huron, Erie and Ontario.

Identification of shoreline flood hazards along the Great Lakes is difficult since lake levels react to long-term weather and climatic trends, in addition to daily or seasonal fluctuations. Many techniques are available to determine shoreline flood hazards, including stage-frequency analysis, topographical analysis, determination of high water marks, and water balance statistical approaches. This study has used a combined probability of still and storm water levels to determine flood hazard areas.

8.2.3. Erosion Hazard Areas

Erosion hazard areas have not yet been clearly defined. As noted earlier, there is little consistency between states and provinces on how erosion rate information is established. Basin-wide consistency is required.

Considerable progress has been made in this study toward understanding the erosion processes that influence coastal morphology (physical changes), especially as they relate to cohesive and sandy shorelines. Using the shoreline classification, erosion rate and erosion sensitivity information, and using the guidelines for erosion setbacks established in this report, erosion hazard areas could be identified.

8.2.4. Recommendations

The Board recommends that efforts be initiated to standardize hazard mapping methodologies across the Great Lakes-St. Lawrence River region and that efforts continue to identify and map all flood and erosion hazard areas in the system.

The Board further recommends that procedures be developed for allowing broad access to such maps for general use.

8.3. DATA NEEDS AND USE

Data is a cornerstone to understanding. Without data and scientific research, decisions are made without firm grounding. Throughout this study, considerable efforts have been made to gather information about the potential impacts of measures. In some cases, this required gathering new data, but time restrictions often necessitated reliance on existing information. A number of data gaps need to be filled to improve bases for decision-making and to provide opportunities for implementation of improved technology.

8.3.1. Erosion/Recession

Most shoreline erosion studies have used historic bluff recession rate data for a limited number of shore types. This information is not consistent between states and provinces and has only rarely been based on long-term monitoring of the shoreline. Although this information was adequate to complete the work of this study, a comprehensive recession rate database would have permitted a more thorough evaluation of the relationship between water levels and erosion. A comprehensive database would include periodic (monthly or yearly) investigations of recession rates and nearshore profiles for all shore types. It would permit states and provinces to begin developing consistent erosion setback lines.

The erosion studies conducted within this study determined that not all shoreline erosion is affected by water level changes. While erosion can be reduced for some types of shoreline by reducing the water level range, this is not true for all shore types. For cohesive shorelines where the lake bottom follows an equilibrium profile shape, for example, the influence of reducing the range of lake levels would result in minimal reduction (less than 5%) to the existing long-term recession rates. This finding could have significant implications for the use of existing erosion stage-damage curves, which imply a direct relationship between water levels and erosion damage.

Erosion stage-damage curves may not adequately estimate the impact of changes in still-water levels on erosion damage. Any future work carried out to determine potential erosion damage should be based on the type of information gathered through the erosion sensitivity work. Examples of these types of studies were carried out for Berrien County, Michigan on Lake Michigan, Oswego County on Lake Ontario, and for Central Lake Erie, Ontario.[124]

8.3.2. Recommendation

The Board recommends that long-term monitoring of shoreline erosion and bluff recession be undertaken and that future erosion damage assessments consider, or be based on, information and methodologies developed during this study to improve these approaches.

8.3.3. Land Use and Land Use Trends

Individual tasks conducted for the Reference Study generated baseline land use information for the majority of the Great Lakes and St. Lawrence River shorelines. This information is not complete, however. There are gaps in the Canadian portions of information gathered for Lakes Huron and Superior. The United States and Canadian databases are similar, although not identical. The United States land use database is inconsistent in temporal coverage, with information within the State of Michigan having been generated for 1979 conditions, while the shoreline information of the other seven Great Lakes states is from 1988-90. Nevertheless, the information generated was useful in determining the potential for both inundation and erosion damage along the shorelines.

Due to the dynamic nature of land uses along the shoreline, it is essential that this information be updated periodically and made uniform across the region. Information on land use and land use trends is critical for assessing future impacts of fluctuating Great Lakes-St. Lawrence River water levels and for making appropriate planning decisions.

8.3.4. Recommendation

The Board recommends that the United States and Canadian land use mapping systems be updated on a periodic basis and that they be designed and developed cooperatively to promote uniformity.

8.3.5. Determination of Damage

A limitation of the potential damage estimates for this study was the lack of an accurate inventory of all properties, structures, and improvements within the erosion and flooding hazard zones along the shorelines. The existing damage data bases for erosion and flooding vary in age, method of collection and reliability. The stage-damage curves rely primarily on historical damage estimates gathered during the high water periods of the 1970's and 1980's. Although the curves provide reliable estimates of the historical expenditures that resulted from the high water periods, reliance on historical damage limits the applicability of the data to estimates of potential future damage. It also increases the chance of errors every time the curves are updated.

Continual updating of flood and erosion stage-damage curves will not be adequate for long-term determination of damage. A new damage survey is required, and it should consist of the largest sample possible. However, even a very small sample can yield information that is superior to that which is currently available.

124Working Committee 2, Potential Damages Task Group, *Final Report* (March 1993).

Any effort to collect new data should be accompanied by a carefully prepared strategy to collect and process the acquired data.[125] A damage survey combined with continual updating of land use and land use trends can provide accurate estimates of potential damage along the Great Lakes-St. Lawrence River shoreline. The estimated cost of obtaining a stratified random sample of Great Lakes-St. Lawrence River riparian property is $250,000 to $500,000. Future potential damage estimates should be generated using accurate estimates of structures and lands at risk within accepted hazard area delineations. This information would be useful in making decisions on balancing water between Lake Ontario and the St. Lawrence River during periods when Lake Ontario is high and high water supplies to the system are forecast.

8.3.6. Recommendation

The Board recommends that a potential damage sample survey be undertaken in the future to improve flood damage estimates. The Board further recommends that the first priority for the potential damage sample survey be Lake Ontario and the St. Lawrence River.

8.3.7. Wetlands

Wetland research for the Reference Study made use of available data, or collected new data, during a very short time period. Short-term studies that assess long-term processes cannot provide complete insight into the interactions between water level changes and wetlands of the Great Lakes-St. Lawrence River System. Natural and human resource management and protection strategies based on short-term studies risk error, because real data taken during fluctuation events are not available. Long-term evaluation (e.g., monitoring studies) of the effects of lake levels, connecting channel levels, and flow variations would improve the understanding of the wetland resources in the Great Lakes-St. Lawrence River System and increase opportunities for maintenance and improvement of the wetland resource.

A limitation of the Reference Study was the lack of a comprehensive wetland inventory for the entire Great Lakes-St. Lawrence River Basin. Although a complete wetland inventory was available in the United States, it was limited in its level of detail and not comprehensively verified by field work. An inventory comparable to the United States database was not available in Canada. As a result, numerical estimation of the total acreage of wetlands at risk to future changes in the natural water level regimes was not possible.

The current regulation plan for Lake Ontario (Plan 1958-D with deviations) has caused negative impacts on Lake Ontario shoreline wetlands and on the St. Lawrence River flood plain forests at Lac Saint-Louis as a result of a reduced water level range and increased flow fluctuations respectively. Further study of these impacts and potential future impacts should be conducted.

8.3.8. Recommendation

The Board recommends that a comprehensive wetlands inventory be completed and that long-term assessments of the effects on wetlands of variations in levels and flows be continued.

8.3.9. Climate Change

Although global climate models (GCMs) are the best tool for predicting future climates and climate change, the need continues for further improvements. Confidence in regional climate patterns based directly on GCM output is relatively low, and there is no consistent evidence regarding changes in climate variability or storminess. Increased confidence in the geographical patterns of climate change requires new simulations with improved coupling of atmospheric and ocean processes, and with radiative forcing scenarios that include aerosols.

[125] Yoe, Charles., *A Critical Review of Stage-Damage Curves, Existing and Updated U.S. and Canadian.* For the Potential Damage Task Group of Working Committee 2, (June 1992).

Accurate predictions of future climate require two things: 1) inclusion all of the major natural and human factors known to affect climate; and, 2) prediction of future magnitudes of atmospheric concentrations of greenhouse gases. The first condition is only partially met with current GCM experiments, since the experiments include only radiative forcing induced by greenhouse gases. Thus, their results relate only to the greenhouse component of climate change and do not account for other factors. This incomplete accounting, however, does not negate their results, since it is still believed that greenhouse gases produced by humans are the greatest contributor to the greenhouse effect. The second condition will be met when a specific prediction (as opposed to a scenario) of future atmospheric concentrations of greenhouse gases can be made. This will require an improved understanding of social, technological and economic processes that contribute to production of greenhouse gas emissions.

8.3.10. Recommendation

The Board recommends that refinement of Global Climate Models be continued to improve their predictive capability and use as a planning tool.

The Board further recommends that efforts continue to develop a binational assessment of the potential impacts of climate change on the Great Lakes-St. Lawrence River System and to coordinate a response to the expected climate changes.

8.3.11. Geographic Information System

Geographic information system (GIS) technology has dramatically changed the rate at which data that is referenced geographically can be produced, updated and disseminated. This computer-based technology has made the production and analysis of geographic information more efficient and has changed the way this information is perceived and used. Almost all of the data gathered for the Levels Reference Study is spatially-related to the Great Lakes-St. Lawrence River System. The size of the system requires large databases. GIS not only allows data storage and management capabilities, it also allows data to be updated easily and permits spatial analysis of the data. This might include anything from simple map overlays to more sophisticated "what if" scenarios. It makes sense that data, both digital and attribute, gathered in this study and others should be housed in a GIS database to provide optimal use.

GIS has been used for a number of projects within this study. These include: shoreline classification of the geomorphology, level of shore protection, sub-aqueous and erosion sensitivity characteristics of the shoreline, land use inventory and trend data, historical wetland studies, and site specific studies.

The land use database produced in this study is extensive but not fully integrated. Land use information for the United States shoreline has been fully incorporated into a geographic information system. Land use for the Canadian shoreline is in geographic information system and spreadsheet formats, which, in its present form, provides useful static land use information. Land use information contained in the Canadian Coastal Zone Database has not been standardized or integrated. A fully operational geographic information database would have the capability to undertake powerful and accurate planning and management "what if" scenarios to predict future land use changes and potential impacts along the shoreline.

Development and use of hazard maps can be a costly and time-consuming venture. GIS use will allow data to be updated regularly and much more easily than it has been in the past. Relating hazard area information with land use information can prioritize those areas requiring remedial land use practices. This can be done with the GIS by overlaying hazard area information with land use information. This combined information can also be used to determine potential property damage. Hazard areas should be identified and digitized into the land use GIS database.

The wetland inventory should be implemented and maintained in a GIS database. Such a database would allow for updating information and accurate spatial analysis. The data-

Glossary

Barrier Beach: Long sand beach that separates a back shore bay, lagoon, or low lying area such as a wetland from the open water. The barrier beach is generally formed through long-shore drift of sediment and is prone to overwash that allows water to enter the backshore area.

Basis of Comparison (BOC): The BOC is a set of water levels and flows that are used as a reference for assessing the impacts of changes to the existing system due to possible lake regulation plans and the crisis management plan. The BOC is calculated for a 90-year period using 1900-1989 supplies. It gives the water levels and flows that would have occurred each month of that period if all current regulation plans, current channels and existing diversions had been in effect over that entire period. The water supplies used to calculate the BOC are the supplies that actually occurred (historic supplies) during the 90 years from 1900-1989.

Black Rock Lock: The Black Rock Lock and Black Rock Canal near Buffalo, New York, where Lake Erie drains into the Niagara River, provide a protected waterway for vessels around the reefs, rapids and fast currents in the upper Niagara River.

Canadian Coastal Zone Database: Information on the various attributes of the key components of the Canadian Great Lakes ecosystem (including land use, shore type, bathymetry, 1:100 year flood line), gathered and stored in a geographic information system.

CFS (cubic feet per second): The units by which flows in the Great Lakes-St. Lawrence River System are measured. CFS units may be converted to their metric equivalent, cubic metres per second (cms) using (1 cms = 35.315 cfs).

CMS (cubic metres per second): The units by which flows in the Great Lakes-St. Lawrence River System are measured. CMS units may be converted to their metric equivalent, cubic feet per second (cfs) using (1 cms = 35.315 cfs).

Chicago Diversion (Lake Michigan Diversion at Chicago): Diversion of water through the Illinois waterway to the Mississippi River is for water supply, sewage disposal, power generation and navigation. The amount of water diverted is set at an average of 3,200 cfs (90 cms) by a 1980 order of the United States Supreme Court.

Control Structure: A gated structure (similar to a dam) placed in the river to allow adjustable retardation of flow from the upstream lake.

Criterion C: A requirement, in Lake Superior's regulation plan that calls for a specified flow during low water periods. When Lake Superior's level is less than 183.0 metres (600.5 feet), Criterion C requires that the total discharge from the lake shall be no greater than that which would have occurred prior to installation of structures in the St. Marys River.

Detailed Site Study: For this study, detailed site studies involved the investigation of selected locations to gather information on flooding, erosion and low water impacts caused by either natural conditions or a given lake level regulation scenario.

Equilibrium Profile: A cohesive shore profile that has reached its natural shape.

Evapotranspiration: The evaporation of water from land and transfer of moisture from vegetation to the air.

Federal Emergency Management Agency (FEMA): The federal agency in the United States that handles the National Flood Insurance Program.

Geographic Information System (GIS): A computer based information tool that captures, displays and manipulates geographically referenced data to assist in the decision-making process.

Glacial Till: Soil left after the retreat of the glaciers primarily composed of clay, sand and gravel.

Ice Booms: Consist of a series of floating timbers designed to assist with the formation of stable ice cover and to reduce the possibility of ice jams in connecting channels and the St. Lawrence River during the winter months. Booms are installed each winter in the St. Marys River, at the outlet of Lake Erie and in the St. Lawrence River. They are removed each spring.

International Great Lakes Datum (IGLD): The reference system by which Great Lakes-St. Lawrence River Basin water levels are measured. It consists of benchmarks at various locations on the lakes and St. Lawrence River, which are referenced to a point in the St. Lawrence River that roughly coincides with sea level. All water levels are measured in feet or metres above this point. Movements in the earth's crust necessitate the updating of this datum every 25-30 years. The first IGLD was based upon measurements and benchmarks that centered on the year 1955, and it was called IGLD (1955). The most recently updated datum uses calculations that center on 1985, and it is called IGLD (1985). All water level measurements in this document are referred to IGLD (1955).

Iroquois Control Dam (Iroquois Dam): Extending across the St. Lawrence River at Iroquois, Ontario, this dam can be used to regulate the flow of water from Lake Ontario, but is usually used only to assist in the formation of a stable ice cover in the winter, and to prevent water levels from rising too high in Lake St. Lawrence, which is located between this dam and the Moses-Saunders Power Dam.

LWD (Low Water Datum): In Canada, this is referred to as Chart Datum. LWD is a reference level on each of the Great Lakes that is used on navigation charts. Low Water Datum (or Chart Datum) is the level below which boats have less depth of water to the lake bottom than is shown on the navigation chart. Low Water Datum should not be confused with International Great Lakes Datum (IGLD), which is defined above.

Long Lac and Ogoki Diversions: These two diversions are separate but they are often considered together because they both divert water into Lake Superior that originally flowed north to James Bay. These diversions were developed in the 1940's to generate hydropower and, in the case of the Long Lac diversion, to transport pulpwood logs.

Long Sault Dam: Located near Long Sault, Ontario, and near the Moses-Saunders Power Dam, this dam acts as a spillway when outflows from Lake Ontario are larger than the capacity of the power dam.

Measure: Any action that could be taken to alleviate the adverse consequences of fluctuating Great Lakes-St. Lawrence River water levels.

Moses-Saunders Power House Power Dam: This dam extends across the St. Lawrence River between Cornwall, Ontario, and Massena, New York. This dam is used for hydropower generation, as well as to regulate the level of Lake Ontario.

Multi-Criteria Multi-Objective Measures Evaluation: A process used to rate various measures or options based on a set of agreed upon evaluation criteria.

Non-Structural Measure: Non-structural measures include beach nourishment, land filling, bluff drainage, bluff stabilization and similar shoreline practices.

1:100 Year Flood Line: The one in one hundred year flood line denotes the elevation at which there is a 1% risk of being flooded in any year. This elevation line is generally used to define the flood hazard area.

Order of Approval: An order issued by the International Joint Commission that specifies conditions to be met in the implementation of actions that affect the levels and flows of boundary waters.

Regulation Plan: A system of procedures established by the International Joint Commission that governs the operation of structures that control the outflow from a lake.

Relict Dune: A sand dune that is no longer actively building.

Riparian: For the purposes of this study, any individual who owns property that borders on the Great Lakes-St. Lawrence River System.

Risk Analysis: An analysis that evaluated the probability of flood damage occurring at differing elevations along the shoreline and assessing the probability of damage levels being exceeded.

SEO: This acronym refers to Lakes Superior, Erie and Ontario and is a three lake regulation plan that would require dredging and control works at the Niagara River (see chapter 4).

SHMEO: This acronym refers to Lakes Superior, Michigan-Huron, Erie and Ontario and is a five lake regulation plan that would require dredging and control works at the the St. Clair, Detroit and Niagara Rivers (see chapter 4).

SO: This acronym refers to Lakes Superior and Ontario and is a two lake regulation plan that would require no new dredging or control works (see chapter 4).

Stage-Damage Curve: A graph developed by plotting the amount of dollar damage anticipated for a range of flood water elevations (or stages) caused by high lake levels. Stage-damage curves were also used in this study to plot erosion damage. Stage-damage curves that were developed for the St. Lawrence River differed from those prepared for the lakes, because the stage part of the curves was based upon river flows, rather than water levels.

Stillwater: The level of the water measured without the influence of storms or waves

Storm Surge: A surface tilt of a lake caused by strong winds continually blowing over the water body in one direction for a number of hours.

Structural Measure: Structural measures include land use and shoreline measures such as shore protection works, including seawalls, breakwaters, groins, revetments, artificial headlands, artificial islands, dikes and similar practices. This reference to structural measures does not include structures to regulate the levels and flows of the Great Lakes and St. Lawrence River.

2xCO_2: Double the present concentration of carbon dioxide in the atmosphere, which is predicted to result in global warming.

Welland Canal: Originally built in 1829, the canal diverts water across the Niagara Peninsula from Lake Erie to Lake Ontario. Used primarily for deep draft navigation and hydropower generation, the canal also supplies water for industrial and municipal use, and for water quality enhancement. The present Welland Canal is a modified version of that built between 1913 and 1932 and has been an integral part of the St. Lawrence Seaway since 1959.

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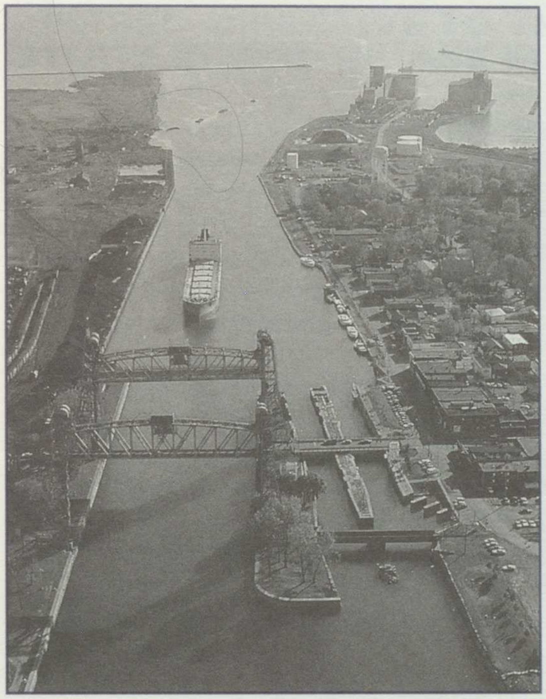
Appendices



A Directive

B Reference

C Response to Reference and Directive

D Summary of Public Forums and Written Comments on Draft Final Report

E Questions and Answers on Draft Final Report

F Study Team

Directive

REVISED DIRECTIVE TO THE LEVELS REFERENCE STUDY BOARD (PHASE II)

1. The governments of Canada and the United States forwarded the Reference, dated August 1, 1986 (Attachment 1) to the Commission for the examination and report pursuant to Article IX of the Boundary Waters Treaty of 1909.

2. The Commission submitted an initial report to Governments by letters dated November 14 and December 10, 1986 which addressed the immediate emergency existing at the time the Reference was received.

3. Concurrently, the Commission established a Task Force to obtain additional technical information on all possible high-level crisis measures. Based on the Report of the Task Force (October 1987), the Commission submitted an interim report to Governments *(Interim Report on 1985-86 High Water Levels in the Great Lakes-St. Lawrence River Basin)* in October 1988.

4. In April 1987 the Commission approved a Directive establishing the Project Management Team (PMT) to be responsible for on-going project management and the conceptual, technical and administrative integration of the study.

5. Based on the advice of the PMT, the Commission advised Governments by letter of December 10, 1987 that the study requirements would be addressed in two phases. The PMT submitted their Phase I Progress Report and seven Annexes to the Commission in July 1989 and the Commission transmitted a complete set of reports to Governments by letter of August 25, 1989.

6. On February 8, 1990, the Commission established the Levels Reference Study Board (Phase II), hereinafter referred to as the Board, to undertake, through appropriate governmental or other entities in Canada and the United States, the necessary investigations and studies and to advise the Commission regarding each issue raised in the Reference, except item number 2 and that answered by paragraph 3 above, namely:

   a) propose and evaluate measures which governments could take, under crisis conditions, to alleviate problems created by high and low lake levels;

   b) examine past, present, and potential future changes in land use and management practices along the shorelines of the Great Lakes, their connecting channels and the St. Lawrence River;

   c) determine, to the maximum extent practicable, the socio-economic cost and benefits of alternative land use and shoreline management practices and compare these with the revised costs and benefits of lake regulation schemes;

d) investigate any feasible methods of improving the outflow capacity of connecting channels and the St. Lawrence River;

e) develop an information program which could be carried out by responsible governmental agencies to better inform the public about lake level fluctuations.

The Board is requested to examine, in a systemic context, the effects both within and outside the basin of the measures it considers on:

(1) domestic water supply and sanitation;

(2) navigation;

(3) water supply for power generation, industrial and commercial purposes;

(4) agriculture;

(5) shore property, both public and private;

(6) flood control;

(7) fish, wildlife and other environmental aspects;

(8) recreation and tourism.

Wherever appropriate, the Board is encouraged to use improved analytical techniques which would best represent the changing conditions and socio-economic values in the Great Lakes region. In order to assess the viability of lake level regulation, the Board should take into account changes in land use practices induced by actions which previously have affected levels in the Great Lakes basin.

In the event that the Board's investigations show that new or altered works or other regulatory measures appear to be economically and environmentally practicable, it shall determine the full costs and benefits of such works or measures and indicate how the various interests on either side of the boundary would be affected thereby. In addition, the Board shall determine the need for and costs of remedial or compensatory works or measures which may be adversely affected by any proposed regulatory measures.

7. In the conduct of its investigation, the Board should make use of relevant information and technical data heretofore available, or which may become available during the course of the investigation. The Board's attention is specifically drawn to the Phase I Progress Report and its seven Annexes, as well as the following Commission interim reports and letters:

(a) Initial letters to Governments – November 14 and December 10, 1986.

(b) Letter to Governments (Phase I and II) – December 10, 1987.

(c) Plan of Study; transmittal letter to Governments – March 15, 1988.

(d) *Interim Report on 1985-86 High Water Levels in the Great Lakes-St. Lawrence River Basin* – October 1988.

(e) Phase I transmittal letter to Governments – August 25, 1989.

8. The Board shall prepare and submit for Commission approval, as soon as possible, but no later than May 15, 1990, a Plan of Study ("POS") for the investigations it proposes to undertake. This shall include a schedule of the estimated time, costs and personnel involved in the completion of each of the necessary tasks, and an outline of how the various Reference matters will be addressed.

9. In developing its POS, the Board should be guided by the following considerations:

   (a) The POS shall include but not be limited to the objectives in Attachment 2.

   (b) The POS shall make provision for the involvement and participation of the public and the various interests at all levels of the study. This involvement and participation is to assist in the conceptualization, implementation and review of activities pertinent to the study.

   (c) The POS shall make provisions for information exchange with the public, undertaken in consultation with the Commission.

10. The Board shall carry out its programs in accordance with the Plan of Study approved by the Commission. If it appears to the Board at any time in the course of its investigations and studies that the programs should be modified, it shall so advise the Commission and request instructions.

11. The Board shall submit to the Commission its final report and appendices, if any, no later than September 1, 1991.

12. The Board shall consist of a U.S. Section and a Canadian Section, each having five members. Each section shall contain one member drawn from a federal agency, two members drawn from state or provincial agencies, and two non-governmental members. One non-governmental member shall be appointed directly to each section of the Board. Each section shall also contain one non-governmental member designated by the Citizens Advisory Committee as provided in paragraph 14. The Board may also appoint a Study Director, and the Commission may appoint the Director as a member of the Board.

13. Notwithstanding 12 above, the Board shall act as a unitary body, carrying out its investigations jointly in both countries as a coordinated and integrated effort.

14. The Board shall appoint a Citizens Advisory Committee (Committee) consisting of an equal number of members for the U.S. and Canada. The Committee shall be an advisory committee to the Board and the Board shall prepare its terms of reference. The Committee shall select two of its members, one from the U.S. and one from Canada, to serve as members of the Board as provided in paragraph 12. The members of the Committee shall participate as volunteers but will be reimbursed for their travel expenses and per diem expenses. Pursuant to its terms of reference, the Committee shall organize itself and meet as it deems appropriate. Its operational plan and budget once approved by the Board shall be incorporated into the POS.

15. The Board may establish such committees and working groups as may be required to discharge its responsibilities effectively and may enlist the cooperation of federal, provincial or state departments or agencies in Canada and the United States. The duties and composition of any such committees shall be consistent with the Plan of Study as approved by the Commission.

16. Members of the Board and of its committees and working groups serve in their personal and professional capacity under the direction of the Commission.

17. The Board shall maintain liaison with the Commission's International Lake Superior, Niagara and St. Lawrence River Boards of Control, as well as the Great Lakes Water Quality and Science

Advisory Boards, so that each may be aware of any activities of the other Boards which may be useful to it or may have a bearing on its activities.

18. The Board shall submit bi-monthly reports to the Commission describing the progress that has been made and any problems that have arisen in the investigation. Regular semi-annual reports should be submitted at least two weeks prior to the Commission's semi-annual meetings in the spring and the fall.

19. Reports, records of meetings and other documents prepared by the Board, its committees and work groups shall be available for public view.

Attachments:
As stated.

Approved by the Commission at Ottawa on February 8, 1990, as revised at Washington, D.C. on April 20, 1990.

ATTACHMENT 1

(See Appendix B)

ATTACHMENT 2

Objectives for Phase II

Objective 1 **Principles**: Establish a set of guiding principles that the Commission could propose to Governments to assist them in dealing with fluctuating water levels in the Great Lakes-St. Lawrence River Basin. Examples of two broad categories of principles that should be considered are those that improve cooperative decision-making, and those that provide for an appropriate amount of flexibility for future conditions.

Objective 2 **Short-term Support Studies**: Conduct short-term studies in several areas to supply information needed for successful completion of the other Phase II objectives. Such studies would be of different duration and should include:

(1) **GIS**: Continue the development of the Geographic Information System (GIS) initiated in Phase I by adding data and "intelligence" so as to be able to assess the potential impacts of fluctuating water levels and potential measures.

(2) **Climate**: Develop and test possible responses to various climate change scenarios, including those studies in Phase I.

(3) **Erosion**: Enhance Phase I information on the interrelationship of coastal erosion with fluctuating water levels, storm events, recession rates and shoreline morphology to confirm or reject Phase I conclusions regarding shoreline erosion processes.

(4) **Wetlands**: Complete the Phase I wetland inventory and relate extreme water level fluctuations to the structure and function of sensitive wetland ecosystems.

(5) **Damage Potential**:

(a) Obtain additional information on the number and location of structures and users at risk in the Basin. Assess both the effect of these uses on the shoreline as well as the vulnerability of the various user groups to fluctuating high and low water levels.

(b) Categorize the types of human uses of the shoreline and quantify them in such a way as to provide damage assessments needed for Objective 3 (Measures and Evaluation).

(6) **Lake Regulation**: Develop and test over a range of partial-to-total structural control options to confirm or reject the conditional conclusion in Phase I that lake regulation measures (Type I) are probabaly ill-advised. This information will assist in the model runs (Objective 3) and in assessing the environmental and economic costs of structural controls.

(7) **Regulation Plans**: Further examine existing Regulation Plans 1977 and 1958-D to determine if any adjustments are appropriate following the identification of the significant effects of extreme water levels on various users in the Basin, and in particular recreational interests. The examination may also include results from Task 4 of this objective and other interests as appropriate.

(8) **Policy Models**: Develop one or more policy models incorporating such factors as hydrology, the effectiveness of measures, and activities and sensitivities of various interest groups and alternative forms of interjurisdictional cooperation, to aid in evaluation and decision-making in the Basin.

(9) **Forecasting**: Compile information on weather, storm and wave forecasting in the Basin, identify areas where improvements can be made, and implement those areas that are feasible.

(10) **Frequency Analysis**: Determine whether or not it is feasible to perform a frequency analysis of both high and low lake levels and, if so, undertake such an analysis.

Objective 3 **Measures and Evaluation**: Evaluate a range of management measures on a variety of type-specific sites throughout the Basin. This objective could be fulfilled by undertaking the following tasks:

(1) **Type-Specific Sites**: Identify and characterize several type-specific sites that encompass the variety of natural ecosystems and land and water uses in the Basin, including various institutional/jurisdictional frameworks and U.S. and Canadian interests. Selection should address signficant environmental, economic, jurisdictional and geographic factors. Some possible examples include, but are not limited to, the following:

- densely populated lake front residential area (Chicago; Toronto)
- existing shoreline residential area (north shore Lake Erie)
- riparian reach particularly susceptible to damage (Saginaw Bay)
- area likely to experience pressure for future development (Illinois shoreline north of Chicago)
- sensitive environmental reach (Long Point and Point Pelee on Lake Erie)
- agricultural area (Ohio on Lake Erie)
- industrial hub (Gary/south Chicago)
- intensive commercial recreation centre (Thousand Islands area)
- hydropower node (Niagara complex)

- sensitive navigational reach and connecting channel (St. Clair/Detroit River; St. Lawrence River and Montreal Harbour)
- changed land use (Lake Ontario shoreline)

(2) **Information Bases**: For each site, compile a set of detailed and comprehensive information that will be both biophysical and socio-economic. Some of this information will be in mapped format for the GIS.

(3) **Application**: Apply each of the six types of measures described in Phase I, plus an environmental enhancement option, by entering appropriate sets of parameters into a basin-wide hydraulic model and the GIS.

(4) **Interests**: Identify and characterize for each site the interests and their environmental and socio-economic components at risk.

(5) **Evaluation**: Further develop and apply the evaluation framework initiated in Phase I to the measures being tested to determine if the framework should be accepted, modified or replaced. In addition, apply benefit/cost analyses to the measures being tested. These applications should also test the results of Objective 1 (Principles), to the extent possible.

(6) **Inter-Jurisdictional Arrangements**: Examine existing arrangements for inter-governmental cooperation and coordination, including the role of State/Provincial and federal agencies in supporting local governments in managing the system by involving representatives of the various interests and organizations.

(7) **Conclusions**:

(a) Summarize findings and conclusions from each site study.

(b) Generalize findings from site studies to other similar locations in the Basin to produce conclusions on the efficacy of alternative courses of actions, including those with Basin-wide application.

Reference

On August 1, 1986, the Secretary of State for External Affairs for the Government of Canada and the Secretary of State for the Government of the United States sent the following Reference to the International Joint Commission, through identical letters addressed respectively to the United States and Canadian Sections of the Commission:

I have the honour to inform you that the Governments of Canada and the United States of America, pursuant to Article IX of the Boundary Waters Treaty of 1909, have agreed to request the Commission to examine and report upon methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes - St. Lawrence River Basin. In doing so, the Governments acknowledge previous Commission reports on regulation of Great Lakes levels, which have encouraged appropriate jurisdictions to institute improved shoreline management practices.

The Governments note that the previous reports were based upon recorded water supplies which have subsequently been exceeded, that economic conditions have changed, and that improved analytical techniques may now be available. The Governments conclude, therefore, that further investigation is now required to revise previous reports and develop appropriate methods to alleviate the adverse consequences of fluctuating water levels.

Accordingly, the Commission, building upon previous studies, should:

1. *propose and evaluate measures which governments could take, under crisis conditions, to alleviate problems created by high and low lake levels;*

2. *review its previous lake regulation studies and revise their engineering, economic and environmental evaluations;*

3. *examine past, present and potential future changes in land use and management practices along the shorelines of the Great Lakes, their connecting channels and the St. Lawrence River;*

4. *determine, to the maximum extent practicable, the socio-economic costs and benefits of alternative land use and shoreline management practices and compare these with the revised costs and benefits of lake regulation schemes;*

5. *investigate any feasible methods of improving the outflow capacity of connecting channels and the St. Lawrence River;*

6. *develop an information program which could be carried out by responsible governmental agencies to better inform the public on lake level fluctuations; and*

7. *consider any other matters that the Commission deems relevant to the purpose of this study.*

The Commission is requested to examine the effects both within and outside the basin of the measures it considers on:

(1) domestic water supply and sanitation;

(2) navigation;

(3) water supply for power generation, industrial and commercial purposes;

(4) agriculture;

(5) shore property, both public and private;

(6) flood control;

(7) fish, wildlife and other environmental aspects;

(8) recreation and tourism; and

(9) such other effects and implications which the Commission may deem appropriate and relevant.

Wherever appropriate, the Commission is encouraged to use improved analytical techniques which would best represent the changing conditions and socio-economic values in the Great Lakes region. In order to assess the viability of lake level regulation, the Commission should take into account changes in land use practices induced by actions which previously have affected levels in the Great Lakes basin.

In the event that the Commission's investigations show that new or altered works or other regulatory measures appear to be economically and environmentally practicable, it shall determine the full costs and benefits of such works or measures and indicate how the various interests on either side of the boundary would be affected thereby. In addition, the Commission shall determine the need for and costs of remedial or compensatory works or measures to offset costs to the interests which may be adversely affected by any proposed regulatory measures.

In conducting its investigations and in preparing its report the Commission shall use data which is available now or which is developed during the course of its study. In addition, the Commission shall seek the assistance, as required, of specially qualified personnel in Canada and the United States. The Governments, subject to their applicable laws and regulations, shall make available, or as necessary, seek the authorization and appropriation of funds required to provide promptly to the Commission the resources needed to discharge its reference obligations within the specified time period. The Commission shall develop, as soon as practicable, study cost projections for the information of Governments.

The Commission, subject to the availability of adequate appropriations, should proceed with the studies as expeditiously as practicable and present its final report to Governments no later than May 1, 1989. The Governments also request that an interim report, focusing on measures to alleviate the present crisis, be submitted no later than one year from the date the Commission's study board actively begins its work.

Appendix C

Response to Reference and Directive

Requests From the Reference:

1. *Propose and evaluate any measures which Governments could take, under crisis conditions, to alleviate problems created by high and low lake levels.*

   RESPONSE: The Commission submitted an interim report to Governments responding to this issue in October 1988. During the final phase of the study, a Crises Conditions Task Group was formed jointly by Working Committees 3 and 2 to develop components of and a procedure for developing a comprehensive crises conditions response plan. The Task Group examined both water level regulation measures and land based emergency response and planning measures. Approximately 150 measures and combinations of measures were investigated. Critical water level thresholds (both high and low) for each lake in the system have been identified. Emergency responses to both extreme high and extreme low water levels have been developed. The Board product that responds in detail to this issue is in Chapter 5 of the Final Report and Annex 6 - Crises Condition Responses.

2. *Review previous lake regulation studies and revise their engineering, economic, and environmental evaluations.*

   RESPONSE: This study built on information contained in previous studies and developed new information. The Great Lakes and St. Lawrence River hydrologic and hydraulic numerical models were integrated to produce levels and flows data for each lake and river segment in the basin under a variety of water level regulation scenarios. Scenarios examined include those reviewed in earlier studies but also go well beyond the work previously completed, both in the scope of investigation (i.e., from individual lake basins to five-lake system-wide plans), and in the range of conditions examined (i.e., from lake level ranges historically experienced to those that could result from extended wet and dry conditions and from climate change).

   An "Optimization Model" was developed and used to attempt to achieve an acceptable balance of water levels and flows throughout the basin in accordance with preferences expressed by a number of interest groups participating in the study. The "Optimization Model" is limited and can only be used under total system (five lake) management. The existing model needs considerable work before it can be utilized for routing through the system where controls do not exist. the existing model is just a preliminary step in the development of a universal model.

Annex 3 - Working Committee 3 Report provides details on the work completed in reviewing previous engineering studies and in developing improved analytical techniques to comprehensively address water level regulation issues from a basin-wide perspective.

Levels and flows data from the various water level regulation scenarios were provided to Task Groups in Working Committees 2, 3, and 4. Economic and environmental impact assessments were completed on these scenarios and also on alternative land use and shoreline management measures.

The assessments included quantitative estimates of changes in impacts under a variety of alternative future conditions for shoreline property. The hydropower studies were based on the configuration of the system in the year 2000 and determined the impact in comparison to the Basis of Comparison (without project condition) if the supplies in the past were repeated. Both Commercial Navigation and Recreation Boating reflect the 1989 condition. No future projections of fleet composition or increased recreation boating were made. Qualitative evaluations were completed for other impact categories, including, infrastructure, agriculture, and other recreation and tourism.

In all these cases, new work was completed to check past estimates of impacts and to improve the methodologies and techniques applied in developing current estimates. New work included:

a. Estimates of damage caused by erosion to shore property around the basin, with an assessment of how erosion damage might change under alternative water level regulation scenarios. Shoreline erodibility was classified and mapped based on specific shoreline characteristics (Annex 2 - Working Committee 2 Report).

b. Estimates of damage caused by flooding to shore property around the basin, with an assessment of how flooding damage might change under alternative water level regulation scenarios (Annex 2 - Working Committee 2 Report). Previously used stage-damage curves were updated, and a risk analysis was completed to estimate the likely range within which flood damage would be expected to occur under future conditions (Annex 2 - Working Committee 2 Report).

c. Estimates of future avoided costs of shore protection and estimates of past expenditures on shore protection during the 1985-1987 period were developed (Annex 2 - Working Committee 2 Report).

d. Thirteen detailed site studies were conducted, covering locations on each of the lakes and the St. Lawrence River, to better assess specific problems of affected interest groups and potential responses to these problems (Annex 2 - Working Committee 2 Report).

e. Recreating boating site studies were conducted in the United States and Canada. The only lake not covered as part of this effort was Lake Michigan (Annex 3 - Working Committee 3 Report).

f. Surveys of residential riparian property owners were conducted to obtain information on incidence of flooding and erosion problems and to determine the perceptions of respondents regarding potential solutions (Annex 2 - Working Committee 2 Report).

g. Impact studies for other affected interest groups were completed in making comparisons of future conditions with and without potential measures in place. The hydropower studies identified possible alternatives to replace energy and power losses and its replacement value. Commercial navigation studies included impacts to overseas shipments. Recreation boating used site specific information that was extrapolated to system-wide impacts.

c. Forty-one study planning objectives were established, to ensure that significant concerns of each of the affected interest groups and water users were considered in the impact assessment and measures evaluation process.

d. Four core criteria with nine sub-criteria were developed to ensure that both land use and water level regulation measures were evaluated on the same basis. The nine subcriteria applied in the measures evaluation included: benefit cost analysis; other economic and social impacts; ecological productivity; environmental purity; distribution of impacts among affected interests; distribution of impacts among affected regions; technical feasibility; operational feasibility; and legal and public policy feasibility.

e. The information and data on the economic and environmental impacts of potential measures, including benefits and costs, were included in the summary *"Blue Book"*. This document was provided to all study participants and was used in reaching agreement on the comparative strengths and weaknesses of both land use and shoreline measures and water level regulation measures.

f. Annex 4 - Working Committee 3 Report is the study document which provides details of how the multi-criteria measures evaluation process was developed and applied in responding to this request of the Reference.

5. *Investigate any feasible method of improving the outflow capacity of connecting channels and the St. Lawrence River.*

RESPONSE: Working Committee 3 examined a number of alternative water level regulation scenarios that included as features the increase in flows through the St. Clair-Detroit, Niagara, and St. Lawrence Rivers. Engineering reviews were completed that, in some cases, involved estimates of the amount of dredging that could be required in the channels to increase outflows, and the associated estimates of dredging and disposal costs. In other cases, changes in regulated outflows under current regulation plans for Lake Superior and Lake Ontario were examined. Lake Ontario outfow coordination with Ottawa River discharges to the St. Lawrence River was also considered. Finally, the retention of water within the lakes under low water conditions was included as part of the plans that involved new regulatory works along the St. Clair-Detroit and Niagara Rivers and St. Lawrence River below Montréal. Work completed in responding to this request of the Reference is contained in Annex 3 - Working Committee 3 Report.

6. *Develop an information program which could be carried out by responsible governmental agencies to better inform the public on lake level fluctuations.*

RESPONSE: During 1989 and 1990, a Communications Task Group was formed and produced a report entitled *A Coordinated Communications Program on Fluctuating Water Levels in the Great Lakes-St. Lawrence River Basin.* During the final phase of this study, Working Committee 1 reviewed the options developed in the report. Details on this subject are contained in Chapter 7 and Annex 1 - Working Committee 1 Report.

7. *Consider any other matters that the Commission deems relevant to the purpose of this study.*

RESPONSE: The process by which this final phase of the study has been conducted is deserving of a comment. The Phase II Directive required that active citizen participation within the study be achieved. The Board recognizes the outstanding contributions made by the citizen participants within the study as one of the most important aspects of the study. The Citizens Advisory Committee has performed a valuable service in identifying issues to be addressed, critically reviewing technical work as it was being developed, and contributing to the findings, conclusions, and recommendations of the study. Citizen members of the Study Board and the working committees have been most effective as full and active participants in contributing to the work and discussions that have taken place in all areas of the study. More such bridges are needed between Government agencies with responsibilities for water level issues and the affected interest groups and citizens. Recommendations on a Communications Program for Governments with a permanent Clearinghouse for information on water levels issues and the establishment of a Great Lakes-St. Lawrence River Advisory Board including citizen members will improve public participation.

8. *The Board is requested to examine, in a systemic context, the effects both within and outside the basin of measures in considers.*

RESPONSE: The Board concentrated its investigation on impacts within the basin. The Board believed that impacts outside the basin would not be critical factors in the assessment of measures to be considered. Therefore impacts outside the basin were not a specific part of the Plan of Study, although out of basin impacts were considered in some specific areas.

Requests from the Directive:

Objective 1

Principles: Establish a set of guiding principles that the Commission could propose to Governments to assist them in dealing with fluctuating water levels in the Great Lakes-St. Lawrence River Basin. Examples of two broad categories of principles that should be considered are those that improve cooperative decision- making, and those that provide for an appropriate amount of flexibility for future conditions.

RESPONSE: Working Committee 4 was responsible for developing a set of guiding principles to assist Governments in the future management of water levels problems. Agreement was reached on a set of eleven principles. The principles, and background on their development, are contained in Chapter 3 and Annex 4 - Working Committee 3 Report.

Objective 2

Short-term Support Studies Conduct short-term studies in several areas to supply information needed for successful completion of the other Phase II objectives. Such studies would be of different duration and should include:

(1) **GIS:** Continue the development of the Geographic Information System (GIS) initiated in Phase I by adding data and "intelligence" so as to be able to assess the potential impacts of fluctuating water levels and potential measures.

RESPONSE: A significant amount of new information has been obtained that is with Geographic Information System use in both the United States and Canada. Important products from this study include mapping and summary statistics on distribution and extent of shore types, completed in conjunction with the erosion processes work; and information on past and future shoreline land use trends (Annex 2 - Working Committee 2 Report). Potential applications might be developed from data collected on the shoreline classification; existing shore protection; land use and land use trends; flood and erosion damage experiences; data obtained from detailed site studies; data from wetland studies; and responses obtained from the residential riparian surveys. Additional development of the Geographic Information System will require a coordinated and long term commitment by federal, state and provincial agencies.

Time and budget limitations and competing priorities precluded an extensive effort to further develop GIS packages as stand alone products of the study.

(2) **Climate:** Develop and test possible responses to various climate change scenarios, including those studied in Phase I.

RESPONSE: Working Committee 3 has done extensive work in this area, producing water level scenarios that overlaid extended wet and dry periods on the 90 year Basis-of-Comparison levels and flows data to determine how effective existing regulation plans would be in maintaining acceptable water levels. In addition, a double CO_2 climate change scenario was produced which projects that, due largely to greatly increasing rates of evaporation, levels and flows could decrease significantly below those historically experienced (Annex 3 - Working Committee 3 Report).

(3) **Erosion**: Enhance Phase I information on the interrelationship of coastal erosion with fluctuating water levels, storm events, recession rates and shoreline morphology to confirm or reject Phase I conclusions regarding shoreline erosion processes.

RESPONSE: A substantial amount of new work was completed by the Erosion Processes Task Group of Working Committee 2 on this subject. Findings reflect a much more complex analysis of this subject, with geologic characteristics of both offshore and onshore materials; offshore contours; degree of shore protection; and wave, current, and water level conditions all identified as potentially significant factors to the erosion process. Results of this work are contained in Annex 2 - Working Committee 2 Report.

(4) **Wetlands**: Complete the Phase I wetland inventory and relate extreme water level fluctuations to the structure and function of sensitive wetland ecosystems.

RESPONSE: The Phase I wetland inventory was not completed; however, a substantial amount of new work was completed by the Natural Resources Task Group of Working Committee 2 on this subject. Both field studies and conceptual, computer based numerical modeling were performed. A significant concern is that Lake Ontario wetlands have suffered under the current regulation of Lake Ontario. Results of this work are contained in Annex 2 - Working Committee 2 Report.

(5) **Damage Potential**:

(a) Obtain additional information on the number and location of structures and users at risk in the basin. Assess both the effect of these uses on the shoreline as well as the vulnerability of the various user groups to fluctuating high and low water levels.

(b) Categorize the types of human uses of the shoreline and quantify them in such a way as to provide damage assessments needed for Objective 3 (Measures and Evaluation).

RESPONSE: Additional surveys of residential riparians in Ontario, Québec, and among Native Americans were completed to obtain a comprehensive set of information on the incidence of shoreline flooding and erosion damage in this category throughout the basin. Additional studies of other affected water users were conducted to determine the direction and magnitude of impacts likely to be experienced if measures were implemented that would affect water levels and flows in the basin. Results from the riparian surveys are contained in Annex 2 - Working Committee 2 Report under the Social Impacts Task Group. Other impact studies are reported in the Annex 2 - Working Committee 2 Report, particularly sections under the Potential Damage Task Group and the Land Use and Shoreline Management Task Group; Annex 3 - Working Committee 3 Report, under the Evaluation Studies and Methods Task Group; and the Annex 4 - Working Committee 3 Report, under the Evaluation of Measures.

Detailed site studies and investigations of past and future shoreline land use trends were completed to obtain more specific information on vulnerabilities of various groups to extreme water level conditions. Results from these studies are contained in Annex 2 - Working Committee 2 Report under the Land Use and Shoreline Management Task Group.

(6) **Lake Regulation**: Develop and test over a range of partial-to- total structural control options to confirm or reject the conditional conclusion in Phase I that lake regulation measures (Type I) are probably ill-advised. This information will assist in the model runs (Objective 3) and in assessing the environmental and economic costs of structural controls.

RESPONSE: Working Committee 3 devoted a large portion of its investigations to developing and examining a variety of water level regulation measures. A system wide, numerical hydrology and hydraulics model was developed to provide levels and flows data for the assessment of impacts resulting from changes to the Basis-of-Comparison levels and flows conditions. A description of the various regulation plans that were examined is contained in Annex 3 - Working Committee 3 Report. Results of the impact assessments of the various regulation plans are contained in the Impacts of Measures for Evaluation - Summary (Blue Book), supported by additional information in Annexes 2, 3, and 4.

(7) **Regulation Plans**: Further examine existing Regulation Plans 1977 and 1958-D to determine if any adjustments are appropriate following the identification of the significant effects of extreme water levels on various users in the basin, and in particular recreational interests. The examination may also include results from Task 4 of this objective and other interests as appropriate.

RESPONSE: Working Committee 3 developed a number of modifications to the existing regulation plans to determine if improved level and flow conditions could be obtained for recreational, riparian, environmental, navigation, and hydropower interests. Impact assessments and evaluations were completed for measures that included adjustments to the existing regulation of Lake Superior and Lake Ontario. Results of the review of these plans are contained in Chapter 5 and the *"Blue Book"*, supported by additional information in Annexes 2, 3 and 4 - Working Committees 2, 3, and 4 Reports.

(8) **Policy Models**: Develop one or more policy models incorporating such factors as hydrology, the effectiveness of measures, and activities and sensitivities of various interest groups and alternative forms of inter jurisdictional cooperation, to aid in evaluation and decision-making in the basin.

RESPONSE: The multi-criteria measures evaluation process applied in the final phase of the study is an example of decision-making using the criteria identified above. Alternative forms of inter jurisdictional cooperation were also explored by Working Committee 4 in its task on development of guiding principles and review of institutional arrangements. Annex 4 - Working Committee 3 Report contains information on both these subjects. A Policy Model was not developed as a product of this study.

(9) **Forecasting**: Compile information on weather, storm, and wave forecasting in the basin, identify areas where improvements can be made, and implement those areas that are feasible.

RESPONSE: The forecasting issues have been examined by Working Committee 3 in the completion of its technical work and the Crises Conditions Task Group of Working Committees 2 and 3. Without significant improvements in long-range precipitation and temperature forecasts, substantive improvements in the accuracy of water supply forecasts are not possible. Of the methods reviewed, the Great Lakes Forecasting Package performed marginally better. Some improvement in Net Basin Supply forecasts for all models could be expected with advancements in modelling, data collection and weather forecasting. Working Committee 3 and Working Committee 1, in its work on public information, communications, and awareness, suggest ways to improve the coordination and dissemination of existing forecast information (Chapter 8 and Annex 3 - Working Committee 3 Report).

(10) **Frequency Analysis**: Determine whether or not it is feasible to perform a frequency analysis of both high and low lake levels and, if so, undertake such an analysis.

RESPONSE: This subject has been examined by Working Committee 3. The working committee reviewed existing statistical techniques and new techniques. This review included existing statistical models, time series modeling of levels and supplies, and methods of estimating the joint probability of waves, storm surge and static water levels. Recommendations for changes and further studies are made (Chapter 8 and Annex 3 - Working Committee 3 Report).

Objective 3

Measures and Evaluation: Evaluate a range of management measures on a variety of type-specific sites throughout the basin. This objective could be fulfilled by undertaking the following tasks:

1) **Type-Specific Sites**: Identify and characterize several type-specific sites that encompass the variety of natural ecosystems and land and water uses in the basin.

RESPONSE: Thirteen detailed site studies were conducted in this final phase of the study, seven in the United States and six in Canada. All lakes and the St. Lawrence River were covered in the selection of the detailed sites, as well as the mix of affected land and water uses, including: low density and high density residential; commercial/industrial; recreational; and agricultural sites. Annex 2 - Working Committee 2 Report presents the information obtained from the detailed site studies under the Land Use and Shoreline Management and Potential Damage Task Groups. Detailed site studies on wetlands were separately conducted by the Natural Resources Task Group, with these results also reported in Annex 2 - Working Committee 2 Report. Detailed site studies on recreation boating were conducted by Working Committee 3. The results are reported in Annex 3 - Working Committee 3 Report. Available information from the site studies was used as part of the multi-criteria measures evaluation process.

(2) **Information Bases**: For each site, compile a set of detailed and comprehensive information that will be both biophysical and socio-economic. Some of this information will be in mapped format for the GIS.

RESPONSE: Information obtained through conduct of the site studies in some cases made use of existing information already contained in Geographic Information System formats. In other cases, new information was obtained in a manner to be compatible with existing Geographic Information System usage in the United States and Canada and anticipated usage in both countries. Although Geographic Information System applications were used in a few of the site studies the linkage between all of the site studies and Geographic Information Systems was not completed.

(3) **Application**: Apply each of the six types of measures described in Phase I, plus an environmental enhancement option, by entering appropriate sets of parameters into a basin-wide hydraulic model and the GIS.

RESPONSE: Each of the six types of measures were considered in the measures evaluation process in the final study phase, although a re-categorization of the measures took place. An environmental enhancement option was pursued as part of Working Committee 3's development of an optimization model. A revised regulation plan for Lake Ontario focused on seasonal and long term water levels adjustments to improve conditions for wetlands.
A variety of water level regulation measures were run through the basin-wide hydraulic model. Impact assessments on these measures were completed and evaluations were conducted. Due to time and budgetary restrictions, Geographic Information System applications as part of the measures evaluation process were not developed.

(4) **Interests**: Identify and characterize for each site the interests and their environmental and socio-economic components at risk.

RESPONSE: The site studies were conducted with an emphasis on the single water or land use judged to be most impacted by the water level conditions at each site. Information on other impacted land and water uses was also obtained at each site when it was readily available. The results of the site studies are contained in Annex 2 - Working Committee 2 Report, under the Potential Damage Task Group.

(5) **Evaluation**: Further develop and apply the evaluation framework initiated in Phase I to the measures being tested to determine if the framework should be accepted, modified or replaced. In addition, apply benefit/cost analyses to the measures being tested. These applications should also test the results of Objective 1 (Principles), to the extent possible.

RESPONSE: The multi-criteria measures evaluation process applied in the final phase of the study incorporated many features of the evaluation framework initiated in Phase I. The inventory of measures considered; the affected interest groups and water uses considered; the impact assessments completed; the evaluative criteria that were applied; and the evaluation of measures that was completed were common features of the evaluation process. Much more in-depth work was completed in the final study phase on the water level regulation scenarios that were developed; impact assessments; application of the evaluative criteria; and the evaluation of measures. The evaluation process involved all study participants and the Workshop culminating the process included close to 70 participants.

Benefit/cost analysis was one of nine sub-criteria applied in the measures evaluation process. Other sub-criteria related to the environment, distribution of impacts, and feasibility were reflective of the guiding principles developed during the study.

(6) **Inter-Jurisdictional Arrangements**: Examine existing arrangements for inter-governmental cooperation and coordination, including the role of State/Provincial and federal agencies in supporting local governments in managing the system by involving representatives of the various interests and organizations.

RESPONSE: Working Committee 4 prepared a report entitled *Institutional Review and Development of Guiding Principles for Future Management of Water Level Problems in the Great Lakes-St. Lawrence River Basin* that addresses this subject in detail. Part of this work included a mail survey, conducted under contract, of state and provincial and federal agencies, as well as interest groups and organizations involved with water issues within the basin, to determine their capabilities in addressing water level issues. This subject was also a key issue for discussion during the Policy and Public Forums.

(7) **Conclusions**:

(a) Summarize findings and conclusions from each site study.

(b Generalize findings from site studies to other similar locations in the basin to produce conclusions on the efficacy of alternative courses of action, including those with basin-wide application.

RESPONSE: The results from the site studies are provided in Annex 2 and 3 - Working Committee 2 and 3 Reports.

In most cases, analysts involved with the site studies found it very difficult to generalize findings from the site specific to the basin wide. The information obtained through the conduct of the site studies was useful in substantiating adverse impacts and in considering the effectiveness of potential measures. Due to time and budget constraints, however, which limited the scale and scope of what could be accomplished, it was in most cases (although attempted for recreation boating) determined that the site specific information, in and of itself, could not be reliably extrapolated to reach findings on the impacts of measures on a system-wide basis. This information was instead used to supplement the findings reached from the more in-depth technical studies that were accomplished on issues such as erosion processes; flooding and erosion damage estimates; and the impact studies completed for affected interest groups and water uses.

Appendix D

Summary of Public Forums and Written Comments on Draft Final Report

Sault Ste. Marie, Ontario, February 22, 1993

Approximately 52 people attended this meeting. Most of the discussion at the meeting concerned the management of Lake Superior water levels. Lake Superior shore property owners feel that levels are too high on Lake Superior. They are concerned about the maximum level exceeding 602 feet, and would prefer a maximum of 601.5 feet. The Draft Final Report indicated that the two-lake regulation plan would increase Lake Superior's highs, and this is opposed by shore property owners. They would prefer to see the average Lake Superior level held lower, so that in times of high supplies, additional water could be stored on Lake Superior.

Support was expressed for the three-lake regulation plan Measure 1.18, and it was suggested that some of the $10 to $20 million proposed for implementation of land use and shoreline management measures should be spent on further regulation of water levels. Property owners expressed opposition to land use measures; they do not want to lose their property rights.

Others present expressed the views that: land use measures are a good idea; a shoreline management plan implemented in the Sault Ste. Marie area has wide public support; and that wetlands must be protected. Some felt that wetland growth should be encouraged as a natural shore buffer.

Some citizens appreciated the explanations that were given during the discussion period, because they had failed to find this information in the report.

Chicago, Illinois, February 23, 1993

Approximately 87 people attended this meeting. The meeting was attended by a large group of shore property owners who were very disappointed that the Board had not recommended implementation of the three-lake regulation plan. This group felt that: the benefit/cost analysis presented in the Draft Final Report was wrong; the costs to riparians, including erosion damage and the cost of shore protection, were underestimated; and future property values were not adequately considered. Questions were raised by riparians about the stage-damage curves and the site studies, specifically, whether the results of the site studies validate the stage-damage curves.

The Board was urged bt the riparians to reconsider three-lake regulation, to study it more, and to try to address the environmental problems associated with it. The results of the environmental studies were questioned by shore property owners. Concern was also expressed about the effects of high water levels on nuclear power plants and sand dunes.

In the opinion of some who attended the meeting the crisis recommendations do not go far enough to protect shore property. They felt that the triggers should be lower and actions should be taken earlier, in anticipation of high levels. Support was expressed for immediate implementation of the Black Rock Lock flow increases and the use of the Chicago diversion to lower water levels on the middle lakes.

Leaders of environmental groups expressed support for the study recommendation against further regulation. They also supported the land use measures. Some expressed regret that $12 million had to be spent to reach the same conclusion as previous studies. They also felt that the impact on fisheries and the effects of dredging contaminated sediments did not receive adequate treatment in the study.

Shore property owners felt that the study's land use recommendations cause undue hardship to them. They feel that their property rights should not be restricted. Questions were raised about the costs of the land use measures. Shore property owners felt that the recommendations will provide no relief for them.

Buffalo, New York, February 24, 1993

Approximately 140 people attended this meeting. They fell into three basic groups: 1) Lake Erie shore property owners who support further regulation of the system, specifically the three-lake regulation plan; 2) Lake Ontario shore property owners who are very unhappy with the current regulation of Lake Ontario; and 3) leaders of environmental groups who oppose further regulation of the lakes and support land use management measures.

Lake Erie property owners said that they want "regulation, not relocation." They were very critical of the study. They support the three-lake regulation plan Measure 1.18 and feel that it should receive further consideration and implementation. The costs of construction were questioned, especially the St. Lawrence mitigation works. The negative environmental effects were questioned. Several riparians said that they cared about the environment, too. The increased damage on Lake Ontario and the St. Lawrence River were questioned. Graphs were presented, by riparians, which showed that regulation on Lakes Superior and Ontario had been effective in preventing record high levels. Concern was expressed about the manmade obstructions in the Niagara River that are making Lake Erie levels unnaturally high. It was felt that these obstructions should be removed, or dredging should be done to compensate for them.

Lake Ontario property owners and representatives of municipalities told the Board about the problems that they are currently experiencing due to high levels on Lake Ontario. They fear that the situation will worsen in the spring as the seasonal rise in levels begins. They feel that the levels on Lake Ontario are being mismanaged by the St. Lawrence River Board of Control, and that the control structures are being operated to favor shipping and hydropower and hurt shore property owners. They feel that more water should have been discharged last fall and that "Criterion k" should have been invoked sooner. They want representation on the Board of Control, and they oppose land use measures because they believe that they are not workable in developed urban areas.

Leaders of environmental groups supported the Board's decision not to recommend further regulation. They feel that the environmental damage of further regulation is too high to be mitigated and wetlands must be protected. They question the merits of spending taxpayers' money to protect private landowners who represent less than one percent of the basin population. They support land use management as the better way to reduce future property damage, and feel that more than the $10 to $20 million should be spent on this type of measure. They encouraged adoption of the "sustainable development" philosophy. They feel that water level regulation projects create a false sense of security and lead to greater damage in the future.

The need for better communication was raised. Municipal leaders felt that property owners need to be better informed about what water levels to expect in the near future.

Dorval, Québec, February 25, 1993

Approximately 82 people attended this meeting. Several leaders of environmental groups and environmental agencies were present. A presentation was made by a citizen on the impacts of fluctuations on fauna concluding that regulation has hurt fauna in the St. Lawrence River. Environmental groups generally supported the study recommendations. They complimented the Board on involving the public, and hoped that some type of citizen involvement would continue in regulation decisions. They supported the land use management measures, and the decision not to further regulate the system. They were quite concerned about the possible effects of climate change.

Recreational boaters were pleased with the recommendation to add a new criteria for recreational boating to the regulation plans. However, there is still a concern about Measure 1.21 because it would decrease water levels on Lac Saint Louis in August. This would be detrimental to boating. Questions were raised about the rapid fluctuations sometimes observed in the levels of Lac Saint Louis, and how the Ottawa River flow is taken into consideration in the regulation of Lake Ontario.

The Board was complimented by one citizen on adopting a global approach to the issue, a sharing and equitable distribution of the effects of fluctuating water levels. However, he urged the Board to go a little further, to broaden the 1909 Boundary Waters Treaty along the lines of the Helsinki Rules. This citizen suggested that a new guiding principle be added on the equitable distribution of beneficial effects and the optimal utilization of waters.

Written Comments

The following is a summary of the written comments received on the Options Document and Draft Final Report through March, 11, 1993. A total of 249 letters were received. Approximately 95% of the letters were from addresses in the United States.

The majority of the letters (193 or 78%) were supportive of the study recommendations. This group was composed of citizens from all of the Great Lakes states, a few from Ontario, and a few from Texas, California, Georgia, Saskatchewan, Connecticut, Florida, Utah and North Carolina. Many of these citizens were associated with the Audubon Society and other environmental groups, others did not mention any association, and a few described themselves as owners of Great Lakes shoreline property. This included letters from one U. S. federal agency, state agencies in the states of Illinois, Michigan, New York, Ohio, and the province of Ontario.

The position of this first group was that land use and shoreline management measures, especially erosion setbacks and flood elevation requirements, real estate disclosure, and acquisition of shorelands, are the most appropriate way to deal with property damage associated with fluctuating water levels. This group was firmly opposed to any further regulation of Great Lakes-St. Lawrence River water levels through the dredging of channels and the construction of control structures. The reasons cited for this were: concerns about possible adverse effects on wetlands, wildlife, and water quality; the high cost of such structures; and the relatively small reductions in flooding and erosion damage.

A minority of the letters (31 or 12%) were opposed to the draft recommendations. This group consisted of riparian property owners from the Great Lakes states and Ontario, one congressman from Wisconsin and two members of the Pennsylvania legislature.

Ontario (which would already be high at such outflows) or Lake Erie. Alternatively, the water would have had to have been discharged from the system prior to the maximum flow period. Since supplies to the lakes cannot be accurately forecast months in advance, early discharge of water in anticipation of high supplies later could only be done at the risk of lower-than-desired water levels later. In either case, the overall benefits of Measure 1.18 for Lakes Michigan, Huron and Lake Erie would be reduced.

Q: *How were the benefit-cost ratios for Measure 1.18 developed? Where did the numbers come from? Why did they not include past expenditures on shore protection?*

A: The benefit-cost ratio for Measure 1.18 was developed by determining the economic benefits of implementing the three-lake regulation plan and comparing these with the costs. The benefits due to reduced flood and erosion damage, as well as decreased shore protection costs, were determined for riparian properties. The losses or gains to hydropower, commercial navigation and recreation boating were also estimated.

Past expenditures on shore protection were not taken into account, because these costs have already been incurred and cannot be recovered. In economic terms, they are referred to as sunk costs. However, the future costs of shore protection that might be avoided with Measure 1.18 were computed. The value of current shore protection (assuming it is well-engineered) and the value of potential future protection were estimated. The estimated reduction in the amount of protection required due to implementation of Measure 1.18 was considered a benefit and included in the benefit-cost calculation.

Q: *If Lakes Ontario and Superior are regulated, why is there flooding and erosion on their shorelines?*

A: One of the major causes of damage from erosion and flooding is the effect of storms on the large surfaces of the lakes. Regulation plans have a limited ability to reduce the severity of maximum and minimum stillwater levels, but they have almost no impact on storm water levels. Research for this study also found that many types of shoreline continue to erode independently of water level fluctuations. Regulating water levels can reduce the rate of recession along some types of shoreline but the amount of this reduction will be very small.

Continued flooding and erosion problems on these two lakes, and on the St. Lawrence River also underscores the fact that regulation of water levels and flows remains imprecise, due to limits in the ability to forecast future water supplies, and the variability of the weather.

Q: *There are a number of power plants, including nuclear power plants, along the shorelines of the lakes. Would not the implementation of additional regulation reduce the potential impact of high water levels on nuclear facilities?*

A: Not necessarily. Power plants, including nuclear power plants, can be affected by both high and low lake levels. Low levels reduce the amount of water available for cooling; high levels increase the possibility of flooding or erosion. High lake levels pose very little danger to nuclear power plants which must meet conditions set by the Nuclear Regulatory Commission. Plants must be protected to the maximum probable flood elevation, which is well above any recorded level and certainly much higher that the high levels of 1985-87. Similar regulations exist in Canada. If extremely high levels were to threaten the operations of a plant, the plant would be shut down, as is done now in threatening conditions.

Q: *Are the stage-damage curves used in the study accurate?*

A: Yes. The stage damage curves came from previous studies; they were updated to include the damage that occurred between 1985 and 1987 and the current value of property and structures affected by high lake levels. The study used the curves to determine if additional investigation of dredging and the construction of new control works was justified.

Members of the study team conducted a sensitivity analysis for the curves that reflected flooding damage in order to check their accuracy, and to evaluate the effect that modifications to the curves would have on the benefit-cost ratio. The analysis confirmed that the costs of Measure 1.18 exceed its benefits.

Q: *What consideration was given to the dredging and disposal of contaminated material in the evaluation of the five- and three-lake regulation plans?*

A: The costs of construction in locations expected to contain contaminated material include the costs to dredge and dispose of that material. The study did not identify sites for disposal.

Q: *The study found that implementing Measure 1.18 would have a negative environmental impact on wetlands. How could this conclusion be reached without an inventory of wetlands?*

A: A complete inventory of all wetlands along the entire Great Lakes-St. Lawrence River shoreline is not available. However, there is sufficient information to indicate that three-lake regulation would have negative impacts on existing wetlands. It was not necessary to know the total area of wetlands to determine that there would be a reduction in the amount of wetlands on Lakes Michigan-Huron, St. Clair, and Erie.

The study also examined the effects on wetlands of Lake Ontario regulation and found that regulation has been detrimental. An inventory of wetlands on the United States side of Lake Ontario was used in this analysis. It is expected that similar impacts on the wetlands of Lakes Michigan-Huron, St. Clair and Erie would result from similarly compressing the range of their water level fluctuations.

Q: *What is the impact of extreme water level highs and lows on wetlands, and why is wetland diversity so important?*

A: Extreme highs and lows maintain the diversity of plants that define a wetland. High lake levels periodically eliminate dominant plants. When levels recede, less competitive species are able to grow from seed, complete at least one life cycle and replenish the wetland seed bank before being replaced with the more dominant plants. This maintains plant diversity which, in turn, allows habitat diversity and the resultant variety of fish and wildlife that depend on the wetlands. Wetlands need one high period and two consecutive low periods every 10 years on average to maintain this diversity.

Wetlands also filter pollutants, they serve as a buffer against shoreline erosion, and they allow an opportunity for ground water recharge. Therefore, a reduction in the diversity or extent of wetlands affects the health of the Great Lakes-St. Lawrence System.

Q: *The Board recommends implementation of modifications to the Lake Superior regulation Plan similar to those proposed in Measure 1.21. Will this increase the maximum elevation of Lake Superior?*

A: No. These modifications were tested using 90 years of water supply record from 1900 to 1989. This testing showed that the implementation of this particular measure would reduce the mean elevation of Lake Superior by approximately 0.03 metres (0.11 feet). Only once during those 90-years would the high levels have exceed 183.49 metres (602 feet). It should be noted, however, that the Study Board is also recommending that the Lake Superior Board have discretionary authority to modify plan flows under extreme conditions to help prevent such an event. In addition the Study Board is recommending that further consideration be given to minor modifications to the plan so that exceedance of 183.49 metres (602 feet) would not occur during the test period.

Q: *Why not lower the mean of Lake Superior more so that there is the capability of additional storage of water in Lake Superior during periods of high supplies to benefit both Lake Superior and Lakes Michigan-Huron?*

A: The study examined two measures that lowered the mean level of Lake Superior by 0.15 metres (0.5 foot) and 0.3 metres (1 foot). These measures would have significant effects on several interests in the basin. Commercial harbors along Lake Superior would have to be dredged at a considerable capital cost. Lower levels on Lake Superior would reduce the ability of fish to swim upstream to spawn in tributaries. Native Americans opposed the lowering of Lake Superior levels because it would negatively affect their traditional lifestyles.

Q: *Would improvement in the ability to forecast weather improve the capability to regulate the lakes?*

A: Yes. Improving the ability to forecast precipitation would improve the ability to forecast water supplies to the system; thus, the ability to operate regulation structures. The Study Board has recommended improvements to data collection and modeling so that advances in forecasting precipitation could be incorporated in the forecasts of water supply. However, advances that could forecast precipitation months into the future have not yet been made.

Q: *Why doesn't the Board implement the emergency preparedness plan now since Lake Erie and Lake Ontario are at higher than average levels?*

A: The Study Board is charged to make recommendations to the International Joint Commission. The Commission will, then, make recommendations to the United States and Canadian governments. The Study Board does not have the authority to implement any of the measures recommended in this report. The Board has made important recommendations on emergency preparedness that involve manipulation of existing diversions into and out of the system and between Lakes Erie and Ontario during high and low water levels. One of these recommendations is to increase the capacity of the Black Rock Canal on the Niagara River to allow an increase in Niagara River flows of approximately 340 cubic metres per second (12,000 cubic feet per second). It should be pointed that it is unlikely that this measure would be used to reduce current high water levels on Lake Erie, because of the very high levels on Lake Ontario.

The Board has also recommended a series of land-based emergency responses. Many of the responses, such as emergency preparedness plans, emergency sandbagging, shore protection, and storm forecasting and warning networks have been used in many municipalities throughout the Great Lakes-St. Lawrence River System and can be rapidly implemented.

Q: *Since flow changes through the Welland Canal are part of the emergency plan and Lake Ontario's level is high, why hasn't the flow through the canal been reduced in order to reduce the water supply to Lake Ontario?*

A: The Board does not have the authority to reduce flows through the Welland Canal. Reducing flows to Lake Ontario by reducing flows through the Welland Canal would increase water levels on Lake Erie at a time when its levels are also high.

Q: *What are the recommended measures that will provide relief to shoreline property owners?*

A: The recommendations fall into more than one category. Depending upon the particular water supply and lake level condition, emergency preparedness plans will provide some relief to the impacts of high-and low-lake levels. In addition, local protection plans would provide protection during high-and low-level events.

The Board also recommends that a fund of $10 to $20 million per year be established for implementation of land use and shoreline management measures. This money would be used to plan and implement remedial and preventive measures, thus resulting in a reduction in the potential for damage.

Minor modifications are proposed to existing regulation plans for Lakes Superior and Ontario, which would also provide some small reduction in damage from high-and low-lake levels.

Q: *The Board is recommending implementation of a series of shoreline management measures. Won't these infringe on individual property rights and devalue shoreline property?*

A: Some measures the Study Board is recommending will require property owners to meet certain conditions if they wish to locate on Great Lakes-St. Lawrence River shorelines. Many of these measures are already in use in some areas. Building setback and elevation requirements would be based upon reasonable estimates of potential flood and erosion damage. Structures that comply with these regulations could have their values increased, if the risk of damage is lessened.

The Study Board also recommends that a seller be required to advise a potential purchaser when a structure is in an erosion or flood hazard area. Making this information available protects the prospective buyer. This should not cause a change in the real value of the property.

The Study Board also recommends acquisition of developed and undeveloped hazard lands, when it is appropriate. However, the Board has stressed that such acquisitions should take place on a willing buyer/willing seller basis wherever possible. The Board also emphasizes the need for citizen involvement in development of comprehensive land use and shoreline management programs.

Q: *Who establishes the setback and elevation limits?*

A: The agency responsible for setback and elevation limits varies from jurisdiction to jurisdiction. The Study Board recommends the limits be established after consultation among federal, provincial/state and local governments. The process should provide for full public participation by those who would be affected by the setback and elevation limits.

Q: *One of the recommended shoreline management measures is a land acquisition program. Does this mean that I will be forced to give up my shoreline property to the government?*

A: No. The board has not recommended a basin-wide program for acquisition of all shoreline property. Rather, it recommends that land acquisition be considered as one possible option, along with a series of other possible shoreline management measures, in areas where it is most appropriate and feasible (for example in areas where damages repeatedly occur, or in currently undeveloped natural areas), and only on a willing seller/willing buyer basis.

Q: *How can setbacks and other shoreline management measures possibly be of any benefit to already developed shoreline areas?*

A: Measures such as setbacks and other development limitations will have a much broader application in undeveloped areas. However, setbacks can be effectively applied to redevelopment of lots, or in combination with other measures such as dwelling relocation. Floodproofing and elevation requirements can ensure that any redevelopment, or reconstruction is done in a manner that reduces the potential for flood damage to a structure. Existing structures can be retrofitted to add floodproofing. In areas where it is possible, structures can be moved back on the lot and removed from the hazard zone. In many instances (such as in major cities and metropolitan areas), the only option available may be well-engineered and community based shoreline protection. There are many shoreline management options available for developed areas and, like land acquisition discussed above, the type of shore management action will depend to a great extent on the specific characteristics of the site or area under consideration.

Q: *Is the Study Board recommending hazard insurance for Canada?*

A: No. The Study Board is recommending modifications to the existing hazard insurance program in the United States.

Q: *How can the Study Board make broad recommendations for the implementation of shoreline management measures, when their costs, benefits and impacts have not been adequately examined?*

A: Unlike previous water level studies, this study carried out a thorough examination from the outset of all the shoreline management measures recommended in the final report. Data and information was collected on the extent and application of each measure throughout the basin, the costs of implementation of the measure, the degree to which each measure reduced actual or potential flood and erosion damage, the degree to which each measure impacted (either positively or negatively) other interests and the natural environment, and the institutional barriers or facilitators that had been encountered in their implementation. This information was utilized by the Board, Citizens Advisory Committee and other study participants to conduct the evaluation of measures, and it marks the first time such measures have been evaluated on a par with possible lake regulation scenarios.

Q: *If the Great Lakes should experience a repeat of the 1985-87 lake levels, what would the damage be if no preventive measures were taken, and how much would the damage be reduced if SEO-Extended was in place?*

A: It is estimated that a repeat of the 1985-87 levels would result in $561 million in flood and erosion damage along the Great Lakes shoreline if no new preventive measures were taken. The implementation of SEO 1.18 would reduce the estimated flood and erosion damage to $235 million, for a damage reduction of $326 million.

Flooding damage along the Canadian portion of the St. Lawrence River are not included in this analysis, since SEO 1.18 includes measures to prevent an increase in these damage.

Appendix F

Study Team

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