LEVELS REFERENCE STUDY
GREAT LAKES-ST. LAWRENCE RIVER BASIN

ANNEX 2
LAND USE AND MANAGEMENT

SUBMITTED TO
THE LEVELS REFERENCE STUDY BOARD
BY WORKING COMMITTEE 2
MARCH 31, 1993

FINAL REPORT

Submitted to the
Levels Reference Study Board
by

WORKING COMMITTEE 2

Land Use and Management

March 31, 1993

Final Phase
Levels Reference Study
International Joint Commission

ISBN 1-895085-46-2

EXECUTIVE SUMMARY

On August 1, 1986 the Governments of Canada and the United States, in response to record high water levels on four of the five Great Lakes, issued a Reference to the International Joint Commission (IJC) to examine and report upon methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes - St. Lawrence River Basin.

This Reference Study was completed in two phases. The Phase I Study culminated in a Progress Report with seven annexes, dated July 1989 and identified problems related to the management of water level issues and explored potential avenues for problem-solving. It recommended that a broad planning approach be developed which would include, among others: 1) the development of a guiding set of principles designed to provide broad guidelines for future decisions regarding water level issues; 2) the development of an overall strategy for deploying measures, encompassing the needs of the entire basin, as well as the circumstances of specific locales; and 3) the development of a framework for an effective governance system, including considerations for the role of interests and the public.

The Phase II Study, began in late 1990, has continued and expanded the work begun in Phase I. To guide this second, and final Phase, the IJC established the Levels Reference Study Board, who in turn, established four Working Committees to carry out the specific tasks called for in the Directive.

This report details the activities of Working Committee 2, who had the responsibility for examining the physical shoreline of the Great Lakes-St. Lawrence River Basin and the effects of water level changes on shore processes, including long and short-term recession. They estimated potential shore property damages of both high and low water and they examined the natural resource impacts of fluctuating water levels for wetlands, fisheries and water quality. Social impacts were studied through various surveys and land use and management practices in place along the shoreline were evaluated for their effectiveness and impacts. The Working Committee established a number of "Task Groups" to address the above responsibilities.

Erosion Processes Evaluation

The Erosion Processes Task Group developed a comprehensive mapping and classification scheme and characterized Great Lake-St. Lawrence River shorelines according to a number of criteria, including: the geomorphic origin; the composition of the sub-aqueous (underwater) portion of the shoreline profile; and the extent to which shorelines are protected by structures. This classification, combined with an evaluation of the impact of water level changes on erosion rates of specific shore types, and the development of an erosion sensitivity index, helped determine the impacts of long-term and short-term water level fluctuations on erosion rates and processes. Generally, it was predicted that approximately 32% of the Canadian and 29% of the

U.S. Great Lakes shoreline (excluding connecting channels and the St. Lawrence River) would experience some type of erosion reduction, or benefit, as a result of compressing the range of water levels, with the remainder of the shore either experiencing no erosion, or no reduction in erosion. Information generated in these studies was stored in a Geographic Information System database which allowed easy identification of the most "erosion susceptible" shorelines of the Great Lakes - St. Lawrence River basin.

Social Impacts

The Social Impacts Task Group completed a survey of riparians along the shorelines of the Great Lakes and the Ontario and Quebec portions of the St. Lawrence River, as well as a survey of Native North Americans who live throughout the entire basin. The task group undertook a thorough analysis of these survey results and has developed and tested a number of different hypotheses. The task group has also reviewed and analyzed Phase I reports on the commercial/industrial, agriculture, commercial fishing, and municipal interest groups to extract relevant information for use in impact and measures evaluation. The surveys indicate that erosion is the most common problem reported by all riparians on the shoreline of the Great Lakes and the St. Lawrence River. High water levels and erosion were the primary reasons given by respondents for actions taken. It was also found that there was only a relatively small difference in reported damage between riparians living on regulated lakes and those living on unregulated lakes. This would imply that regulation on Lakes Superior and Ontario has not eliminated damages. No single measure stands out as being the most preferred among respondents. Although regulation scenarios may have positive social impacts on the middle lakes, the connecting channels and the St. Lawrence River riparians will not fare well. Previous studies indicate that municipalities view erosion as a major problem, that commercial and industrial facilities have some degree of tolerance to level changes, that agricultural lands are primarily impacted when dykes are overtopped, and that commercial fishing suffers from low water problems.

Potential Damages

The Potential Damage Task Group employed a number of techniques in order to develop estimates of damages to shoreline interests as a result of fluctuating water levels and as a result of measures that might be implemented to reduce the ranges in these fluctuations. Existing stage-damage curves for flooding and erosion were updated for inflation and to incorporate other data that may have changed between 1979-1992. In addition, a series of detailed site studies were undertaken to obtain site specific information on damages. In applying these updated curves and the data collected from the site studies, to both existing and possible future water level scenarios, it was found that no one regulation plan proposed was able to eliminate all flood damages on all reaches of the Great Lakes - St. Lawrence River shoreline. In addition, all plans resulted in a shift or redistribution of the benefits and impacts of fluctuating levels and flows. The 5-Lake plan that provided the greatest compression in water level range, "SMHEO-50", was found to decrease average annual flood and erosion damages by 25%, but would increase Lake Ontario and St. Lawrence River damages by 45%. Similar results were found in the evaluation of four 3-Lake plans.

The Task Group also explored issues related to shoreline protection and found that expenditures for protection of riparian properties between 1985-1987 amounted to over $68 million on the U.S. shoreline and between $25-$34 million on the Canadian shoreline. Examinations were also undertaken to determine the future shore protection costs that could be avoided with reduced water level range scenarios in place. Savings under a number of the regulation plans were found to be significant, for example, over $340 million in savings being associated with the SMHEO-50 regulation plan and $330 million associated with the 1.18 SEO 3-Lake regulation plan.

Land Use and Shoreline Management

The Land Use and Shoreline Management Task Group reviewed and assessed a number of shoreline management practices in place throughout the Great Lakes - St. Lawrence River basin to determine those that have been successful in preventing and minimizing flooding and erosion damages. Included here was a review of practices such as land acquisition, infrastructure adaptation and regulation of property use in hazard areas. Part of this effort involved developing common terminology, and a working definition for Great Lakes "shoreline management." Of the measures examined, setback and floodproofing requirements were shown to be very effective in reducing damages, particularly in undeveloped areas. Acquisition or relocation of properties and structures was also considered as an effective measure, but would only be justifiable in areas where significant infrastructure is at risk. Shore protection was also an effective measure, but only when it has been properly designed. Tax incentives and deed disclosure measures were found to be limited in their extent, and where applied, not very effective. Similarly, implementation mechanisms, such as loans and grants, have had limited effectiveness as they have been primarily used for the construction of protection and not for other possible measures like relocation.

Analysis of land use found that the general trend in the basin over the last several decades has been a general and often rapid increase in shoreline development (primarily residential) at the expense of natural areas (forests and wetlands). Loss of agricultural land to support this development has also occurred. Examinations of future trends found that this increase in development will continue, but that some land will be converted into recreational, as opposed to residential uses.

Natural Resources Impacts

The Natural Resources Task Group conducted a number of studies to determine the impacts of fluctuating water levels on wetlands, fish and water quality in the Great Lakes - St. Lawrence River basin. They documented and mapped wetlands and assessed impacts of reduced ranges in water level fluctuations on selected wetlands. They also determined how fluctuations in the flows of the St. Lawrence River affected wetland vegetation. Results of these studies found that changes in wetland and wetland plant community characteristics are directly correlated with long term water level fluctuations on the Great Lakes, their connecting channels, and on the St. Lawrence River. Plant communities at elevations that are flooded periodically each ten to twenty years and dewatered for successive years between floods have the greatest diversity of wetland vegetation. A model of wetland area changes that occur in response to level changes also indicated that fluctuations are indeed important to the maintenance of the current extent of coastal marshes and of course the waterfowl, fish, mammals, and other animals that they support.

Studies of the effects of water level fluctuations on fish suggest that water level is a critical element in fish reproduction and maintenance of populations. Minor differences in elevation at critical times of the year can have major influences on reproductive success. Fish reproduction is also apparently dependent upon the existence of dynamic processes. Northern pike spawning success is improved by rising water levels.

The studies on how past regulation regimes have affected wetlands on Lake Ontario and the St. Lawrence River indicate that reduction of the water level fluctuation ranges on Lake Ontario have had a significant negative effect on the extent, diversity, and integrity of wetlands on its shores, and that water level regulation has caused losses of floodplain forests along the St. Lawrence from flooding and erosion.

Crisis Conditions Task Group

The Crisis Condition Task Group (a joint Task Group of Working Committee 2 and Working Committee 3) was responsible for developing an overall crises response plan for the Great Lakes - St. Lawrence River Basin, which would see implementation of a number of short-term measures to alleviate extreme water level situations. As a component of this plan, the Task Group determined a series of "threshold" water levels at which shoreline interests would begin to suffer major adverse impacts and examined both engineering measures, as well as "land based" responses, such as emergency evacuation and flood protection plans. Members of Working Committee 2 had key responsibility for examining the extent and effectiveness of 23 land based measures and also provided suggestions for the future implementation of many of these.

ACKNOWLEDGEMENTS

A report of this magnitude could not have come together without the assistance of many people. While it is not possible here to outline all of these efforts in detail, what follows is a brief discussion of significant contributions to the tasks of Working Committee 2 and the preparation of this report.

First and foremost, we would like to express our sincere appreciation to all of the Task Group Co-chairs, members and associates for their hard work and dedication over the course of Phase II. A list of the full membership of Working Committee 2 can be found in the Appendices to this report.

Secondly, while this report, and the work described therein, was a collective effort of WC2 and the Task Groups, a number of others made significant contributions. Coordinating and editing the written work of the different Task Groups, all working on a number of diverse tasks, was quite a challenge and we are grateful to the efforts put forth by **Chris Stewart** in this regard. Similarly, coordination of the Task Groups themselves and of all Working Committee 2 activities, was no less important. These tasks were handled admirably by **Wendy Leger** who, as WC2 Coordinator, carried out many of the thankless tasks needed to keep us all informed and appraised of various activities within the Reference Study.

In addition to the task group members listed in the Appendix, there were a number of "behind the scenes" people who played key roles in completing the tasks required, or who went above and beyond the call of duty when asked to do so by task group members. On the U.S. side, these include: **Lt. Col. Tom Sydelko** (USACE-Chicago), who was initial co-chair of the Potential Damages Task Group; **Andrew Morang**, (USACE-CERC-Vicksburg), **Charles (Lyle) Thompson** (USACE-Detroit), and **Charlie Johnson** (USACE-Chicago), who completed some of the shore classification mapping; **Roger Gauthier** (USACE-Detroit) and his more than capable GIS staff, most notably **Lisa Jipping, Gordie Thompson, and Bill Kempisty**, who played key roles in completion of tasks for the Erosion Processes, Potential Damages and Land Use Task Groups; and **Scott Thieme, Joe Mantey and Matt McPherson** (also USACE-Detroit) who provided critical input to the Potential Damages Task Group. On the Canadian side, we would like to acknowledge: **Philip Baker** (Environment Canada) who provided a series of detailed shoreline videos that greatly assisted in the shoreline classification work; **Mark Law and Linda Piazza** (Ontario Ministry of Natural resources) who assisted in the completion of the erosion sensitivity classification; **Harold Leadlay and Tom Madden** (Environment Canada) who assisted with data collection for the Crises Condition and Erosion Processes Task groups respectively; and **Terry Craddock** (Environment Canada), who diligently and patiently endured many hours of photocopying, envelope stuffing, briefing book binding, and many other day-to day-to-day tasks, so that information and material could be distributed in a timely fashion to Working Committee, Study Board and CAC members, as well as to the general public.

A number of consultants were retained to complete many of the tasks undertaken by Working Committee 2. While they were remunerated for their services, a number of them went beyond the terms of their contracts to complete the tasks requested of them. We would like to thank all of the consultants for their efforts in this regard, but in particular **Scott Duff** (Ecologistics Limited), **Reid Kreutzwiser** (University of Guelph), **Rob Nairn** (Nairn Inc.), and **Dave Anglin** (W.F. Baird and Associates).

Finally, we would like to thank those members of the Study Board, CAC and International Great Lakes Coalition, particularly **Fred Brown, Joe Milauckas, Sharon Hazen and Bob Ozanne,** for their input and critical comment on many of the products produced by Working Committee 2. In addition, we would like to thank all those scientists and researchers who had opportunity to review and comment upon various aspects of our work, as well as other agency personnel and members of the general public who provided input to our Committee through written communication, or through attendance at one of the many public sessions that were held. Our work has benefitted greatly from this input.

Ralph Moulton
Canadian Co-Chair
Working Committee 2

Donald Hey
United States Co-Chair
Working Committee 2

Members

Stan Taylor
Janet Planck
Daniel Waltz
Chris Stewart
Laurie Maynard
Edith Fuller
Wendy Leger
Maurice Lewis
Francis Boudreau
Wes MacLeod
Scott Painter
Michelle Nicolson

George Stafford
Joan Pope
Terry Yonker
Bill Wiesmueller
Kerry Kehoe
Roger Gauthier
John Kangas
William Van Regenmorter
Joe Milauckas
Fred Brown
Martin Jannereth
Oscar Dittrich
John Gannon
Glenda Daniel

WORKING COMMITTEE 2 FINAL REPORT

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 1: INTRODUCTION

No Figures

SECTION 2: PROCEDURES FOR CONDUCTING IMPACT ASSESSMENTS

SECTION 3: EROSION PROCESSES TASK GROUP

SECTION 4: SOCIAL IMPACTS TASK GROUP

SECTION 5: POTENTIAL DAMAGES TASK GROUP

SECTION 6: LAND USE AND SHORELINE MANAGEMENT TASK GROUP

No Figures

SECTION 7: NATURAL RESOURCES TASK GROUP

SECTION 8: CRISES CONDITION TASK GROUP (WC2 AND WC3)

No Figures

LIST OF TABLES

SECTION 1: INTRODUCTION

No Tables

SECTION 2: PROCEDURES FOR CONDUCTING IMPACT ASSESSMENTS

No Tables

SECTION 3: EROSION PROCESSES TASK GROUP

SECTION 4: SOCIAL IMPACTS TASK GROUP

SECTION 5: POTENTIAL DAMAGES TASK GROUP

SECTION 6: LAND USE AND SHORELINE MANAGEMENT TASK GROUP

SECTION 7: NATURAL RESOURCES TASK GROUP

SECTION 8: CRISES CONDITION TASK GROUP (WC2 AND WC3)

WORKING COMMITTEE 2 - LAND USE AND MANAGEMENT

FINAL REPORT

1.0 INTRODUCTION

1.1 Background and Overview of Prior Reference Study Activities

On August 1, 1986 the Governments of Canada and the United States, in response to record high water levels on four of the five Great Lakes, issued a Reference to the International Joint Commission (IJC) to examine and report upon methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes - St. Lawrence River Basin.

The IJC submitted an initial report to Governments by letters dated November 14 and December 10, 1986. The letters described actions the IJC had taken, actions recommended to be taken by Governments, and measures to lower water levels that were technically feasible, using existing facilities, which might be implemented immediately.

The IJC formed a Task Force in the fall of 1986 to undertake a technical evaluation of measures that could be implemented within approximately one year to reduce high water levels. The Task Force submitted a summary report of its analyses to the IJC in October 1987. The IJC subsequently transmitted an Interim Report to Governments on November 22, 1988 that contained the Task Force summary and included additional recommendations for actions Governments could take.

1.1.1 Phase I Directive

The IJC sought broad expert advice for developing the longer term implications of the Reference. By Directive dated April 10, 1987, the Commission engaged the services of water resource agencies of the federal governments of both the United States and Canada (primarily Environment Canada and the U.S. Army Corps of Engineers (USACE)) to help conduct a study that would answer the many questions asked in the Reference. These government agencies, through their respective budgetary authorities, have been funded annually since 1987 to provide this required technical and administrative support to the IJC.

A Project Management Team was organized with affiliated functional groups to respond to concerns identified in the Reference concerning hydrology, hydraulics, and climate; coastal zone resources and management; socio-economic and environmental impact assessments; public participation and communications; and systems analysis and synthesis. The scope of the undertaking led to a decision to conduct the Reference Study in two phases.

1.1.2 Phase I Progress Report

The Phase I Study culminated in a Progress Report with seven annexes, dated July 1989 (Project Management Team, 1989). The reports are:

Main Report	Living with the Lakes: Challenges and Opportunities
Annex A	Past and Future Water Level Fluctuations
Annex B	Environmental Features, Processes and Impacts: An Ecosystem Perspective on the Great Lakes - St. Lawrence River System
Annex C	Interests, Policies and Decision Making: Prospects for Managing the Water Levels Issue in the Great Lakes - St. Lawrence River Basin
Annex D	The Great Lakes Ecosystem Perspective: Implications for Water Levels Management
Annex E	Potential Actions to Deal with the Adverse Consequences of Fluctuating Water Levels
Annex F	Evaluation Instrument
Annex G	Public Information Program

This first Phase identified problems related to the management of water level issues and explored potential avenues for problem-solving. It recommended that a broad planning approach be developed which would include, among others: 1) the development of a guiding set of principles designed to provide broad guidelines for future decisions regarding water level issues; 2) the development of an overall strategy for deploying measures, encompassing the needs of the entire basin, as well as the circumstances of specific locales; and 3) the development of a framework for an effective governance system, including considerations for the role of interests and the public.

1.1.3 Phase II Objectives, Goals and Study Process

The Phase II Study continued the work begun in Phase I to examine and report upon methods of alleviating the adverse consequences of fluctuating water levels. To guide this Phase, the IJC established the Levels Reference Study Board, who in turn, established four Working Committees to carry out the specific tasks called for in the Directive.

1.2 Working Committee and Task Group Organization and Objectives

1.2.1 Overall

The four Working Committees and their responsibilities were:

Working Committee 1 - Public Participation and Information had the main responsibility of ensuring that the public was kept well informed and that they had ample opportunity for input into study tasks. In addition, the committee addressed the specific request of the Reference for a long term communications program that could be implemented by governments.

Working Committee 2 - Land Use and Management was primarily responsible for addressing environmental, physical and social settings and their interrelationships within the Great Lakes-St. Lawrence River Basin.

Working Committee 3 - Existing Regulation, System-Wide Regulation and Crisis Conditions examined the causes of water level fluctuations and the ranges that occur as a result of both natural and anthropogenic effects. They also examined possible future changes that may occur as a result of climatic change, or as a result of the implementation of system-wide regulation, or the alteration of existing regulation plans.

Working Committee 4 - Principles, Measures Evaluation, Integration and Implementation utilized information provided by Working Committees 2 and 3 to develop principles for study evaluation, applied these principles in an evaluation methodology and undertook the actual evaluation of measures.

Each Working Committee solicited federal, provincial and state department agencies in Canada and the United States, as well as the Citizen's Advisory Committee and other members of the public with appropriate expertise, for participation on the Working Committee, as well as on various Task Groups within each Committee. Co-Chairs and Coordinators were appointed for each Committee, as well as two Study Board Liaison members to facilitate communication between the Board and the Committee. Each Working Committee was responsible for bi-monthly progress reports to the Study Board and was responsible for the preparation of interim and final reports with appropriate supporting material and documentation.

1.2.2 Working Committee 2

Working Committee 2 had the responsibility for examining past and present and estimating potential future changes in land use and management practices along the shorelines of the Great Lakes, their connecting channels and the St. Lawrence River. They also undertook studies which supported the evaluation of actions, especially in the areas of damage assessment, natural resources impact assessment and social impacts assessment.

The main objectives of Working Committee 2 were to identify the environmental, physical, and social characteristics and interrelationships of the Great Lakes-St. Lawrence River System, evaluate the influences/impacts of fluctuating water levels, and make recommendations for government and non-government actions (federal/provincial/state/municipal/non-government organizations). In addition, Working Committee 2 was directed to promote the establishment of partnerships to address the adverse consequences of fluctuating water levels; to promote the Committee and ultimately government and non-government agencies as stewards of natural resource data and technical information; and to be active partners in the development and promotion of public education, communication and technology transfer, and to promote a better public awareness and understanding of the shoreline environment.

To accomplish these objectives, the Committee formed a number of Task Groups. The **Erosion Processes Task Group** examined the physical shoreline and the effects of water level on shoreline processes and erosion. The **Potential Damage Task Group** utilized a number of techniques to provide estimates of past and potential flood and erosion damages throughout the basin. The **Natural Resource Task Group** looked at the natural resource impacts of fluctuating water levels for wetlands, fisheries and water quality. Social impacts were examined through various surveys by the **Social Impacts Task Group**, while the **Land Use and Shoreline Management Task Group** examined and evaluated various land use and management practices along the shoreline for their effectiveness and impacts.

1.2.3 The Task Groups

Erosion Processes Task Group

A key issue examined in Phase I was the interrelationship between erosion and water level fluctuations. As a result of this examination, a controversy ensued between various experts and interest groups over whether erosion, specifically long-term erosion, is influenced by fluctuating water levels. In light of this controversy, the Levels Reference Study Board, specifically Working Committee 2, was directed to further explore and enhance any information available on this interrelationship in order to either confirm or reject Phase I conclusions regarding shoreline erosion processes and their relationship to water level fluctuations. To accomplish this the Working Committee established the **Erosion Processes Task Group**. Specific tasks and the results of this Task Group are discussed in Section 3.

Social Impacts Task Group

In Phase I of the Reference Study, attempts were made to identify and characterize the various interests around the basin and to determine their sensitivities to fluctuating water levels. A census of riparian properties was conducted to compile an accurate and comprehensive information base. Using this inventory, a survey was administered to a sample of property owners to gain a greater understanding of riparian experiences, their views on the water levels issue, and on what they see as solutions to the problems associated with high and low levels. A questionnaire similar in format was developed for both a U.S. and Canadian survey. The surveys for the Ontario portion of the Great Lakes - St. Lawrence River shoreline were completed in 1990. The U.S. survey was also administered at that time. At the start of Phase II, analysis of this data was still to be undertaken. As well, the survey had not been undertaken for the Quebec portion of the St. Lawrence River, or for Native interest groups. To accomplish these remaining tasks, Working Committee 2 established the **Social Impacts Task Group**. Results of this work are described in Section 4.

Potential Damages Task Group

Fluctuating water levels have caused a great deal of damage to property around the Great Lakes - St. Lawrence River Basin. Extreme high and low levels have the potential to cause serious damages. Estimates of the potential amount of damage and the incidence and frequency of damage would provide a better indication of those potentially at risk and a better understanding of the problem. The **Potential Damages Task Group** was established in order to gather this information, as well as to provide information on reductions in potential damages (if any) that might occur if certain measures were put in place. Results of this Task Group's work can be found in Section 5.

Land Use and Shoreline Management Task Group

Two key responsibilities charged to Working Committee 2 under the Phase II Directive, were to examine past, present and potential future changes in land use and management practices along the shores of the Basin and to determine, to the maximum extent practicable, the socio-economic costs and benefits of these practices, so that they could be compared to the revised costs and benefits of lake regulation schemes. To handle these responsibilities, the **Land Use and Shoreline Management Task Group** was formed. Their work is presented in Section 6.

Natural Resources Task Group

Coastal wetlands are critical elements of the Great Lakes - St. Lawrence River ecosystem and represent a significant resource. Wetlands serve as important habitat for fish and wildlife, provide a buffer to the effects of land based activity on water quality, and help protect the shoreline from erosion and recession. Wetlands also directly and indirectly support numerous consumptive and non-consumptive human uses. Phase I addressed a number of key questions regarding the relationship between fluctuating water levels and the productivity, quality and extent of wetland habitat. To build upon these findings and to provide, where possible, reliable quantitative data on this relationship, Working Committee 2 established the **Natural Resources Task Group.** Results of this work are presented in Section 7.

Crises Condition Task Group (Working Committee 2 and Working Committee 3)

One of the first items in the Directive to the IJC was a request to propose and evaluate any measures which governments could take, under crisis conditions, to alleviate problems created by high and low water levels. This was to build upon the results of the 1988 Interim Report (International Joint Commission, 1988) and provide more detail on these measures, including development of an overall crisis response plan. To carry out these activities the **Crises Condition Task Group** was established. This group, comprised of members and associates of both Working Committee 2 and Working Committee 3, examined and reported upon a series of hydraulic and land-based crisis response measures. A brief description of their work is found in Section 8 of this report. Further details are included in the full Working Committee 3 report, as well as the full report of the Crisis Condition Task Group.

REFERENCES

International Joint Commission, 1988. Interim Report on 1985-1986 High Water Levels in The Great Lakes St. Lawrence River Basin. Ottawa, Washington, Windsor, 27pp.

Project Management Team, 1989. Living With The Great Lakes: Challenges and Opportunities. A Progress Report To The International Joint Commission, Phase I, IJC Levels Reference Study, 108pp. plus seven Annexes.

2.0 PROCEDURES FOR CONDUCTING IMPACT ASSESSMENTS

2.1 Introduction

A key requirement of Working Committee 2 was to provide an assessment and evaluation of various water level regulation and shoreline management practices that are in place, or could be put in place, throughout the Great Lakes - St. Lawrence River System. A component of this evaluation was to provide information on the impacts of these measures (i.e. their costs and benefits, how they reduce / eliminate or exacerbate damages, environmental impacts, social impacts, etc.). To assist in conducting this impact assessment, the Levels Reference Study Board developed a series of procedural guidelines that all Working Committees and Task Groups were required to follow. While not all of these guidelines applied directly to the work carried out by Working Committee 2, they are outlined briefly here, so as to provide a basis for the impact assessment information that is presented and discussed throughout this report.

2.2 Study Evaluation Principles

A series of guiding principles were developed and considered in conducting evaluations and making findings, conclusions and recommendations during Phase II of the Levels Reference Study. These were:

a) that existing and future beneficial uses be considered and that the fundamental character of the Great Lakes - St. Lawrence River System will not be adversely affected;

b) that any recommendations for action be environmentally sustainable and respect the integrity of the Great Lakes - St. Lawrence River ecosystem;

c) that any actions to address the adverse consequences of fluctuating water levels should not be implemented unless they produce a net benefit to the Great Lakes - St. Lawrence River System and not result in undue hardship to any particular group;

d) that structural and non-structural measures and combinations of structural and non-structural measures be considered to determine the optimum response to the adverse consequences of fluctuating water levels for the entire Great Lakes - St. Lawrence River ecosystem; and

e) that decision making with respect to the management of the Great Lakes - St. Lawrence River System should be open, respecting the full range of interests affected by any decisions, and facilitating their participation in the policy process.

2.3 Plan Formulation Guidance

The Plan Formulation Guidance (PFG) established a common set of baseline assumptions and conditions that were applied by all Working Committees and their Task Groups in the conduct of impact assessments. In other words, the PFG established the "ground rules" by which the impact assessments and measures evaluation process were fairly applied. The guidance is divided into three major categories: past expenditures; future avoided costs; and baseline conditions. Each is discussed briefly below. A more detailed discussion can be found in the document, "Procedures For Conducting Impact Assessments" (Levels Reference Study Board, 1991).

2.3.1 Past Expenditures

A large amount of damage to public and private property was experienced during the high water levels of 1985-1987. During this period, a substantial amount of money was spent on shore protection works to reduce or avoid damages to property and to ensure continued operation of utility, commercial or industrial facilities. The guidance for the use of the past expenditures is provided below.

Historic data on shore protection investments and facility operation costs was used to develop estimates of future expenditures that may be avoided with the implementation of certain measures. It was also used for problem identification and background information as part of the representative site studies and as input into the multi-criteria evaluation process. These data were not considered as damages in the impact assessment and evaluation of measures under future conditions.

Past damages to property and land, including shore protection works, were used to identify problem areas and the magnitude of problems experienced, as well as to update stage-damage information.

Changes in property values attributable to fluctuating water levels were not considered as a factor in benefit and cost comparisons. Any information that established an impact in this area was reported (qualitatively and narratively) for use in the multi-criteria evaluation process.

Income losses that arose due to disruptions in service and business operations were not included in developing benefit and cost comparisons, however they were important in identifying previous problems, and where they could be determined, they were included in the evaluation process as a regional impact.

2.3.2 Future Avoided Costs

An essential purpose of the impact assessment and measures evaluation process was to compare future conditions on the lakes, channels and shorelines of the Great Lakes - St. Lawrence River Basin with measures in place and without measures in place. The determination of "future costs avoided" involved anticipating or projecting what actions might (or might not) need to be taken to reduce future damages depending on whether certain other measures are implemented. As these kinds of relationships are often quite difficult to devise, a series of guiding statements were provided:

1. Equal consideration will be given to all interest groups and impact categories;
2. Both benefits and disbenefits will be identified where possible;
3. For measures involving new or altered works, a determination will be made of the need for and costs of remedial or compensatory works or measures that may be required to offset costs to the interests as a result of the new measure;
4. In determining future costs avoided, either the reduced costs of protection, or the shoreline and shore property damages prevented, may be claimed, reach by reach, but not both.
5. The key question to be kept in mind in conducting the impact assessments is: How do proposed water level and flow regulation measures, shore protection measures, shoreline management and land use measures, or incentive based and "adaptive" measures, reduce (or increase) future damages?

2.3.3 Baseline Conditions

A number of baseline conditions were established for this Study. First, the base year for analysis of 1993 was selected. A comparison of benefits and costs for the various measures was undertaken assuming this as the base year for analysis. In other words, measures in all categories were considered as if they were on line and in operation in 1993.

Second, a 50 year period of analysis was used, based on the engineering design life typically considered in large scale water resource projects. All costs involved in the various measures were developed so that any facilities or programs recommended would be in place for a 50 year period.

A range of interest rates was applied in discounting future benefits and costs to present worth, due to differences between interest rates in Canada and the United States, as well as the expected fluctuation of rates over the course of the study period. Impact assessments and the evaluation of measures were thus made using interest rates of 6, 8, 10 and 12 percent.

There were a number of other assumptions regarding existing and future conditions for the various interest groups that had to be made. For commercial navigation, the existing use of the system was assumed to continue in the future. For both hydropower and recreational boating, increased use of the system was expected, and expansions of facilities already planned were included in the impact assessments. For the residential, commercial and industrial, water supply, public infrastructure and recreation (other than boating) categories, it was anticipated that more intensive use would take place. Any expanses in these uses was also considered. It was further assumed that for all other categories (fish, wildlife, commercial fisheries, Native North Americans) except agriculture (which may see a reduction in use due to conversion of land to other uses), the primary concerns they face will continue into the future.

2.4 Measures For Examination

A number of measures to alleviate the adverse consequences of fluctuating water levels were put forth for detailed analysis. They can be grouped loosely into four main categories: 1) water level and flow regulation practices; 2) land use regulatory practices; 3) land use incentive based practices; and 4) shoreline protection alternatives. Working Committee 2 had the responsibility of examining and assessing measures found within all of these categories. Water level and flow regulation practices were evaluated by the Potential Damages Task Group, the Social Impacts Task Group and The Natural Resources Task Group. Land use regulatory and incentive based practices, as well as shore protection alternatives were examined by the Land Use and Shoreline Management Task Group. A brief introduction to these categories is provided below. Complete descriptions of the water level regulation scenarios can be found in the full report of Working Committee 3, as well as in Working Committee 4 (1992).

2.4.1 Water Level Regulation Scenarios

Measures in this category are those designed to physically manipulate or control the actual levels of the lakes and flows of the connecting channels. They commonly involve construction of dams and control structures, dredging of channels, and the development of operating plans for the structures. Three broad categories of Water Level Regulation Scenarios were examined: 1) review existing regulation plans for lakes Superior and Ontario; 2) five-lake regulation plans; and 3) three-lake regulation plans.

Review Existing Regulation Plans

This involved a complete review of all existing regulation plans (Plan 1977A on Lake Superior and 1958D on Lake Ontario) to determine if improvements could be made in their operation.

Determinations were also be made to see if it was feasible to improve coordination between Lake Ontario and Ottawa River Regulation. Finally, potential crisis related modifications to existing inter and intra basin diversions such as Long Lac-Ogoki and the Chicago diversion were examined.

Five Lake Regulation Plans

These measures would see the construction of control structures in the St. Clair, Detroit, and Niagara Rivers, thereby affording the potential to regulate water levels in all the Great Lakes. A number of operational variations to this five lake plan were examined, including a five lake scenario that maximized benefits to riparians, as well as an "optimized" scenario, which attempted to balance the benefits and losses to all interest groups under consideration.

Three Lake Regulation Plans

These measures examined a number of options for construction of control structures in the Niagara River to enable the full regulation of Lake Erie, with the existing regulation on lakes Superior and Ontario comprising the other two lakes. This measure also included examination of increases or decreases in current diversions out of Lake Erie, such as the Welland Canal and the New York State Barge Canal. Associated modifications to Lake Ontario's regulation plan were also be examined.

Two Lake Regulation Plans

A series of measures that would see improvements to the existing regulation plans of Lake Superior and Lake Ontario were also examined.

2.4.2 Land Use Regulatory Based Practices

Regulatory based practices are those in which certain regulations, restrictions, by-laws, etc. would be applied or enforced to control or modify existing shoreline uses in a manner that will minimize the potential "conflict" with shoreline processes and water level fluctuations. Regulatory based practices include:

- Setback Requirements
- Elevation Requirements
- Habitat Protection Measures and Regulations
- Shore Alteration Requirements and Regulations
- Deed Restrictions and Regulations

- Development Controls For Public Infrastructure
- Non-Structural Land Use Practices (Eg. Acquisition)

2.4.3 Land Use Incentive Based Practices

Incentive based practices are those which are designed to provide incentives (or disincentives) to the various shoreline user groups to encourage changes in the way they use the shoreline. Examples of measures in this category that have been considered for further evaluation are:

- Tax Incentives / Disincentives
- Loans
- Grants
- Insurance

2.4.4 Shore Protection Practices

Shore protection alternatives quite simply are engineered methods by which sections of the shoreline are protected from flooding, wave action, erosion, etc. From a shoreline management perspective, measures in this category which have been considered for further evaluation include the following:

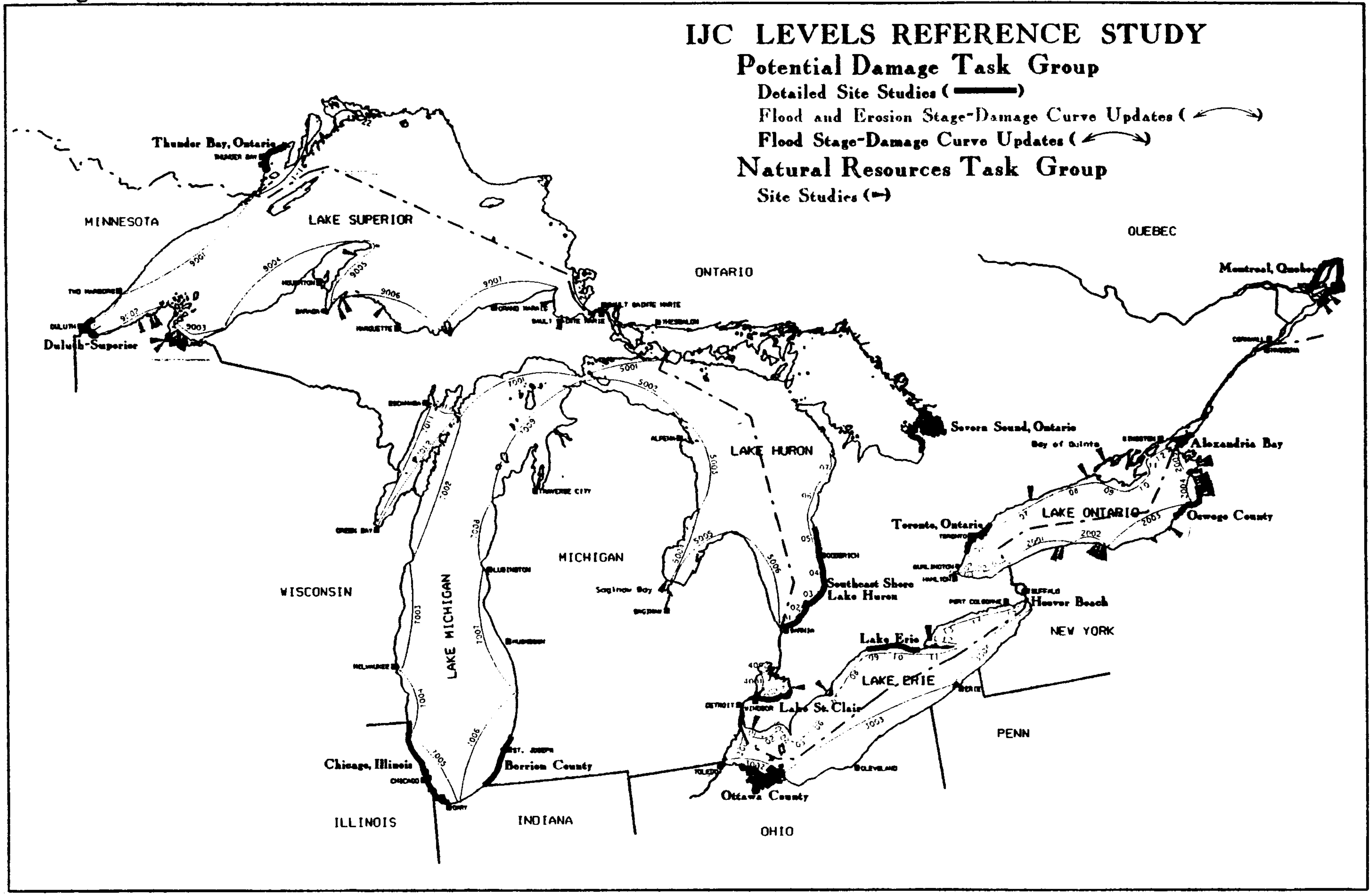
- Local, Large Scale, Structural Community Protection Projects (e.g. Dikes, Levees,Seawalls, Revetments)
- Local, Large Scale, Non-Structural Community Protection Projects (e.g. Beach Nourishment, Vegetation Planting, Bluff Grading)

2.5 Areas For Examination - Basin-Wide vs Site Specific

The analysis, assessment, cataloguing and mapping tasks conducted by Working Committee 2 were carried out at two levels of detail within the basin: both basin-wide and site specific. Where possible, information on a basin-wide extent was provided. Recognizing that it would not always be possible to provide information from such a large study area, the Study Board also established a series of "Detailed Site Studies" at which detailed site specific information was provided. The sites chosen to be examined in detail (SEE FIGURE 2.1) included, for Canada:

- Thunder Bay, Ontario (Lake Superior)
- Severn Sound, (Georgian Bay-Lake Huron)
- Windsor to Belle River, Ontario (Lake St. Clair)
- Port Glasgow to Clear Creek, Ontario (Lake Erie)
- Toronto, Ontario (Lake Ontario)

Figure 2.1 Location of Detailed Site Studies, Reach Studies and Wetland Studies



- Montreal, Quebec (Lac St. Louis-St. Lawrence River);

and for the United States:

- Duluth, Minnesota / Superior, Wisconsin (Lake Superior)
- Chicago, Illinois (Lake Michigan)
- Berrian County, Michigan (Lake Michigan)
- Ottawa County, Ohio (Lake Erie)
- Hoover Beach, New York (Lake Erie)
- Oswego, New York (Lake Ontario)
- Alexandria Bay, New York (St. Lawrence River)

A series of wetland sites were also chosen by the Natural Resources Task Group for detailed investigations of the impacts of fluctuating water levels. In addition, the Potential Damages Task Group carried out a series of "reach" studies for the purposes of updating stage-damage curves. These sites and reaches are also indicated on FIGURE 2.1.

2.6 Impact Categories

A number of impact categories, or interest groups have been defined for Phase II of the study. Analysis of the impacts of measures took place for all of these groups where appropriate. Impact categories include: residential shore property; commercial and industrial; recreational; public infrastructure; agricultural; natural resources (wetlands, fisheries and water quality); hydropower; commercial navigation; commercial fisheries; and Native North Americans.

2.7 Study Planning Objectives

A series of Study Planning Objectives have been defined for each of the impact categories, along with a specific method of measurement that was used in realizing the objective. For the impact categories Working Committee 2 has been asked to examine (with the exception of the Natural Resources Task Group), the Study Planning Objectives can be summarized as follows:

- Reduce flood, low water, and erosion damages and associated costs to the impact category.

The methods of measurement to accomplish this objective can be summarized as:

- Determine the difference in average annual erosion, extreme high and extreme low water damage to structures and property, with versus without the practice in place; and

- Determine the differences in losses (or costs incurred) from the use of, and protection of, property along shoreline areas vulnerable to erosion, low water and flooding conditions, with versus without the practice in place.

For the Natural Resources Task Group, Study Planning Objectives can be combined into:

- Avoiding or reducing adverse impacts to wetlands, water quality, fish and wildlife as a result of fluctuating water levels and flows and their extremes.

The methods of measurement included:

- identification of long-term changes in total wetland habitat area;
- identification of changes in the level of toxic or chemical contamination, with versus without the measure; and
- identification of changes in the number and types of plant and animal species, with versus without the measure.

REFERENCES

Levels Reference Study Board, 1991. Procedures For Conducting Impact Assessments. Phase II, IJC Levels Reference Study, 62pp.

Working Committee 4, 1992. Impacts of Measures For Evaluation - Summary (The Blue Book). Phase II, IJC Levels Reference Study, 285pp.

3.0 EROSION PROCESSES TASK GROUP

3.1 Introduction

The first phase of the Reference Study examined a number of issues, including the relationship between shoreline erosion and water level fluctuations. Based on conceptual models of known processes and some site specific field data sets, a conclusion of IJC Functional Group 2 (1989) was:

> *"The long-term rate of recession for many shore types is essentially independent of water level fluctuations, although erosion will temporarily increase or decrease as a result of higher and lower levels, respectively."*

Other Phase I findings referred to an insufficient level of development on predictive models and the difficulty of understanding the complex interaction of fluctuating water levels and their influence on erosion processes at the various time scales (Functional Group 2, 1989; Davidson-Arnott and Law, 1988). There was a general lack of understanding regarding the rate at which erosion rates respond to water level changes and there was subsequent controversy between various experts and interest groups over whether erosion is, or is not, influenced by fluctuating water levels.

Much of this controversy focused around the difference between long-term and short-term erosion and the type of shoreline being considered. For some shore types erosion may be the direct result of a specific event and temporary in nature (e.g. sandy shores). For other shore types, erosion may be a long-term cyclic process which results in a permanent land loss (i.e., clay bluffs). In addition, the effects of short-term water level fluctuations relative to a long-term pattern of recession were considered by some to be an inconsistency in temporal scales. Short-term fluctuations in the recession rate may not affect the long-term averaged recession rate, but may still be devastating to a specific interest. To further explore these findings and to develop quantitative information on the relationship between erosion and water level fluctuations, Working Committee 2 established the Erosion Processes Task Group.

A number of different tasks were carried out so that the Task Group could adequately assess the effects of water level changes on the erodibility of various shore types. These tasks will be outlined here, including the development and application of a three tiered shoreline classification scheme, the development and refinement of a nearshore profile model to analyze erodibility of different shore types, and the development and application of an erosion sensitivity classification system for the various shore types defined.

3.2 Development and Modification of A Shoreline Erodibility Classification Scheme

3.2.1 Rationale

To quantify the influence of lake-level effects on erosion, a comprehensive shoreline classification scheme was developed for the Great Lakes -St. Lawrence River Basin. While a number of previous Great Lakes classification and mapping activities have been undertaken at both national and provincial or state levels (eg. Hands, 1970; Herdendorf, 1988; Bowes, 1989; Podor, 1991), they have usually been specifically designed to address a particular research question or environmental problem and therefore were not suitable for the Task Group's mapping purposes. They have also tended to be geologic or geomorphic in nature, without consideration to the susceptibility of the shore type defined to various agents of erosion, in particular, any sensitivity to lake level effects.

In light of this, the Erosion Process Task Group developed a scheme that incorporated factors directly influencing the erodibility of a particular shoreline. This resulted in the development of a "three-tiered" classification approach. Details on the three "tiers" are provided below.

3.2.2 The "Three-Tiered Approach"

The shore "type" classification developed for this project was a three tiered scheme, specifically developed to capture those elements of the shore character which may be important to consider when examining the response of the shore to lake level fluctuations. The first tier was a typing based strictly on the geomorphic nature of the shoreline (e.g. whether it is a dune-beach complex or a bluff). The second tier of information was the amount of shore protection present in a specific reach (i.e. the percentage of shore length protected). The third tier was the nearshore (sub-aqueous) shore type, that is, the type of sediment found under the water. The scheme also had to be designed to be:

- cross-shore oriented (i.e. insensitive to littoral effects);
- inclusive of all the Great Lakes and Connecting Channels;
- a generic grouping into which clusters of parameter details may be grouped;
- generally and visually meaningful;
- based on data extractable from aerial photos, maps and literature (i.e. no site visits); and
- key on parameters which are important in terms of shore erodibility.

Subaerial Geomorphic Classification

This component of the classification scheme was based purely on the geomorphic nature of the shoreline. Using the base of scientific knowledge that currently exists regarding types of shorelines found throughout the basin, 17 categories were developed for this tier:

1) High (>15m(50ft)) Bluff
2) High (>15m(50ft)) Bluff With Beach
3) Low (<15m(50ft)) Bluff
4) Low (<15m(50ft)) Bluff With Beach
5) Sandy / Silty Banks
6) Clay Banks
7) Sandy Beach / Dunes
8) Coarse Beaches
9) Baymouth-Barrier Beaches
10) Bedrock (Resistant)
11) Bedrock (Non-Resistant)
12) Low Riverine / Coastal Plain
13) Open Shoreline Wetlands
14) Semi-Protected Wetlands
15) Composite
16) Artificial (for Canada; Unclassified for U.S.)
17) Unclassified (for Canada; Artificial for U.S.)

Shoreline Protection Classification

This second tier of classification highlighted the extent to which certain segments or reaches of the shoreline are protected. No judgements were made as to the effectiveness and quality of the protection, but instead only on the percentage of shoreline that was protected within the reach. Similarly, the classification did not specify the type of structural protection in place (eg. seawall, groyne). The primary reason for this being that the majority of the information was derived from air photos and mapping products (see Section 3.2.5). As a result, it was difficult to determine the quality and effectiveness of the structures.

There were 6 categories developed for this tier:

1) Highly Protected: 70-100% of reach / segment protected.
2) Moderately Protected: 40-70% of reach / segment protected.
3) Minor Protection: 15-40% of reach / segment protected.
4) No Protection: >85% of reach / segment is unprotected.
5) Non-structural
6) Unclassified

Subaqueous Classification Scheme

It is becoming increasingly apparent in the literature that the erosion of the nearshore, subaqueous portion of the shore profile is a key agent in the overall recession and erosion of the shoreline. In an attempt to include the effect of this on the erodibility of Great Lakes -St. Lawrence River shorelines, a third tier of classification was included. This was a simple geomorphic classification of the type of material found in the nearshore zone (from the waterline to the 5m (16ft) depth contour). The classes below are simple, and relate to the predominant geology found.

There were 6 categories developed for this tier:

1) Clay
2) Sand
3) Sand / Gravel Lag Over Clay
4) Bedrock (Resistant)
5) Bedrock (Non-Resistant)
6) Unclassified

Final Classification

By superimposing these three tiers of information on top of one another, a three component shore type classification was developed. This classification represented a fourth level of information, with each shore type assigned an appropriate identification code. Using this classification and other physical process databases, assessments were then made on the response of each shore type to various water level conditions and regimes. Results of these types of analyses are discussed in Section 3.4 and 3.5.

3.2.3 Peer Review and Modification

The classification scheme outlined above underwent a significant amount of review prior to being finalized. This review was conducted by a number of Great Lakes shoreline professionals in the fields of engineering, geology and geography. Their comments and suggestions were incorporated and a revised scheme was generated. This revised scheme was then provided to the personnel conducting the mapping (see Section 3.2.5) who, after some initial application, suggested further changes. Finally, after additional discussion at a peer review workshop held by the Task Group, the scheme was revised into the version presented above.

3.2.4 Historical Shoreline Change (Recession) Rates

It was also important that known recession rate values for the Great Lakes shoreline be added to the shoreline classification data base. These rates served a number of purposes: 1) they identified those sections of shoreline where recession has or has not been a significant problem; 2) they identified types of shoreline where recession has or has not been a significant problem; and 3) they provided a starting value of recession to which the Task Group could apply the results of the erosion evaluation project (i.e. how much would this rate change, if any, as a result of changes in water level regimes?).

Published recession data (where available) was compiled on a reach by reach basis (Canadian shoreline), utilizing a series of previously defined reaches, and on a kilometre by kilometre basis (U.S. shoreline). All data were entered into respective Geographic Information System (GIS) data bases of both countries. Further detail on the collection of this recession data can be found in the reports entitled, "Great Lakes Shoreline Classification and Mapping Study: Canadian Side" prepared by Geomatics International (1992), and in the report entitled, "Summary, Shore Mapping and Classification Project : United States" (United States Army Corps of Engineers, 1992).

3.2.5 Application to Great Lakes - St. Lawrence River Shoreline

The United States Shoreline

Mapping of the U.S. shoreline of the Great Lakes Basin and the St. Lawrence River was performed by the U.S. Army Corps of Engineers (USACE) under direction of the Coastal Engineering Research Center (CERC), Vicksburg, Mississippi. The basin was divided into zones, with classification being performed by a coastal specialist with experience in that zone. This section will describe the methods and data sources used to classify each region.

The U.S. shoreline was classified using various published and unpublished data sources, videotapes, aerial and oblique photographs, and personal knowledge. The mappers reviewed their materials and wrote the shore type, protection level, and offshore type on U.S. Geological Survey topographic map sheets. The map sheets were then sent to USACE Detroit District, where the classifications were entered into a GIS data base. Note that the map sheets were used merely as a convenient base upon which the mappers could write their classifications and notes. The shorelines in the GIS database were not based on the map sheets but rather on recent aerial photographs. Many portions of the shore, especially along barrier spits and sandy coasts, have changed significantly since the maps were printed. In addition, shore protection structures and other shoreline filling activities have caused major changes in some areas. Nevertheless, the quadrangles were sufficiently accurate to use as a base for the notes, and the elevations of the bluff crests were a valuable interpretive tool in some areas.

No specific reaches were defined along the U.S. shorelines. The interpreters classified the shore type and protection level to as great a degree of detail as they deemed necessary to adequately represent the shore in the region in which they were working. For example, along the south shore of Lake Erie, the protection level changed frequently because of the many towns and harbours present. Also, the shore type often changed abruptly between various bluff types and river mouths and barriers. In contrast, in the northeast corner of Lake Ontario and in the St. Lawrence River, the shore was classified as bedrock with protection level 4 (minimal or no protection) for tens of kilometres (miles). In general, the minimum length that the shore was subdivided was about one quarter kilometre (0.15 mile), whereas there was no maximum limit. In addition, the primary factor that was used to subdivide the shore was the shore type classification. However, occasionally a major change in the protection level created an obvious geologic effect, therefore causing a break in both shore and protection type. A typical example is the beginning of an armoured harbor or confined disposal facility.

Canadian Shoreline

Classification of the Canadian shoreline was done on a reach by reach basis with the geomorphic and protection classification being carried out simultaneously from Environment Canada and Ontario Ministry of Natural Resources colour shoreline videotapes, or vertical black and white aerial photographs. These were supplemented by other information including the Great Lakes Shore Damage Survey Coastal Zone Atlas (Haras and Tsui, 1976), surficial geology maps, nearshore sediment characteristic maps, and Remedial Action Plan reports. Where information on the nature of the subaqueous material was evident from these sources, it was also coded. In some cases the information was sufficient to provide a definitive classification (e.g. sand bars or bedrock visible in the nearshore). In other cases there was some evidence, but it was not sufficiently definitive and this was noted for future verification from other sources.

Problems and Limitations

It is important to emphasize that the process of shoreline classification as carried out here was essentially subjective and based almost entirely on descriptive criteria. This was dictated by the extensive nature of the work required and by the classification scheme itself. In the geomorphic classification the only quantitative element is the use of 15 metre (50 feet) height to distinguish between high and low bluffs. In the protection classification, classes 1-4 are distinguished on the basis of percentage of shoreline protected, but here, these are estimated visually, not measured directly. It is also important to recognize that this is the most "time-variable" item in the classification scheme (i.e. while shore type and subaqueous shore type will remain unchanged over time, the amount of shore protection present can change rapidly from year to year). As such, this classification represents the nature of shore protection as of the most recent aerial photographs, and may change significantly in the future. Some simple descriptions of the characteristics of the shore types and example locations were provided with the classification scheme. Ultimately however, classification of each reach was the result of the subjective interpretation of the individual doing the work and was based on their understanding of the classification scheme, the information available and the experience of the individual. Because of this subjectiveness, and the number of classifiers conducting the work, occasional inconsistencies in the classification were detected. In one example (Berrien County, Michigan), large sections of shoreline were classified as "sandy-silty banks" (i.e. Geomorphic Class 5), as opposed to a more realistic classification of "low bluff" (i.e. Geomorphic Class 3 or 4) simply because the classifier held a different definition of a sandy-silty bank than that envisioned by the Task Group in the development of the classification scheme. For the Berrien County site, the shore was reclassified accordingly, but the possibility exists that other such inconsistencies are present.

Two other types of limitations or potential sources of error were noted during the classification procedure: 1) problems related to the nature of the classification itself; and 2) problems related to limitations in the sources of information.

The first set of limitations arose from the fact that no simple classification scheme could encompass adequately the range of shoreline characteristics that exist in the Great Lakes, particularly in the case of the geomorphic and subaqueous classifications. Each shore type was distinctive in the classification, but in reality there was a continuum, so that there always existed reaches which were borderline between two classes. An example of this occurred in distinguishing between baymouth-barriers (G9), semi-protected wetlands (G14) and sandy beach / dunes (G7). A second example occurred in areas of bedrock shoreline with small bays and pocket beach development. In these cases, there was often a transition from bedrock shorelines with a veneer of sand (G10) to sandy beaches (G7). There was no clear measure of how much sand (width of beach, thickness, continuity alongshore) was needed to make the transition from a bedrock shore to a sandy beach. Similarly, on the Canadian shoreline, large reaches may include a number of different shore types, but because each reach had to be assigned only one shore type, the predominant shore type would apply. Using the previous example, it is likely that a reach of this nature was classified as a bedrock shoreline, even though there are many areas of sandy beach within it. This is an important limitation to consider when attempting to apply classification results to a site specific area.

The second set of problems in classifying segments of the shoreline arose from the limitations imposed by the data sources or by limitations in the definitions found in the classification scheme itself. As an example, it was extremely difficult using videotapes, and virtually impossible using aerial photographs, to distinguish the size of the beach material. Thus, in some cases coarse beaches (G8) may have been classed as sandy beaches (G7) and vice versa. In many instances indirect evidence, such as the presence of dunes or of multiple sandbars in the nearshore, as well as the familiarity of the classifiers with the shoreline, enabled the distinction to be made. The classification scheme also distinguished between non-resistant bedrock (G11) and resistant bedrock (G10), but it was not defined quantitatively. Moreover, this distinction was not readily apparent on the primary data sources. Some information could be derived from geologic maps and reports, but again, this required matching the description of the rock type with some measure of resistance. Finally in areas of highly variable lithology it was necessary to know the characteristics of the bedrock that was in the subaqueous zone or at the shoreline, which may not necessarily have been the formation that was seen as outcropping on the land.

Because the videotapes and photographs used as the primary sources may have been taken in different years or at different seasons, there may have been some variation in water level and also the vegetation exposed at the shoreline. This could have affected, for example, the distinction between bluffs and bluffs with beach, or the ability to identify emergent vegetation on sheltered shorelines.

Classification by level of protection was generally easily accomplished, particularly for those sections where a videotape was available. Shore parallel structures were more difficult to identify in vertical aerial photographs, but areas where these were likely to be present could be picked out readily by the presence of houses near the shoreline and sometimes by the existence of some shore-perpendicular structures. Careful analysis of the photographs using a magnifying glass or stereoscope then enabled a reasonable estimate of the appropriate protection category.

Information on the subaqueous profile was the most limited and resulted in an appreciable percentage of the shoreline in some areas (primarily upper Great Lakes and portions of the St. Lawrence River in Canada, and the St. Clair River, Lake St. Clair and the Detroit River in the United States) that could not be classified reliably.

In summary, the greatest difficulties experienced were with the geomorphic classification for the reasons outlined above. Roughly 70-80% of the reaches could be placed in a geomorphic class with relatively little difficulty, but the other 20-30% either required gathering of additional material or the judgement of the classifier to choose between two different classes. However, in almost all cases it was possible to assign a reach to a definite class, and rarely was it necessary to resort to the unclassified category.

Quality Control

Once the classification procedure was completed, draft maps and background information were circulated to appropriate personnel on both the Canadian and U.S. shoreline for quality control checks to ensure general accuracy, highlight any blatant classification errors, and provide data for areas that were unclassified. Due to time constraints on the Task Group, a detailed quality control program could not be undertaken. Instead, certain mapped segments of the shoreline were forwarded to agencies for checking on a "spot check" basis. Results of these spot checks indicated no major discrepancies. While this allowed the Task Group to have a high degree of confidence in the classification results, some errors or inconsistencies in classification (as discussed earlier) may be present.

3.2.6 The Mapping Product and Summary Statistics on Distribution and Extent of Shore Types

The final products of this classification and mapping exercise consist of: 1) a series of hardcopy maps showing the classified shorelines (available for viewing at the USACE Detroit District office and the Environment Canada office in Burlington, Ontario); 2) a digital GIS compatible database of the classification, including information on recession rates for each of the shore types identified (retained in the Intergraph GIS of the USACE and the SPANS GIS of Environment Canada); and 3) a series of summary statistics indicating length of shore type per reach, or total kilometres (miles) of shore type, for example.

Shoreline Mapping and Classification Product (Canada)

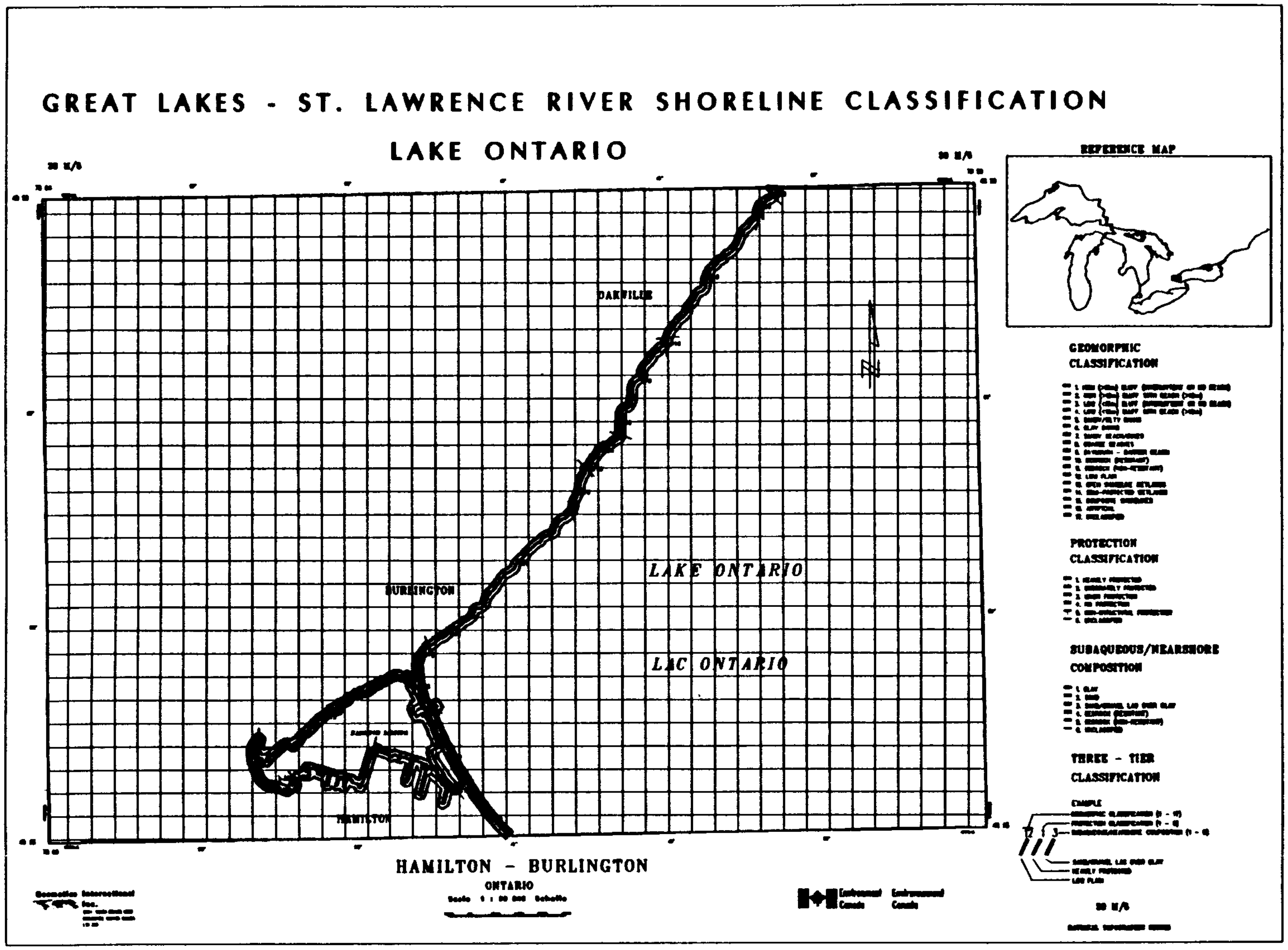
The mapping of the shore type classifications onto hardcopy maps was accomplished by digitizing the shoreline represented on 1:50,000 scale National Topographic Series (NTS) map sheets for the lower Great Lakes (south of Severn Sound) and from 1:250,000 scale NTS map sheets for upper Lake Huron / Georgian Bay and Lake Superior.

In order to present the three tier shoreline classification scheme on hardcopy maps as a set of three distinct parallel lines, each section of shoreline (reach) was digitized and coded to a pre-assigned reach number. The reach number was the link to the classification codes which were entered into Dbase files. The reach number, geomorphic classification, protection classification, nearshore classification and the three-tiered composite classification were extracted from the dBase files and input into ARC/INFO GIS where they formed "reach-by-reach" look up tables which linked each classification type to the appropriate reach number for that section of shoreline. The "protection" class (represented by yellow lines and line styles on the hardcopy maps) follow the original shoreline, with the "geomorphic" class (multiple colours and line styles) being a parallel offset on the land side of the actual shoreline and the "nearshore" class (blue lines and line styles) being a parallel offset on the water side. A scaled-down page size black and white representation of the final Canadian mapping product is illustrated in FIGURE 3.1.

Shoreline Mapping and Classification Product (U.S.A.)

The encoding of the three-tiered classification information into the U.S. GIS was accomplished by using the shorelines mapped from the most recent aerial photography available. The digital mapped shoreline became the graphic storage medium for each segment of each of the three-tiered classifications. The photography used to generate the digital shorelines was acquired in 1979 for the State of Michigan and in 1987-89 for the other seven Great Lakes States at a scale of 1:24,000.

Figure 3.1 An Example Shore Classification Map-Canadian Shoreline



Each of the three-tier shoreline classification schemes was plotted on a hardcopy map, at the scale desired, and in combination with any related information (i.e., road networks, political subdivisions, etc.) for referencing. A fourth composite map was generated which differentiated the shoreline by homogeneous geomorphic/protection/subaqueous characteristics. These homogeneous "reaches", frequently less than five kilometres (3.1 miles) in length, were later used for defining erosion susceptibility characteristics. This approach differs from the Canadian example, due to the nature and intent of the differing GIS systems.

The U.S. shoreline mapping project did not directly attach the recession rate information to the digital mapping information, but rather was generated as a "spreadsheet" file by one-kilometre (0.6 mile) segments, using the same digital mapped shoreline. For the erosion sensitivity activities this one-kilometre (0.6 mile) segmentation was visually referenced to the composite class information to arrive at a final mapped product and summary statistics.

The graphic representation of the composite map has been developed using distinct colour, patterning, and line weights to accommodate any perturbation generated from using the three base classification schemes. The U.S. system allows for distinct summary statistics to be generated for each of the three-tiered classes, or for the composite classes. Percentile statistics for each of the three-tier classifications and for the composite class all use the same referenced shorelines. Hence, all statistics are directly related. The U.S. shoreline mapping project has been referenced to mapping of political divisions, by county and state. Summary statistics by shoreline length are generated by state/county and by lake/river to provide further information for detailed studies. A scaled-down page size black and white representation of the composite map for one U.S. township is provided as FIGURE 3.2.

Classification Results - Canadian Shoreline

Lake-by-lake statistical summaries are provided for the geomorphic, protection and nearshore classifications individually and as a composite three-tiered classification. These statistical summaries have been broken down to give statistics for each individual lake and connecting channel. In order to provide a complete summary of the study area shoreline, the lake-by-lake statistical summaries were also combined to form an entire Great Lakes - St. Lawrence River system summary for each of the geomorphic, protection and nearshore classifications (TABLE 3.1).

TABLE 3.1 indicates the number of classes found on a particular lake or connecting channel, the classification type, the number of occurrences and percentages based on the number of reaches for the lake or channel and the length of shoreline and percentages for that particular class type. The total number of classification types, the total number of reaches and the total shoreline length for the entire basin is also shown on each table.

Figure 3.2 An Example Shore Classification Map-United States Shoreline

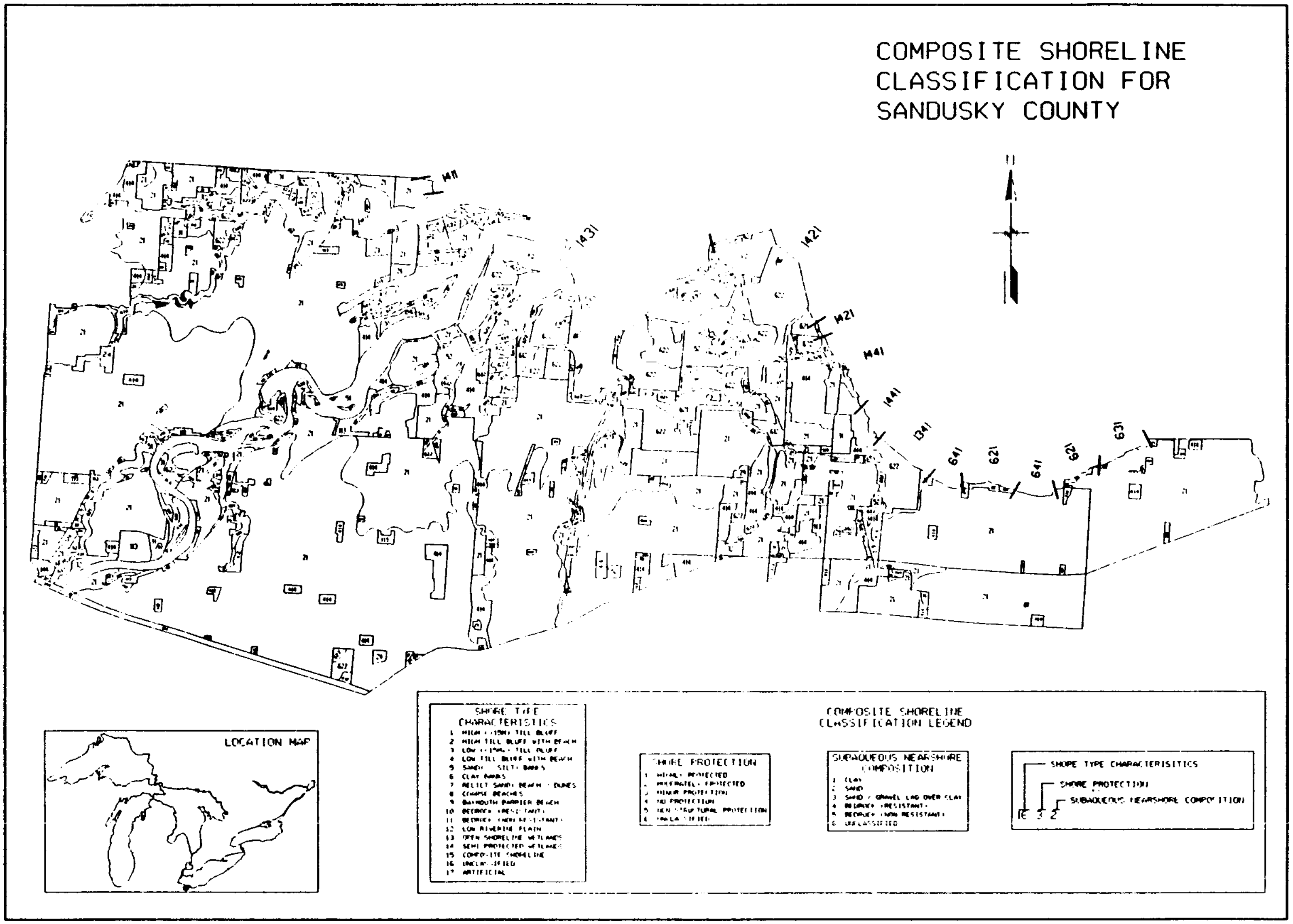


Table 3.1 Great Lakes - St. Lawrence River Classifications- Canadian Shoreline
Source: Geomatics International (1992)

GREAT LAKES - ST. LAWRENCE RIVER GEOMORPHIC CLASSIFICATION

NUMBER	GEOMORPHIC CLASS		OCCURRENCES		SHORE LENGTH (km)	
1	1	High Bluff	51	2.6%	227.30	2.0%
2	2	High Bluff & Beach	22	1.1%	71.47	0.6%
3	3	Low Bluff	122	6.2%	365.33	3.2%
4	4	Low Bluff & Beach	37	1.9%	75.45	0.6%
5	5	Sand/Silty Banks	35	1.8%	151.56	1.3%
6	6	Clay Banks	26	1.3%	105.99	0.9%
7	7	Sandy Beach/Dunes	319	16.2%	1,121.54	9.8%
8	8	Coarse Beach	127	6.4%	697.03	6.1%
9	9	Barrier Beach	107	5.4%	250.36	2.2%
10	10	Bedrock (Resistant)	602	30.5%	5,372.20	46.8%
11	11	Bedrock (Non-Resist)	27	1.4%	125.00	1.1%
12	12	Low Plain	200	10.1%	1,125.37	9.8%
13	13	Open Shore Wetlands	98	5.0%	810.24	7.1%
14	14	Semi-Protected Wtlnds	65	3.3%	390.13	3.4%
15	15	Composite Shoreline	0	0.0%	0.00	0.0%
16	16	Artificial	124	6.3%	516.60	4.5%
17	17	Unclassified	11	0.5%	63.56	0.6%
TOTAL	17		1973	100.0	11,469.13	100.0

GREAT LAKES - ST. LAWRENCE RIVER PROTECTION CLASSIFICATION

NUMBER	PROTECTION CLASS		OCCURRENCES		SHORE LENGTH (km)	
1	1	Heavily Protected	213	10.8%	827.98	7.2%
2	2	Mod Protected	129	6.5%	534.43	4.7%
3	3	Minor Protection	201	10.2%	1,052.57	9.2%
4	4	No Protection	1394	70.6%	8,879.63	77.4%
5	5	Non-Struct Protect	1	0.1%	2.26	0.0%
6	6	Unclassified	35	1.8%	172.26	1.5%
TOTAL	6		1973	100.0	11,469.13	100.0

GREAT LAKES - ST. LAWRENCE RIVER NEARSHORE CLASSIFICATION

NUMBER	NEARSHORE CLASS		OCCURRENCES		SHORE LENGTH (km)	
1	1	Clay	117	5.9%	594.37	5.2%
2	2	Sand	297	15.0%	1257.90	11.0%
3	3	Sand/Gravel over Clay	193	9.8%	612.61	5.3%
4	4	Bedrock (Resistant)	676	34.3%	3425.27	29.9%
5	5	Bedrock (Non-Resist)	32	1.6%	71.82	0.6%
6	6	Unclassified	658	33.4%	5507.16	48.0%
TOTAL	6		1973	100.0	11,469.13	100.0

The percentage of each classification type by lake and connecting channel for geomorphic, protection and nearshore classifications have been summarized in TABLES 3.2, 3.3 AND 3.4 respectively, in order to highlight the variations between the lakes. In TABLE 3.2, the contrast between the largely bedrock shorelines of the upper Great Lakes and the softer shorelines of the lower Great Lakes is clearly evident. Bedrock shorelines account for roughly 60% of Lakes Superior and southern Huron (south of Severn Sound) and 80% of northern Lake Huron, while bluff shorelines account for less than 2% on Superior and northern Huron and about 9% on southern Lake Huron.

Almost half (46.8%) of the entire Great Lakes - St. Lawrence River shoreline is classified as resistant bedrock, yet only 30.5% of the shoreline reaches defined for the Basin were classed the same. This is a result of the less variable shoreline found on the upper Great Lakes, which resulted in longer reaches being defined as compared to the more diverse shoreline along the lower Great Lakes and St. Lawrence River, which required shorter, more frequent reaches to be defined in order to accommodate this greater variability in shore types.

With regard to the five main lakes, Ontario is by far the most diverse geomorphically, with a percentage of its shoreline falling into all but one of the 16 main categories. It also has the highest percentage (10.7) of artificial shoreline (excluding the connecting channels), due to the intense residential and industrial development at its western end. Lake Erie is fairly evenly weighted between "bluff" shorelines (42.4%) and "beach" shorelines (37.2%) with a predominance in the high bluff category (27.8%). Wetlands predominate in the reaches of the St. Marys River (39.6%), St. Clair River (30.8%), Lake St. Clair (61.1%), and the Detroit River (46.4%).

All of the shore types are well represented on all of the water bodies with the notable exception of the "composite" category which did not occur on any water body (this is due to the limitations of the classification scheme itself rather than to the lack of composite shorelines in the Basin). High bluff shorelines are found primarily on the Lake Erie shoreline, as are barrier beaches, Long Point, Point Pelee, and Rondeau being notable examples. Coarse beaches compose a large percentage of the Lake Superior shoreline, while clay banks predominate in the Niagara River and low plains are significant percentages of the Lake Ontario and St. Lawrence River shoreline.

The contrast between the lakes found for the geomorphic classes is also evident for the protection classes (TABLE 3.3). Shorelines that have high or moderate protection account for 24.2%, 34.3% and 37.9% of the shorelines of Lake Ontario, Erie and St. Clair respectively. In contrast, less than 10% of the shoreline for the upper lakes has this degree of protection. In total, a large proportion (77.4%) of the Great Lakes - St. Lawrence River shoreline was classified as having no protection.

Comparison of nearshore classes (TABLE 3.4) is made difficult by the lack of information on parts of lake Ontario, as well as large sections of the upper Great Lakes and for the St. Lawrence River. However, as would be expected from examination of the geomorphic classification,

Table 3.2 Geomorphic Classification Summary Table-Canadian Shoreline

Geomorphic Class	Percent Shoreline by Lake or Connecting Channel											
	Lake Superior	St. Marys River	Northern Huron	Southern Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence
Shore Length (km)	2541.2	292.4	3377.3	1210.9	91.3	139.2	106.6	623.5	58.8	1135.9	1892.0	11469.1
1. High Bluff	0	0	0	2.2	0	0	0	27.8	0	2.4	0	2.0
2. High Bluff & Beach	0	0	0	5.4	0	0	0	0.7	0	0.2	0	0.6
3. Low Bluff	0.4	0	1.6	0.7	29.9	0	0	7.4	5.3	17.0	1.3	3.2
4. Low Bluff & Beach	0	0	0.03	0.7	0	0	0	6.5	0	1.5	0.5	0.6
5. Sand/Silt Banks	0.1	1.8	0	1.4	1.0	20.5	30.4	2.8	0	0.6	2.2	1.3
6. Clay Banks	0	0	0.4	0	15.6	6.3	2.8	2.6	54.2	1.4	0.2	0.9
7. Sand Beach/Dunes	10.0	8.3	12.2	24.6	0	0.3	0	16.0	0	2.9	0	9.8
8. Coarse Beach	19.4	3.9	3.0	1.6	0	0	0	0	0	4.9	1.0	6.1
9. Barrier Beach	0.3	0	0	0	0	0	0	21.2	0	9.3	0.4	2.2
10. Bedrock (Resistant)	60.2	34.8	76.7	57.5	0	0	0	1.3	29.3	17.2	12.4	46.8
11. Bedrock (Non-resistant)	0	0	3.5	0.4	0	0	0	0	0	0.2	0	1.1
12. Low Plain	1.5	8.3	0	0.2	17.1	7.4	0	0	3.4	20.1	42.5	9.8
13. Open Shore Wetland	6.0	4.5	0.5	0.5	30.8	55.9	46.4	10.0	0	6.0	17.8	7.1
14. Semi-protected Wetland	0.8	35.1	2.2	1.2	0	5.2	0	0	0	5.6	5.8	3.4
15. Composite Shore	0	0	0	0	0	0	0	0	0	0	0	0
16. Artificial	1.5	3.3	0	3.9	5.6	4.3	20.5	3.7	7.8	10.7	12.7	4.5
17. Unclassified	0	0	0	0	0	0	0	0	0	0.1	3.3	0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: km x 0.621 = Miles

Table 3.3 Protection Classification Summary Table-Canadian Shoreline

Protection Class	**Percent Shoreline by Lake or Connecting Channel**											
	Lake Superior	**St. Marys River**	**Northern Huron**	**Southern Huron**	**St. Clair River**	**Lake St. Clair**	**Detroit River**	**Lake Erie**	**Niagara River**	**Lake Ontario**	**St. Lawrence River**	**Great Lakes St. Lawrence**
Shore Length (km)	2541.2	292.4	3377.3	1210.9	91.3	139.2	106.6	623.5	58.8	1135.9	1892.0	11469.1
1. Heavily Protected	**1.3**	**4.0**	**0**	**5.0**	**69.1**	**32.7**	**49.7**	**17.3**	**60.7**	**15.1**	**13.0**	**7.2**
2. Moderately Protected	**1.3**	**2.7**	**0**	**3.9**	**8.4**	**5.2**	**37.5**	**17.0**	**10.0**	**9.1**	**9.6**	**4.7**
3. Minor Protection	**5.0**	**4.4**	**0.3**	**10.4**	**0**	**18.7**	**12.8**	**11.5**	**29.3**	**19.2**	**23.3**	**9.2**
4. No Protection	**92.0**	**89.0**	**99.7**	**80.3**	**22.5**	**43.2**	**0**	**54.2**	**0**	**48.5**	**50.6**	**77.4**
5. Non-structural Protection	**0**	**0**	**0**	**0.2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.02**
6. Unclassified	**0.5**	**0**	**0**	**0.2**	**0**	**0.2**	**0**	**0**	**0**	**8.1**	**3.5**	**1.5**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100**

Note: km x 0.621 = Miles

Table 3.4 Nearshore Classification Summary Table-Canadian Shoreline

Nearshore Class	Percent Shoreline by Lake or Connecting Channel											
	Lake Superior	St. Marys River	Northern Huron	Southern Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence
Shore Length (km)	2541.2	292.4	3377.3	1210.9	91.3	139.2	106.6	623.5	58.8	1135.9	1892.0	11469.1
1. Clay	5.6	17.9	0	0.4	3.1	0	0	22.3	0	12.1	6.1	5.2
2. Sand	5.7	20.0	1.3	9.4	33.8	100	56.9	27.1	0	12.0	18.9	11.0
3. Sand/Gravel Lag over Clay	0.2	17.4	0	12.1	63.1	0	43.1	31.6	0	8.2	0.9	5.3
4. Bedrock (Resistant)	51.3	36.4	13.2	67.1	0	0	0	18.9	0	33.4	13.8	29.9
5. Bedrock (Non-resistant)	0	0	0	0.9	0	0	0	0	0	5.4	0	0.6
6. Unclassified	37.2	8.3	85.5	10.1	0	0	0	0	100	29.0	60.3	48.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: km x 0.621 = Miles

bedrock dominates the upper lakes and extensive sections of Lake Ontario. TABLE 3.4 also indicates the lack of nearshore information which exists for the upper lakes and the St. Lawrence River.

Classification Results - United States Shoreline

As in the Canadian presentation, summary statistics are provided for the geomorphic, protection and nearshore classifications per lake or connecting channel and basin wide (TABLES 3.5, 3.6, AND 3.7). This information has been compiled from more detailed county-by-county and lake/river statistical summaries included in the Erosion Processes Task Group's final report.

In TABLE 3.5, the distinctive geomorphic character of each lake and connecting channel dominates the resultant statistics. As is the case with the Canadian shorelines for the upper Great Lakes, the United States shoreline of Lake Superior is dominated by bedrock (approximately 62%). Lake Michigan, with the longest shoreline in the U.S., is dominated by sandy shores (63% in Class 7-9), while Lake Ontario's shore tends to be either bedrock (42%) or cohesive till bluffs (35% in Class 1-4). The shorelines of Lakes Huron and Erie are the most diverse. There is a slight dominance of sandy (34%) and wetland (25% in Class 13 and 14) shores for Lake Huron, while the shoreline of Lake Erie is evenly divided between bedrock, cohesive bluff, sandy, wetland and artificial shores (approximately 20% falling into each category).

The U.S. side of the connecting channels tends to be either bedrock (St. Lawrence River -60%), wetlands (St. Mary's River - 49%; Lake St. Clair - 58%), or artificial (St. Clair River - 81%; Detroit River - 60%). The Niagara River is low sandy banks (53%) and artificial (13%) for it's upper reaches, but incised into bedrock (26%) throughout its lower course.

TABLE 3.6 shows that the most heavily protected areas in the basin are along the connecting channels (St. Clair River - 22%; Detroit River - 45%; Niagara River - 32%). The most extensively protected shoreline in any of the lakes is the United States side of Lake Erie (23% heavily protected, only 45% unprotected). While over 45% of the Lake Michigan shoreline is considered protected, the majority of this is minor protection (33%) resulting in a large number of small, localized structures. Lakes Superior, Huron and Ontario are largely unprotected (91%, 80% and 78% respectively).

Most of the nearshore in the basin is bedrock (60%) with non-cohesive material covering 24% of the nearshore (TABLE 3.7). The nearshore of Lake Erie is the most cohesive with 30% in Class 1. The nearshore bottom of Lake Michigan is the most non-cohesive (49%), while the nearshore zones of Lakes Superior, Huron and Ontario are largely bedrock (77%, 70% and 84% respectively).

A comparison of the geomorphic character of the U.S. and Canadian shorelines of the basin results in some interesting variability (TABLE 3.8). Although both shorelines are dominated by

Table 3.5 Geomorphic Classification Summary Table-United States Shoreline

Geomorphic Class	Percent Shoreline by Lake or Connecting Channel - United States											
	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River
Total Shoreline Length (km)	2564.0	389.7	2711.7	1784.7	34.0	464.6	126.9	999.2	111.5	678.3	646.4	10511.0
1. High Bluff	0.8	0	2.5	0	0	0	0	7.9	0	0	0	1.6
2. High Bluff & Beach	1.3	0	9.7	0.9	0	0.7	0	2.0	0	6.6	0	3.6
3. Low Bluff	1.0	0.9	2.1	0	0	0	0	3.0	0	2.0	0	1.2
4. Low Bluff & Beach	0.5	0	1.1	2.6	0	0	0	8.1	0	26.8	6.8	3.4
5. Sand/Silt Banks	1.3	12.0	0.3	1.9	0	0	0	0.8	53.0	0	0	1.8
6. Clay Banks	1.9	0	0	0	0	0	0	4.8	0	0	9.4	1.5
7. Sand Beach/Dunes	8.8	1.1	53.7	15.3	0	0	0	0.7	0	7.5	0.1	19.3
8. Coarse Beach	2.4	0	0.8	17.1	0	0	0	3.6	0	0	0	4.0
9. Barrier Beach	3.3	1.0	8.5	1.7	0	0	0	16.2	0	4.4	0	5.1
10.Bedrock (Resistant)	61.3	21.4	3.7	28.3	0	0	21.1	0	20.5	41.0	60.2	28.4
11. Bedrock (Non-resistant)	0.3	0	7.0	0	0	0	0	17.2	5.8	0.7	0	3.6
12. Low Plain	0.2	0	0	0.1	18.8	0.8	1.5	0.4	2.6	0	7.1	0.7
13. Open Shore Wetland	1.2	40.1	1.3	22.5	0	57.5	12.3	2.4	4.7	7.4	4.1	9.6
14. Semi-protected Wetland	7.2	8.6	2.7	2.1	0	0	5.0	14.7	0.4	2.0	5.0	5.0
15. Composite Shore	2.9	0	0	0.7	0	0	0	0	0	0.2	2.5	0.9
16. Artificial	5.7	14.9	6.6	7.1	81.2	41.0	60.2	18.2	13.0	1.3	10.5	10.3
17. Unclassified	0	0	0	0	0	0	0	0	0	0	0	0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.6 Protection Classification Summary Table-United States Shoreline

Protection Class	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River
	Percent Shoreline by Lake or Connecting Channel - United States											
Total Shoreline Length (km)	2564.0	389.7	2711.7	1784.7	34.0	464.6	126.9	999.2	111.5	678.3	646.4	10511.0
1. Heavily Protected	5.1	6.2	8.9	2.1	22.0	5.2	45.1	23.3	31.5	1.5	12.0	8.4
2. Moderately Protected	0.9	0.7	2.9	1.3	61.1	35.3	12.2	7.8	16.3	1.8	1.5	4.7
3. Minor Protection	1.1	8.1	33.3	8.9	6.2	9.0	1.1	20.5	22.4	18.3	0.3	14.5
4. No Protection	92.8	78.1	54.8	83.9	10.7	50.2	41.6	45.4	29.8	78.4	86.2	71.2
5. Non-structural Protection	0.1	6.9	0.1	3.8	0	0.3	0	3.0	0	0	0	1.2
6. Unclassified	0	0	0	0	0	0	0	0	0	0	0	0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.7 Nearshore Classification Summary Table-United States Shoreline

Nearshore Class	Percent Shoreline by Lake or Connecting Channel - United States											
	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River
Total shoreline Length (km)	2564.0	389.7	2711.7	1784.7	34.0	464.6	126.9	999.2	111.5	678.3	646.4	10511.0
1. Clay	4.8	0	2.2	0	0	0	0	30.4	0	1.1	35.1	6.9
2. Sand	13.1	0	17.2	26.6	0	0	0	16.0	0	6.4	2.1	14.2
3. Sand/Gravel Lag over Clay	0	0	31.7	0	0	0.3	23.7	14.3	0	2.1	0	10.0
4. Bedrock (Resistant)	77.1	100.0	44.9	70.0	0	0	0	14.3	94.2	83.1	62.8	57.6
5. Bedrock (Non-resistant)	0	0	2.8	0	0	0	0	19.7	5.8	0.8	0	2.7
6. Unclassified	5.0	0	1.2	3.4	100.0	99.7	76.3	5.4	0	6.5	0	8.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.8 Comparison of United States and Canadian Shoreline Classification

Class Type	U.S.	Canada
Geomorphic		
Cohesive (1-4)	9.8%	6.4%
Banks (5,6)	3.3	2.2
Sandy (7,8,9)	28.4	18.1
Bedrock (10,11)	32.0	47.9
Plain (12)	0.7	9.8
Wetland (13, 14)	14.6	10.5
Artificial (16)	10.3	4.5
Composite (15)	0.9	0.0
Protection		
Heavily Protected	8.3	7.2
No Protection	70.5	77.4
Nearshore		
Clay (Cohesive)	6.9	5.2
Non-Cohesive	23.7	16.3
Bedrock	60.7	30.5
Unclassified	8.7	48.0

bedrock, only 32% of the U.S. shore falls in this category, compared to 48% of the Canadian shoreline. The U.S. side of the basin also contains more sandy shores (28%) than the Canadian side (18%) and also has a higher percentage of artificial shoreline (10% compared to 5% on the Canadian side). Only 10% of the U.S. shoreline and 6% of the Canadian shoreline are cohesive bluffs. In addition, there are a higher percentage of wetlands along U.S. shorelines (15% compared to 11% in Canada). These results show the U.S. shoreline of the basin to be more developed and more erodible than the Canadian shores. It is also interesting to note that cohesive shorelines do not dominate that much of the entire Great Lakes - St. Lawrence River basin, yet they have received significant study and tend to be located in some of the more developed and erosion prone areas.

3.3 Erosion Processes Evaluation

3.3.1 Objectives and Approach

The primary objectives of the Erosion Evaluation study were to review the findings and conclusions from Phase 1 (which primarily stated that long-term rates of recession for many shore types is independent of water level fluctuations), and to evaluate the relationships between lake levels and erosion. Specifically, the purpose of this work was to provide percentage reductions in recession rates of various shoreline types (defined in the classification scheme), as a result of a reduction in the range of water levels that might occur under new water level regulation scenarios. In order to address these objectives, the various processes which cause shore erosion had to be understood and the factors which influence local sensitivity to those processes identified. The contribution of water level elevations and fluctuations to local erosion rates could only be isolated through some procedure which allowed for some quantification of the process-response relationship.

In order to develop this understanding, along with quantifying evidence of the interrelationship between fluctuating water levels and erosion processes, several standard scientific approaches commonly used to analyze complex natural processes were considered. They included:

1) conceptual models and deductive reasoning;
2) analytical models derived from theoretical descriptions of natural processes;
3) monitoring of the prototype and the conduct of field experiments;
4) building representative and controlled physical models of nature in laboratory facilities; and
5) simulation of nature with numerical models based on the analytical understanding of 2) and through testing with data available from 3)

Of these, Procedure 5) was the only mechanism suitable for quantifying the interrelationship between water levels and erosion in terms of the Reference Study. The technology of "cross-shore" profile change numerical simulation emerged approximately 20 years ago and has primarily been confined to studies of sandy profiles. Recent studies and model technology advances have lead to the development of models which can now be used to address subaqueous cohesive sediment responses. This allows the application of numerical simulation to a variety of the shore types found throughout the Great Lakes-St. Lawrence River basin. In order to apply Procedure 5) to the Reference Study, data from previous field studies (Procedure 3) and from laboratory studies being conducted at the Canada Centre For Inland Waters (CCIW) (Procedure 4) were used to calibrate and verify the numerical model. Peer review and scientific documentation from other studies were also used to test the model results (Procedure 1).

3.3.2 Description of The Advanced Nearshore Profile Model

The numerical evaluation of the impact of water level change on shore types was performed with a coastal engineering cross-shore modelling technique called the Advance Nearshore Profile Model (ANPM). For a more detailed technical description of this model the reader is referred to the Erosion Processes Evaluation Paper (Nairn, 1992) as well as to Nairn (1990a and b) and Nairn (1991a and b).

In simple terms, this numerical model has been developed to provide a comprehensive description of the coastal processes which influence the evolution of coastal morphology. The model simulates coastal change under a number of different conditions and readily identifies the underlying reasons for a particular form of beach profile response. An important feature of the model is that it is based on coastal processes. Thus, the predictions and findings of the model can be linked directly to the physics of those processes, allowing for a fundamental understanding of the interrelationships between the processes and profile response. The beach profile version of the model has been extensively applied in both research and engineering design situations for both sandy and cohesive shorelines and is capable of considering the impact of seawalls and other impermeable strata such as clay, till, or rock, on the response of the shoreline.

The ANPM is one of the best available cross-shore models for conducting the work required by the Task Group. It has been a number of years in development and incorporates a number of components that were developed, tested and verified by other coastal researchers prior to incorporation into the ANPM. For example, wave transformation equations in the model are based on methods developed by Battjes and Janssen (1978) and Battjes and Stive (1985). Currents are accounted for in equations originally developed by Swart (1978), Swart and Loubser (1979), Craik (1982), Svendsen et al (1987) and Southgate (1989) to name a few. Finally, the model calculates sediment transport using equations developed by Bagnold (1963, 1966), Bowen (1980), Bailard (1981), and Stive (1986). In addition, interest in the development of the ANPM has come from many international agencies, including England's Imperial College of Science and Technology, Netherland's Delft Hydraulics Laboratory, the U.S. Army Corps of Engineers Coastal Engineering Research Center and Canada's National Research Council Hydraulics Laboratory, as well as numerous private coastal engineering firms throughout Canada.

3.3.3 Data, Sites, Water Level Scenarios and Time Scales Evaluated

Data Sets and Sites

While the ultimate goal of the erosion evaluation exercise was to evaluate the change in erosion rates for each of the shore types identified in the classification scheme, given a reduction in the range of water levels, the time and budget allowed for this task made reaching this goal difficult. In addition, data required for model input, particularly detailed recession rate and profile information for each of the shore types defined, was not readily available, or did not exist. As such, for the purposes of the erosion evaluation exercise, the shore types identified in the geomorphic level of the Classification Scheme have been grouped into the broad (not necessarily exclusive) categories of: a) sandy shores; b) cohesive shores; c) bedrock; d) wetland; and e) composite. Detailed quantitative analysis using the ANPM was undertaken for sandy and cohesive shores only, as they cover the largest number of erodible shore types in the classification scheme and they had the best readily available profile data to be used as input to the model.

In selecting sites (and related profile data) for analysis, certain criteria had to be met. First and foremost, the sites had to be representative of the refined sub-categories of the classification system. Second, a record of profile change (with respect to shape and position out to a depth of at least 4 metres (13 feet)) over a certain period of time, or at least an initial profile and an estimate of the long term rate of recession, had to be available. Third, wave hindcast information, used to describe the wave climate, and historical water levels, on either a daily, monthly or twice yearly basis, were needed. Fourth, in the case of sandy shores, some description of the grain size variation across the profile was required and fifth, for cohesive shores, a description of the stratigraphy of the substratum (especially below the water level) and some information on the quantity and volatility (mobility) of the sand cover was sought.

Using these criteria, a series of sites were selected for detailed analysis. They were, for cohesive shorelines:

1) Scarborough Bluffs, Lake Ontario (Toronto)
2) Grimsby, Ontario, Lake Ontario
3) Port Burwell, Ontario, Lake Erie
4) Maumee Bay, Lake Erie (Ohio)
5) Goderich, Ontario, Lake Huron
6) Kenilworth, Illinois, Lake Michigan
7) Lake County, Ohio, Lake Erie

Analyses was also conducted utilizing data from a cohesive profile laboratory test conducted at CCIW in Burlington, Ontario.

For sandy shorelines, the sites chosen for analysis included:

1) Little Sable Point, Michigan, Lake Michigan
2) Indiana Dunes, Indiana, Lake Michigan
3) Abino Dunes, Ft. Erie, Ontario, Lake Erie
4) Van Wagners Beach, Hamilton, Ontario, Lake Ontario

Application of The Numerical Model

There were three parts to the application of the model for the individual sites. The first was a detailed review of the available field data and a description of the shoreline in relation to the classification scheme proposed.

The second element involved the calibration and verification of the numerical modelling techniques for the local conditions, using the field data collected at the above sites. For cohesive shores, the calibration exercise consisted of simulating the profile change that actually occurred over the period of time separating two surveys (ranging from several years to several decades). For example, if real field data (i.e. profiles) had found a 10 metre (33 feet) total recession at a study site between 1969-1992 (note these are hypothetical numbers), then the model was calibrated so that it would also show a 10 metre (33 feet) total recession for that same period. The calibration tests (and subsequent modelling tests) were performed using wave data obtained through a wave hindcasting procedure (using historical wind data to determine historic wave activity), as well as historic water level data covering the period of record.

For sandy shores, calibration involved the verification of the numerical modelling technique and the chosen input data. Model tests on sandy shores were always performed with wave hindcast data in an hourly time series format (i.e. chronological compared to the statistical summary approach for cohesive shores). Sandy shores adjust much more rapidly and these adjustments will influence future changes. Therefore statistical wave data was inappropriate for these types of applications.

The third, and most important part (for this project) of each case study consisted of a series of hypothetical tests to investigate "what if?" scenarios for different water level conditions. These new water level conditions were input to the numerical model, along with the previous hindcasts of historic wave conditions to predict erosion rates that would have occurred in the past under these circumstances. Three separate scenarios were investigated. The first of these were 25% and 50% reductions in the current range of water levels about chart datum. For example, a level of 1.4 metres (4.6 ft.) above chart datum would be reduced to 0.7 metres (2.3 ft.) under the 50% range reduction scenario and a level of -1 (-3.3 ft.) metre would be increased to -0.75 metres (-2.5 ft.) under the 25% reduction scenario. In the third scenario, the predicted water levels from Working Committee 3 under a 5 lake regulation plan (referred to as SMHEO-50) have been considered. The SMHEO-50 plan results in only minor changes to the levels of Lake Ontario, approximately a 25% reduction, about the long-term mean, in the water level range of Lake Erie, and approximately a 50% reduction, about the long-term mean, to the lake levels on Lakes Huron and Michigan. Little or no change occurs for Lake Superior. The results of the SMHEO-50 test runs were compared to the predicted profile changes using the Basis of Comparison (BOC) lake levels. BOC levels are similar but not identical to the actual historic lake levels. They represent those levels that would have existed over a 90-year period if existing lake level regulation, diversions, and dredging had been in place throughout that time.

3.3.4 Response of Various Shore Types To Water Level Scenarios

Cohesive Shorelines

A cohesive shore (e.g. clay bluff) erodes and recedes because of the removal and loss of the cohesive sediment (both in the bluff and offshore). Once this material is eroded by the action of waves, it cannot reconstitute itself; it's 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 alongshore or offshore. A critical point to understanding evolution of cohesive shores is that bluff recession is highly dependant upon the continual downcutting of the nearshore, that is the continual erosion of that part of the shore profile underwater. This downcutting is a very complex process, however in general terms, there are two basic mechanisms which cause most of the downcutting of cohesive profiles: 1) the abrasion process of sand being moved by waves over the cohesive sediment; and 2) the role of turbulence generated in the wave breaking process once it reaches the exposed lake bed. A number of other variables also affect the rate at which this downcutting process occurs. These include: the resistance of the lake bottom material to erosion - gravel or bedrock materials will be more resistant, thus downcutting will be less; the amount of sand covering the profile - a small amount may act as an abrasive agent, exacerbating the downcutting, while a thick layer may serve to protect the profile from downcutting; and the depth of water offshore.

The downcutting and recession of a cohesive shore, as described above, will occur even at a static or constant water level as it is driven by wave action alone and is active under any water level condition. The position of the lake level does, however, influence where the downcutting takes place across the profile and as a result may influence the rate at which the shoreline erodes. For example, results of the model tests carried out, found that for cohesive shores, where downcutting of the subaqueous portion of the profile was a key factor in the overall recession process, there were three categories of response to the water level reduction scenarios. First, where the lake bottom followed an equilibrium profile shape, the influence of a reduction in the range of lake level fluctuation resulted in a less than 5 % reduction to the existing long-term recession rates. Second, at sites where the cohesive profile deviated from the equilibrium profile shape, particularly between the shore and depths of 2.5 m (8.3 ft.) below the long term mean water level, reductions in the long term recession rate of between 5 and 50 % were found: 5 % to 20 % reductions being associated with sites featuring one of the following characteristics resulting in a more erosion resistant lake bottom -

1) the presence of a different (harder) type of till;
2) the formation of a lag deposit of cobbles or boulders;
3) a bedrock outcrop; or
4) the presence of a persistent sand bar;

50 % reductions in the long term recession associated with sites having very wide and shallow nearshore shelves at an elevation of less than 1 m (3.3 ft.) below the long term mean lake level.

Finally, at sites where the backshore bluff and the lake bottom are protected by a large beach and only rarely subjected to the erosive forces of wave action, the reduction in the range of lake level fluctuation may eliminate or considerably reduce existing recession rates.

Sandy Shorelines

Unlike cohesive shores, sandy shores may experience long term erosion, stability or even accretion. In a discussion of the dynamic changes of a sandy beach, the question of time scale must be clearly recognized. In the long term, sandy beaches may be growing, stable or eroding depending on the net sediment budget. If there is more sand coming into an area than there is going out, the beach will be accreting; a net long term loss of sediment results in erosion of a sandy shore. Finally, a stable sandy shore will have a balanced sediment budget. These long term changes generally occur in response to the pattern of alongshore or littoral drift of sediment. In general, changes in the water level will not appreciably alter the alongshore or littoral drift patterns that result in the long-term development of eroding or accreting sandy beaches. In other words, the net sediment budget for a particular area of interest is not typically influenced by lake level. In contrast, the trend in lake level changes can have a significant impact on short term storm event erosion caused by cross-shore sediment transport. Storms that occur during periods of rising lake levels can result in much greater short term erosion than storms in declining water level periods. The changes in sandy beaches follow a concept similar to the equilibrium shapes of cohesive shores described earlier. At any site, depending on the local wave conditions and the grain size of the beach sediment, there will be a typical equilibrium profile shape. On the Great Lakes, this shape may represent a very gross average of the actual shape as it will not account for the bar - trough features; nonetheless, the principles that this concept is based on will still be valid.

The position of this equilibrium shape is known to respond to changes in the mean water level. For an increase in water level, the profile position changes through erosion of the beach and offshore deposition. Therefore, during a period of rising water levels, storm events will result in greater erosion of the beach and less recovery will follow in the summer months - resulting in a net shoreward shift of the equilibrium profile shape. Conversely, during a period of falling water levels, the profile adjusts to its new preferred position through decreased erosion during storms and increased recovery during the summer months. Erosion problems relating to these reversible changes in the beach position arise when development encroaches on the natural dynamic range of the shoreline.

In the modelling exercise for sandy shorelines, it was predicted that reductions in the range of water level fluctuation would reduce the width of the active beach zone. In other words the maximum inshore extent of erosion would be shifted offshore. The extent of this benefit will depend on the local characteristics of profile shape, storm surge magnitude and wave climate. The level of benefit will also be determined by the proximity of shoreline development to the active beach zone. Because of the importance of storm surge in severe erosion events, the reduction in the width of the active beach zone is quite small in most cases. Therefore a benefit will only arise where buildings are constructed near the inshore fringe of the existing active beach zone. In some cases, where relict dunes (i.e. dunes which are not actively building) have been eroded or where the sand supply has been depleted by updrift structures, the recovery of the dune may be very slow or even incomplete. In these site specific instances, it was predicted that increased lake level regulation would provide a benefit; the level of this benefit depending on the local coastal processes and the magnitude of the local storm surge. For sandy shores that consist of barrier beaches prone to overwash into a backshore bay, lagoon or low-lying area, it was predicted that a reduction in the range of water level might significantly reduce or eliminate the erosion due to backshore losses. The level of benefit gained at these sites will once again depend on the local conditions of beach crest height, storm surge and local coastal processes.

3.4 An Erosion Sensitivity Index for Shoreline Types

The determination of the location and extent of certain shore types (Classification and Mapping Project) and the evaluation of how certain shore types will respond to changes in water level (Erosion Processes Evaluation) were only two pieces of the complete puzzle that the Task Group needed to solve. It was also necessary to identify the types, location and extent of shore types that experience a change in recession as a result of water level change and specify (quantify) on a lake-by-lake basis, the length and percentage of these. For a number of site study areas, segments of shoreline where recession was predicted to be eliminated or reduced were identified and further investigations were carried out to determine the potential economic benefit that might occur (i.e. the change in erosion damages with and without a reduction in water levels). This will be discussed further in Section 5.2.4.

To quantify lengths and percentages of shoreline that will undergo changes in recession, the results of both the Classification and Mapping and Erosion Processes Evaluation projects were combined through a two step process. The first was to define a group of "erosion sensitivity" categories, based on the results of the Erosion Processes Evaluation and on generally accepted scientific principles of shore profile change behaviour. The second was to develop an "expert" system for assigning each of the shore types defined in the Mapping and Classification Project, into one of these sensitivity categories. These two steps are described in more detail below.

3.4.1 Erosion Sensitivity Categories

Erosion sensitivity in this case refers to how a particular shoreline type is predicted to respond to a reduction in water level range, as determined primarily in the Erosion Processes Evaluation Project but also on generally accepted scientific knowledge regarding the response of shorelines to water level and wave activity changes. Eight categories have been determined based on recession reductions that were estimated to occur under the maximum 50% reduction of water level range scenario (assumed to be the "best" case). These are defined below.

Category 1A - No Recession

This would account for all shorelines where recession currently does not occur, and thus, would not occur under a reduced water level regime. This would include all bedrock and artificial shorelines, as well as those that are heavily protected, presently accreting, or presently stable.

Category 1B - No Reduction

This category accounts for all shore types where a reduction in the range of water levels would have no, or an insignificant, impact on the recession rate of the shore type.

Category 2 - Minimum Reduction in Recession

This would account for all shore types where recession rates are reduced only 0-5% from their long term averages. Shore types here would generally be cohesive, with the bottom following an equilibrium profile to a depth of 2.5 metres (8.3 ft.) below long-term means, historic recession rates of 0.3 m (1 ft.)/yr or more, and minimum sand cover present.

Category 3 - Moderate Reduction in Recession

This would account for all shore types where recession rates are reduced from 5-20% of their historic rates. Generally these would be a cohesive shore, with resistant till, bedrock, cobble or bolder lag, or sand cover offshore to a depth of 2.5 metres (8.3 ft.) below long-term water level means.

Category 4 - Significant Reduction in Recession

This would account for all shore types where recession rates are reduced from 20-50% of their historic rates. Again, examples of these areas would be composed of cohesive shores, have high recession, and shallow offshore or basin to a depth of 2.5 metres (8.3 ft.) below the long term mean water level. This category is broken into 3 categories depending on the distance of the 2.5 metre (8.3 ft.) contour offshore. For example, results of the Erosion Processes Evaluation found that for the case studies where the reduction in recession fell between 5 and 20%, the 2.5 metre (8.3 ft.) contour was, at most, 260 metres (850 feet) offshore, whereas for the example with a 36% reduction, the contour was located 1400 metres (4600 feet) offshore. Assuming from this that the reduction in recession varies somehow with the distance of the 2.5 metre (8.3 ft.) contour, the Task Group developed the following sub-categories: 4A - 20% reduction in recession - 2.5 metre (8.3 ft) contour greater than or equal to 300 metres (985 feet) offshore; 4B - 30% reduction in recession - 2.5 metre (8.3 ft) contour greater than or equal to 500 metres (1640 feet) offshore; and 4C - 50% reduction in recession - 2.5 metre (8.3 ft) contour greater than or equal to 1000 metres (3281 feet) offshore.

Category 5 - Elimination of Recession

This category covers all those shore types where it is predicted that a reduction in water level range would completely eliminate recession of the shoreline. It is likely that this category would be represented by cohesive shores with a protective beach present. While not always the case, recession rates would likely be less then 0.3m (1 ft.)/yr.

Category 6 - Reduction In Storm Induced Beach Erosion

These types of sandy shorelines would not necessarily experience a net reduction in recession, but there would be a reduction in the active beach zone (i.e. the inshore limit of storm erosion will be shifted offshore). Any net benefits to development would be a function of how close to the active beach zone it is. Minimal benefits would be realized at areas where storm surges are significant.

Category 7 - Reduced Recession of Sandy Profiles

Shore types in this category would be sandy shores, most likely with relict (inherited) dunes and spit features (i.e. formed by processes and conditions no longer occurring). While recession would be reduced, it could be possible that the relict dunes would continue to experience erosion, but only under the most severe combination of high water and storm surge.

Category 8 - Unclassifiable

This category represents shore types where there is insufficient site data or a shore type that was not tested in erosion processes evaluation.

3.4.2 Development of "Expert" System for Sensitivity Classification

The Erosion Processes Evaluation Project examined the response of two basic shore types, sandy shores and cohesive shores, to water level reduction. While there was some refinement of this classification to look at variables such as nearshore slope, sand cover, etc., the final results did not specifically address each of the shore types defined in the Shoreline Classification and Mapping exercise. As such, some knowledge based decisions were made to assign the classification categories (geomorphic, protection and nearshore sub-aqueous) to the eight categories defined above for erosion sensitivity.

These knowledge based decisions essentially took the form of a series of "if / then" statements, i.e. if it's this shore type, then it falls in this sensitivity category. To begin formulating these statements, consideration first had to be given to the data elements involved. Recall that there were 17 categories in the geomorphic classification (G1-17). Based on the results of the Erosion Evaluation Process, these could be compressed into 6 loosely defined categories: cohesive (G1-4);

beach (G7-9); bedrock (G10-11); low banks / wetlands (G5-6, 12-14); artificial (G16); and unclassified (G15, 17).

Similar groupings were carried out for the protection and nearshore classes. For protection, consideration was primarily given to those shore types that were heavily protected, as it was assumed they will remain this way and there will be no recession. Thus protection was split into protected (P1) and not protected (P2-6). In the nearshore category it was known from the Erosion Processes Evaluation report that downcutting is a key process in recession and that it will continue unabated if the nearshore is composed of clay, but may be reduced if sand, gravel, or other erosion resistant materials are located in the nearshore. As such, this category was grouped into three categories: unhindered downcutting (S/N 1); limited downcutting (S/N 2-5); and unclassified (S/N 6).

A final key data element was the historical recession rate that had been determined for each shore type. For this, three key categories were identified: accretionary or stable; less than 0.3 m(1 ft.)/yr; and greater than 0.3 m (1 ft.)/yr (the value 0.3 m (1 ft.)/yr being identified as a key to determining erosion sensitivity of a shore type in the Erosion Evaluation Report). Unfortunately, a comprehensive, basin-wide recession rate database does not exist for the Great Lakes - St. Lawrence River basin. As such, recession rate data was not available for many sections and reaches of the shoreline. In these cases, for the purposes of erosion sensitivity classification, the recession rate was assumed to be greater than 0.3 m (1 ft.)/yr.

Other factors taken into consideration included the influence of surge, the nearshore slope (i.e. the distance of the 2.5 metre (8.3 ft.) below long-term mean level contour offshore), and whether or not a sandy shoreline was considered relict from an earlier period of ample sediment supply.

Using these data elements, a series of criteria were determined for assigning the Classification shore types to an erosion sensitivity category. They are presented below in TABLE 3.9 and in a schematic in FIGURE 3.3.

3.4.3 Application to Great Lakes - St. Lawrence River Shoreline

The "expert" system as described above is not a true expert system in the sense that there were a few subjective decisions that had to be made to assign a shore type into a sensitivity category. As such, the application of this system to the shore mapping had to be done manually and the appropriate sensitivity rankings then entered into the data base for the generation of statistics.

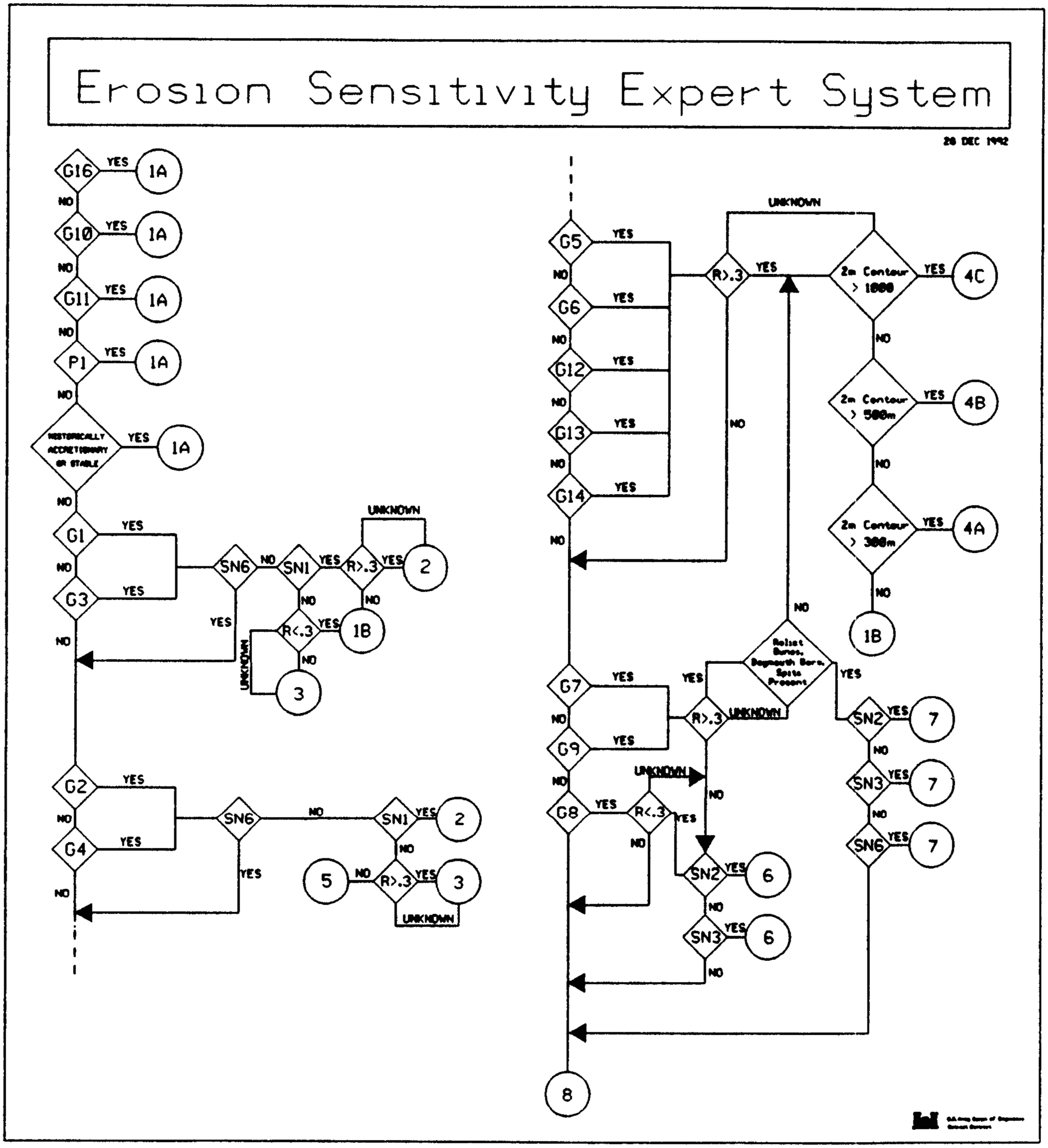
The procedure to accomplish this utilized the classification maps produced in the Classification and Mapping Project. For each reach (Canada), or 1 kilometre (0.6 mile) segment of shoreline (U.S.) and associated composite category (see Section 3.2.6) presented on the map, the "expert" system was applied to assign that reach / segment an erosion sensitivity category. Where necessary, bathymetric maps showing the position of the 2 metre (6.6 ft.) depth contour were

Table 3.9 Erosion Sensitivity (ES) Categories and Criteria

	EROSION SENSITIVITY CRITERIA				
ES CATEGORY	**GEOMORPHIC**	**PROTECTION**	**NEARSHORE**	**RECESSION**	**COMMENTS**
1A. No Recession	G10, G11, G16	P1	S/N 1-6	Accretionary or Stable	
1B. No Reduction	G1, G3	P2-6	S/N 1-6	< 0.3m (1 ft)/yr.	
2. Minimum or Insignificant (<5%) Reduction	G1, G2, G3, G4	P2-6	S/N 1	> 0.3m (1 ft)/yr. or unknown.	If recession < 0.3 m (1 ft)/yr., GO TO 1B.
3. Moderate (5-20%) Reduction	G1, G2, G3, G4	P2-6	S/N 2-5	> 0.3m (1 ft)/yr. or unknown	If recession < 0.3 m (1 ft)/yr., TEST FOR 1B OR 5
4A. Significant (20%) Reduction	G5, G6, G12, G13, G14	P2-6	S/N 1-6	> 0.3m (1 ft)/yr. or unknown	2.5 m (8.3 ft) contour > 300 m (.2 mile) offshore. If < 300m GO TO 1B.
4B. Significant (30%) Reduction	G5, G6, G12, G13, G14	P2-6	S/N 1-6	> 0.3m (1 ft)/yr. or unknown	2.5 m (8.3 ft) contour > 500 m (.3 mile) offshore. If < 300m GO TO 1B.
4C. Significant (50%) Reduction	G5, G6, G12, G13, G14	P2-6	S/N 1-6	> 0.3m (1 ft)/yr. or unknown	2.5 m (8.3 ft) contour > 1000 m (.6 mile) offshore. If < 300m GO TO 1B.
5. Elimination of Recession	G2, G4	P2-6	S/N 2-5	< 0.3m (1 ft)/yr.	
6. Reduction in Storm Induced Beach Erosion	G7, G8, G9	P2-6	S/N 2,3 (Most Likely)	< 0.3m (1 ft)/yr.	Active beach/dune system - good sediment supply
7. Reduced Recession of Sandy Profiles	G7, G9	P2-6	S/N 2,3 (Most Likely)	> 0.3m (1 ft)/yr. or unknown	Relict beach/dune system. If 2.5 m (8.3 ft) contour < 300 m (.2 mile) offshore GO TO 4
8. Unclassified	Will include all combinations not resolved to identify Categories 1-7.				

Geomorphic: G1-High Bluff; G2-High Bluff and Beach; G3-Low Bluff; G4-Low Bluff and Beach; G5-Sand/Silt Banks; G6-Clay Banks; G7-Sand Beach/Dunes; G8-Coarse Beach; G9-Barrier Beach; G10-Bedrock (Resistant); G11-Bedrock (Non-Resistant); G12-Low Plain; G13-Open Shoreline Wetlands; G14-Semi-Protected Wetlands; G15-Composite Shorelines; G16-Artificial; G17-Unclassified.
Protection: P1-Heavily Protected; P2-Moderately Protected; P3-Minor Protection; P4-No Protection; P5-Non-Structural Protection; P6-Unclassified.
Nearshore: S/N 1-Clay; S/N 2-Sand; S/N 3-Sand/Gravel Lag Over Clay; S/N 4-Bedrock (Resistant); S/N 5-Bedrock (Non-Resistant); S/N 6-Unclassified.
Note: 2.5 m (8.3 ft) contour refers to depth below long-term mean water level.

Figure 3.3 Expert System Flow Chart



consulted to determine if a reach fell into specific categories. For the Canadian shoreline, this number (CAT1-8) was then pencilled directly on to the map sheet, next to the corresponding composite class number. Recall that a series of reach-by-reach tables were also produced for each lake. For the appropriate reach number, the erosion sensitivity category number was written in a new column on these tables following the composite classification number. Every reach number for every lake was assigned an erosion sensitivity category in this manner. Once completed, the erosion sensitivity numbers were entered into the reach-by-reach data base such that detailed statistics could be generated for each lake. On the U.S. shoreline, the erosion sensitivity category was entered directly into the mapping data base, and the statistics generated accordingly.

In the application of the expert system, each reach of shoreline was considered independent of the lake or channel it was on, and consideration was only given to what would happen to the recession rate of a reach if the water level it "sees" was reduced. For example, under the SMHEO-50 plan, Lakes Superior and Ontario levels may not change, and thus, in reality, the erosion will not change from what has historically occurred. In doing the erosion sensitivity classification however, it was assumed that if the water level in front of reach X was reduced, whether that level in reality can or can not be reduced, then the recession rate of shoreline X would change by a factor of Y (based on the expert system). In addition, the erosion sensitivity categories as developed, pertain to the results of modelling, theory, knowledge, etc. of coastal processes and shoreline response on lake shorelines, not connecting channel (or riverine) shorelines. The erosion sensitivity classification however, has been applied equally to both types of shores in an effort to address the entire basin with the same level of uniformity. However, the many other factors which affect erosion on riverine shorelines (flow velocity, discharge, ice, and ship wake for example) have not been considered in the modelling process. In light of this, erosion sensitivity figures presented for connecting channels and the St. Lawrence River, as well as those for the entire Great Lakes - St. Lawrence River Basin (including connecting channels), should be treated cautiously. To highlight these possible differences, basin-wide figures are presented in TABLES 3.10 AND 3.11 in two ways: lakes only; and lakes plus connecting channels and St. Lawrence River.

3.4.4 Distribution and Extent of "Erosion Sensitive" Shore Types

Canadian Shoreline

TABLE 3.10 highlights the percentage of shoreline length falling into each of the erosion sensitivity categories for each lake and connecting channel, and for the overall basin. It also presents results for the lakes only. On an overall basin-wide scale (excluding the connecting channels and St. Lawrence River), it is predicted that approximately 68%, or 6130 km (3807 miles) of the lake shorelines would fall within the "No Recession" and "No Reduction" categories. Only 0.7%, or 63 km (39 miles) of lake shorelines were predicted to fall in the "Elimination of Recession" category, however 6%, or 578 km (359 miles) of lake shoreline is

Table 3.10 Erosion Sensitivity Classification Summary - Canadian Shoreline

	Lake or Connecting Channel											
	Lake Superior	St. Marys River	Northern Huron	Southern Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River*	Great Lakes Only **
Total Shore Length (km)	2541.2	292.4	3377.3	1210.9	91.3	139.2	106.6	623.5	58.8	1135.9	1892.0	11469.1	9028.0
Erosion Sensitivity Index Categories	Percent Shoreline by Lake or Connecting Channel												
1A. No Recession	61.1	39.9	80.3	62.8	69.2	33.0	49.7	17.4	90.0	35.3	27.1	55.6% (6376.8km)	61.8 (5579.3km)
1B. No Reduction in Recession	3.2	16.1	3.1	3.1	22.5	0	50.3	12.7	10.0	21.6	6.4	6.9 (791.4)	6.1 (550.7)
2. Minimum (0-5%) Reduction in Recession	0.4	0	0	0.4	0	0	0	10.1	0	5.4	0	1.2 (137.6)	1.4 (126.4)
3. Moderate (5-20%) Reduction in Recession	0	0	0	3.1	0	0	0	18.4	0	3.6	1.7	2.0 (229.4)	2.2 (198.6)
4A. Significant (20%) Reduction in Recession	2.2	28.6	0	1.2	0	0.3	0	1.8	0	9.8	39.0	8.9 (1020.7)	2.1 (189.6)
4B. Significant (30%) Reduction in Recession	1.5	5.0	1.2	0.7	0	0	0	0.8	0	2.7	7.8	2.5 (286.7)	1.4 (126.4)
4C. Significant (50%) Reduction in Recession	1.4	0	0	0	8.3	66.7	0	10.1	0	6.0	13.5	4.6 (527.6)	2.9 (261.8)
5. Elimination of Recession	0	0	0.2	3.4	0	0	0	2.6	0	0.2	0	0.6 (68.8)	0.7 (63.2)
6. Reduction in Storm Induced Beach Erosion	30.2	10.4	15.2	24.7	0	0	0	15.6	0	12.2	0.8	16.2 (1858.0)	20.1 (1814.6)
7. Reduced Recession of Sandy Profiles	0	0	0	0.6	0	0	0	10.5	0	3.1	0.4	1.0 (114.7)	1.2 (108.3)
8. Unclassifiable	0	0	0	0	0	0	0	0	0	0.1	3.3	0.5 (57.3)	0.1 (9.0)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: * Includes Connecting Channels and St. Lawrence River ** Includes Great Lakes Only Plus Lake St. Clair **For Conversion: km x .621 = miles**

predicted to undergo "significant" (20-50%) reduction in recession rates. Just over 20%, or 1815 km (1127 miles) of lake shoreline are predicted to experience reductions in storm induced erosion of sandy beaches.

Over 60% of the St. Lawrence River shoreline falls in the 20-50% reduction in recession categories. This is accounted for by the abundance of low plain and wetland shorelines (see Section 3.2.6), as well as a number of reaches with shallow offshore areas. Similarly, 66.7% of the Lake St. Clair shoreline, which is dominated by wetlands, clay banks, low bluffs and shallow depths, fall in the 50% reduction in recession category.

On Lake Ontario and Lake Erie, distribution among the erosion sensitivity categories is very uniform, however over 55% of the Lake Ontario shoreline falls in the "No Recession" and "No Reduction" categories. On Lake Erie, this total is somewhat less (30%), and 28% of the shore falls into the 0-20% reduction categories, with another 26% falling into the sandy beach categories, "Reduction in Storm Induced Beach Erosion" (6) and "Reduced Recession of Sandy Profiles" (7). On Lake Ontario, 12% of the shoreline will undergo a "reduction in storm induced beach erosion."

For Lake Huron (northern and southern) and Lake Superior, the shoreline falls primarily within the two sensitivity categories of "no recession" and "reduction in storm induced beach erosion", with the majority of shoreline on both lakes falling into the "No Recession" category. Over 30% of the Lake Superior shoreline falls within the "reduction in storm induced beach erosion" category, indicating a surprisingly high percentage of "soft" shoreline on that lake. The southern Lake Huron shoreline contains the highest percentage of shoreline (3.4%) that falls within the "Elimination of Recession" category.

The connecting channels (St. Mary's, St. Clair, Detroit, and Niagara Rivers) are dominated by shoreline that falls within the "No-Recession" and "No Reduction" categories. The St. Mary's River however contains over 33% of shoreline falling into the 20-30% reduction categories, as well as 10% of shoreline that would experience a "reduction in storm induced beach erosion." On the St. Clair River, 8% of the shore would experience a 50% reduction in recession.

For the Canadian shoreline of the Great Lakes - St. Lawrence River basin), approximately 37%, or 4245 km (2636 miles) of the total length (including connecting channels and the St. Lawrence River) would notice an "erosion benefit" from a 50% reduction in the range of levels that currently occur. For the lakes only, this is reduced to 32%, or approximately 2890 km (1795 miles) of lake shoreline. The majority of this benefit would occur on Lake Erie, where almost 70% of the shoreline would experience a benefit of some degree.

United States Shoreline

As in the Canadian presentation, summary statistics are provided for the erosion sensitivity classification in TABLE 3.11. These statistical summaries have again been broken down to provide information for each individual lake and connecting channel. This information has been compiled from more detailed county-by-county and lake/river statistical summaries included in the Erosion Processes Task Group's final report.

On an overall basin-wide scale, 65.8% of Great Lakes shoreline fell within either the "No Recession" or "No Reduction" categories. The percentage is slightly higher if the connecting channels and St. Lawrence River are included (68.9%) due primarily to the significant extent of the connecting channels that is bedrock or heavily protected. Otherwise, the percentages falling into each Erosion Sensitivity Index Category is very similar for both the lakes and the basin-wide computation.

Through this analysis, it has been found that, based on the shoreline type classification, the two currently regulated lakes have the least potential for reduced erosion rates through a reduction in the range of water level fluctuation. Only 7.5% of the Lake Superior shore fell within erosion sensitivity categories 2-7, while 89.1% either experiences no recession, or for which there is no potential to reduce the recession rates. The Lake Ontario shore is also greatly influenced by extensive bedrock exposures at the shoreline or in the nearshore, resulting in 63.3% of the shore experiencing no potential for reduced erosion. The Lake Ontario shore does contain a couple of major relict sandy barrier beach and dune areas, particularly in the eastern end of the lake. These areas (approximately 20%) do have the potential for reduction or elimination of recession, particularly for a reduction in storm-induced (short-term event) damages.

The greatest potential for reduced recession via a reduction in the range of lake levels would be realized in Lake St. Clair (39.3% in category 4C), and to a lesser degree in Lake Huron (18.6% in category 4C). The shallow nearshore areas of these two lakes, and the western end of Lake Erie (8.4% in category 4C) are similar to the Maumee Bay type area analyzed in the modelling procedure, where there is potential for a significant reduction in recession rates. Approximately 25% to 30% of the shoreline of the three middle lakes (Michigan - 28.1%, Huron - 30.4% and Erie -24.2%) have the potential for reduced rates of long-term erosion.

Lake Michigan has the highest percentage of its shores which are sandy and therefore has 8.5% of its shores exhibiting the potential for reductions in storm induced beach erosion. The 14.2% of Lake Michigan, the 3.8% of Lake Huron, the 6.3% of Lake Erie and the 19.7% of Lake Ontario that fall into categories 5, 6 and 7 are shores for which the combination of lake level fluctuation, the occurrence of storms, and the alongshore availability of sediment supply will actually control the local recession / accretion cycles.

In general, 29.2% of the United States Great Lakes shoreline (excluding the connecting channels and the St. Lawrence) has the potential to realize a benefit with reduced lake level fluctuation. Except for those shallow nearshore, cohesive shores which fell in categories 4A-C (14.8%), the level of that reduction in recession is probably not significant - although it would depend upon the historical recession rate and the relative proximity of development to the shoreline. A

Table 3.11 Erosion Sensitivity Classification Summary - United States Shoreline

Erosion Sensitivity Index Categories	Percent Shoreline by Lake or Connecting Channel - United States												
	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River*	Great Lakes Only**
Total Shoreline Length (km)	2564.0	389.7	2711.7	1784.7	34.0	464.6	126.9	999.2	111.5	678.3	646.4	10511.0	9202.5
1A. No Recession	69.7	38.2	21.6	36.7	85.2	40.0	81.2	53.1	57.4	44.0	70.4	46.1	43.9
1B. No Reduction in Recession	19.4	34.5	35.6	11.3	14.8	20.0	18.8	13.7	42.6	19.3	26.1	22.8	21.9
2. Minimum (0-5%) Reduction in Recession	0	0	0.4	0	0	0	0	1.8	0	0	0	0.3	0.3
3. Moderate (5-20%) Reduction in Recession	3.2	0.9	10.5	2.5	0	0.7	0	8.8	0	0.3	1.1	6.1	6.8
4A. Significant (20%) Reduction in Recession	0.6	0	3.7	4.3	0	0	0	3.1	0	0	0	2.1	2.4
4B. Significant (30%) Reduction in Recession	1.8	0.9	9.5	5.0	0	0	0	2.1	0	0	0	4.0	4.5
4C. Significant (50%) Reduction in Recession	0.9	25.4	4.0	18.6	0	39.3	0	8.4	0	0	0	7.9	7.9
5. Elimination of Recession	0.1	0	2.6	0.7	0	0	0	4.3	0	16.6	0	2.3	2.6
6. Reduction in Storm Induced Beach Erosion	0.9	0	8.5	2.7	0	0	0	1.8	0	1.3	0	3.1	3.6
7. Reduced Recession of Sandy Profiles	0	0	3.1	0.4	0	0	0	0.2	0	1.8	0	1.0	1.1
8. Unclassifiable	3.4	0	0.5	17.7	0	0	0	2.7	0	0.5	2.5	4.4	4.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: * Includes Connecting Channels and St. Lawrence River ** Includes Great Lakes Only Plus Lake St. Clair slightly higher percentage of the Canadian shoreline (32%) has the potential for reduced recession rates, although only over 6% fell in the critical 4A-C categories. The greater length of U.S. shoreline which is heavily protected probably reduced the areas which could realize a potential benefit.

3.5 Discussion and Analysis

3.5.1 Introduction

The primary goal of the Erosion Processes Task Group was to re-evaluate the conclusions reached in Phase I of the Reference Study and to develop quantitative information on the relationship between erosion and water level fluctuations. To provide this quantification, the Task Group devised a shoreline classification scheme, conducted computer simulations of the response of a number of shore types to water level change, produced estimates of the percentage reduction in recession of the various shore types as a result of water level change, and identified the lengths and percentages of Great Lakes - St. Lawrence River shoreline where these reductions in recession might take place. In carrying out these studies, the Task Group was faced with many limitations and had to make a number of key assumptions, all of which are critical to the understanding and interpretation of the results presented in this section. In addition, discussion with other technical experts, members of the public and the Citizens Advisory Committee have raised a number of issues which need to be discussed further.

3.5.2 Findings Relative to Phase I

As previously discussed, one of the key findings of Phase I was stated as:

> *"The long-term rate of recession for many shore types is essentially independent of water level fluctuations, although erosion will temporarily increase or decrease as a result of higher and lower levels, respectively."*

The two major concerns that the Task Group used to test this finding were the issues of long-term versus short-term rates of recession and the relative importance of different shoreline types in influencing the erosion process. Although true within the context of long-term recession rates, this statement does not properly address the issue of the impact of short-term (monthly) water level fluctuations on incremental changes in the recession rates. Long-term recession rates do exhibit some variability through time. Incrementally, the recession rate may be faster or slower for any individual time period within the long-term record. This variability may be due to the cyclic failure patterns of cohesive bluffs (commonly observed as accellerated recession during high water periods), variations in groundwater discharges, a particular sequence of lake storms, or changes in sediment supply as structures are constructed along the shore, or as rivers and updrift shorelines release sediment to the nearshore. There will even be short-term change in the shoreline recession rate, for some, but not all, shoreline types, in response to sustained periods of high or low lake levels (i.e., increased recession during high levels, decreased recession during low levels). However, as long as the long-term mean water level is constant, the long-term average recession rate for the majority of shore types in the Great Lakes basin will not be impacted by the changes in the short-term water level range.

In addition, the subject statement from Phase I is true in the generic sense that the shoreline types in the Great Lakes for which well documented, scientifically collected monitoring data have been developed, are shoreline types which are not significantly influenced by lake level fluctuations (i.e. equilibrium, cohesive shore bluffs). There are other shoreline types, which have been identified during the previous discussion on erosion sensitivity, whose recession and accretion patterns do mirror the occurrence of storms, or incremental changes in the water level range.

The primary finding of the studies conducted by the Erosion Processes Task Group is that some shores of the Great Lakes are sensitive to changes in monthly mean lake levels, while others are not. For the majority of the Great Lakes shoreline, local geology, exposure to storm waves, the activities of man, and sediment supply and balance are far more significant in impacting long-term recession rates, than are changes in the water level range.

A parallel to the concept that a variation in range is insignificant in effecting long-term recession rates can be seen through a comparison with ocean shorelines that experience different ranges in tide levels. The highest tidal ranges in the continental United States are found in New England (approximately 3-7 metres (10-23 feet)), South Carolina-Georgia (approximately 2-3 metres (7-10 feet)), and Oregon-Washington (approximately 2-4 metres (7-13 feet)). A study sponsored by the United States Geological Survey found that recession rates in New England and Oregon-Washington were generally less than 1 metre (3.2 feet) / year and much of the Georgia coast is actually accreting. The highest recession rates (greater than 5 metres (16 feet) / year) in the continental U.S. are actually found along the shoreline of Louisiana (tide range of less than 0.5 metres (1.5 feet)) and the barrier islands of Virginia's outer coast (tide range of 1-1.5 metres (3.2-5 feet).

3.5.3 Study Limitations and Data Needs

For the purposes of the Phase II Levels Reference Study, a logical, new approach was taken to define the impact of lake level fluctuations on recession rates based on shoreline classification. The basic premise that different shoreline types in the lake system will be more susceptible to the influences of changes in the range of lake levels is sound. Well-accepted coastal engineering theories and data results from a number of studies support the course laid out for this study. However, the results presented here should be considered as a reconnaissance and test of the procedure, rather than as the final word in defining the erodibility of specific shoreline types throughout the Great Lakes system. There are a number of limitations associated with this work. These include the limited and missing data on shore or offshore geology and recession rates, the development and basin-wide application of the classification scheme, the limited number of shoreline types assessed through the simulation studies, the assignment of erosion sensitivity, and the need to evaluate changes in erodibility due only to lake level fluctuations, with minimal regard to other causative factors and processes. These limitations are discussed further below.

Development and Application of The Shoreline Classification Scheme

The shorelines of the Great Lakes are complex and highly variable. In many areas they have been modified significantly by the activities of humans. The variability in descriptive data throughout the literature, between states and across Canada, the limited availability of recent good-quality aerial photography and/or oblique video tapes, the lack of information on nearshore geology and bathymetry, and the generality of the classification scheme, made it impossible to assure an equal level of quality and detail in the classification across the basin. The limited time and budget allocated to the study did not allow for additional data collection or for field verification of the classification. In addition, several different coastal geological experts were used to apply the classification scheme across the basin. This resulted in some variability in interpretation, particularly between the U.S. and Canada, and between different lakes on the U.S. side. The classification results for the Canadian shoreline should be fairly consistent, as only two classifiers conducted this phase of the study. Although the classification of several shore sections were re-evaluated to cross-check the initial classification, there was insufficient time to conduct a broad ranging quality control check. Therefore there are probably some sections of the shoreline which may have been mis-classified and cases where similar shores may have been interpreted into different classes.

In spite of these limitations, the classification and resultant database is the first basin-wide attempt to recognize and quantify the complex nature of the Great Lakes shore. The GIS database allows for quick visualization of the spatial extent of different shore types. These data can be periodically and incrementally retrieved, updated and utilized for a range of other scientific and coastal zone management purposes.

Data Needs and Future Improvements

The general classification scheme has been found to be sound and easily applicable. However, quantitative definition of specific elements for each class would improve the consistency of the classification across the basin. Field verification and further cross-checking of the classification results are recommended. Additional data is needed on nearshore geology and bathymetry, including nearshore slope. Additional and consistent data is needed on historical recession rates. The level of protection classification will need to be periodically updated. The protection classification scheme developed for this study does not recognize the quality or effectiveness of the protection, only the extent of shoreline covered. To be true to the purposes of the classification scheme, verification is needed that a "heavily protected shore" is well-engineered to provide a predictable design life and level of protection.

Simulation Modelling and Field Verification

Cross-shore simulation modelling was used as a tool during this study to quantify the profile and shoreline response of some basic shore types found in the Great Lakes basin. The ANPM model utilized, is founded upon the same physical parameters and sediment behaviour understandings which have been used during the 20 years or more of cross-shore model development. The ANPM and its predecessors have been used internationally in many fresh and salt water coastal settings to predict profile response to changes in absolute water level (i.e. sea level rise, storm surges) and to storm waves. Cross-shore modelling is a standard engineering tool in coastal studies for designing beach fills, hurricane protection dunes, and profile adjustments to changes in sediment supply or hydrodynamic conditions.

The ANPM is a state-of-the-art hydrodynamic and sediment response model which is unique in its capability to reproduce the process of subaqueous cohesive bed downcutting. It also can be used to transpose the sandy material across the profile from the beach to the offshore and vice versa. Scientific studies of the downcutting process and of those parameters that impact the rate of cohesive erosion are limited. However, the model was adapted and calibrated for various sites around the Great Lakes using data results from several high quality field monitoring programs. The model was then exercised assuming scenarios of lake level range reductions for these calibrated study sites.

High quality recession monitoring data was not available for all shore types identified during the classification and mapping exercise. This limited the model application to only four sandy shore sites and seven cohesive shore sites throughout the basin. No sites existed on Lake Superior and there was only one site on Lake Huron. The cohesive shore sites did not represent the full range of offshore slopes, historical recession rates, nearshore geology, sand blanket characteristics, and bluff or bank stratigraphy conditions found throughout the basin. The sandy shore sites did not represent the full range of sediment supply, longshore transport rates, nearshore geology, grain size, or beach geomorphology found throughout the basin. Available monitoring data limited the number of generic shore types which could be assessed. Incremental data on profile response to rising and falling water level cycles is also limited. Thus, the modelling was conducted primarily as a means of quantifying some generic shoreline types under stylized lake level change conditions. Although improvements in these components of the modelling procedure would have allowed a more complete and thorough analysis of shoreline response, the modelling results produced, allowed significant improvements in the understanding of shore processes and profile response, particularly in cohesive shore settings, and allowed detailed quantification of the degree of impact for those sites which were modelled.

Data Needs and Future Improvements

The process of shore and profile erosion in cohesive shore environments is poorly understood, which limits the ability to predict the response of the shore relative to changes in sediment cover and differing characteristics of the cohesive material. Good quality, continuous monitoring of a range of shore types is needed to better understand those parameters which affect shoreline erosion and to be able to develop tools which can be used to predict shoreline response. Future work with the ANPM model for different shore types and under a wider range of water level range scenarios is needed. Additional work is needed in modelling profile response of sandy shores under differing rates of sediment supply and for time frames longer than those associated with episodic events.

Development and Application of Erosion Sensitivity Classification Index

The classification scheme, the simulation model results, various basin level data sets, and experience with and knowledge of coastal processes was used to develop an erosion sensitivity classification index, which was then applied basin-wide. The erosion classification scheme developed in support of this study was limited by the number of shore types which could be modeled (based on limited data) and the variety of water level scenarios which could be tested (based on limited funding). In reality, each shore is affected by local factors which combine in different ways throughout the basin, resulting in an erosion sensitivity which is susceptible to an array of processes.

In developing and applying the erosion sensitivity criteria, assumptions were made which tend to support an "overestimation of the erosion reduction benefit." In particular, the model simulation was based on a 50% reduction in the range of water level. This maximum potential benefit was applied universally throughout the basin, even to lakes which, under all of the water level scenarios proposed, would not experience a reduction in water level range of this magnitude (i.e. Lakes Ontario and Superior). Also, where the recession rate was unknown, the assumption was made that the recession rate was greater than 30 cm (12 in) per year, driving the unknown recession rate locations into the classes which could see some benefit with reduced lake level ranges.

The erosion sensitivity classification is a scientifically based, logical approach toward classifying the complexities of the Great Lakes shorelines. It is an "expert system", which is based upon scientifically generated estimates of possible impacts of water level reductions on erosion rates for various shores. This type of approach has not been attempted before for assessing the Great Lakes shoreline and it's sensitivity to water level range fluctuations. In that way, it is both a research and development effort, and also an appropriate application of scientifically accepted principles. There are undoubtedly some site specific errors in the application of the erosion sensitivity classification. However, the cumulative results are felt to be appropriate for the decision-making purposes of this Reference Study.

Data Needs and Future Improvements

The general structure of the erosion sensitivity criteria is sound. With increased data, there is the potential to sub-divide some of the classes to include variability in sand cover extent, sand supply and the offshore potential for downcutting. Improvements in the erosion sensitivity classification will be realized by improvements in the classification, and increases in recession, nearshore slope, and nearshore geology data. Better, longer and more varied site monitoring data, collected on a regular basis across a range of water level conditions, will improve the application of this approach for other scenarios and its use for site specific coastal management decision making.

3.6 Summary

The Erosion Processes Task Group developed a comprehensive mapping and classification scheme and characterized Great Lakes - St. Lawrence River shorelines according to a number of criteria, including: the geomorphic origin; the composition of the sub-aqueous (underwater) portion of the shoreline profile; and the extent to which shorelines are protected by structures. This classification, combined with an evaluation of the impact of water level changes on erosion rates of specific shore types, and the development of an erosion sensitivity index, helped determine the impacts of long-term and short-term water level fluctuations on erosion rates and processes.

Specifically, it was predicted that approximately 32% of the Canadian and 29% of the U.S. Great Lakes shoreline (excluding connecting channels and the St. Lawrence River) would experience some type of erosion reduction, or benefit, as a result of compressing the range of water levels to 50% of their current range, with the remainder of the shore either experiencing no reduction in erosion, or with no erosion to start with. This information was stored in a GIS database which now allows easy identification of the most "erosion susceptible" shorelines of the Great Lakes - St. Lawrence River basin.

Overall, it was found that for some shore types, recession rates are completely independent of lake levels, and that for others, there is a direct, although small, relationship between changes in lake level range and recession rates. This study did not refute the concept that short-term erosion rates may be accelerated during higher lake levels for some specific shore types. However, there are significant sections of the Great Lake's shoreline which are either not currently eroding, or for which there is no potential for reduction in the recession rates, given the range of projected lake level reductions. The critical issue for lakeshore management purposes, is to compare the occurrence of shores whose erosion rates are sensitive to water level fluctuations, to the present recession rates, land uses and potential economic impacts.

REFERENCES

Bailard, J.A., 1981. An Energetics Total Load Sediment Transport Model For A Plane Sloping Beach. Journal of Geophysical Research, Vol.86, No.C11:10938-10954.

Bagnold, R.A., 1963. Beach and Nearshore Processes. In: The Sea, M.N. Hill (ed.), Interscience, New York.

Bagnold, R.A., 1966. An Approach to the Sediment Transport Problem From General Physics. Geological Survey Professional Paper 422-I, 37pp.

Battjes, J.A. and Janssen, J.P., 1978. Energy Loss and Setup Due to Breaking of Random Waves. Proceedings of the 16th International Conference on Coastal Engineering, p. 569-588.

Battjes, J.A. and Stive, M.J.F., 1985. Calibration and Verification of a Dissipation Model for Random Breaking Waves. Journal of Geophysical Research, Vol.90, No.C5: 9159-9167.

Bowen, A.J., 1980. Simple Models of Nearshore Sedimentation: Beach Profiles and Longshore Bars. In: The Coastline of Canada, S.B. McCann (ed.), Geological Survey of Canada Paper 80-10, p.1-11.

Bowes, M.A., 1989. A Review of the Diversity of Geomorphological Features in the Great Lakes Shorezone of Canada. Technical Paper #4, Heritage Resources Centre, University of Waterloo.

Craik, A.D., 1982. The Drift Velocity of Water Waves. Journal of Fluid Mechanics, Vol.116:187-205.

Davidson-Arnott, R.G.D. and Law, M.N., 1988. Impact of Great Lakes Water Levels on Shore Processes - Workshop Summary. Functional Group 2, Phase I, IJC Levels Reference Study, 22pp.

Functional Group 2, 1989. 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. Report Submitted to the Project Management Team, Phase I, IJC Levels Reference Study, 169pp. plus Appendices.

Geomatics International, 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side. Final Report Submitted to the Erosion Processes Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 44pp. plus Appendices and Maps.

Hands, E.B., 1970. A Geomorphic Map of The Lake Michigan Shoreline. Proceedings of the 13th Conference on Great Lakes Research, p. 250-265.

Haras, W.S and Tsui, K.K. (eds.), 1976. Great Lakes Coastal Zone Atlas. Environment Canada and Ontario Ministry of Natural Resources, Canada Ontario Great Lakes Shore Damage Survey.

Herdendorf, C.E., 1988. Classification of Geological Features in the Great Lakes Nearshore and Coastal Areas. Research Proposal to the Protecting the Great Lakes Nearshore and Coastal Diversity Project, International Joint Commission / Nature Conservancy, Windsor.

Nairn, R.B., 1990a. Validation of a Detailed Alongshore Sediment Transport Model. Proceedings of Euromech 262, Sand Transport in Rivers, Estuaries and the Sea, Wallingford England.

Nairn, R.B., 1990b. Prediction of Cross-Shore Sediment Transport and Beach Profile Evolution. PhD Thesis, Department of Civil Engineering, Imperial College, London, 391pp.

Nairn, R.B. 1991a. Description of the Advance Nearshore Profile Model. 20pp.

Nairn, R.B., 1991b. Problems Associated With Deterministic Modelling of Beach Erosion Events. Proceedings Coastal Sediments '91, ASCE, Seattle, Washington.

Nairn, R.B., 1992. Erosion Processes Evaluation Paper. Report Submitted to the Erosion Processes Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 165pp.

Podor, A.P., 1991. Descriptions of Shoreline Types Concerning Sensitivity to Oil Spills; Lake Ontario, Canada. Environment Canada, Environmental Emergencies Section, Environmental Protection - Ontario Region.

Southgate, H.N., 1989. A Nearshore Profile Model of Wave and Tidal Current Interaction. Coastal Engineering, Vol.13: 219-245.

Stive, M.J.F., 1986. A Model for Cross-Shore Sediment Transport. Proceedings of the 20th International Conference on Coastal Engineering, p. 1550-1564.

Svendsen, I.A., Schaffer, H.A. and Hansen, J.B., 1987. The Interaction Between the Undertow and the Boundary Layer Flow on A Beach. Journal of Geophysical Research, Vol.92, No.C11: 11845-11856.

Swart, D.H., 1978. Vocoidal Water Wave Theory, Volume 1: Derivation. National Research Institute for Oceanology, South Africa. CSIR Report No. 357, 137pp.

Swart, D.H. and Loubser, C.C., 1979. Vocoidal Water Wave Theory, Volume 2: Verification. National Research Institute for Oceanology, South Africa. CSIR Report No. 360, 130pp.

United States Army Corps of Engineers, 1992. Summary, Shore Mapping and Classification Project: United States Shoreline. Memorandum for Record, Coastal Engineering Research Centre, Vicksburg, Mississippi, 14pp.

4.0 SOCIAL IMPACTS TASK GROUP

4.1 Introduction

The residential shoreline property interest is an important interest and one that is difficult to characterize. In the past, there has been no clear indication of the number of residential properties located along the shoreline, and given the size and diversity of this interest group, generalizations about how they have been affected by fluctuating water levels are difficult.

A census of riparian properties in Canada and the United States was undertaken to compile a comprehensive information base. Using this inventory, a survey was administered to a sample of American and Canadian property owners to gain a greater understanding of their experiences, their views on the water levels issue, and on what they see as solutions to the problems associated with high and low levels. Native North Americans were also surveyed.

Riparian interests are not the only ones to experience social impacts. However, due to time and money constraints the Levels Reference Study Board decided that no new studies would be carried out for other interests such as commercial/industrial or agricultural. Information gained in these areas would be based on previous reports.

This section details the activities of the Social Impacts Task Group in conducting the above surveys and presents the methodologies and analysis that were utilized, along with a summary of the finding of the surveys.

4.2 Survey Methodologies and Analysis

4.2.1. Introduction

Four survey questionnaires were administered to a sample of residential riparian property owners along the Great Lakes-St. Lawrence River shoreline. Specifically, these survey questionnaires were administered to U.S. shoreline property owners, Ontario and Quebec residents living on the shorelines and to all Native American bands bordering the Great Lakes-St Lawrence River System.

A questionnaire was developed jointly by U.S. and Canadian study participants. It was designed to gain insight into two main areas. First, it asked questions about the property and the experiences of the respondent with erosion, flooding and fluctuating water levels. Secondly, the questionnaire sought the perceptions of respondents in terms of their knowledge of various measures to alleviate problems associated with fluctuating water levels, and their views on possible solution to these problems.

In the U.S., a telephone survey was administered to 6,000 shoreline property owners, and the data was entered directly from the interview into a computer. A mail survey was administered to a random sample of 24,770 Ontario shoreline property owners. Over 14,000 of these questionnaires were returned for a response rate of approximately 57%.

In Quebec, the survey was administered by telephone to ten of sixty municipalities. In all, 495 interviews were conducted for a 52% response rate. The Native Survey was administered to all 40 reserves located on the Canadian and U.S. shorelines of the Great Lakes-St. Lawrence River, with thirty-two of these responding.

Analysis of all four surveys was guided by a series of core hypotheses which were designed to address a number of study planning objectives. These hypotheses centred around erosion, flooding, high water low water, actions taken, and opinions on actions governments could take to try and alleviate the problems associated with fluctuating water levels.

4.2.2 United States Census and Survey

The U.S. Census and Survey were conducted by a professional survey research firm under contract with Chicago District of the U.S. Army Corps of Engineers (USACE, 1990)

U.S. Census

The initial task of the surveys was the identification of all residential riparian properties along the Great Lakes-St. Lawrence River shoreline. Information was collected from county assessors' offices, or their equivalents. Information included property locations, enumeration of structure, owners names, addresses and phone numbers. Properties were stratified by shoreline classification into fifty reaches. Each reach subsequently became a sampling frame from which properties were chosen for the survey.

Information obtained from the assessors office was loaded into a computer database. Codes which identified the reach, subareas, state and county were entered for each property in the database. The database was sent to a telecommunication specialty service to obtain as many telephone numbers as possible.

Approximately 66,000 residential properties were found to be located on the U.S. shoreline of the Great Lakes-St. Lawrence River. TABLE 4.1 shows the breakdown in number of properties by lake and connecting channel.

U.S. Survey

A systematic random sample design was selected. To ensure that the sample properly represented the entire population, the chosen statistical precision had a confidence level of 90% with a standard error of plus or minus 6.8%. The calculated number of properties

Table 4.1 Census of Residential Shoreline Property Owners

Region	**U.S. Census # of Properties**	***Canadian Census # of Properties**	**Native Census # of Communites**
Lake Superior	6,050	1,500	9
St. Mary's River	2,000	1,100	4
Lake Michigan	21,050	NA	1
Lake Huron	13,650	17,600	20
St. Clair River	1,300	500	2
Lake St. Clair	3,700	1,100	0
Detroit River	700	500	0
Lake Erie	8,200	4,500	1
Niagara River	950	300	0
Lake Ontario	7,200	6,400	0
St. Lawrence River Ontario/U.S.	1,200	4,100	2
St. Lawrence River Quebec	NA	7,100	1
Total	**66,000**	**44,700**	**40**

Note: Numbers are rounded to the nearest 50

* *Property totals were done by county. Estimates of distribution were made where counties span more than one waterbody. The numbers presented are preliminary and do not include Manitoulin Island.*

needed to achieve this was 6000. This was divided into the total number of properties in a given reach to determine the skip interval for the systematic random sample.

The questionnaire was developed by the Chicago District, U.S. Army Corps of Engineers, and Environment Canada. The U.S. questionnaire was specifically designed for telephone inquiry. The two surveys were 90% similar and covered these major topical areas:

- Past experience with water level fluctuations (erosion, flooding, low water and high water)
- Actions taken in response to fluctuating water levels
- Knowledge of related government programs/regulations
- Opinions about possible government actions
- Motivations for purchase of the property.

All telephone interviewing was conducted by a professional survey research organization. Up to four attempts were made to contact a qualified respondent at each telephone number in the sample. When contact was made, the interview was administered from the Computer Assisted Telephone Interviewing (CATI) screen. CATI data were downloaded to a mainframe computer and were checked for internal consistency of answer patterns and valid codes using a computer based consistency check program. The cleaned data were entered into a Statistical Package for Social Sciences (SPSS) program.

4.2.3 Ontario Census and Survey

The Ontario Census and Survey was conducted by the Water Planning and Management Branch of Environment Canada (Water Planning and Management Branch, 1990).

Ontario Census

As with the U.S. survey, the first step in the sampling process was to compile a census of names and addresses of all shoreline property owners along the Great Lakes-St. Lawrence River shoreline (including connecting channels) in Ontario. Tax roll assessment maps were used to determine the property roll number of each property along the shoreline. These roll numbers were matched against the tax assessment records of the Ontario Ministry of Revenue.

Approximately 37,600 residential riparian properties were found to be located on the shoreline (this did not include Manitoulin Island as there were problems with the tax roll information). TABLE 4.1 shows the approximate number of properties by lake and connecting channel.

Ontario Survey

The list of residential shoreline property owners obtained was stratified by lake and river, and then by county. Within each county, a random sample of shore property owners was generated using a computer program. A 95% confidence level with a standard error of plus or minus 10% was used to choose the sample. This meant that the surveyors could be confident that the sample represented the population 19 out of 20 times.

The survey method chosen was a mail survey. The questionnaire was adapted from the U.S. survey for the purposes of mailing. It was determined that approximately 8,000 responses were required to achieve the required confidence level. Assuming a one third response rate, 24,770 questionnaires were mailed out stratified by county. As already mentioned, 14,000 surveys were returned, yielding a fairly high response rate of 57%.

The returned questionnaire responses were entered into a mainframe computer and were checked for internal consistency of answer patterns and valid codes using a computer based consistency check program. The cleaned data were entered into an SPSS program.

4.2.4 Quebec Census and Survey

The Quebec Census and Survey was conducted by Lavalin Environment Ltd. under contract with Environment Canada (Lavalin Environment, 1992).

Quebec Census

The study area for the Quebec survey encompassed the segment of the St. Lawrence River between Cornwall and Lake Saint-Pierre, a stretch of about 400 kilometres (249 miles) of shoreline. The river segment was divided into six physically and biologically homogeneous sections: Lake Saint-Francois; Lake Saint Francois to Lake Saint-Louis, Lake Saint-Louis; Montreal archipelago; Repentigny to Tracy; and Berthierville and the Iles de Sorel.

Due to budget constraints it was determined that a full census of the shoreline would not be possible. Among the 60 municipalities within the study area, ten representative municipalities were selected based on geography, biogeography and riverside land use. The ten municipalities are representative of all the municipalities in the overall study area.

Census information for each of the ten municipalities was found in municipal records. Using municipal cadastral maps the lot subdivision and last four digits of the administrative number were obtained. This was matched against the cadastral index which yielded the name of the owner and street address of the lot. The name and street address were then used with the local telephone directory to obtain the owners telephone number.

In the ten municipalities censused, 1,610 lots were found to be located on the Quebec portion of the St. Lawrence River shoreline. If extrapolated for the entire study area, approximately 7,100 residential properties are located on the St. Lawrence River shoreline. This might be an overestimate if one takes into account the Montreal region where the number of riverside lots is small.

Quebec Survey

A telephone survey was selected as the most efficient survey method for Quebec. The desired statistical precision for this survey was a 95% confidence level plus or minus 3.7%. The target number of surveys was 700. The questionnaire used in the Ontario survey was adapted for use in Quebec with minor changes.

Surveyors determined that only 58% of the property owners were listed in the phone book. Telephone numbers for 944 owners were obtained out of a total of 1,610 censused lots. Thus, it became necessary to modify the sampling procedures. The survey became a census with it being necessary to survey all the listed owners to achieve the target of 700 interviews. Of the 944 property owners telephoned, there were 495 completed surveys yielding a 52.3% response rate. The survey responses were entered directly into a spreadsheet package.

4.2.5 Native Americans Census and Survey

The Natives Census and Survey were administered by the Walpole Island First Nation under contract to Environment Canada (Walpole Island Heritage Centre, 1991)

Natives Census

Obtaining the Canadian First Nations census was made possible through communications with Indian and Northern Affairs Canada (INAC) and the Assembly of First Nations (AFN), in Ottawa, Ontario. These two organizations had published maps documenting Ontario First Nations in Canada.

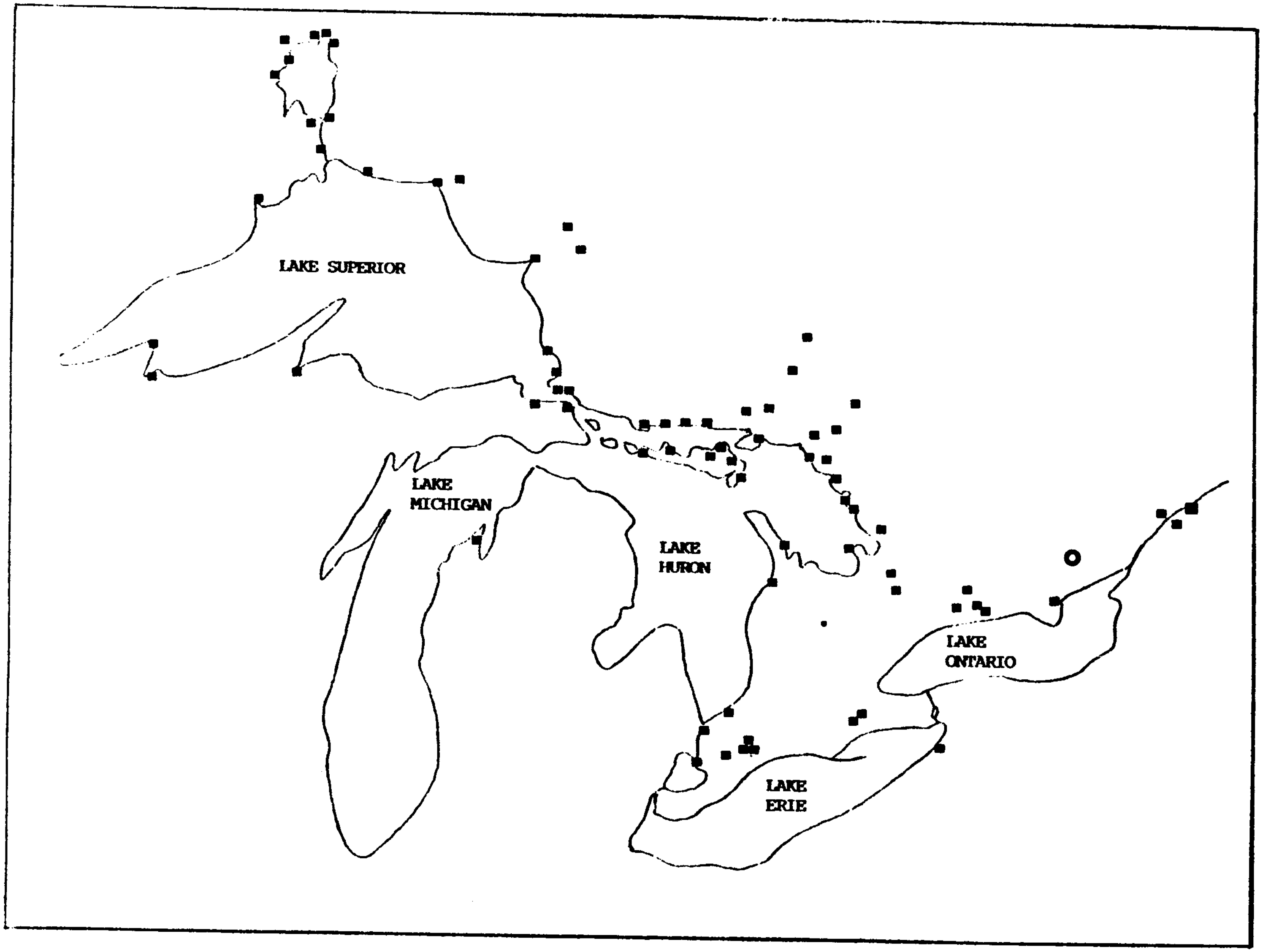
Numerous offices of the Bureau of Indian Affairs (BIA), a federal department of the United States government, were contacted by telephone to obtain the American Native communities census list.

It was determined that a total of 40 Native communities border the Great Lakes/St. Lawrence River system shorelines with 31 in Canada and 9 in the United States. One community was located in the Quebec portion of the St. Lawrence River. This is shown in FIGURE 4.1.

Native Survey

The questionnaire used in the Ontario survey was adapted somewhat for the Natives survey

Figure 4.1 Native Communities of The Great Lakes - St. Lawrence River Basin



although much of the content stayed the same to allow for comparisons.

The survey was administered to only one band member - the Chief/Tribal Chairman, Band Administrator or other designate (i.e. person believed to be most familiar with the Great Lakes-St. Lawrence River system water and shoreline conditions of their territory), who responded on behalf of the entire community.

The survey was administered to all 40 Native Communities identified in the census. The majority of the surveys were completed via telephone. A total of 13 were administered via facsimile transfer. Three communities were visited and personal surveys were conducted for each. As a result, 32 of the eligible 40 Native communities completed and returned the questionnaire, resulting in a 80% return ratio.

4.2.6 Hypothesis Testing and Statistical Analysis

Survey analysis of the Ontario, Quebec and Native Surveys was undertaken by Ecologistics Limited under a contract to Environment Canada (Ecologistics Limited, 1992). United States survey analysis was conducted by the St. Paul District of the U.S. Army Corps of Engineers.

For the purposes of this Reference Study, analysis was targeted to produce results that would be most pertinent to addressing the study planning objectives. In order to coordinate the survey results with the study planning objectives and to integrate the results of analysis, a series of core hypotheses were developed to direct the analysis as follows:

- **erosion** - Are there are statistically significant variations by location in the incidence of erosion; the types of property damage caused by erosion; and the perceived causes of erosion?

- **flooding** - Are there statistically significant variations by location in the incidence of flooding; the types of property damage caused by flooding; and the perceived causes of flooding?

- **high water levels** - Are there statistically significant variations by location in the incidence of high water levels and the types of damage caused by high water levels?

- **low water levels** - Are there statistically significant variations by location in the incidence of low water levels and the types of damage caused by low water levels?

- **action response** - Are there statistically significant variations by waterbody in protective actions taken and whether the actions taken vary by the type of impact (i.e. flooding, erosion, low levels) ?

- **opinions** - Are there statistically significant variations by location in the opinions on the types of lake level regulation that could be undertaken; government aid programs for riparian property owners; government action programs to deal with impacts; and the most preferred government action to deal with impacts?

4.3 Survey Findings

4.3.1 Introduction

The following survey results are presented by core hypothesis. The highlights from each of the four surveys are presented. Tables are used to provide insightful information. Percentages in the tables given for the entire survey refer to the percent of the population. Percentages given by region refer to the percent for that waterbody (i.e. 82% of respondents from Lake Michigan).

4.3.2 Characteristics of the Interest

Demographic data from the survey respondents in both the U.S. and Canada characterize riparians as a mature group (more than half of the respondents are over the age of 51). Many are long-time shoreline residents, with approximately 30% having owned their property for more than 25 years. In the U.S., 59% of the shoreline residences are year-round and 39% are seasonal. In Ontario, this breakdown is almost opposite with 37% year-round and 53% seasonal. Property market values were fairly well dispersed, but the greatest percentage of respondents reported having a property value of between $60,000 - $120,000. This was broken down as follows: Ontario (27.4%); Quebec (40.3%); and the U.S. (39.2%). About one quarter of those people living on the U.S. and Quebec shorelines reported having property values greater than $180,000, while Ontario had over 40% of respondents having a property value greater than $180,000.

Native communities have a mix of commercial, residential and traditional land uses and structures. They use their shoreline areas primarily for fishing (93.8%) and recreation (81.3%). The populations of the Native Communities varied greatly although the majority had under 2000 people.

4.3.3 Erosion

The hypothesis that there are statistically significant variations in the incidence of erosion by location was confirmed. Erosion is common along much of the Great Lakes-St. Lawrence shoreline as was shown in earlier sections of this report. Findings from the four surveys indicate that erosion is a more common problem to shoreline residents than flooding, high water or low water levels. Overall, 60% of the Ontario survey respondents, 57% of the U.S. respondents, and 66% of the Native communities reported having experienced erosion of their shoreline property. Lake Erie riparians reported the highest incidence of erosion (82%) in the Ontario survey, while

Lake Michigan had the highest percentage (65%) of respondents reporting an erosion problem in the U.S. survey (see TABLE 4.2). Quebec respondents living on the St. Lawrence River (below Cornwall) had the least percentage of respondents reporting an erosion problem, however, of those who did report experiencing erosion many lived on the shoreline of Lake St. Louis (50%).

The surveys reveal that damage to beaches, lawns and gardens were the most common forms of erosion damage reported (see TABLE 4.3). Native communities also commonly experienced damage to their boat launch facilities and roads. This table also reveals that a relatively small percentage (5% or less) of respondents reported damage to their dwellings.

4.3.4 Flooding

The hypothesis that there are statistically significant variations in the incidence of flooding by location was confirmed. Flooding was the least commonly reported problem of the 4 impact categories (erosion, flooding, high water, and low water). The U.S., Ontario and Quebec survey responses were very close with 21%, 27% and 24% respectively, of respondents reporting that they experienced flooding. Native Americans reported that 44% of their communities had experienced flooding. Lake St. Clair respondents reported the highest incidence of flooding in both the U.S. (63%) and Ontario (72%) surveys. They also reported the highest percentage of first floor flooding (14%). Quebec respondents reported the highest percentage of flooding in Lake St. Louis, but reported no flooding damage from Lake St. Francois to Lake St. Louis. The surveys reveal that flooding in the yard was the highest reported damage and that relatively few people reported having first floor flooding (see TABLE 4.4).

4.3.5 Causes of Flooding and Erosion

The subset of property owners who had experienced erosion were asked what they believed to be the main cause of their erosion. For the U.S. and Ontario surveys, responses were similar: storm-driven waves only - U.S. 5%, Ontario 10%; high water levels only - U.S. 18%, Ontario 23%; and both storms and high water levels - U.S. 67%, Ontario 57%. In Quebec, 31% attributed erosion to high water levels and 26% attributed it to ship wake. Native communities who had experienced erosion held yet a different view, with 31% seeing storm driven waves as the main cause and 25% feeling that neither storms nor high water levels caused erosion.

Riparians who had experienced flooding (a subset of the entire sample) were asked about the causes of flooding. Again, the U.S. and Ontario responses were similar: storm-driven waves only - U.S. 6%, Ontario 7%; high water levels only - U.S. 26%, Ontario 17%; and both storms and high water levels - U.S. 54%, Ontario 71%. In Quebec, 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.

Table 4.2 Incidence of Damage

Region	**% of Properties experiencing Erosion**	**% of Properties experiencing Flooding**	**% of Properties experiencing High Water**	**% of Properties experiencing Low Water**
Lake Superior				
U.S.	64%	16%	74%	65%
Canada	49%	17%	41%	45%
St. Mary's				
River U.S.	52%	24%	77%	89%
Canada	53%	24%	63%	70%
Lake Michigan				
U.S.	65%	14%	84%	85%
Lake Huron				
U.S.	47%	23%	77%	85%
Canada	58%	28%	66%	63%
St. Clair River				
U.S.	36%	41%	67%	55%
Canada	66%	57%	64%	57%
Lake St. Clair				
U.S.	38%	63%	63%	55%
Canada	66%	72%	68%	58%
Detroit River				
U.S	41%	43%	56%	63%
Canada	70%	57%	61%	61%
Lake Erie				
U.S.	62%	28%	76%	75%
Canada	82%	40%	64%	46%
Niagara River				
U.S.	34%	31%	52%	58%
Canada	51%	33%	37%	30%
Lake Ontario				
U.S.	61%	19%	75%	72%
Canada	52%	13%	32%	30%
St. Lawrence R. above Cornwall				
U.S.	15%	11%	51%	75%
Canada	44%	17%	28%	34%
St. Lawrence R. below Cornwall				
Canada	33%	24%	38%	25%
Total U.S.	57%	21%	76%	77%
Total Ontario	60%	27%	53%	48%
Total Natives	66%	44%	75%	68%

Table 4.3 Types of Erosion Damages Reported

Erosion Damage	U.S. Survey (Percent)	Ontario Survey (Percent)	Quebec Survey (Percent)	Natives Survey (Percent)
Dwelling Unit	4%	5%	1%	9%
Other Buildings	5%	5%	1%	13%
Lawn/Gardens	30%	31%	18%	16%
Beach	39%	40%		38%
Steps to Beach	24%	22%	5%	25%
Boat Launch	11%	13%	3%	31%
Pier/Dock	12%	14%		25%
Roads	3%	4%	1%	28%
Wetlands	NA	NA	NA	25%
Water Frontage	55%	NA	19%	NA
Depth of Property	55%	NA	17%	NA
Other	8%	10%	9%	16%

Table 4.4 Types of Flooding Damage Reported

Flooding Damage	U.S. Survey (Percent)	Ontario Survey (Percent)	Quebec Survey (Percent)	Natives Survey (Percent)
Water in the Yard	17%	21%	22%	25%
Water In the Basement of the Primary Building	5%	4%	13%	NA
Water Entering the First Floor	4%	4%	2%	9%
Wetlands	NA	NA	NA	19%
Roads	NA	NA	NA	25%
Other	NA	8%	0%	16%

Note: Number reported are the percentage of the total.

4.3.6 High Water

The hypothesis that there are statistically significant variations in the incidence of high water levels by location was confirmed. High water levels were reported as a problem with 76% of U.S., 53% of Ontario, 55% of Quebec and 75% of Native respondents reporting high water level problems.

4.3.7 Low Water

The hypothesis that there are statistically significant variations in the incidence of low water levels by location was confirmed. In both the Ontario and U.S. surveys, respondents on the St. Mary's River reported the highest incidence of low water level problems (70% and 89% respectively). Two-thirds of Native communities reported low water level problems and in Quebec, Lac St. Louis respondents reported the highest incidence of low water level problems. In all surveys, an increase in beach area was the most commonly reported impact, which in many instances can be considered a positive impact.

4.3.8 Actions Taken

The hypothesis that there are statistically significant variations in actions taken by location was confirmed. The most common form of protective action taken by all respondents was reinforcement of the shore with stone, concrete or wood (see TABLE 4.5). In Ontario, 58% of riparians reported taking this action, while 45% of the U.S. respondents claimed to do so. Similarly, 45% of Quebec riverfront residents and 44% of Native communities took some form of protective action. Other measures commonly taken included the use of fill or sand and the building of breakwaters. Relatively few riparians (12% or less) reinforced the dwelling unit or physically moved the buildings and their associated furnishings (7% or less). Native communities undertook measures to build floating docks, adjust dock heights, and/or extend their docks.

Quebec respondents and Native communities were prompted primarily by erosion to take measures to protect their shorelines, while the majority of Ontario and U.S. riparians were prompted by high water levels (43% and 34% respectively). In all surveys, high water levels and erosion were the two main reasons for taking action. Flooding was the least common reason for riparians to take action.

4.3.9 Opinions

The hypothesis that there are statistically significant variations in opinions by location was confirmed. A number of questions in the surveys sought to determine whether or not a significant variation existed between respondents opinions regarding types of lake level regulation, and the respondents location. In the U.S., 45% of the respondents believe that lake

Table 4.5 Action Taken Before and After Purchase of Property

Action Taken	United States Survey	Ontario Survey	Quebec Survey	Native Survey
Reinforced Buildings	9.3%	6.7%	1.6%	12.5%
Raised Buildings	7.2%	8.8%	2.2%	18.8%
Moved Buildings	4.1%	3.9%	0.8%	18.8%
Removed Furnishings	4.2%	2.8%	0.4%	3.1%
Brought in Fill	37.1%	28.0%	9.7%	34.4%
Built Groynes	10.8%	10.2%	3.2%	15.6%
Reinforced Shoreline	45.3%	42.8%	73.9%	43.8%
Built Dykes	10.7%	4.0%	1.6%	15.6%
Built Breakwaters	23.5%	18.4%	5.0%	28.1%
Grew Plant Cover	21.9%	14.2%	8.9%	25.0%
Adjusted Height of Dock	20.5%	20.2%	6.5%	46.9%
Built Floating Dock	4.2%	8.1%	1.0%	56.3%
Extended Dock	13.4%	14.8%	4.2%	37.5%
Extended Water Intake	5.4%	13.0%	0.8%	25.0%
Other	11.3%	4.3%	5.2%	21.9%
Embanked Yard	NA	NA	26.0%	NA

level regulation by governments will stop most flooding and erosion. In Ontario, a slight majority felt this way (57%), while in Quebec, 64% of respondents had this same belief. Most Native communities, on the other hand, did not agree with this statement.

The riparians surveyed demonstrated mixed feelings as to whether natural (45% Ontario, 58% U.S.) or human (39% Ontario and 36% U.S) forces were responsible for water level fluctuations (see TABLE 4.6).

Strong support was given by respondents to the statement that governments manage the levels of the Great Lakes to satisfy the needs of shipping and hydro electric power interests (refer to TABLE 4.6). There was also strong agreement with the statement presented in the questionnaire that if a property owner is aware of the risk of living by the water and is prepared to accept the risk, then he/she should be allowed to do so.

4.3.10 Preferred Government Actions

The surveys asked people their opinions on a number of measures. 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 (see TABLE 4.7).

Support by respondents for construction of dams and channels to regulate water levels, received the following levels of support: U.S. - 41%; Ontario - 58% Quebec - 65% and Native Communities - 13%.

When asked what government action the riparians would most favour, there was no clear majority response for a single measure. The most preferred measure by U.S. respondents (by only 15%) was to provide tax credits for building shore protection followed by the construction of dams to regulate water levels. In Ontario, respondents' most preferred action was to construct dams to regulate water levels (25%). The highest percentage of respondents who most preferred regulation measures came from Lake Erie and Lake St. Clair residents in both Canada and the U.S. Native communities preferred that governments provide grants to individuals constructing shore protection devices (29%), while 20% of Quebec respondents preferred that the government construct shore protection devices to save their shoreline property (refer to TABLE 4.7).

4.3.11 Regulated versus Unregulated Lakes

Survey analysis was done to compare impacts on regulated (Lakes Ontario and Superior) versus unregulated lakes (Lakes Michigan, Huron, Erie and St. Clair). In Ontario, 10% more riparians on unregulated lakes reported incidence of erosion damage than riparians on regulated lakes, while in the U.S. there was a 2% difference in the percentage of reported erosion. In Ontario, 21% more riparians on unregulated lakes reported experiencing a flood event than those on regulated lakes, while in the U.S. there was only a 2% difference. Reports of both high water levels and low water levels were more commonly reported on unregulated lakes by percentages of between 10 and 30 percent.

Table 4.6 Opinions of Survey Respondents

Statements	U.S.	Survey	Ontario	Survey	Quebec	Survey	Native	Survey
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
Water levels changes are necessary for wetlands	59%	27%	43%	29%	52%	20%	63%	31%
Dams will stop flooding and erosion	45%	46%	54%	25%	56%	18%	38%	47%
Storms cause most flooding and erosion	49%	45%	44%	45%	24%	57%	38%	56%
Gov't manages lake levels for shipping and hydro	73%	16%	69%	11%	69%	5%	78%	16%
L. Superior and Ontario are more effectively managed.	37%	17%	48%	13%	NA	NA	53%	28%
Setbacks impinge on property rights.	54%	38%	44%	39%	27%	52%	NA	NA
Man cannot control nature through dams.	58%	37%	65%	25%	48%	27%	69%	19%
If aware of risk people should be allowed to live on shoreline.	88%	9%	77%	17%	69%	15%	NA	NA
Shoreline protection has no effect on neighbours.	27%	66%	28%	58%	29%	36%	22%	44%
Human activites are responsible for flooding and erosion	36%	57%	37%	45%	31%	48%	66%	25%

Table 4.7 Preferred Actions

Government Action	U.S. Survey		Ontario Survey		Quebec Survey		Native Survey	
	In favour	Most preferred	In favour	Most preferred	In favour	Most preferred	In favour	Most preferred
Construct Dams	40%	15%	52%	24%	48%	19%	13%	7%
Shore Protection	61%	10%	51%	7%	61%	20%	66%	16%
Hazard mapping	78%	12%	77%	7%	86%	10%	100%	16%
Emergency Action	NA	NA	62%	10%	66%	2%	53%	3%
Tax Credits/Grants	59%	16%	60%	13%	66%	5%	97%	26%
Flood Insurance	28%	2%	27%	1%	41%	1%	91%	0%
Acquisition	30%	2%	23%	2%	52%	3%	NA	NA
Setbacks	61%	15%	69%	19%	82%	13%	68%	19%
Forecasts	69%	10%	71%	4%	65%	2%	94%	7%

4.4 Other Social Studies

4.4.1 Introduction

In addition to the Riparian Surveys, Environment Canada contracted Triton Engineering to review a number of documents prepared primarily in Phase I of the Levels Reference Study, and to provide an assessment of impacts of fluctuating water levels on specific interests (Triton Engineering, 1992). Information in these previous documents focused on characterizing the interests and the impacts of fluctuating water levels. Very little information was available on the impacts of various measures on the interests.

The impact assessments focused on qualitative assessments of the impacts of fluctuating water levels on public infrastructure, industrial and commercial facilities, agriculture, commercial fisheries and social impacts to residential shoreline property owners.

TABLE 4.8 provides a summary of the impacts to each interest group of high water levels, low water levels, fluctuating water levels and erosion. The following section discusses the primary impacts to each interest.

4.4.2 Public Infrastructure

Government agencies have reported infrastructure impacts in four main areas: transportation, water and sewer, public buildings and parks, and erosion or flooding of protective 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.

It appears that the impact that causes the greatest concern for public infrastructure is erosion. A 1986 survey by the University of Michigan (Marans et al., 1988) indicates that among public agencies along the U.S. and Canadian shoreline, with the exception of Lake Ontario, all of the respondents are of the opinion that high lake levels are a problem. The concerns appear to be most acute at the local level (i.e. township, county, municipality). Although the survey focused on high water levels, shoreline erosion was the greatest concern.

4.4.3 Industrial and Commercial Facilities

The industrial and commercial land uses along the shoreline of the Great Lakes - St. Lawrence River Basin are significant (Stewart and King, 1989). The types of uses by industrial and commercial interests include:

Industrial	- Grain Elevators
	- Pulp and Paper Processing

Table 4.8 Summary of Impacts - Great Lakes - St. Lawrence River Shoreline

INTEREST GROUP AREA OF CONCERN	HIGH WATER LEVEL	LOW WATER LEVEL	FLUCTUATION IN WATER LEVEL	SHORELINE PROCESSES (Erosion, Sedimentation)
A. Public Infrastructure (water supply, sanitation, other public facilities)	- flooding of public works including roads, and other facilities.	- exposure of "unsightly" shore protection works and loss of access to shoreline - exposure of water intake structures, loss of supply	- impact on effectiveness of shoreline protection - potential impact on ' water intake facilities - lack of ability to provide accurate information to public	- erosion of public facilities, particularly roads and services - loss of public land and facilities - sedimentation of intake or disposal works - lack of funds to deal with shoreline process
D. Industrial and Commercial Facilities (property damage)	- flooding impact to property and facilities - conflict of need to locate facilities close to shoreline for transportation access and exposure to high water damage potential - high levels can increase shippping capacity - impact on commercial business through loss of beach and recreational opportunities - increased boating potential	- impact on shipping costs (reduced loading on boats) - potential for loss of shipping channel - structural impact on docking facilities (dry rot in wooden piers) - impact on business through loss of recreational boating opportunities - damage to boats in charter boat companies or cruise operations - increased recreational beach opportunities	- lack of predictability of impact on shipping - lack of ability to predict water levels and modify operations to meet changes	- need for erosion protection facilities to protect investment - dredging requirements for shipping channel - loss of beach areas and associated recreational opportunities - loss of navigational channels and associated recreational boating - accretion of some beaches can increase recreational potential

Table 4.8 Summary of Impacts - Great Lakes - St. Lawrence River Shoreline
(continued)

INTEREST GROUP AREA OF CONCERN	HIGH WATER LEVEL	LOW WATER LEVEL	FLUCTUATIONS IN WATER LEVEL	SHORE PROCESS (Erosion, Sedimentation)
E. Agriculture (property, crop losses, dyking problems)	- potential crop damage on flooded lands - potential breach or overtopping of dykes and resulting crop damage - damage is discrete and not variable with water level (i.e. above a specific water level at top of dyke, flooding damages will be severe) - need for pumping in conjunction with dyking to prevent crop damage - possible reduction in crop yields in areas closest to shoreline due to increased water table (waterlogging)	- possible reduction in ability to transport crops and resulting monetary losses		- loss of table land due to erosion - damage to dyking facilities leading to repair costs - damage to dyking facilities and potential for flooding of table lands and resulting crop damage

Table 4.8 Summary of Impacts - Great Lakes - St. Lawrence River Shoreline (continued)

INTEREST GROUP AREA OF CONCERN	HIGH WATER LEVEL	LOW WATER LEVEL	FLUCTUATIONS IN WATER LEVEL	SHORE PROCESSES (Erosion, Sedimentation)
F. Residential Shore Property (Social Impacts)	- anxiety created through fear of property loss and risk to life is significant - potential for loss of equity or savings with loss of home. No insurance coverage available unless "Act of God" - potential for diverse opinion on society sharing cost of protection/repair - loss of enjoyment of property (beaches)	- loss of enjoyment with any negative impact on boating and degrading of aesthetics - increased enjoyment possible with larger beach area - possible reduction in aesthetics with exposure of shoreline (i.e. "mud flats")	- some level of anxiety with fear associated with rising water levels	- anxiety created through loss of property and associated costs and risk - loss of equity or savings through costs required for basic protection
H. Commercial Fisheries (commercial fish stocks, income, shoreside facilities)	- damage to docks and fishing equipment (boats, nets)	- navigation problems, docking and river systems. Loss of access to fishing areas	- opinions are inconsistent however some feel that fluctuating levels result in lake changes and fish movement that makes it difficult to locate good sources of fish - some feel that fluctuating levels are needed for maintenance of healthy shoreline ecosystem which will benefit fishery - operational problems on shoreside facilities	- potential damage to docking facilities

- Iron and Steel Production
- Petroleum and Chemical Refining
- Metal Mining and Refining
- metal Fabrication, Casting and Plating
- Food Processing
- Other minor manufacturing and support industries

Commercial
- Hotels, Motels, Resorts
- Marinas
- Other supporting uses (i.e. restaurants, stores)

Since the industrial and commercial uses are somewhat diverse there is little consensus on the nature of the impacts. Some of the differences identified in the literature review by Triton Engineering (1992) are outlined in the following:

i) A number of commercial businesses are strongly dependent upon beachfront recreation for economic viability. For this group, high water levels and the associated loss of beach area is a major negative impact.

ii) For marina operators, tour boat companies and other commercial business relying on near-shore and harbour navigation for their businesses, low water levels represent the highest impact.

iii) Industrial groups that rely on shipping benefit from potential for increased loads with high water levels and suffer negative impacts with low levels.

The information presented in earlier reports indicate some level of tolerance in this group to changing water levels. The data indicates that when lake levels remain within a "boundary" zone of one or two feet of the long term monthly average, impacts are minimal. The conclusion was drawn that, except for businesses that depend upon beachfront recreation, all commercial and industrial groups benefit from slightly higher than average lake levels (Triton Engineering, 1992). Above this point (i.e. 1-2 ft. above average), it was judged that flood damages to structures will outweigh the benefits.

4.4.4 Agriculture

Agriculture uses are not as directly linked with the shoreline as are the commercial and industrial uses outlined above, however, a significant number of agricultural lands are located along the shoreline. Agricultural land use in the Great Lakes - St. Lawrence River Basin is predominantly located along the lower lakes, especially along Lake Ontario and the St. Lawrence River.

By far, the greatest concern expressed by agricultural representatives (Triton Engineering, 1992) was related to high water levels. Specific impacts include the flooding of low lying crops and potential crop loss, overtopping of dykes, and reduction in crop yield associated with high water tables near the shoreline.

Previous reports (Functional Group 3, 1989) indicate that existing dyking can provide effective protection from high water levels to a specific level. Once water levels exceed this, damages can be significant. Damage does not increase proportionally with increasing levels but is significant once protection is breached.

4.4.5 Residential Shore Property (Social Impacts)

The riparian surveys considered social impacts in terms of shore property owners' perceptions of water level problems and opinions on solutions. Other studies consider social impacts to include the trauma and disruption of lives when people are forced to evacuate, time spent in repairs and cleaning after damages, time spent in emergency accommodations, time spent fighting flooding or erosion, along with associated financial strain (Bernstein et. al, 1989). Social impacts also include any change in outlook on living along the shoreline and beliefs about changes needed to minimize the conflict between humans and nature. These types of social impacts are not addressed in the riparian surveys.

Previous reports reviewed by Triton Engineering (1992) indicate that flooding can cause serious social negative impacts. When homes or other structures are flooded, there is a level of trauma in addition to stress from financial losses, disruption of living pattern, and possible risk to life. The level of anxiety is increased if the financial loss is significant and no insurance coverage or assistance is available. The potential loss of property value is also a concern.

Shoreline erosion is viewed by shoreline owners as a major negative impact. Loss of property can be very upsetting and devalue the property.

Shoreline residents have indicated that property values have dropped during past periods of extreme fluctuation in water levels as well as when shoreline damage is extensive (Bernstein et al., 1989).

Negative social impacts as a result of low water levels are generally related to reduced aesthetics (i.e. exposure of "mud flats") and loss of use of boat docking where it exists. However, positive benefits of low water levels can also be realized with an increase in beach front area.

4.4.6 Commercial Fisheries

Commercial fishing has declined in past years as a Great Lake industry (Brown et. al., 1989). Studies indicate that the decline is expected to continue. Nevertheless, the size of the industry is significant, with the reported value of the total 1986 catch in the United States at $17,000,000 (Brown et al., 1989) and a total 1984 catch of $33,700,000 in Canada.

Impacts to commercial fishing include impacts to fish stocks, loss of income and impacts to shore side facilities. The commercial fishing industry is generally less concerned with high water levels than low water levels. Some damages to facilities have been reported in the form of repairs. Low water levels are the most significant impact reported. Commercial fishermen are dependent upon their docking facilities for unloading their catch and moving boats. Low water levels can cause problems with docking facilities resulting in difficulties in unloading and the need for dredging.

All commercial fishermen in the Great Lakes, except for Lake Ontario and Lake Superior indicated a problem with low lake levels.

4.5 Discussion of Impacts of Measures

4.5.1 Five Lake Regulation Plans

Five Lake regulation plans extend the regulation of the outflows that now exists at outlets of Lakes Superior and Ontario to the outlets of Lakes Michigan-Huron and Erie. Five lake plans would require structures and dredging in the St. Clair-Detroit River system and in the Niagara River, and further dredging of the St. Lawrence River. In addition, control gates and training walls would be necessary in the connecting channels and the St. Lawrence River. The objective of these plans is to narrow the range of water level fluctuations on the lakes.

The riparian surveys indicate a fairly high level of support (greater than 40% in U.S., Ontario and Quebec) for additional regulation of the Great Lakes-St. Lawrence River. TABLE 4.7 shows that in Ontario and Quebec the building of dams was the most preferred measure and the second most preferred in the United States. Regulation however, was not well supported by the Native communities who view actions to control nature as contrary to their traditional beliefs and culture.

Reducing the range in water level fluctuations could provide a greater sense of security for those people living on the middle lakes since these lakes receive the greatest reduction in water level fluctuations. Such a measure may also help to reduce some of the trauma of flooding and erosion if these events and their associated damages became less common. However, regulation could also create a false sense of security, since erosion and flooding cannot be completely eliminated by any regulation plan.

Residents along the connecting channels may not experience the same social benefits with the building of dams. The construction of these structures could take many years. Lives of people living on their shorelines could be greatly disrupted by construction activity. Flooding and erosion along the connecting channels could continue in spite of new structures.

The St. Lawrence River interests are likely to have an increase in negative social impacts with the implementation of a five lake regulation plans. Water level fluctuations would increase considerably creating greater distress and anxiety among interests. The social implications associated with dredge disposal such as choosing disposal sites would be significant.

4.5.2 *Three Lake Regulation Plans*

This measure extends the regulation of outflows that now exist at the outlets of Lakes Superior and Ontario to the outlet of Lake Erie (Niagara River). This measure uses the existing structures in the St. Mary's River and St. Lawrence River and places control structures in the Niagara River. Dredging and other modifications would be made in the Niagara and St. Lawrence Rivers.

A three lake plan may result in some positive social impacts to Lake Erie shoreline residents and to a lesser degree to Lake Michigan-Huron shoreline residents since regulation of Lake Erie water levels will have upstream implications for Lakes Michigan/Huron. There may be a greater sense of security and less anxiety. However a three lake plan, as with any plan, will not eliminate damages and therefore will not eliminate social impacts. Again, as it involves new structures it goes against the traditional beliefs of the Native communities.

Shoreline residents on the Niagara River will likely have their lives disrupted somewhat with the construction of the structures, and the dredging. As with five lake regulation, the St. Lawrence River does not experience positive benefits. Fluctuations in the water levels and flows on the St. Lawrence will increase and so too will the anxiety of the shoreline interest.

4.5.3 *Two Lake Regulation Plans*

Two lake regulation plans are modifications to the existing lake regulation plans for Lakes Ontario and Superior. They require no new structures. These plans are not likely to have any major social impacts as the modification proposed for evaluation will not change the existing system enough to cause people major concern. Some positive social impacts may be realized if interests feel that they are now being considered within the development of a new two lake regulation plan.

4.5.4 *Land Use Regulatory Practices*

Land use regulatory practices are specific types of actions that either limit, reduce, or eliminate the potential for damage to shoreline property. The list of measures being investigated by the Levels Reference Study include: setback requirements; flood proofing and/or elevation requirements; relocation programs; permitting programs; development controls; habitat protection requirements; and acquisition activities (see Section 6).

Survey respondents showed a high level of support for setback requirements with greater than 50% of respondents from each survey being in favour of this measure (refer back to TABLE 4.7). However, the question in the survey referred to all new shoreline buildings, thus respondents who already have structures on the shoreline may not have viewed such requirements as a measure that would affect them. People who wish to build new structures on their property may be frustrated and angered if they are not allowed to build because of a setback requirement.

Property acquisition programs received much less support from survey respondents (see TABLE 4.7). Acquisition generally has negative social impacts associated with it as properties are bought out and people must leave their homes. These negative social impacts will be lessened if acquisition is implemented on a willing seller / willing buyer basis.

4.5.5 Land Use Incentive Based Practices

Incentive based practices include a variety of financial incentives or disincentive methods which can effect human activities along the shorelines. Incentive based practices include loans and/or grants, taxation changes, deed restrictions and insurance programs.

The riparian surveys asked about two of the incentive based measures: tax credits for shore protection and insurance programs.

Tax credits for shore protection received a high level of support from survey respondents and was the most preferred measure by the U.S. respondents. The portion of the total sample indicating a preference for this measure was only 15%.

As Native communities are not subject to taxes, a question on government grants for shore protection was asked in its place. This was the most preferred measure by the Native Communities, and favourable responses to this question amounted to 97% of all Native communities surveyed.

Insurance programs, which are available in the U.S. but not in Canada, were not highly favoured by respondents from either country. Support for this measure was less than 30% in the Ontario and U.S. surveys and it received negligible support as a most preferred measure (2% or less) (see TABLE 4.7). The measure fared slightly better in Quebec where 40% of respondents were in favour. Native communities showed strong support for this measure with 91% of the 32 Native Communities being in favour of government subsidized flood insurance.

4.5.6 Shore Protection Alternatives

Structural protection approaches include construction of dykes, levees, and berms to protect from flooding, and revetments, groins, and seawalls to protect against erosion. Non-structural approaches include beach nourishment and bio-stabilization actions.

A large number of shoreline property owners surveyed had taken action to protect their shoreline. The most common action was to reinforce the shore with stone, concrete or wood (see TABLE

4.5).

Riparian survey respondents were generally in favour of government funded shore protection action with a majority of respondents (greater than 50%) indicating they favoured this measure. Positive social impacts might include a greater sense of security as a result of protection from the impacts of flooding and erosion. Negative social impacts may be realized in some cases when water levels drop and a protection work spoils the aesthetics of an area. Negative social impacts may also occur if a shoreline property owners protection is negatively affecting his/her neighbours property (e.g. depleting sand supply with groins).

4.6 Summary

All hypotheses tested in this study were confirmed to vary significantly by location. Findings from the surveys indicate that erosion is experienced by a majority of riparians in the U.S. (59%) , Canada (57%), and in a majority of Native communities (66%). Damages to the beach, lawns and gardens were the most common forms of damage reported. Native communities also commonly experienced damage to their boat launch facilities and roads. The following percentages of shore property owners had erosion damages to their homes: U.S. - 4%; Ontario - 5%; and Quebec - 1%. In addition, 9% of the Native communities surveyed had erosion damage to homes.

Considerably fewer riparians have experienced flooding. Flooding was experienced by 21% of riparians in the U.S., 28% of Canadian riparians, and 44% of the Native communities. For all impact categories (erosion, flooding, high water and low water), a small percentage of riparians reported damage to their homes (less than 5%).

Storms combined with high water levels were seen as the main cause of both flooding and erosion by Ontario and U.S. survey respondents. In Quebec, high water levels only and ship wakes were the main causes identified for flooding and erosion, while Native communities felt storms were the main cause of flooding and erosion. It was also found that there was only a relatively small difference in reported damage between riparians living on regulated lakes and those living on unregulated lakes.

Large numbers of riparians have taken direct action to protect their property from erosion and flooding. The most frequently reported actions were: reinforcing the shore with stone, concrete, or wood; bringing in fill or sand; building breakwaters; and growing protective cover. High water levels and erosion were the primary reasons given by respondents for actions taken.

No single measure stood out as being the most preferred among respondents. Measures supported by a majority (greater than 50%) of riparians include: shore protection; hazard land maps; emergency actions; tax credits; setbacks and emergency forecasts. Although regulation scenarios may have positive social impacts on the middle lakes, connecting channel and St. Lawrence River riparians are not likely to experience positive social impacts.

Previous studies reviewed (Triton Engineering, 1992) indicate that municipalities view erosion as a major problem, that commercial industrial facilities have some degree of tolerance to level changes, that agricultural lands are primarily damaged when dykes are overtopped, and that commercial fishing industry suffers more from low water level problems.

REFERENCES

Bernstein, P., Sudar, A. and Jones, G. Riparian Residential Work Group Report. A Background Report to Functional Group 3, Phase I IJC Levels Reference Study, 76pp.

Brown, J., Brown, T., Jones, G. and Sudar, A., 1989. Non-Riparian Recreation Work Group Report. A Background Report to Functional Group 3, Phase I IJC Levels Reference Study, 93pp.

Ecologistics Ltd., 1992. Hypothesis Testing of Riparian Surveys: Ontario, Quebec and Native North Americans. Prepared for the International Joint Commission Levels Reference Study.

Functional Group 3, 1989. Annex C: Interests, Policies, and Decision Making: Prospects for Managing the Water Levels Issue in the Great Lakes-St. Lawrence River Basin. International Joint Commission Water Levels Reference Study - Phase I.

Lavalin Environment, 1992. Study of Water Level Fluctuations: Effects of Water Level Variations on Riverfront Property Owners, St. Lawrence River, Quebec Segment. Environment Canada.

Marans, Robert W., Bulkley, J.W., Anambutr, R., Fan, J., and MacKenzie, S., 1988. Trends and Emerging Environmental Issues in the Great Lakes: Perceptions and Assessments. Institute for Social Research and School of Natural Resources, The University of Michigan, Michigan Sea Grant College Program Report # MICHU-SG-89-201.

Social Impacts Task Group, 1993. Final Report. Submitted to Working Committee 2, Levels Reference Study Board, Phase II, IJC Levels Reference Study.

Stewart, C.J. and King, B., 1989. Commercial and Industrial Work Group Report. A Background Report Submitted to Functional Group 3, Phase I, IJC Levels Reference Study, 50pp.

Sudar, A. and Nelson, G. Survey of Great Lakes - St. Lawrence River Riparian Property Owners in the United States. U.S. Army Corps of Engineers. Internal Report Prepared for the Social Impacts Task Group, Working Committee 2.

Triton Engineering, Ltd., 1992. Review and Analysis of Previous Studies: Final Report. Prepared for the International Joint Commission Levels Reference Study.

U.S. Army Corps of Engineers, 1990. The Impacts of Great lakes Fluctuating Water Levels on United States Residential Riparian Properties (Part I: Aggregate Results). Planning Division, Chicago District - USACE, 84pp.

Walpole Island Heritage Centre, 1991. Natives Survey - Water Level Study. Prepared for the International Joint Commission Levels Reference Study.

Water Planning and Management Branch, 1990. Riparian Survey - Ontario Shoreline, Preliminary Draft, Environment Canada.

5.0 POTENTIAL DAMAGES TASK GROUP

5.1 Introduction

The Levels Reference Study was initiated, in large part, because of public concern about storm and water level related damages to both private and public lands and buildings along the shoreline, as well as concern over possible future damages under certain water level scenarios. Phase I of the Study examined the types of damages and problems that shoreline property interests had experienced during both high and low water periods, as well as the types of actions these interests took to alleviate any of the problems that they experienced. In Phase II, Working Committee 2 was directed to further investigate the potential damage issue by:

- Obtaining additional information on the number and location of structures and users at risk in the Basin and to 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; and

- To categorize the type of human uses of the shoreline and quantify them in such a way as to provide damage assessments needed to complete the evaluation of measures designed to alleviate adverse consequences of fluctuating water levels.

Related to this, WC2 was also directed to:

- 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.

In this regard, the Potential Damages Task Group developed an approach and evaluation process for determining potential damages from fluctuating water levels that could be incurred in the future by shoreline interests throughout the Great Lakes - St. Lawrence River system. This approach considered potential damages which could be incurred in the future, based upon proposed measures for further regulation of Great Lakes water levels and/or changes in land use and shoreline management practices.

The tasks involved in this approach, and described in this section, included the following major items.

- Previously prepared stage-damage curves were updated to incorporate data collected subsequent to their development (e.g. inundation and erosion damages that have occurred from 1985-1987, inflation factors, new shoreline development). These curves were used to calculate potential damage information for the various water level scenarios under consideration and potential benefits that would be attained under water level management scenarios.

- An uncertainty analyses was conducted on the results of the inundation stage-damage curves to determine whether or not cost-benefit decisions made were sensitive to varying degrees of probability.

- Detailed site studies were completed for specific areas to obtain information on past damages and impacts, and help assess possible measures for which a large amount of information is not readily available.

- Changes in potential recession damages for several water level scenarios, at a number of the site studies were calculated using information generated by the Erosion Processes Task Group (see Section 3).

- Past expenditures on shoreline protection were determined, particularly during the 1985-1987 high water period.

- The costs of shore protection that could be avoided with the implementation of certain water level regulation scenarios were also determined.

The methodologies and results of each of these tasks is presented in turn below. More detailed discussion of each task and a full listing of the results of these analyses is included in the Potential Damages Task Group Final Report.

5.2 Stage-Damage Curve Updates For Flooding and Erosion

5.2.1 Introduction

The potential flooding and erosion damages expected for each water level scenario and the differences (benefits/disbenefits) between scenarios were derived from simulated mean monthly water level and outflow data. Since the same water supplies are used under each of the alternative water level scenarios, with only differing outflow conditions, simulated water levels provide a common measure of likely future variability. The only constraint is that each of the water level regulation measures are limited by the magnitude and sequence of supply events which occurred over the recorded past. The challenge posed by the Levels Reference Study is to relate impacts derived using simulated water levels for existing and alternative future measures to expected erosion and inundation damages in the future.

U.S. and Canadian efforts within the Potential Damages Task Group towards the goals outlined above were coordinated along the lines of common methodologies, making best use of available data. This requirement led to the estimation of potential damages being accomplished largely through refinements to the techniques used in the 1981 IJC International Lake Erie Regulation

Study Board (ILERS, 1981), which saw the development of stage-damage curves for flooding and erosion for both the Canadian and U.S. shorelines. Subsequent to this, flooding curves were also developed for the Canadian shoreline of Lake Superior by Marshall, Macklin, Monaghan (1988) under a contract with Environment Canada and the Ontario Ministry of Natural Resources. These curves were updated for use in this study.

Several factors can change stage-damage relationships subsequent to their initial development. Those considered in updating the curves included:

a) inflation and increase in property value;

b) new development and upgrading of existing development in hazard areas;

c) removal of hazard-prone buildings (e.g. destroyed by flooding or erosion, purchased by government agency and removed);

d) construction of shore protection and dyking - these can reduce future damages, but damages can also be damaged themselves.

e) damage mitigation measures such as raising of flood prone structures and moving structures back from the shoreline.

5.2.2 Overview of Methodologies

Stage-Damage Curve Updates - U.S. Shoreline

The inundation and erosion stage-damage curves developed under the ILERS for the U.S. shoreline were based upon 37 reaches portrayed in Figure 2.1. These reaches were defined as stretches of shoreline which had similar orientations to wave action, similar geomorphology, and somewhat similar land use characteristics. For each of the 37 reaches, one composite inundation stage-damage curve and ten separate monthly erosion stage-damage curves were initially developed. Background information on the methodologies employed for developing these relationships can be found in Appendix C of the ILERS report (1981).

The composite ILERS inundation stage-damage curves were developed to incorporate all inundation damages and related emergency response costs that were reported over the 1972-1976 high water period. These reported damages explicitly included costs for repair of flood damages to residential, commercial, industrial, institutional, and public infrastructure along the shoreline.

The original ILERS inundation stage-damage curves for the U.S. were developed and calibrated using recorded monthly peak storm water levels, one per month, for the time period 1972-1976, corresponding to the damage surveys. The shape of the original ILERS inundation stage-damage curves was based on physical and land use characteristics of the shoreline, topographic and structure elevation data, Operation Foresight (U.S. Army Corps of Engineers) stage-damage curves, and other available flood studies.

The original ILERS erosion stage-damage curves for the U.S. were generated based upon an assumption that damages are directly proportional to the amount of wave-energy striking the toe-of-the bluff. Hence, reported damages for the period of 1973-1976 were essentially distributed over the ranges of observed mean monthly water levels for the same period. The basic components used in the development of the procedures are the 1972-1976 damage data, water level data for the period 1967-1976, wind speed and direction data (1966-1976) and physiographic information for each reach. Although the hindcasting of wave-energy was done on a year-round basis, only the ice-free months of March through December were utilized. January and February were not used since the nearshore area of the Great Lakes is generally ice-covered and protected from wave action.

The original ILERS inundation and erosion stage-damage curves for the U.S. were founded upon damage data collected under a comprehensive and consistent basin-wide survey program of damages incurred over the 1972-1976 period. No such comprehensive and consistent damage surveys were conducted for the 1986-1987 period. Updates to the stage-damage curves to reflect 1992 conditions are generally based upon limited damage data, limited field investigations, and professional knowledge and judgement of the shoreline.

The first major updates to the U.S. curves were conducted and reported by DeCooke (1991). These efforts were conducted under contract to the U.S. Army Corps of Engineers. They involved incorporating available damage and mitigation costs for the period 1985-1987 and applying adjustments in inflation to bring the curves to 1989 common dollar values. These updates incorporated information collected on-site for two reaches on Lake Superior, those being Reaches 9001 and 9002.

Further updates to the U.S. curves were undertaken for four selected reaches and reported by Argiroff (1992). These four reaches were: 1) Reach 7006, Lake Michigan (Gary, Indiana to South Haven, Michigan); 2) Reach 4001, Lake St. Clair (Mt. Clemens to Detroit, Michigan); 3) Reach 3001, Lake Erie (whole Michigan shoreline); and 4) Reach 2002, Lake Ontario (Hamlin Beach to Rochester, New York). These updates were conducted to confirm or modify procedures employed by DeCooke (1991) for the remaining 33 U.S. reaches.

To update these curves, a number of procedures were used. The first was to determine the indices required to update the 1981 curves (which were based on 1972-1976 data) to monetary values comparable to the years in which new high water damage data was identified and recorded. The indices used to update the damage values are from the Engineering News Record - Building Cost Index (BCI). Ratios of these indices were used to update damages from a recorded year to a later year. For example, if the BCI in 1975 was 1306 and the BCI in 1986 was 2483, then 1986 dollars would equal 1975 dollars x 2483/1306.

A second step was to determine the approximate period of high water levels. U.S. Monthly Water Level Bulletins were reviewed to look for consecutive years in which the lowest level of one year did not fall below the preceding or following year's highest level. The review indicated the last two high water periods both covered four year periods (1972-1976 and 1983-1987).

Base data for the 1981 damage curves was collected over the four year high water period from 1972 to 1976. A similar range of data collection did not take place during the 1980's high water period. Shore damage information is commonly stated to be collected for 1985-1987, but in the majority of cases it was only collected in 1985 and 1986. Furthermore, there is no data recorded for 1983 and 1984. For this report, a duration of 52 months was used for tabulating the monthly stage-damage data for the entire 1980's high water period. 1986 however, the year for which there is established data, was considered the "base" year, as this was the year in which the majority of damage data (collected during 1985 and 1986) was provided. The curves were thus recalibrated in proportion to the 1986 recorded damage (i.e. the total of the monthly damages for the recalibration period - in this case 24 months - was equal to the total damage reported for the entire high water period).

The third step was to record, by reach, the appropriate high water elevation for each of the 52 months of the 1980's high water period from the appropriate water level gauge data. For inundation, the maximum monthly water elevation was used. For erosion, the mean monthly water elevation was used. Total damages were then determined for any period from 12 months to 52 months. A straight line interpolation was made from the 1975 damage curve data (i.e. 1981 ILERS report) to arrive at a monthly damage estimate for each appropriate recorded gauge elevation.

The fourth step in the process was to review historical damage data for each reach to determine the inundation and erosion damages recorded for the 1980's high water period. Where damage data was incomplete or missing, field investigations were carried out. These consisted of brief tours of the shoreline area, obtaining any permits for construction that were issued since the 1972-1976 high water period, and selected interviews with riparians.

In cases where field investigations was not sufficient, the curves were updated by taking into account the changes in land use that have occurred (growth index) and the estimated value of shore protection works installed between the two high water periods, the cost index, and an "affluence" index, which represents the increase or decrease to the value of improvements, or contents, between high water periods.

Finally, as a check on the validity of the recorded damage, permits which were issued during 1984-1987 were reviewed. The capital expenditures listed in the permits were used to determine if the recorded damages properly reflected the mitigation costs.

In the end, "re-calibration" factors for the 1981 ILERS curves were developed this way for reaches 3001, 4001, and 7006. Re-calibration factors for all other reaches were taken from De

Cooke (1991). The arithmetic mean of two update factors was used to bring the curves from 1986 to 1992 dollars. One was the ratio of the ENR BCI for January 1992, to the annual value for 1986. The other is the Consumer's Price Index (CPI) for all household commodities from 1986 to January 1992. The ILERS curve for reach 2002 (where there were no 1980's reported damages to re-calibrate to) was updated from 1975 dollars to January 1992 dollars with a factor determined using the same averaging technique.

Erosion

Re-calibration factors for the 1975 ILERS curves were developed as previously described, along with the inundation factors, for reaches 3001, 4001, and 7006. Re-calibration factors for all other reaches were taken from De Cooke (1991). A growth factor was used to bring the curves from 1986 to 1992 dollars. One was the ratio of the ENR BCI for January 1992, to the annual value for 1986. This factor is the ratio of the national median price of Single Family Residential (SFR) houses sold for 1991 divided by that for 1986. The resulting curve ordinates are taken as January 1992 dollars (inflation from the 1991 annual value to January 1992 is neglected). The ILERS curve for reach 2002 (where there were no 1980's reported damages to re-calibrate to) was updated from 1975 dollars to January 1992 dollars with a factor determined using a similar factor from 1975 to 1991.

Stage - Damage Curve Updates - Canadian Shoreline

Flood Damage Curves

A computer model called FLDAM was used to update the damage curves based on DEVELOPMENT CHANGES along the shoreline. This model estimates damages to residential, commercial, and industrial properties based on the first floor elevation, low opening elevation, structure quality, and first floor area (commercial and industrial) of each new structure. The model uses individual stage damage curves for each type and quality of building. The curves are based on an extensive survey of southern Ontario homes. The development changes which were modelled with the use of FLDAM included: new structures; existing structures with new shore protection; replacement structures (required both new and old structure information); and removed or acquired structures. The new damages which were estimated using FLDAM, based on changes to the shoreline, were added to the old damage curves to produce the total damage curve for each reach.

Extensive information was required to determine the changes to development on the shoreline since the 1973 survey. Ontario Conservation Authorities (CAs) with shoreline represented by existing curves were contacted and interviewed to obtain all pertinent information concerning the changes which have occurred to the shoreline since 1973. Actual numbers of structures and elevations were obtained from a comparison of recent mapping with 1973 shoreline mapping unless specific information was available from the CAs. In the majority of areas, extremely detailed structure information was not available, nor was 1973 shoreline mapping. In these cases, recent mapping was compared to the Great Lakes Coastal Zone Atlas (Haras and Tsui, 1975) to evaluate development changes along the shoreline.

All residential structures were assumed to be one storey, medium quality homes without a basement unless more specific information was received. Commercial and industrial properties were identified based on the building footprint, location, and surrounding development types. Structures with a footprint less than 45 m^2 (485 ft^2) were assumed to count for only half a structure.

Landscaping damages and marine building damages were accounted for using the indirect damages function of FLDAM. FLDAM uses a percentage of the total damages to represent indirect damages. A factor of 15% was used in this study for the cost of indirect damages. In addition, a further 6% increase was assumed for long duration flooding to account for the increase in costs due to extended periods of inundation. These factors are recommended indices for southern Ontario (Paragon Engineering Limited, 1984).

Content damages and structure damages were calculated separately due to different INFLATION factors assessed to each type of damage. The residential structure unit damage curves in FLDAM represent 1984 price levels while the commercial and industrial structure unit damage curves represent 1979 price levels. These values were both updated to 1991 price levels using both the Consumer Price Index (CPI) and New Housing Index (NHI).

The Consumer Price Index is an average value of inflation which is averaged over all consumer products and the entire province. The New Housing Index is available by region in Ontario (major cities) and is broken down into both house and land increase per year per region. The NHI is similar to the Building Construction Index (BCI) since the NHI relates the annual variation in the cost of a new house (both land and structure). The BCI indicates the annual variation in building products. Annual values of the CPI and NHI were obtained from Statistics Canada for the period of 1972-1991.

Reduction in structure flooding was accounted for using the FLDAM model. Flooding damages to the structures were assessed with and without NEW SHORELINE PROTECTION. Flooding damages which occurred without the shoreline protection appear as removed structure damages, while damages which occurred with the new shoreline protection in place appear as new structure damages. The total damages reflect the difference between the unprotected and protected damages which results from the addition of the new protection.

To estimate damages to new shore protection, damages which were recorded for shore protection in the 1973 survey (Haras and Tsui, 1975) were extrapolated. The cost of shore protection damage attributable in each reach was based on the percentage of total shore protection for the entire lake which was located in that particular reach during the 1972-1973 period. For example, if 30% of the total shore protection for a lake occurred in one reach, then 30% of the shore protection damages assessed in 1973 were assumed to have occurred in that reach. This assumption is premised on a uniform distribution of shore protection types, age, and quality in each reach. This assumption, although not entirely accurate, was reasonable for the scope of this study.

New protection damages were estimated in each reach based on a ratio of new shoreline protection length as of 1991 (from sources such as the Conservation Authority or recent erosion reports, or shoreline management reports) compared to the length of old shoreline protection in 1972-1973. Since the original shore protection cost was a specific value and not in a curve format, the assumption was made that the new shore protection damages curve would maintain the same shape as the total damages curve. In this way, a fixed percentage of the curve was updated at each water level. The percentage of the curve which was updated was set equal to the percentage of total reach damages attributable to shore protection damages in 1973. The total flood damages (excluding shore protection damages) for each reach in 1973 were taken from an internal document concerning the International Lake Erie Regulation Study.

In certain instances the available information indicated that the amount of shoreline protection had decreased from 1973 to 1991. In these cases, no cost was assumed for new shoreline protection.

Erosion Damage Curves

The original erosion damage curves were based on the cost of land lost due to erosion. The cost was originally based on assessment data in 1973, and later updated to 1978 dollars based on market value sales during the period from 1973 to 1978. Real estate property, and especially shoreline property, has increased dramatically in price over the past several years. In recognition of this, real estate brokers were contacted to determine current **MARKET VALUE CHANGES** in shoreline property prices.

The existing erosion curves account for the eventual loss of structures within the 50 year erosion line due to undercutting. In order to maintain consistency, a new 50 year erosion line was delineated based on updated Conservation Authority estimates of erosion rates, or using erosion rates provided in Shoreline Management Plans. In the absence of new erosion rate information, long term rates were assumed to be equal to the photogrammetrical rates provided in the Great Lakes Coastal Zone Atlas (Haras and Tsui, 1975). The structures located within this line were summed per reach to determine the number of properties which could be potentially lost to erosion over the next 50 years.

A unit cost of land was derived for a lot with and without a structure on it. This cost was based on the area of property and was expressed as a dollar value per kilometre of reach per metre of shoreline eroded. This price is indicative of a residential shoreline property value, however, since the original land cost values are from assessment data, which reflects land use, the real cost of erosion may be distorted. For example, a half acre shoreline lot may cost $150,000 whereas if the shoreline is part of a large farm that same half acre may only be valued at $500. If the market value costs for residential shoreline properties were used to update all of the erosion curves, the change in values would have been quite pronounced. Therefore, to reflect current land uses, and the costs which would be associated with these uses, land use data was taken into account.

Land use data compiled for the Land Use and Shoreline Management Task Group (see Section 6) was used to assess the percentages of land use along the shoreline. The total cost per metre of erosion on a reach was estimated by segregating the shoreline into two classifications: residential (residential, commercial, industrial, transportation and communication, and recreational); and other (agricultural, undeveloped, forest, grassland, bare, extraction, wetlands).

It was assumed that the erodible length of shoreline had the same land use characteristics as the entire reach. The residential segment of the erodible reach length was then divided into two components; lots without structures susceptible to erosion, and lots with structures susceptible to erosion. The division of the residential segment was achieved by determining the length of shoreline required to accommodate the number of structures counted under the 50 year erosion line based on their frontage. The length of shoreline required to accommodate the structures under the 50 year erosion line was multiplied by the unit cost of land with a structure on it. The remaining residential land was multiplied by the unit cost of land without a structure on it. The remaining segment of the erodible reach (not residential) was multiplied by 1979 unit land cost of erosion per kilometre of reach updated to 1991 dollars using the New Housing Index for land only. These three land use components were summed to provide an aggregated cost of erosion per metre of erodible shoreline in 1991 dollars. This cost was then compared to the original value given in the International Lake Erie Regulation Study. The erosion curves were then updated based on the ratio of the new cost/m of erosion to the 1979 cost/m of erosion.

The delineation of the new 50 year erosion line took into account NEW SHORELINE PROTECTION works unless there was direction from the Conservation Authority that the works were ineffective. Therefore, the correction for the reduction in number of structures at risk to erosion was taken into account. However, the change in long term erosion rates produced by new shoreline protection will decrease the curves directly, since the dollars per unit wave energy relationship derived in the Lake Erie Study would be modified by shoreline protection. Therefore the curve was adjusted by a factor equal to the length of erodible shoreline minus a fraction of the length of new shoreline protection divided by the original length of erodible shoreline. The fraction of shoreline protection length was based on the effectiveness of the protection in the mitigation of erosion in the estimation of the Conservation Authority. If no estimation was given, shoreline effectiveness was interpreted from background reports of the shoreline area.

The **LAKE SUPERIOR** curves are based on potential damage estimates developed from a survey of building elevations and applying a generic stage-damage relationship for individual buildings (Marshall, Macklin, Monaghan, 1988). The estimated potential damages for Lake Superior increased from $ 1.8 million in 1987 to $ 2.5 million in 1991 for the maximum water level analyzed. The curves produced represent potential damages at specific water levels. There was no calibration of either the original or the updated damage curves. Twenty-four of the thirty-nine reaches incurred damage at this maximum level. The increase in flood damage costs can be attributed almost entirely to inflation as increases in development along the Canadian Lake Superior shoreline have been minimal. There are no erosion curves for Lake Superior. Erosion damages along Lake Superior are very small, relative to erosion damages along the other lakes.

No new structures could be determined since 1973 within the limit of the flood damage curves on **LAKE HURON**. The Great Lakes Coastal Zone Atlas was used to determine the 1973 conditions along the shoreline since there was no other mapping available for this time period. At times, the comparison between the new mapping and the 1973 atlas was hampered by the heavy cover of vegetation along the shoreline shown in the atlas. All conversations with the Conservation Authorities, however, indicated that the amount of new development within the curve limits would likely be minimal. There has been a considerable amount of new shore protection implemented along the shoreline since 1973, including numerous groyne fields in some reaches. Accordingly, the potential for damages to shore protection has risen substantially. One anomaly was discovered in that one reach was determined to have considerably less shoreline protection in place now than in 1973. This was indicated by not only a comparison of mapping but is also documented in the Lake Huron Shoreline Processes Study (Reinders, 1989). It is possible that this shoreline protection was destroyed in the 1972-1973 period and was never rebuilt. The damage curve was not reduced to account for the reduction in shoreline protection damages due to the uncertainty of the nature of the reduction and the relatively low monetary reduction at the high water level in the curve (approximately $16,000).

In all, 2656 properties were added to the 5 reaches along **LAKE ST. CLAIR**. The original damage survey only investigated properties which were directly on the shoreline. Any properties which were flooded inland were not originally assessed, but have now been incorporated into this analysis. The flat area surrounding the south side of Lake St. Clair abets inland flooding from Lake St. Clair via Little River, Puce River, Ruscom River, and Belle River. The majority of new structures (>90%) added to the curves were inland properties. Considerable shore protection has been implemented in some reaches to mitigate river/lake flooding. These works protect structures in the Belle River and Little River areas.

Most potential **LAKE ERIE** flood damages for a given water level have doubled since the 1981 Lake Erie Study. Damages in one reach of the Detroit River have changed dramatically as a result of new structures. Several of these new structures are estate residential with a high value. Reach 1 of Lake Erie shows a noticeable change in rate of damage with water level at an elevation of 175.4 m (575.46 ft). This occurs due to a new protection structure which protects 20 buildings from flooding. The effect of new protection works for old structures is also noticeable in Reach 2. Reach 9 shows a noticeable increase in damages at 175.8 m (576.77 ft), due to the inclusion of a number of structures at this elevation. Although there is a significant increase in damages (approximately 10 times) the magnitude of damages is relatively minor. This magnitude of damages effect occurs for Reach 15 as well. In total approximately 450 structures were added into the curves, while 200 were either raised, protected, or removed. In three of the reaches there were problems when existing structures were removed, raised, or protected. In reaches 5, 9, and 14, mapping indicated that certain structures clearly had been removed or protected. Damage reduction due to removal, raising or protection of structures was not allowed to exceed the original damage estimate.

Increases in shoreline protection indicate that the majority of Lake Erie shoreline is unprotected (or the protection is not documented). These values are extremely approximate due to the assumptions made concerning the 1972 coverage of shoreline protection and the scope of analysis afforded by the nature of this study.

The revised erosion curves for Lake Erie include reduction factors for new shore protection works which mitigate erosion. The Conservation Authority indicated that works in some reaches were effective, and as such, they were assumed to negate erosion completely in the areas in which they were implemented. In other reaches, there were either negligible increases in shoreline protection or the protection was not for erosion, and/or not located in the portion of erodible reach delineated for land cost calculations.

Most of the **LAKE ONTARIO** potential flood damages for a given water level have doubled since the Lake Erie Study. Particularly high increases were calculated for reaches 8 and 9 due to the substantial increase in shoreline protection in reach 8, and increase in both shoreline protection and susceptible structures in reach 9. In total, 389 structures were added into the curves, while 61 were either raised, protected, or removed. Increases in shoreline protection are approximate due to the assumptions made concerning the 1972 coverage of shoreline protection and the scope of analysis afforded by the nature of this study.

The cost of erodible land has increased by a range of 6 to 30 times since 1979. The average increase for land cost in Lake Ontario is 13 times the cost in 1979 which is higher than the other lakes. This reflects the intense urbanization of southern Ontario (especially within commuting distance to Toronto) which occurred in the 1980's. Residential housing prices between Port Hope and Niagara Falls have increased significantly in recent years. The dramatic increase (29.91) in reach 3 can be attributable to a large market increase in land value and a large increase in residential land use for this reach.

On the **ST. LAWRENCE RIVER**, the existing flood damage curves in the Montreal region are based on combined flows from the Ottawa River, local inflow, and flow in the St. Lawrence River. As such, there is not a direct relationship between Great Lakes water levels and flood damage in this region. Three of the five flood damage curves for this area are related to flow, not water level. For the two Quebec reaches having a stage-damage relationship, the same methodology as used in the Great Lakes was used for estimating potential flood damages. These two reaches represent Lac des Deux Montagnes and Lac St. Louis. The methodology compared recent mapping to mapping from 1974-1976 to determine the new development and assess potential damages to the new development using the FLDAM computer model.

The FLDAM computer model was inappropriate for flow-damage relationships. The 1974-1976 mapping in these regions identified areas which were damaged during the 1974 and 1976 flood events. This information was used to evaluate a maximum water level in each of the flow reaches to be used as a cutoff value for new development in the update analysis. The maximum water level in the three flow-damage reaches were similar to the maximum water level in the other two stage-damage reaches.

The ratio of current total number of structures within the maximum water level compared to total number of damaged structures during the 1976 flood event was used to factor up the flood damage curves in the three reaches with flow-damage relationships. The 1976 event was used, as opposed to the 1974 event, since the 1976 event caused greater damage and is indicative of the full curve.

INFLATION for the St. Lawrence River was taken into account using the Montreal NHI and Ontario CPI index. The breakdown of damages into CPI based versus NHI based damages was based on the maximum compensation payments allowable for specific items. For example, compensation payments for contents in a residential structure were limited to $5,000 whereas structural damages were limited to $8,000. Therefore, for residential structures 3/8 of the curve was updated based on the Consumer Price Index and 5/8 of the curve would be updated based on the New House Index for Structures. Not all damages were related to residential structures however. Consequently, the other damages (farms, businesses, government holdings, emergency measures) were also discretized into NHI versus CPI damages. The portion of the curve updated by the NHI factor was based on the sum of the NHI damages compared to the total damages. A similar procedure was used for the CPI factor. This was done individually for each reach for both the 1974 and 1976 events. The average of the 1974 and 1976 event factors were used to actually update the flood damage curves.

Municipal mapping, and mapping from third parties, such as Ducks Unlimited were used in conjunction with flood risk mapping in Montreal, the Saint-Francois River, and Trois-Rivières to piece together the current level of shoreline development. New development was determined in reaches 1, 2 and 4. No removed structures were determined in any of the reaches and no information was available concerning new versus old shore protection. The flood damages have essentially doubled in all reaches, which reflects the inflation costs between 1979 and 1991. Relatively few new structures (28) were determined within the flood curve limits for the five reaches.

In the original delineation of the Quebec curves a relationship was derived between the outflow of the Lake Ontario into the St. Lawrence River at Cornwall and flood damages. This flow damage curve was updated using the average increase factor (2.14) for the 5 individual St. Lawrence River curves.

There are no erosion curves on the St. Lawrence River.

5.2.3 Water Level Regulation Scenario Evaluation

After both the Canadian and U.S. stage damage curves were updated, they were applied to the various water level regulation scenarios being evaluated to determine the differences in damages that might be expected relative to the basis of comparison water level conditions. This was done for both erosion and flooding.

The updated stage-damage curves were combined with the water level scenarios data to determine average annual inundation and erosion damages for each scenario. For all of the U.S. shoreline and for the Canadian shoreline from Lake Huron through Lake Ontario, a computer program known as CZSEVAL (for Coastal Zone Studies Evaluation) was used to complete this analysis.

CZSEVAL is a package of computer programs that were developed for the International Lake Erie Regulation Study (ILERS, 1981) to combine stage-damage curves for inundation and erosion with water level data in order to determine average annual damages. Some minor modifications were necessary in order to apply the program to this study, but the basic logic of the program remained unchanged.

The evaluation procedures developed were designed with the aim of having identical procedures in both the United States and Canada, to the degree possible. The procedures were developed, for the most part, for use on high-speed computers. The software for the computer programs used in the evaluations is included in the Appendices of the Potential Damages Task Group Report.

Inundation

Inundation is an event process. It occurs occasionally and without regularity. The evaluation procedure assumed that in any one month the mean water level could be combined with recorded short-term rises to generate a population of stormwater levels. This population was generated by month for each reach, and was subsequently converted to dollars, using the stage-damage relationship. The mean of these values was the average annual damage for that reach, for that water level scenario.

Two types of water level data were required: 1) monthly mean water level data for each lake and each regulation plan, provided by Working Committee 3; and 2) monthly maximum storm rise, calculated from gage records of the closest stations to the reaches being evaluated. Storm rise was calculated by subtracting the monthly mean level from the peak hourly level for each month. The difference was the peak storm rise for that month.

An assumption made in this evaluation was that the different regulation plans would affect only the mean water level and not the rise. This was considered reasonable due to the general acceptance of the independence of these two factors. The combined mean water level and rise is referred to as the stormwater level.

In order to determine the stormwater level for each month by reach, historic rise data were combined with the mean water level for corresponding months. For example, if there were 90 years of monthly mean water levels and 75 years of monthly rise data, then each of the 75 rises was added to each of the 90 mean water levels for the corresponding month. This generates a total population of stormwater levels consisting of 90 x 75 x 12, or 81,000 points. It should be noted that several combinations of monthly mean levels and rises may give the same stormwater level.

The CZSEVAL program used the inundation stage-damage curves and the stormwater levels population to calculate the damage corresponding with every stormwater level. The calculated damage was multiplied by the frequency of the associated stormwater level and summed for the total population. The average annual damage was taken as the mean of this damage population.

It should be noted that monthly damages may be caused not only be a once-a-month stormwater level, but also by other lower levels during the month. Thus, the stormwater levels are an index of damage capacity. The average annual damages, determined as described above, are a good indication of the relative benefits or losses between the regulation plans.

Erosion

Each monthly mean level for a reach was applied to the appropriate stage-damage curve, generating a population of damages for each reach. The average annual damage was taken as the mean of this damage population.

Exceptions

Somewhat different methodologies were used to determine average annual flood and erosion damages for the Canadian sides of Lake Superior and the St. Lawrence River. As described previously, the stage-damage curves for these two areas were developed as part of separate studies, and the format of them differed from the curves for the other lakes. It was necessary for these areas to determine stage-frequency relationships for water levels or flows, and combine these with the stage-damage relationships to determine average annual damages. While the methodologies were different, the results were compatible.

5.2.4 Stage-Damage Curve Variability, Constraints and Uncertainty

As a large portion of the impact analysis for riparian properties would rely on the updated curves, Working Committee 2 felt it was important to provide a critical review of these curves. To do this, an independent reviewer was contracted to examine the curves and report upon their strengths, weaknesses, and variability, and to provide recommendations on limitations for their application in the study. A summary of his findings are presented here (see Yoe, 1992 for full discussion).

- Generating stage-damage relationships from a lump sum estimate of the historical expenditures incurred over a number of years is by definition an arbitrary process. The starting and ending points as well as the shape of the damage curve are assumed, as is the amount of damages at each elevation. This process loses the main advantage of historical damages, i.e., that they are observed damages. The stage-damages "calibrated" were not therefore observed over the range of reported damages.

- The standard for estimating damages does not appear to be willingness to pay. Costs to replace and historical expenditures unadjusted for the adaptive behaviour of residents in the hazard zones appear to have been used.

- Updating damages, always a problem, relied on inappropriate usage of the (Engineering News Record (ENR) index in some cases.

- The CZSEVAL model used to estimate expected annual damages is based on an invariant record of historical storm events. The use of data from a single period rather than from a distribution is limiting. The method by which expected annual damages are estimated appears to rely on unrealistic occurrences of flood damages.

- The inundation-damage data do not appear to include reliably estimated zero damage or first floor elevation damages for structures. Zero damage elevations for a given reach are, therefore, suspect.

- The erosion damage base used by the U.S. is not as well grounded in concept as is the Canadian damage base. Both governments rely upon severely simplifying assumptions about energy and water level relationships to proceed to expected annual damages.

In light of some of these concerns, adjustments were made to the methodologies for updating the inundation and erosion stage-damage curves used in the CZSEVAL model. One principal adjustment applied was in price indexing. For example, Yoe (1992) had suggested that the use of the ENR index alone to update price levels may be inappropriate and that a mix of indices should be used. As such the Task Group used the following modifications in their approach:

a) flooding (U.S.) - an average of the ENR building cost index and the Consumer Price Index (CPI).

b) flooding (Canada) - CPI for contents, a modified BCI for structure with the composite determined regionally, based on percent of content damage to structure damage during the 1972-1973 damage survey.

c) erosion (U.S.) - based on an index of the median sales price of new homes.

d) erosion (Canada) - based on sales prices of homes and the land component of the New Housing Index for vacant lots.

5.2.5 Results of CZSEVAL Model Output

The results of scenario evaluations for inundation and erosion damages are included in TABLE 5.1. This table includes evaluations for the Basis of Comparison and all scenarios that were carried to the end of the study. The benefits in the form of reduced inundation and erosion damages are also included for each scenario. Partial evaluations were completed for scenarios that were rejected part-way through the study. The results of all scenario evaluations are included in the Potential Damages Task Group report.

For the Canadian shoreline, erosion damages are included for Lakes Ontario, Erie and St. Clair, and for Lake Huron from Sarnia to Point Clark. Erosion evaluations are not available for Lake Superior or for the St. Lawrence River. Inundation damages are included for Lakes Ontario, Erie, St. Clair, and Superior, and Lake Huron south of Southampton. Flooding damages are also included for the Detroit River and St. Lawrence River from Lac St. Louis to Lac St. Pierre.

For the United States shoreline, the stage-damage curves to assess potential inundation and erosion damages developed for the International Lake Erie Study covered all areas of the U.S. Great Lakes shoreline, with three exceptions. These were: the Mexico Bay area of Lake Ontario; from Waukegan, Illinois to Gary, Indiana, on Lake Michigan; and from Ludington to Frankfort, Michigan on Lake Michigan. Stage-damage curves have subsequently been developed for these three areas under this study, providing complete coverage of the U.S. shoreline. Erosion and inundation damages for the U.S. on the St. Mary's, St. Clair, Detroit, and Niagara Rivers are included in the nearest, adjacent downstream lake reaches. Damages reported on the U.S. side of the St. Lawrence River however, are included in the nearest adjacent reach upstream on Lake Ontario.

Table 5.1 Inundation and Erosion Property Damages By Water Level Scenario

INUNDATION AND EROSION PROPERTY DAMAGES, $000 U.S.												
Lake/ River	Basis of Comparison			1.2 SEO Combined			1.4 1977A w/o C			1.18 SEO Extended		
	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL
Superior	1,022	3,491	4,513	960	3,464	4,424	980	3,455	4,435	884	3,368	4,252
Michigan	2,086	13,793	15,879	1,990	13,668	15,658	2,093	13,825	15,918	1,407	12,388	13,795
Huron	1,791	6,782	8,573	1,614	6,706	8,320	1,800	6,797	8,597	889	6,050	6,939
St. Clair	1,917	3,723	5,640	378	3,256	3,634	1,929	3,737	5,666	6	2,550	2,556
Detroit R.*	212	***	212	17	***	17	215	***	215	2	***	2
Erie	4,780	9,489	14,269	2,935	8,190	11,125	4,793	9,508	14,301	1,901	6,805	8,706
Ontario**	723	14,270	14,993	821	15,319	16,140	740	14,334	15,074	769	14,921	15,690
St. Lawrence	7,858	***	7,858	10,465	***	10,465	7,865	***	7,865	10,117	***	10,117
TOTAL	20389	51,548	71,937	19,180	50,603	69,783	20,415	51,656	72,071	15,975	46,082	62,057
Benefit-U.S.				2,108	1,029	3,137	1	(71)	(70)	4,378	4,714	9,092
Benefit-Cda.				(899)	(84)	(983)	(27)	(37)	(64)	36	752	788
Benefit-Total				1,209	945	2,154	(26)	(108)	(134)	4,414	5,466	9,880

* Canada only; United States' portion included in Lake St. Clair

** Includes United States' portion of St. Lawrence River

*** Not evaluated, but considered to be relatively minor

Table 5.1 (continued) Inundation and Erosion Property Damages By Water Level Scenario

INUNDATION AND EROSION PROPERTY DAMAGES, $000 U.S.												
Lake/ River	1.19 SO Environmental			1.20 Superior -.5 ft., 35P			1.21 1977A MOD, 35P			Crisis Conditions 32		
	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL
Superior	928	3,393	4,321	559	3,056	3,615	928	3,393	4,321	982	3,466	4,448
Michigan	2,037	13,733	15,770	2,088	13,790	15,878	2,037	13,733	15,770	1,977	13,567	15,544
Huron	1,698	6,780	8,478	1,727	6,769	8,496	1,698	6,780	8,478	1,618	6,660	8,278
St. Clair	1,752	3,668	5,420	1,659	3,703	5,362	1,752	3,668	5,420	1,265	3,517	4,782
Detroit R.*	179	***	179	160	***	160	179	***	179	110	***	110
Erie	4,684	9,283	13,967	4,730	9,465	14,195	4,684	9,283	13,967	4,391	9,212	13,603
Ontario**	594	14,330	14,924	682	14,084	14,766	689	14,165	14,854	753	14,152	14,905
St. Lawrence	8,257	***	8,257	7,840	***	7,840	7,856	***	7,856	8,105	***	8,105
TOTAL	20129	51,187	71,316	19,445	50,867	70,312	19,823	51,022	70,845	19,201	50,574	69,775
Benefit-U.S.	436	236	672	663	602	1,265	373	323	696	823	800	1,623
Benefit-Cda.	(176)	125	(51)	281	79	360	193	203	396	365	174	539
Benefit-Total	260	361	621	944	681	1,625	566	526	1,092	1,188	974	2,162

* Canada only; United States' portion included in Lake St. Clair

** Includes United States' portion of St. Lawrence River

*** Not evaluated, but considered to be relatively minor

Table 5.1 (continued) Inundation and Erosion Property Damages By Water Level Scenario

INUNDATION AND EROSION PROPERTY DAMAGES, $000 U.S.									
Lake/ River	1.6 1958D MOD 28B			1.6A 1958D MOD 35P			1.6B 1958D MOD 35Z		
	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL	Flood	Erosion	TOTAL
Ontario**	723	14,678	15,401	704	14,185	14,889	754	14,215	14,969
St. Lawrence R.	7,843	***	7,843	7,852	***	7,852	7,864	***	7,864
TOTAL*	20,374	51,956	72,330	20,364	51,463	71,827	20,426	51,493	71,919
Benefit-U.S.	7	(227)	(220)	25	51	76	(16)	30	14
Benefit-Cda.	8	(181)	(173)	0	34	34	(21)	25	4
Benefit-Total	15	(408)	(393)	25	85	110	(37)	55	18

* TOTAL includes Basis of Comparison damages for Lake Superior through Lake Erie

** Includes United States' portion of St. Lawrence River

*** Not evaluated, but considered to be relatively minor

5.2.6 Inundation "Uncertainty" Analysis

In addition to the several modifications previously discussed, Yoe (1992) also recommended that the water level elevation at which flood damages begin be reexamined. The curves indicated that damages could start at relatively low levels, in some cases below long-term average. Intuitively, the Task Group felt it was not reasonable to assume that riparians are flooded almost every year. Floodproofing or relocation of damageable property would likely occur instead. Thus, the Task Group agreed to use a risk-based approach, that is, use the 1 in 5-year recurrence flood level as an approximation of the non-damaging point. The shape or value of the curve was not changed at the higher levels. Because this is an approximation, this recurrence level was varied to see what effect uncertainty would have. That is, for certain reaches it was varied by about 1/2 foot lower to 1 foot higher.

Yoe (1992) also recommended that the flood damage curves be modified to use annual peak levels, instead of 12 peak monthly levels per year as used presently. Also, combined frequency curves incorporating stormwater rises should be used to determine annual damages. The Task Group did this.

Finally, Yoe (1992) recommended that a range of values be used for assessing damage potential at various water levels, instead of using a single value. The Task Group developed these ranges for stage damage curves in all reaches on the U.S. shoreline and for all lakes except Superior and the St. Lawrence River on the Canadian shoreline. Full details on the criteria used to set the upper and lower bounds of these ranges can be found in the Potential Damage Task Group Report.

The modifications described above were incorporated into an "uncertainty analysis" for the evaluation of inundation damages, in recognition of the fact that there is an uncertainty about the exact relationship between water level and damages. The evaluation using stage-damage curves, described in the previous section, is considered the "best estimate" of benefits attainable through water level regulation. The uncertainty analysis is used to provide plausible upper and lower limits for benefits.

This uncertainty analysis defines a range of possible stage-damage relationships which would most likely contain the actual stage-damage relationship. Even if consensus existed on the most accurately recorded damages, potential damages change over time. Factors affecting the stage-damage relationship include changes in type and level of land use and changes in local protection. Change in type of land use may be from the development of vacant land. Change in level of land use would be the replacement of an old vacation home with a year-round home. Changes in local protection make comparison of the two historic damage events extremely difficult.

The uncertainty methodology utilized can be summarized as follows:

Three stage-damage curves were developed for each reach. These represented the highest possible damage, lowest possible damage, and the "most likely" damages that would result from inundation at a number of given elevations. An elevation-frequency curve for each reach was developed from historic storm rise data, and the monthly mean water levels of whatever scenario is under evaluation.

All four of the above curves were combined in a Lotus 123 spreadsheet, which also had the @RISK computer program add-in attached. @RISK performs a "simulation" of 1000 iterations, each time defining a stage-damage curve bounded between the aforementioned maximum and minimum possible damage curves. The likelihood of any particular shape of the curve in each iteration was weighted by the best approximation curve, and by the parameters built into @RISK for a "triangular" distribution.

Each iteration of the possible stage-damage curves was combined with the stage-frequency relationship. This yielded a damage-frequency curve for each iteration, where the area underneath represents average annual damage.

The maximums, minimums, and means of these 1000 average annual damages for each reach were tallied by lake, and summarized in tables. This cumulative distribution of possible average annual damages, for each reach, was the basis for determining "confidence levels" around the expected (mean) annual damage (EAD).

The expected annual benefit (EAB) for a reach under any scenario is the difference between the EAD for the basis of comparison (BOC) water level scenario, and the EAD for that reach under a different water level scenario.

This methodology was used for relative comparisons of damage estimates between the water level plans. The uncertainty analysis was performed on damages for each plan, which were held against a constant BOC. Unfortunately, it was not the best way to estimate confidence in the absolute magnitude of benefits associated with a plan. The EAB for a reach were computed as the difference between the plan damages and the BOC damages, which were derived from separate populations of the possible stage-damage curves.[1] This methodology was referred to as the "inundation uncertainty damage analysis".

A more appropriate way to gauge confidence in the EAD was to perform the uncertainty analysis on the benefits themselves. This required a few additional calculations. At each step in the simulation, as that iteration's stage-damage curve was applied to the plan's frequency curve, it was also applied to the BOC frequency curve. The difference between the two resulting average annual damages was the benefit for that iteration. The 1000 benefits thus derived were therefore

---

[1] Every time an @RISK simulation is run, a new population of stage-damage curves is generated. This is why the results are never exactly the same as previous runs, even if all the inputs are identical.

computed where the plan and BOC operate from the same stage-damage curves. Only the water level frequency curve was changed for a given reach. This methodology was referred to as the "inundation uncertainty benefit analysis".

Results For Plan 1.18 - SEO Extended

The EAB's from this analysis for Plan 1.18 (SEO Extended) are shown in the "Expected" column of TABLE 5.2, for each Canadian and American reach. The remaining columns list the cumulative distribution of the 1000 EAB's. The minimum benefit of the simulation is listed in the "99.9% " exceedance column, while the maximum benefit to come out of the simulation is listed under the "0.1%" exceedance column. The median value is listed under the "50%" column.

The validity of @RISK output statistics depends on the presumed statistical description of the input to @RISK. For this application, such statistics do not exist. The input to @RISK is largely based on professional judgement applied to historical data. Interpretation of the output should be limited to the range of benefits defined. It is probably inappropriate to assume that specific probabilities can be applied to the actual distribution of benefits.

If this assumption is made, however, statements can be made from the attached table about the level of confidence in the EAB. As an example of how to interpret this table, for the "Plan Total" (last row of table) it could be said that there is a 5% chance of the EAB being less than $11.0 million, and a 95% chance that it is less than $18.5 million. It could also be said that the EAB for the entire basin is 90% likely to be between $11.0 million and $18.5 million.

5.3 Detailed Site Studies

5.3.1 Introduction

The rationale behind the detailed site study approach was to be able to examine, in a microcosm, typical flooding and erosion prone areas throughout the Great Lakes - St. Lawrence River Basin at a level of detail that was impossible to apply basin-wide due to time and resource limitations.

The development of detailed information on such matters as stage-frequency damage relationships along vulnerable shoreline areas, the determination of erosion damages and whether they would be affected by changes in the lake regulation regime, the impact of high and low water levels on water supply and sanitation facilities, and recreational impacts from extreme high and low levels are examples where significant information might best be obtained by focusing on specific areas which have experienced these kinds of problems.

It was recognized that the results of the detailed site studies would not in all cases be fully applicable to other locations with similar kinds of problems around the basin. Nevertheless, the

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
LAKE ONTARIO								
2001	221	86	135	152	225	281	293	327
2002	17,961	5,770	10,658	12,129	17,725	24,239	25,893	32,047
2003	3,804	607	1,917	2,275	3,630	5,713	6,255	7,831
2004	3,131	485	1,569	1,954	3,093	4,371	4,729	5,817
2005	2,948	512	1,439	1,792	2,932	4,133	4,456	5,365
US Total	28,065	7,460	15,717	18,303	27,606	38,737	41,624	51,388
ONT1	1,608	909	1,276	1,360	1,609	1,855	1,942	2,172
ONT2	1,725	1,046	1,389	1,460	1,731	1,993	2,051	2,348
ONT3	186	32	106	122	185	251	265	317
ONT5	566	141	323	369	567	755	804	958
ONT6	11,468	4,198	7,719	8,562	11,412	14,506	15,235	17,259
ONT7	2,105	591	1,345	1,507	2,098	2,752	2,917	3,392
ONT8	843	238	528	582	841	1,095	1,167	1,446
ONT9	2,364	684	1,473	1,691	2,350	3,053	3,194	4,031
ONT12	1,042	259	543	642	1,056	1,439	1,527	1,858
Can Total	21,909	8,098	14,702	16,295	21,848	27,698	29,100	33,780
Lake Total	49,974	15,558	30,419	34,598	49,454	66,435	70,724	85,169

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
LAKE ERIE								
3001	1,418,624	779,404	1,067,094	1,141,264	1,417,667	1,695,415	1,785,126	2,098,136
3002	713,905	530,521	616,519	639,006	715,257	787,566	802,718	882,320
3003	455,804	311,347	377,657	394,199	456,122	514,535	526,515	579,531
3004	192,692	86,810	126,651	139,178	190,770	248,882	264,321	324,215
US Total	2,781,024	1,708,082	2,187,921	2,313,647	2,779,816	3,246,398	3,378,680	3,884,201
ERI1	82,537	47,826	63,904	69,027	82,957	96,870	99,858	115,510
ERI2	115,231	72,351	93,165	98,001	115,070	132,698	138,160	154,369
ERI3	4,545	2,519	3,359	3,647	4,516	5,437	5,728	6,801
ERI4	29,270	15,209	21,265	22,938	29,339	35,524	36,873	44,144
ERI5	71,972	41,452	55,039	59,282	72,106	84,907	87,921	102,110
ERI6	7,899	3,869	5,310	5,839	7,869	9,952	10,550	12,565
ERI7	40,171	21,169	28,393	31,174	40,113	49,291	51,884	62,067
ERI9	6,195	4,014	5,008	5,274	6,210	7,106	7,343	8,388
ERI11	94,587	63,018	76,660	80,296	94,617	107,737	111,289	124,731
ERI12	48,508	23,261	35,001	38,322	48,332	58,763	62,098	68,981
ERI13	410,897	291,448	340,170	355,331	410,695	464,864	478,671	520,736
ERI14	286,141	183,912	222,388	236,093	288,438	335,194	348,342	415,974
ERI15	157,757	84,929	126,931	133,581	157,930	180,935	187,508	210,800
PEI1	44,560	27,662	34,777	36,993	44,649	52,141	54,149	67,373
Can Total	1,400,271	882,639	1,111,369	1,175,799	1,402,843	1,621,420	1,680,374	1,914,549
Lake Total	4,181,294	2,590,721	3,299,290	3,489,446	4,182,658	4,867,818	5,059,054	5,798,750

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
DETROIT RIVER (CANADIAN ONLY)								
DTR1	14,025	7,501	10,106	10,785	14,068	17,127	18,033	21,355
DTR2	99,777	72,243	84,119	87,938	99,988	111,724	115,588	124,750
DTR4	282,252	208,441	246,185	254,144	281,918	309,359	319,651	343,387
Can Total	396,055	288,185	340,409	352,868	395,974	438,210	453,273	489,492
River Total	396,055	288,185	340,409	352,868	395,974	438,210	453,273	489,492
LAKE ST. CLAIR								
4001	2,823,461	1,646,431	2,093,553	2,265,790	2,828,473	3,420,760	3,594,384	4,148,698
4002	2,233,681	654,389	1,195,024	1,366,891	2,214,116	3,119,486	3,368,174	4,145,488
US Total	5,057,142	2,300,820	3,288,577	3,632,681	5,042,589	6,540,246	6,962,558	8,294,186
STC1	222,124	170,960	190,983	198,503	221,880	245,674	251,567	271,560
STC2	236,632	128,306	183,822	195,166	237,060	276,225	288,516	332,747
STC3	198,236	133,722	159,599	167,406	197,204	230,024	237,488	275,965
STC4	184,023	127,286	147,565	155,060	183,912	210,550	219,490	243,684
Can Total	841,014	560,274	681,969	716,135	840,056	962,473	997,060	1,123,956
Lake Total	5,898,156	2,861,094	3,970,546	4,348,816	5,882,645	7,502,719	7,959,618	9,418,142

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
LAKE HURON								
5001	565,055	402,694	479,202	498,038	563,625	633,752	649,269	706,542
5002	11,455	8,123	9,518	9,927	11,447	12,904	13,338	14,561
5003	136,786	64,398	90,406	99,534	136,105	175,386	184,557	220,842
5004	688,720	555,960	612,442	624,600	695,602	740,231	747,396	772,013
5005	231,612	96,155	153,327	168,001	230,208	298,409	312,665	359,303
5006	98,934	72,916	84,005	87,252	99,151	109,624	111,755	125,133
US Total	1,732,562	1,200,246	1,428,900	1,487,352	1,736,138	1,970,307	2,018,980	2,198,393
HUR1	96,723	58,868	79,646	82,790	96,914	110,373	113,826	136,153
HUR3	39,310	19,589	29,583	31,730	39,443	46,729	48,445	54,897
HUR4	33,373	22,865	27,349	28,876	33,363	38,000	39,206	43,755
HUR5	35,064	24,685	29,066	30,274	34,945	40,108	41,107	44,668
HUR6	9,117	7,149	7,891	8,175	9,100	10,005	10,272	11,490
HUR7	16,527	11,728	14,113	14,618	16,494	18,429	19,020	20,678
Can Total	230,115	144,884	187,648	196,463	230,259	263,643	271,877	311,641
Lake Total	1,962,678	1,345,130	1,616,548	1,683,815	1,966,397	2,233,950	2,290,857	2,510,034

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
LAKE MICHIGAN								
7001	35,532	21,190	26,629	28,846	35,780	41,558	43,457	49,395
7002	26,704	14,876	19,626	20,848	26,525	32,481	34,022	39,526
7003	358,481	237,881	284,726	303,707	361,609	408,185	418,840	453,810
7004	56,362	5,952	27,869	33,930	56,428	79,953	86,806	103,691
7005	710,593	477,125	571,592	601,305	716,202	802,820	828,538	930,676
7006	516,494	367,701	430,728	444,352	520,643	579,886	596,892	641,391
7007	53,256	12,950	28,284	32,192	52,080	75,831	80,604	103,794
7008	5,445	2,699	3,760	4,078	5,430	6,824	7,233	8,501
7009	65,914	39,617	49,658	53,573	66,934	76,608	78,275	84,786
7010	17,896	11,058	14,162	14,956	18,184	20,437	20,954	23,103
7011	77,091	49,767	61,275	64,541	78,053	88,040	89,875	97,401
7012	77,666	50,978	61,801	66,095	78,516	88,178	91,031	96,906
7013	81,695	52,355	64,213	68,999	82,335	92,864	95,422	103,003
Lake Total	2,083,128	1,344,148	1,644,324	1,737,421	2,098,720	2,393,666	2,471,949	2,735,982
Lake Uncertainty	2,082,255	1,676,844	1,905,339	1,947,310	2,081,591	2,218,181	2,251,996	2,410,619

Table 5.2 Uncertainty Benefit Analysis for Plan 1.18 Three Lake Extended Scenario

Reach	EAB	Percent Chance Exceedance						
		99.9%	95%	90%	50%	10%	5%	0.1%
LAKE SUPERIOR								
9001	7,544	262	2,363	3,161	7,204	12,278	13,584	17,129
9002	72,308	16,726	36,268	44,676	73,444	97,438	103,067	117,941
9003	16,891	4,502	9,935	11,417	17,285	21,515	22,639	26,092
9004	5,486	1,927	3,303	3,785	5,580	6,987	7,379	8,592
9005	4,625	1,834	2,905	3,252	4,709	5,852	6,129	7,098
9006	6,734	130	2,295	2,995	6,405	11,079	12,284	14,929
9007	16,414	5,402	10,131	11,441	16,663	21,013	21,976	25,332
Lake Total	130,002	30,782	67,200	80,727	131,289	176,161	187,056	217,113
Lake Uncertainty	129,925	64,456	92,636	100,547	131,564	156,049	162,870	183,580
Plan Total	14,701,286	8,475,619	10,968,736	11,727,690	14,707,137	17,678,959	18,492,531	21,254,682

All values in January 1992 US dollars. Conversion from Canadian: 0.833

goal in this aspect of the potential damage analysis was to substantially increase the understanding of specific problems by studying them intensively on a smaller scale, and then to apply this increased understanding in the development of recommendations to Governments on appropriate actions for alleviating the adverse consequences of fluctuating water levels and their extremes.

Locations for the detailed site studies were presented in Section 2 (refer to FIGURE 2.1). On the U.S. side, investigations at Duluth, Chicago, Ottawa County, Berrien County, Oswego, Hoover Beach and Alexandria Bay were carried out by various district offices of the Army Corps of Engineers. In Canada, work on the residential sites (Montreal, Toronto and Windsor to Belle River) was carried out by Paragon Engineering (1993) and work on the other sites (Thunder Bay, Severn Sound and Central Lake Erie) by the Water Network (1992), both under contract to Environment Canada. Unfortunately, time constraints prevented an equal level of damage analysis at all sites. This section will present a brief review of all information collected, and analysis conducted, to date for these sites.

5.3.2 Canadian Study Sites

Residential Sites - Windsor to Belle River, Toronto, Montreal

Data Collection

Site inventories were completed for each study area. The inventories included a "windshield" survey to obtain opening elevations and first floor elevations for each structure. In addition, areas with obvious erosion problems were identified and discussions held with local officials and residents to obtain further information related to the damage problems specific to each site.

The inventories were conducted in a similar fashion at each study area, with variations to reflect local conditions and availability of topographic mapping. For **MONTREAL**, little detailed topographic information was available prior to the site visit. Using mapping obtained from the Quebec Ministry of Energy and Resources, 100 year flood elevations were transferred onto the maps and flood susceptible structures were identified for inventory. During the site visit, additional mapping was obtained from local municipalities. Using the contours and spot elevations, elevations of openings and first floors were estimated for 268 structures. In addition, structures were categorized according to style and quality.

In **TORONTO**, 1:2000 topographic mapping was obtained from the Metro Toronto Region Conservation Authority and the Credit Valley Conservation Authority. The 100 year flood line elevations plus an allowance for 0.6 m (2 ft) of wave run-up were transferred onto the maps and structures to be inventoried were identified. Low level oblique colour photography was available and was used to determine structure types and to evaluate shoreline characteristics and damage and erosion potential. Elevations were obtained for 55 structures at risk and structures either removed or added since the mapping was produced were identified and inventoried.

For **WINDSOR TO BELLE RIVER**, aerial photography and topographic mapping covering the study area was obtained. The study area was divided into 92 zones such that each zone had a relatively constant ground elevation. Based on this zone elevation, opening elevations for structures within each zone were estimated for 3199 structures and a quality assessment was made.

Stage-frequency curves were obtained for each site. For Montreal, the data were obtained from a 1985 report entitled, "Zones Inondables - Fleuve Saint-Laurent, Troncon - Lac Saint Louis - Varennes" prepared for the Quebec Ministry of the Environment. This report provided flood stages throughout the study area for the 2, 5, 10, 20, 50, and 100 year floods.

For the Toronto and Lake St. Clair sites, stage frequency data were obtained from Atria Engineering Hydraulics Inc. These data were the preliminary updates of the Basis of Comparison and were provided in the output format of the computer program HYDSTAT. Still water - surge frequency distributions were provided for the winter (January to March), spring (April to June), summer (July to September) and fall (October to December) seasons. The HYDSTAT program, which carries out a multivariate frequency distribution, provides frequency data for a number of distributions. For the purposes of this study, it was assumed that the Pearson III distribution could be used for all seasons for the still water, surge and combined distributions. Stage frequency distributions were also prepared for a number of the water level regulation scenarios that have been put forth for evaluation.

Based on the site inventories and the stage-frequency curves, inundation damages were calculated using the FLDAM computer program developed by Paragon Engineering Limited (1984). It was necessary to make several modifications to the program to deal with the data from the study. These changes were related to the fact that the range of flood levels for lake damages is generally smaller than those associated with river flood levels, for which the program was designed.

For Montreal, stage-damage curves were calculated for six reaches because of river slope and the presence of the Lachine Rapids. For Toronto, damage curves were calculated for the still water plus surge elevations. In addition, damages were calculated for an additional 0.6 m (2 ft) of flood depth due to waves. Calculations similar to those carried out for Toronto were completed for Lake St. Clair. However, because there is significant inland flooding in the Windsor to Belle River site, some additional assumptions were required to account for wave action and inland water levels. For the still water plus surge condition, it was assumed that this water level would be reached in both the shoreline and inland zones. However, for wave conditions, it was assumed that the increased depth associated with wave action would only be experienced along the shoreline. For inland reaches, the effect of waves would simply be to provide a mechanism for water to be transported inland.

Results

Each of the study areas selected for detailed inventory and analysis possess distinctly different attributes that make them unique in terms of both their characterization of conditions throughout the Great Lakes Basin, and the approach used in conducting the surveys and analysis.

The **MONTREAL** site differs from the others primarily in that it is riverine, as opposed to a lakeshore setting. Further, it is older and more established, and, as such the nature of the structures in the study area represents a wider diversity of characteristics. Many of the structures contain basements that consist of a drive down garage and an adjacent traditional basement. This feature complicated the assessment of damages, but is probably typical of some of the older riparian buildings in such a setting. Typically, basements in this study area were serviced by sump pumps, based on the experience of the past history of flooding potential, and the lack of connections to storm sewers. The quality and categories of structures encountered also varied widely, ranging from low quality one story with no basement to high quality two story with basements. Several apartment buildings were encountered in the study area, and special considerations were made to include them in the damage estimates. In addition, many structures combined both commercial and residential uses that reflects the established nature of this portion of the study area. Finally, it was apparent, both as a result of the site investigation and through interviews with local officials, that works had been completed to remediate conditions that contributed to flood damages experienced in the 1970's. These works included both changes to road grades and the installation of shoreline protection, that were included in the assessment of flood damage potential.

The **TORONTO** site, while categorized as Densely Populated Urban Residential for purposes of this study, more accurately represents a lakeshore development on the fringe of a densely populated urban residential area. The shoreline in the study area contains a variety of land uses, ranging from commercial through industrial to the residential sites inventoried. This reach of Great Lakes shoreline included in this study had the fewest number of structures, but they also tended to be of the highest quality. Further complicating the assessment of flood damages was the fact that many of the properties included outbuildings such as boat houses and garages. While the main residential structures were not necessarily exposed to flood risk, the value of the adjacent structures was often significant, and involved careful assessment to determine damage potential.

The **LAKE ST. CLAIR** site was both the most challenging and the most straightforward to assess. The challenge arose from the sheer number of residences to inventory, but at the same time, they were relatively easy to evaluate and categorize. This reach represents a typical shoreline cottage type development, although more recent construction demonstrates an abrupt change in both the quality of newer structures, and the incorporation of measures to mitigate the potential of flood related damages. As a result, damage estimates for this reach must be treated cautiously, since the rapidly evolving characteristics of this study area, both in terms of new structure design and recent flood control works, could lead to overestimates of damage potential.

INUNDATION DAMAGES were calculated at each site for the Base Case (BOC), as well as for the SMHEO-Optimized, SMHEO-50, ONT MOD 28B, and WET/DRY water level scenarios (see Working Committee 3 Report for full description of scenarios). Additional scenarios that were added in the late stages of the Reference Study were not evaluated due to budget and time restrictions. Damages were calculated for a range of wave heights and were quantified by calculating the "expected annual damage" at each site. For those sites where seasonal flood data were used, the expected annual damage was determined from the frequency data for each season, and then averaged to yield an annual value.

The expected annual damages for Lake St. Clair, Toronto and Montreal respectively, are found in FIGURES 5.1-5.3. The results are presented for each scenario, as well as by season. A more detailed discussion of the results is found in Paragon Engineering Limited (1992).

Results for **Lake St. Clair**, indicate that the Base Case and WET/DRY scenarios yield essentially identical damage estimates as compared to existing conditions, whereas the SMHEO-Optimized and SMHEO-50 scenarios result in successfully reduced damage estimates. For **Toronto,** results indicate that none of the scenarios result in decreased damages from those existing for the Base Case, and that the SMHEO-50 scenario actually increases expected annual damage by a factor of approximately 1.5. As with Toronto, results of the analysis for **Montreal** show that none of the scenarios results in reduced damages, and that once again, SMHEO-50 produces the largest increase in damage estimates.

<u>EROSION DAMAGES</u> - In reviewing the background documentation, areas that had been identified as having erosion problems or potential were noted for inspection during the field surveys. In addition, discussions were held with local officials concerning these problems. Almost invariably, the erosion sites visited by the contractor had been repaired and protected, resulting in very few areas where erosion susceptibility is a problem. In the case of **Lake St. Clair,** the potential exists for approximately 18 percent of the shoreline structures to require future investment due to damage to shore protection and erosion (Paragon Engineering Limited, 1992). Assuming an average cost of $5,000 for remedial works, and a 20 year time frame, this translates into an average annual cost of approximately $35,000. As it was felt that this cost was well within the range of costs associated with wave damages in the study area, it was concluded that erosion and shore protection damage costs are represented in the figures presented in Figure 5.1. Similarly, as the entire **Toronto** and **Montreal** shorelines are heavily protected, damage estimates associated with erosion, are accounted for in Figures 5.2 and 5.3.

<u>LOW WATER DAMAGES</u> - In addition to erosion problems, questions were asked concerning problems associated with low water levels. Although some concerns were raised related to marina owners in Montreal, and regarding odours associated with drinking water supplies during low water, no major issues were identified. In addition, as water intakes either were initially constructed well offshore, or had been extended after construction, there were no problems identified related to the security of water supplies.

The various scenarios analyzed, generally result in an overall lowering of the mean levels in Lake St. Clair. While the impacts of this on dock facilities, etc. was not quantifiable, interviews with local officials indicated that this lowering of levels would be a disbenefit to the study area.

Figure 5.1 Expected Annual Damages - Windsor to Belle River

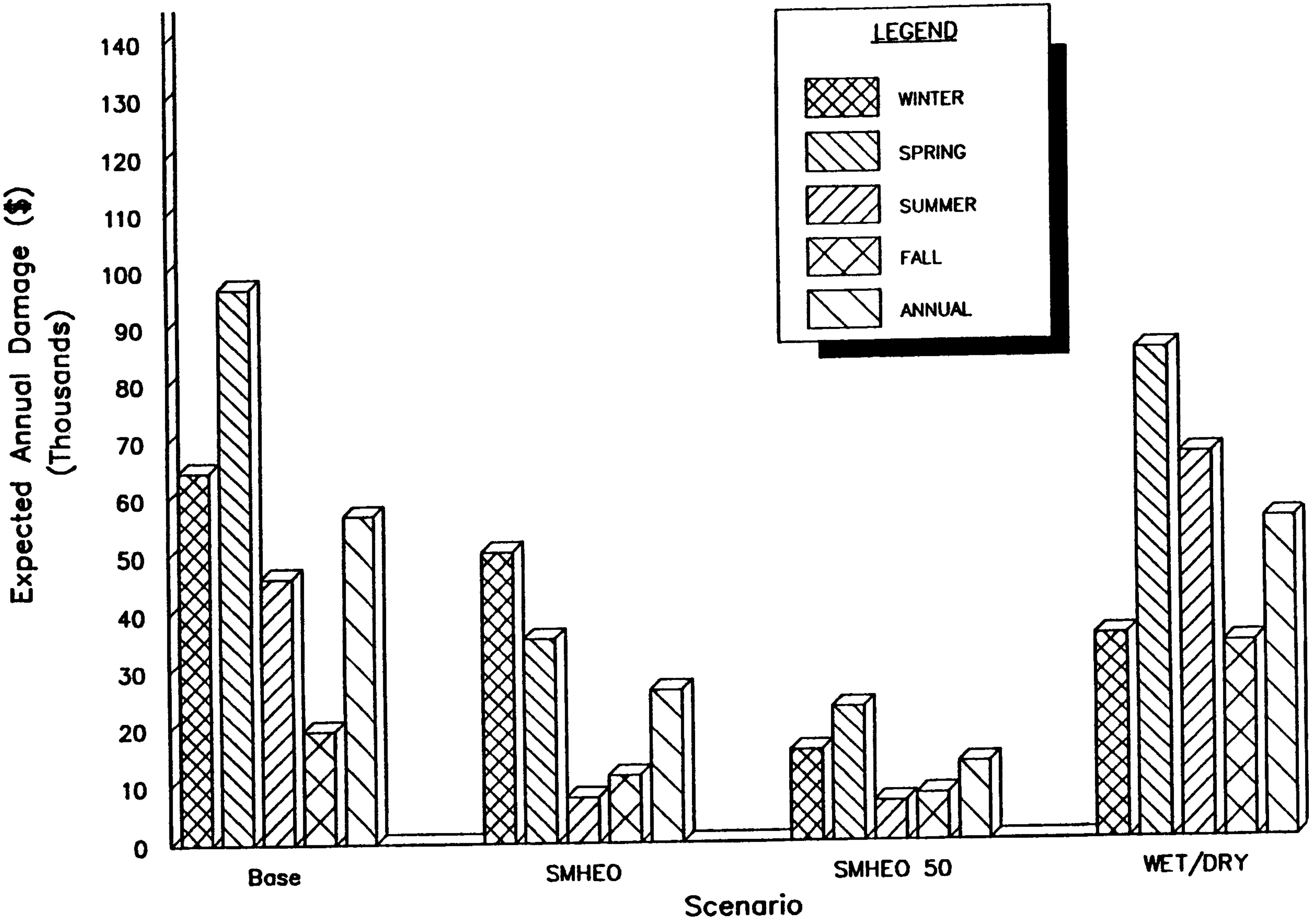


Figure 5.2 Expected Annual Damages - Toronto

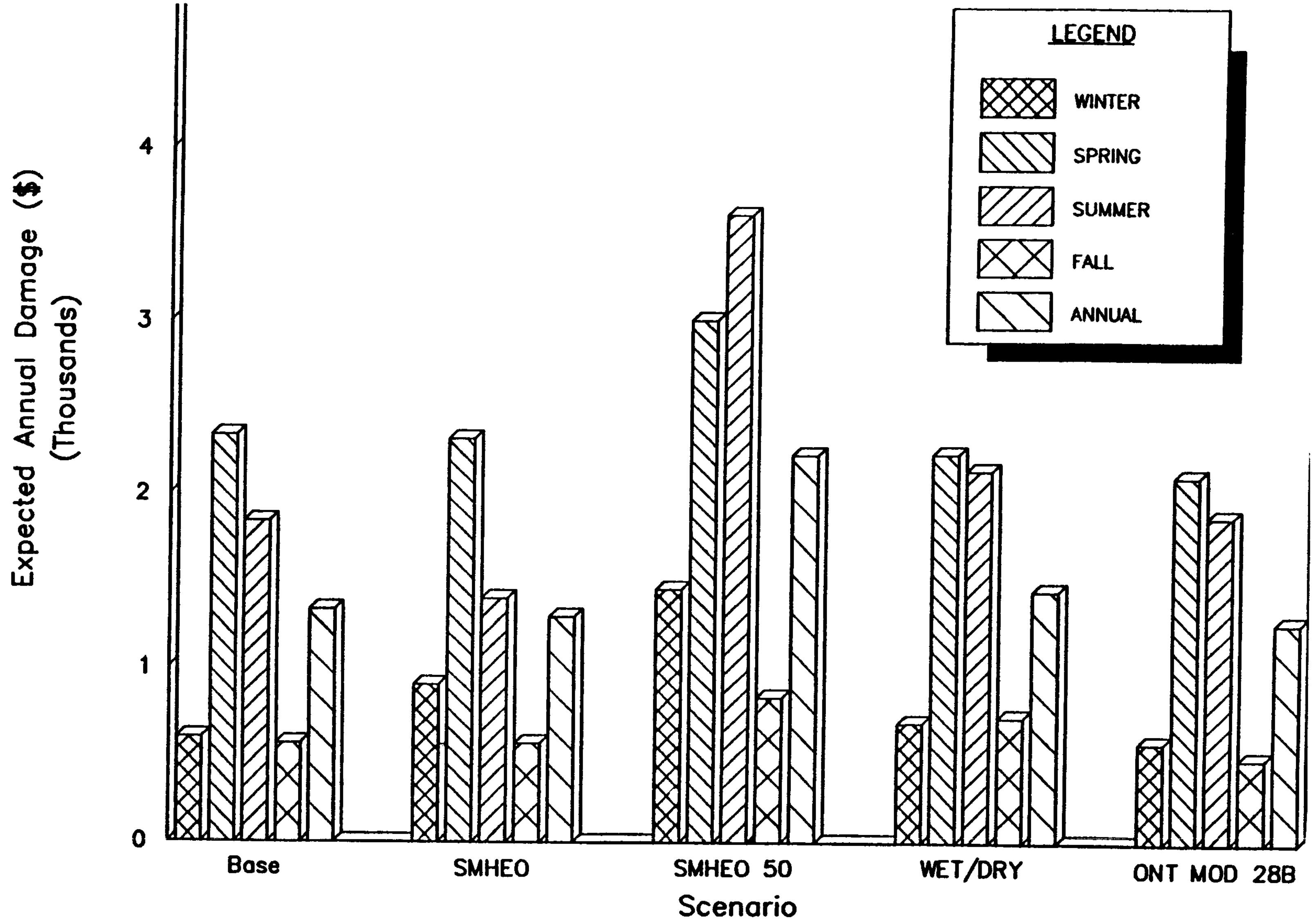
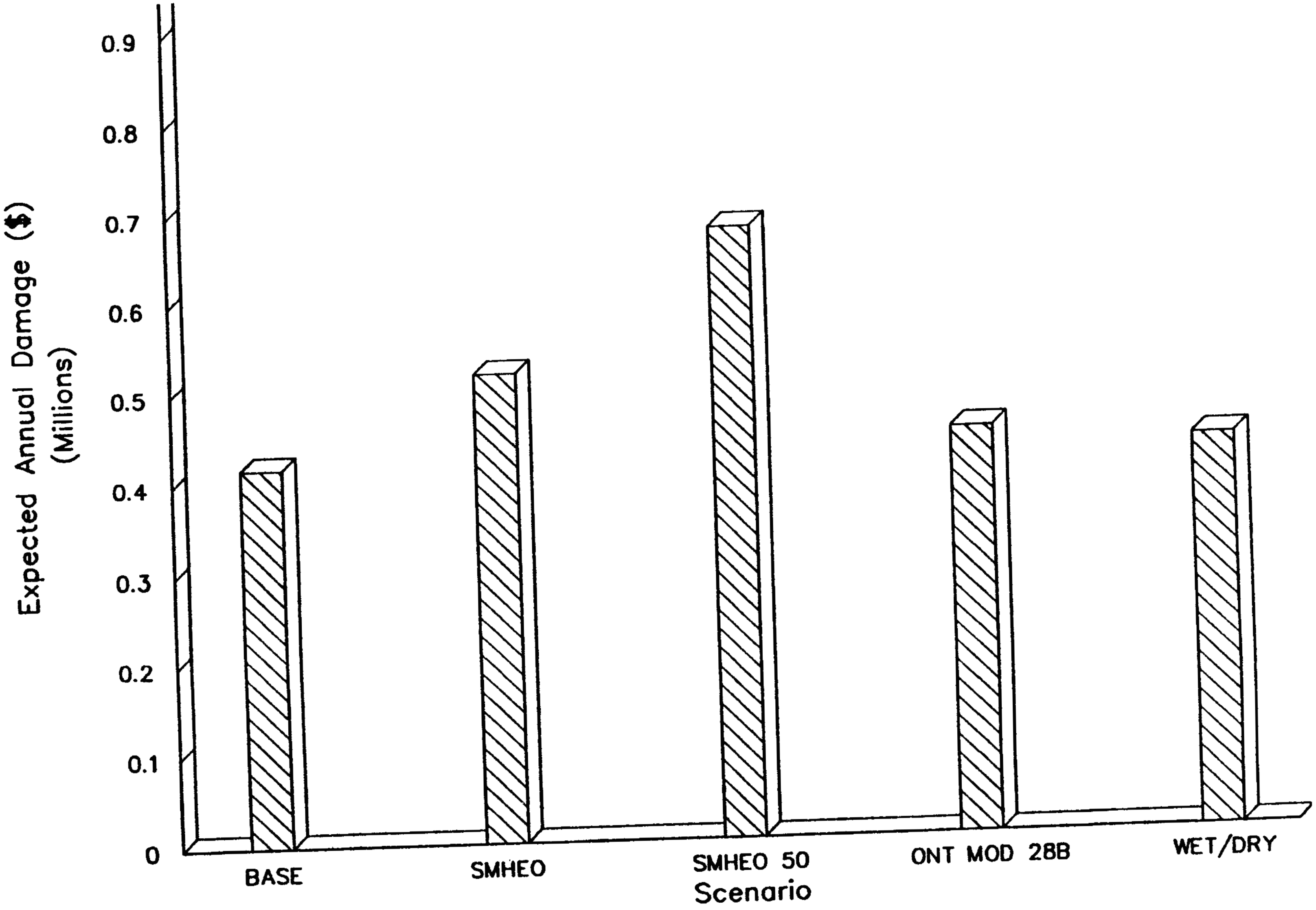


Figure 5.3 Expected Annual Damages - Montreal



Commercial / Industrial, Recreational and Agricultural Sites - Thunder Bay, Severn Sound, Central Lake Erie

Data Collection

A common methodology was adopted for each of the three sites under examination. First, a comprehensive literature review was undertaken to identify existing data available on damages at these three sites. Generally, the impacts are well identified, but little analysis has been made of the costs of impacts, or damages under different water level scenarios. The examination of damages at these sites will use some existing data and collect additional data to improve our knowledge of damages expected under specific water level regulation scenarios.

The work conducted at these sites considers the impacts of fluctuating water levels on each of the interest groups represented at each site (Commercial/ Industrial - Thunder Bay, Recreational - Severn Sound, Agricultural - Central lake Erie). In this way, the basin-wide analysis is better able to address differences in the extent and intensity of the problems experienced on particular bodies of water. An example of data being used for this part of the analysis is the Riparian Survey and Census conducted by Environment Canada.

Existing data sets were supplemented by surveys to collect additional data on estimated cost differences that the interest groups would anticipate with and without the measure in place. This survey was conducted initially by telephone, with supplementary mailouts used to collect detailed information on specific impacts. Further details on these surveys, including sample questionnaires, are provided in the report by the Water Network (1992).

In addition to the basin-wide analysis, the selected study sites were investigated to prepare more accurate estimates of damages with and without measures in place. This was carried out through field trips and detailed local investigation at each site.

Results

THUNDER BAY, ONTARIO - COMMERCIAL / INDUSTRIAL

Land Use: A total of 152 shoreline properties and 31 water lots were included in the study area. They covered an area of over 2200 hectares (5434 acres) and stretched along 28 kilometres (17.4 miles) of shoreline. Over 60% of the shoreline and 1000 hectares (2470 acres) were classified as industrial property. A further 20% of the shore and another 1000 hectares (2470 acres) was classed as railway lands. Other commercial uses like a marina raised the combined industrial / commercial use of the shoreline to 85% of the total. The 31 water lots accounted for a further 127 hectares (314 acres) of coastal properties. These however are in a special class as they are entirely submerged. Their frontage is not shoreline, but a measure of access to the lake. Smaller sections of Thunder Bay are used for cottages (5%), parks, amusement parks, clubs and marinas

(5%), and government property and vacant public land (5%).

Industrial property along Thunder Bay is used for a variety of purposes, with the largest group of industrial property owners being the grain elevator companies. They form an important component of the local economy and also experienced significant damage during the 1986 high water period. Other industrial uses include a shipyard, tug boat service, paper mills, food processing plants, petrochemical plants and power plants

Past Flood and Erosion Damages: Grain elevator companies experienced both increased operating costs and increased remedial capital costs during the record high water level period of 1986. Two operators reported increased operating costs of $125,000 as a result of the need to pump water out of facilities. Three companies incurred remedial capital costs totalling $1,000,000. Three others reported no damages. One company reported a loss of product valued at $8,200 due to high water. Erosion damages were reported by three grain elevators, with remedial costs for these totalling $86,000.

Of the nine other industries located in Thunder Bay, only two reported any adverse impacts. In both cases this was due to erosion of the property resulting in increased operating costs of $50,000 for one firm and remedial capital expenses of $200,000 for the other.

Potential Future Damages: For the grain elevator industries, all survey respondents reported no increase in flooding or erosion damages or costs if a future lake level were to equal that of 1986. This is due to the remedial measures put in place during the 1986 period. If however, levels were 30 cm (12 in) higher than that of 1986, one elevator reported that increased operating costs would be approximately $2,000,000 due to flooding. Another firm identified flooding damages but was unable to estimate potential increased operating costs. With regard to increased remedial capital costs for flooding, three grain elevators reported a total of $921,000. For erosion, only two elevators reported increases in remedial capital costs amounting to $130,000.

Grain elevator officials were also asked to predict damage or increased costs that would result if future lake levels were 90 cm (3 ft) lower than the spring of 1991. Qualitatively, all companies identified water transport problems that would necessitate dredging of the lake bottom. One company reported increased remedial capital costs totalling $2,500,000 to repair wood crib docks that would deteriorate when exposed to air. Another company reported a total potential cost of $84,000,000 if each of its 28 docks had to be replaced for the same reasons

For the other industries in Thunder Bay, none reported any increases in flood related costs if future levels were to exceed 1986 by 30 cm (1 ft). For erosion damages however, one company reported an increase in operating costs of $50,000 if levels were to equal those of 1986 and one other firm reported increased operating costs of $100,000 if future levels were to exceed 1986 levels by 30 cm (1 ft).

Only one of the other industries expected damages or increased costs if a future lake level was 60-90 cm (2-3 ft) lower than the spring of 1991 level. This would come primarily in the form of increased pumping costs of water. In addition, three other firms indicated that they would expect increased costs to be associated with navigation and shipping impacts.

Comparison of Damage Estimates By Water Level Scenario: Estimates of the costs of high and low water impacts for the industrial / commercial sector were derived for the BOC, SMHEO-50, SMHEO-Optimized, SEO, WET/DRY and ONT MOD 28B water level scenarios (see Working Committee 3 Report for full descriptions) based on the results of the industry survey for Thunder Bay and for other industries throughout the basin. A stage damage curve was derived from survey responses to construct a formula to estimate annual costs. The estimated annual cost was then calculated for each of the 90 years for which water level data was provided. Average annual costs were then calculated from 90 year time series data for each of the six scenarios. Basin-wide results are presented below in TABLE 5.3. Lake-by-lake figures can be found in The Water Network (1992) and the Potential Damage Task Group Report.

SEVERN SOUND, GEORGIAN BAY - RECREATIONAL

Land and Water Uses: The Severn Sound study area extends from the towns of Penetanguishene to Honey Harbour Ontario. The town of Midland, located at the centre of the study area, is approximately 142 km (88 miles) north of Toronto and is the largest population centre in the area (13,500). A total population of approximately 25,000 lives in the study area. Tourism and recreation is a significant contributor to the economy of the area. Seasonal visitors associated with over 8000 cottages and resorts create a summer population that is roughly four times that of the permanent local population. This generates approximately $1.1 billion tourism dollars per year, with over $15 million generated in the town of Midland alone.

The dominant recreational activities in the Severn Sound Area are pleasure boating (and associated marina use) and cottage based activities. The sound is in close proximity to over 30,000 islands and creates a haven for pleasure boaters in terms of scenic beauty and a place to anchor for picnics or camping. The aesthetics of the area have also attracted a large number of cottage owners to the area.

Past Flood and Erosion Damages: In general, very few erosion impacts due to high water were experienced by the individuals contacted. The lack of intense residential development and the fact that most developed shorefronts are protected by armourstone has limited the impacts. Georgian Bay Islands National Park experienced some minor impacts due to high water levels. In 1986, docks in the park were raised to accommodate high water levels. Some minor flooding took place, but with very little damage to buildings. High water levels were also reported to be beneficial to habitat, as park biologists noticed increases in rare coastal vegetation and breeding of certain amphibians. The Town of Midland did not experience any major impacts from the high water levels of 1985-1986. A few storms did cause flooding of the town dock, forcing short periods of closure. In the summer of 1988, the core of the dock collapsed (due to old age, not water levels) and the federal government spent $1 million rebuilding it. Some small boathouses

Table 5.3 Commercial / Industrial Potential Damage Estimates By Scenario - Canadian Shoreline

	Water Level Scenarios Evaluated*				
IMPACT TYPE	BOC	WET / DRY	SMHEO 50	SEO	SMHEO-Optimize
Estimated Future Operating Costs ($ million)					
Average Annual Flood Damage	.001	.045	.000	.000	.000
Average Annual Erosion Damage	.011	.012	.011	.007	.016
Totals	.012	.057	.011	.007	.016
Difference Relative To BOC	**.000**	**.045**	**-.001**	**-.005**	**.004**
Damage Estimates Based on Past Operating Costs ($ million)					
Average Annual Flood Damage	.043	.051	.027	.019	.039
Average Annual Erosion Damage	.000	.000	.000	.000	.000
Totals	.043	.051	.027	.019	.039
Difference Relative To BOC	**.000**	**.008**	**-.016**	**-.024**	**-.004**
Estimated Future Remedial Capital Costs ($ million)					
Average Annual Flood Damage	.000	.019	.000	.000	.000
Average Annual Erosion Damage	.000	.003	.000	.000	.000
Average Annual Low Water Damage	.320	.520	.280	.080	.140
Totals	.320	.542	.280	.080	.140
Difference Relative To BOC	**.000**	**.222**	**-.040**	**-.240**	**-.180**
Estimated Remedial Capital Costs Based on Past Expenditures ($ million)					
Average Annual Flood Damage	.228	.248	.221	.149	.313
Average Annual erosion Damage	.063	.068	.063	.043	.089
Totals	.291	.316	.284	.192	.402
Difference Relative To BOC	**.000**	**.025**	**-.007**	**-.099**	**.111**

***Note: ONT MOD 28B was not analyzed for commercial/industrial impacts.**

were impacted, and a local trailer park had to close a number of camp sites due to flooding. One marina spent $200,000 to convert his fixed docks to floating docks.

Past Low Water Damages: Impacts due to low water are a more important issue in Severn Sound due to the shallower water, reduced mooring opportunities and the increased risk of running aground faced by the recreational boating sector. Georgian Bay Islands National Park spent $100,000 to convert to floating docks. In 1991, one dock was not accessible for a short period of time, as water levels were too low for access (even though levels were right on their long term average range). Many boaters experienced damage to boats when running aground. An extreme example of this found one boater experiencing over $10,000 damage when both drives were ripped off his boat. In 1991, the Midland Bay Sailing Club spent $70,000 to dredge their channels and a trailer park spent $5,000 on lowering their docks and reported $8,000 in lost revenue due to camp site cancellations caused by low levels. Some boat charter companies reported lost business and experienced difficulty accessing areas where they normally could cruise. Another company had to convert to floating docks, while another experienced propeller damage (and resulting down time for repair) to their boats. Several lodges in the area reported minor impacts due to lower levels, including extra maintenance to docks, rebuilding of protective and recreational facilities and losses in revenue.

Comparison of Damage Estimates By Water Level Scenario: Estimates of the costs of high and low water impacts for the recreational sector were derived for the BOC, SMHEO-50, SMHEO-Optimized, SEO, WET/DRY and ONT MOD 28B water level scenarios (see Working Committee 3 Report for full descriptions) based on the results of the recreational surveys for Severn Sound and for other recreational interests throughout the basin. A stage damage curve was derived from survey responses to construct a formula to estimate annual costs. The estimated annual cost was then calculated for each of the 90 years for which water level data was provided. Average annual costs were then calculated from 90 year time series data for each of the six scenarios. Basin-wide results are presented below in TABLE 5.4. Lake-by-lake figures can be found in The Water Network (1992) and the Potential Damage Task Group Report.

CENTRAL LAKE ERIE - AGRICULTURAL

Land Use: An important component of the impact assessment for the agricultural sector involved the detailed analysis of the Central Lake Erie shoreline between Clear Creek and Port Glasgow, Ontario. Agricultural properties constitute approximately 78% of this shoreline, most of which are located on top of 25-40 metre (80-130 foot) high bluffs with high rates of recession. Approximately 16% of this shoreline is classed as residential, the majority of which is located in the town of Port Burwell. Small percentages are classed as government property (4%) and commercial/industrial (2%).

Table 5.4 Recreational Potential Damage Estimates By Scenario - Canadian Shoreline

	Water Level Scenarios Evaluated*					
IMPACT TYPE	BOC	WET / DRY	SMHEO 50	SEO	smheo OPT.	28B
Estimated Future Lodge / Resort Operating Costs ($ million)						
Average Annual Flood Damage	.038	.041	.024	.028	.039	.001
Average Annual Erosion Damage	.013	.014	.013	.012	.011	.008
Average Annual Low Water Damage	.019	.025	.005	.014	.008	.000
Totals	.070	.080	.042	.054	.058	.009
Difference Relative To BOC	**.000**	**.010**	**-.028**	**-.016**	**-.012**	**-.061**
Lodge / Resort Damage Estimates Based on Past Damage ($ million)						
Average Annual Flood Damage	.060	.061	.051	.049	.063	.015
Average Annual Erosion Damage	.032	.034	.033	.030	.034	.011
Totals	.092	.095	.084	.079	.097	.026
Difference Relative To BOC	**.000**	**.003**	**-.008**	**-.013**	**.005**	**-.066**
Estimated Future Lodge / Resort Remedial Capital Costs ($ million)						
Average Annual Flood Damage	.045	.048	.027	.036	.034	.003
Average Annual Erosion Damage	.010	.011	.009	.005	.010	.001
Average Annual Low Water Damage	.240	.260	.110	.210	.140	.002
Totals	.295	.319	.146	.251	.184	.006
Difference Relative To BOC	**.000**	**.024**	**-.149**	**-.044**	**-.110**	**-.289**
Estimated Future Damages To Parks ($ million)						
Average Annual Flood Damage	.052	.064	.038	.010	.019	.015
Average Annual Erosion Damage	.120	.120	.110	.110	.110	.009
Average Annual Low Water Damage	.009	.014	.002	.007	.003	.000
Totals	.181	.198	.150	.127	.132	.024
Difference Relative To BOC	**.000**	**.017**	**-.031**	**-.054**	**-.049**	**-.157**

Past Flood and Erosion Damages: Due to the high nature of the bluffs in this area, agricultural properties have not suffered any flood impacts. In addition, only a few farmers used Lake Erie water for irrigation purposes, or experienced impacts during periods of low water levels. The primary water level impact is that of the continued recession of the bluffs and resulting loss of farm property. To determine the nature of these impacts, recession rates were obtained and analyzed to determine the quantity and value of agricultural land being lost per annum. In addition, information on the major field crops being grown was requested in order to obtain an idea of the potential capability of land being lost into Lake Erie. These result are summarized below.

Of seven farms that were visited in this area, all experienced erosion to some degree. This degree varied somewhat, but several of the properties suffered land losses that can be regarded as severe. Erosion problems were particularly severe on farms in Southwold Township, Elgin County. One farmer estimates he has lost 5.3 hectares (13 acres) of arable land since 1963, another estimates a loss of 9 hectares (22 acres) since 1953. A third farmer, whose property is subject to severe gullying, estimates he has lost 12-14 hectares (30-35 acres) since 1947. Lesser erosion losses were reported by farmers in Yarmouth Township. All farmers felt that erosion problems were exacerbated by high lake levels, but that problems resulting from groundwater percolation (causing gullying) were as, if not more significant, a problem over time.

An analysis of recession rates on a reach-by-reach basis was undertaken as a part of this task. It was estimated that approximately 6.7 hectares (16.5 acres) of land are lost annually to erosion. Assuming an average value of $5,000 per hectare (or approximately $2025 per acre) , the value of lost agricultural land is approximately $34,000 per annum (see TABLE 5.5).

Comparison of Damage Estimates By Water Level Scenario: Estimates of the costs of high and low water and erosion impacts for the agricultural sector were derived for the BOC, SMHEO-50, SMHEO-Optimized, SEO, WET/DRY and ONT MOD 28B water level scenarios (see Working Committee 3 Report for full descriptions) based on the results of the agricultural surveys for Central Lake Erie and for other agricultural interests throughout the basin. A stage damage curve was derived from survey responses to construct a formula to estimate annual costs. The estimated annual cost was then calculated for each of the 90 years for which water level data was provided. Average annual costs were then calculated from 90 year time series data for each of the six scenarios. Basin-wide results are presented below in TABLE 5.6. Lake-by-lake figures can be found in The Water Network (1992) and the Potential Damage Task Group Report.

5.3.3 United States Study Sites

The information presented below has been summarized from a series of "Site Study Reports" prepared by the Buffalo and Detroit District Offices of the U.S. Army Corps of Engineers. As of the publication of this report, information for some study areas was not yet complete and could not be summarized here. Where this occurs, information can be found in both the Site Study Reports, and in the Potential Damages Task Group Report.

Table 5.5 Central Lake Erie - Annual Recession Rates and Land Loss Cost By Reach

REACH	Sector Length (m)	Recession Rate (m/yr)	Land Loss (m2/yr)	Unit Cost ($/m2)	AGRI. Loss	AGRI. Cost
W. GR. CANYON	880	1.3	1109	$0.50	1109	$555
W. GR. CANYON	1530	1.2	1867	$0.50	1867	$934
W. GR. CANYON	270	1.4	389	$0.20		
W. GR. CANYON	740	1.3	984	$0.50	984	$492
W. GR. CANYON	790	1.0	774	$ 0.50	774	$387
W. GR. CANYON	260	0.9	221	$0.20		
W. GR. CANYON	330	1.4	469	$0.50	469	$235
W. GR. CANYON	690	1.3	863	$0.50	863	$432
GRAND CANYON	760	1.4	1026	$10.00		
GRAND CANYON	320	1.4	448	$10.00		
GRAND CANYON	380	1.7	650	$0.20		
GRAND CANYON	770	1.4	1086	$35.00		
PORT STANLEY	3050	0.0	0	$35.00		
E. ORCHARD BCH	330	4.2	1383	$35.00		
E. ORCHARD BCH	1440	3.2	4666	$0.20		
E. ORCHARD BCH	950	2.1	1967	$0.50	1967	$984
PUMP STATION	400	1.7	676	$0.50	676	$338
E.PUMP STATION	1030	1.7	1782	$0.50	1782	$891
E.PUMP STATION	860	2.2	1858	$0.50	1858	$929
E.PUMP STATION	930	2.4	2260	$0.50	2260	$1130
E.PUMP STATION	1940	1.6	3162	$0.50	3162	$1581
E.PUMP STATION	1060	1.3	1389	$0.20		
E.PUMP STATION	540	1.1	616	$0.20		
CTY. ROAD 24	1250	1.5	1825	$0.50	1825	$913
CTY. ROAD 24	600	1.2	726	$10.00		
CTY. ROAD 24	1870	1.6	2992	$10.00		
SPARTA	11600	1.8	21228	$0.50	21228	$10614
SPARTA	1500	0.3	375	$35.00		
MOUNT SALEM	200	0.7	130	$35.00		
MOUNT SALEM	9000	1.7	15660	$0.50	15660	$7830
PORT BURWELL	5000	2.1	10500	$0.50	10500	$5250
PORT BURWELL	3100	0.4	1085	$35.00		
DSZ 1-2	2320	0.1	232	$60.00		
DSZ 1-2	3030	0.1	303	$60.00		
DSZ 2-1	300	0.3	90	$5.00	90	$450
DSZ 3-1	2540	0.5	1270	$60.00		
DSZ 3-4	4140	0.5	2070	$60.00		
DSZ 4-1	4342	0.2	868	$60.00		
DSZ 4-2	3329	0.2	666	$60.00		
DSZ 4-3	4316	0.2	863	$60.00		
DSZ 4-4	4598	0.2	920	$60.00		
TOTAL	83285				67074	$33943

Table 5.6 Agricultural Potential Damage Estimates By Scenario - Canadian Shoreline

	Water Level Scenarios Evaluated*					
IMPACT TYPE	BOC	WET / DRY	SMHEO 50	SEO	smheo OPT.	28B
Estimated Future Flood and Erosion Damages To Farms ($ million)						
Average Annual Flood Damage	.071	.076	.073	.045	.061	.050
Average Annual Erosion Damage	.049	.049	.047	.046	.046	.006
Totals	.120	.125	.120	.091	.107	.056
Difference Relative To BOC	**.000**	**.005**	**.000**	**-.029**	**-.013**	**-.064**
Estimated Future Pumping Costs and Dyke Repair ($ million)(Lake Erie Only)						
Average Annual Pumping Costs	.064	.064	.060	.060	.060	n / a
Average Annual Dyking Costs	.046	.051	.004	.002	.001	n / a
Totals	.110	.115	.064	.062	.061	n / a
Difference Relative To BOC	**.000**	**.005**	**-.046**	**-.048**	**-.049**	**n / a**

Duluth, Minnesota / Superior, Wisconsin

Land Use: Duluth/Superior is located at the western tip of Lake Superior and is the boundary between the states of Minnesota and Wisconsin. The two cities are separated by the St. Louis River. Land use in the area is predominantly commercial and industrial, composing almost 38% of the Duluth shoreline, and 45% of the Superior shoreline. "Other" uses, such as beaches, wetlands, forest, bedrock and other undeveloped lands, occupy 31% of the Duluth shoreline and 52% of the Superior shoreline.

With the predominance of commercial and industrial uses, a large portion of the study area (58% in Duluth and 64% in Superior) is considered artificial and is heavily protected with shore protection structures. Wetlands and baymouth-barriers are also present and are largely unprotected.

Past Flooding, Erosion and Low Water Damage: A reach study investigation for Reaches 9001 and 9002 was documented in the report "Lake Superior Damage Assessment of Reaches 9001 and 9002 for High Water of 1985 - 1986" (DeCooke, 1990). This investigation was conducted to determine whether the damage estimates from the States of Minnesota and Wisconsin were consistent with those which had been previously reported. Results showed that Minnesota damages had been overstated and Wisconsin damages understated, and the damage models did not reflect current developments. An update of the stage-damage curves for this area, which incorporated these investigations was documented in the report "Great Lakes Shoreline, United States, Inundation and Erosion Stage-Damage Relationships" (DeCooke, 1991).

The inundation relationship for reach 9002 utilizes water levels recorded at Duluth, Minnesota. The 1985 - 1987 period had a maximum level approximately 23 cm (0.75 ft) higher than the 1972 - 1975 period. A level of 183.8 m (602.5 ft)(IGLD 1955) was exceeded 39% of the time in 1985- 1987 and 8% of the time in 1972 - 1975. Marketing Survey/Census data, prepared in 1989 by the Chicago District Corps of Engineers, showed an approximate 12% increase in private development along the Lake Superior shoreline since 1979. A 1979 survey showed that in reach 9002 there were 185 homes within 100 feet of the water's edge, while the 1989 survey indicated that approximately 25% of these homes have been flooded at least once. The relationship was updated and adjusted to reflect damages from the 1972 - 1976 and 1985 - 1987 periods and higher levels.

The updated erosion relationship for reach 9002 produced damages approximately $582,000 less than what was recorded for the period 1985 - 1987. The greater damage could be attributed to the increase in value along the shoreline and in part the storm conditions which caused the damage during the 1985 - 1987 period (DeCooke, 1991).

Chicago, Illinois

Land Use: Chicago, Illinois is located along the southwestern shore of Lake Michigan. The site study went beyond the city limits and is comprised of the two Illinois counties (Cook and Lake) with Great Lakes shoreline. The study area is bordered on the north by Kenosha County in Wisconsin. It contains the shoreline communities of Waukegan, Evanston and several others; Illinois Beach State Park; a Federal deep-draft harbor at Chicago; and the Lake Michigan Diversion at Chicago. Lake County is comprised of five townships, and Cook County has two townships and the city of Chicago.

Land use along this shoreline is dominated by public and "other" uses. In Cook County, over 53% of the shoreline is public use, most of this being the extensive parkland along the Chicago waterfront. In Lake County, 79% of the shoreline falls into the "other" category. It should be noted however, that over two-thirds of this is comprised of beaches and sand dunes. These areas are most likely privately owned. The residential development on these lands is set back such that the shoreline land use evaluation yields a classification other than residential. Since these properties are actually "developed" further back, the possibility of further development is remote. In response to a questionnaire about land use, Lake and Cook Counties foresee no change in 10-year land use development trends.

The Lake County shoreline is composed mainly of high till bluffs fronted by beaches (40%) along with baymouth-barriers (37%). Relict sandy beaches comprise another 19% of this shoreline. The Cook County shoreline on the other hand, is predominantly artificial (74%) with only 11% each, composed of till bluffs with beaches and relict sandy beaches / dunes. The level of shoreline protection in each county reflects the shore type, with over 73% of the Lake County shoreline having minor protection and almost 74% of the Cook County shoreline being heavily protected. Sand and gravel comprise the material found in the offshore zone of both counties.

Past Flooding, Erosion and Low Water Damages: The principal problem in the Chicago area is damages to shore protection structures. The Illinois State Geological Survey (ISGS) published a report in April 1989 titled "High Water Damage Costs, Illinois Shore of Lake Michigan - 1986 Through 1988". This report was prepared to summarize the condition of the Illinois shore of Lake Michigan, as of summer 1988, in terms of existing damage, construction and repair projects, and costs to governmental agencies and private riparians.

This report verified that the extensive revetments along the Chicago lakeshore were many years beyond their design life, had been poorly maintained and were in a state of disrepair and decay for some time. Nearly half of the Chicago shoreline was in need of immediate action during the 1986 - 1987 high water levels, with an additional 20% needing repairs.

Federal government expenditures for several projects in Chicago totalled nearly 4 million dollars, with State of Illinois expenditures totalling 1.2 million dollars and City of Chicago expenditures totalling 3.2 million. The shoreline area north of Chicago also had large expenditures during this period as follows: Federal, 2.8 million; State of Illinois, 0.75 million; various municipalities, 6 million; and private riparian, 2 million.

In addition, the ISGS produced a "Coastal Atlas, Illinois Shore of Lake Michigan, Revised 1987-88". This atlas shows the shore features, properties, damaged areas, new construction and shore stabilities. It provides a broad overview of the features and condition of each property as of 1988 and is intended to be a guide to areas of concern. Each of the individual 59 maps provides information on specific areas of damage and areas of construction.

Berrien County, Michigan

Land Use: Berrien County is comprised of seven townships, located along the eastern shore of Lake Michigan and is the southern-most county in Michigan. It is bordered on the north by Van Buren County, and on the south by LaPorte County, Indiana, with most locations being within a two-hour drive from Chicago, Illinois. It contains the shoreline communities of St. Joseph, Benton Harbor and New Buffalo; the Warren Dunes and Grand Mere State Parks; a Federal deep-draft harbour at St. Joseph; and recreational boat facilities at New Buffalo and St. Joseph.

Land use in Berrien County is primarily residential riparian (56.8%), with small percentages of commercial (1.2%), public (2.7%), and agricultural (0.4%). The remaining 38.9% falls into an other/undeveloped category, being predominately beaches, sand dunes, woodlands, and outdoor recreation facilities. Land use trends are expected to see continued development pressures as long as undeveloped property remains available.

Berrien County's shore type is predominantly high till bluff with beach (55.9%), followed by high till bluff (>15 m (50 ft)) (31.0%). The majority of the shoreline has minor protection (69.3%) and the nearshore composition is 78.8% sand/gravel lag over clay.

Past Flooding, Erosion and Low Water Damages: The principal problem in Berrien County is bluff line recession which translates into economic loss of property value in the coastal zone. Erosion of beaches and bluffs generally occurs throughout the county's shoreline, particularly during periods of high water. The composition and orientation of the shoreline, the bathymetry of the Lake Michigan nearshore zone, and high water levels have led to considerable erosion and attendant recession of the bluff crest along the shoreline.

The most recent update to damages was documented in the report "Great Lakes Shoreline, United States, Inundation and Erosion Stage-Damage Relationships" (DeCooke, 1991). This update incorporates inundation and erosion damages resulting from the high water period 1985 - 1987.

The inundation relationship for reach 7006 utilizes water levels recorded at Calumet Harbor, Illinois. The 1985 - 1987 period had levels approximately 10.5 cm (0.35 ft) higher than the 1972 - 1975 period. A level of 177.2 m (581.0 feet (IGLD 1955) was exceeded 53% of the time in 1985- 1987 and 76% of the time in 1972 - 1975. Also, a maximum monthly peak level of 582.0 feet (IGLD 1955) was exceeded 30% of the time in 1985 - 1987 and only 1% of the time in 1972 - 1975. This analysis showed damages for the 1985 - 1987 period would be slightly higher than that of the 1972 - 1975 period (with no consideration of additional development). The property along the shoreline of this reach was highly priced and most new construction would include the placement of protective works (DeCooke, 1991). The relationship was updated and adjusted to reflect the 1985 - 1987 damage data and higher levels.

The updated erosion relationship for reach 7006 produced damages of approximately one million dollars more than what was recorded for the period 1985 - 1987. The lesser damage could be attributed to the protection which had been placed. The erosion stage-damage relationships were adjusted to reflect the recorded damages (DeCooke, 1991).

A follow-up study to update the stage-damage relationships for four selected reaches, including reach 7006, was undertaken in 1992 to apply the most reliable documented shoreline damages recorded during the mid 1980's high water period. Additional field data was collected for reach 7006 during February through April 1992 for use in this update. This study is reported in Argiroff (1992).

During December 1985 a storm caused bluff lines to move up to 2.5 meters (8 feet) inland almost overnight, toppling homes, erasing beaches and causing the worst case of erosion in a decade. Fourteen homes were destroyed and approximately 140 more were left within 10 meters (32 feet) of the eroded bluffs.

The majority of the protective structures utilized along the shoreline in reach 7006 were installed to prevent erosion. Groins and revetments are most often used. The toe of the bluff is often revetted to minimize undermining of the bluff. 166 permits were issued for reach 7006 during 1984 - 1987, with 137 including protection features. Of these, 114 were residential, 15 commercial/industrial and 8 for public use. The estimated cost of installing these protective works was $3.2 million, with $1.9 million for residential, $0.85 million for commercial/industrial and $0.45 million for public/institutional.

This study determined that the methodology developed in the 1981 Lake Erie Study and updated by 1985 -1986 recorded and estimated damages appears to be the best means of accomplishing the goals of the Potential Damages Task Group (Argiroff, 1992).

Comparison of Damage Estimates By Water Level Scenario: A detailed analysis of possible changes in erosion damages under reduced water level range scenarios was undertaken for this site. Results of this analysis are summarized in Section 5.4. Further details on the Berrien County area can be found in the appropriate detailed site study report being prepared by the Detroit District Office of the U.S. Army Corps of Engineers and the Potential Damages Task Group Report.

Ottawa County, Ohio

Land Use: Ottawa County is located north and west of Sandusky Bay in Ohio. It lies along the south shore of Lake Erie and includes several small islands in the lake. The county covers 655 sq. km (253 sq mi) in area and approximately 85 km (53 mi) in shoreline length. Land use along the shoreline is widely varied, consisting of several wildlife areas, state parks, beaches, marinas and townships. There are also a number of summer homes and trailer parks. Inland areas are primarily farmland with many small villages and some commercial enterprises.

Two distinct geological regions are present in Ottawa County. Land west of Port Clinton is generally flat, rising gently to the southwest. The land in the eastern portion of the county, including the lake islands, is composed of hard rock outcrops, generally characterized by sharp bluffs rising above the lake level along the northern shore and tapering down toward the south.

Past Flooding, Erosion and Low Water Damages: The flooding and erosion problems along the shoreline of Ottawa County are controlled by lake level, wave action, current patterns, offshore topography, shoreline material and the activities of man.

The islands located between Marblehead and Pelee Point form a barrier which protects the study area from the long easterly fetch of Lake Erie, and hence from easterly storms. Westerly storms, while having high winds of long duration, have no significant fetch over which to generate significant wave activity.

Much of the Ottawa County shoreline is low-lying, being generally less than 1.5 m (5 ft) above the average lake levels. Because of this, flooding from the lake can extend several kilometres (miles) inland. The floodprone area in Ottawa County is approximately 9300 hectares (23,000 acres). Shoreline erosion takes place in areas all along the Lake Erie shoreline. It is particularly evident in the area of East Harbor State Park.

Comparison of Damage Estimates By Water Level Scenario: Stage-frequency relationships, for still water levels only, for the Basis of Comparison and 8 other regulation plans were provided for Ottawa County (see Table 5.7). Existing wave run-up data for this area was added to the still-water frequency curves to establish a final storm induced frequency curve. This curve was used in the damage calculations for the residential and commercial categories. The still water levels were used for the calculation of agricultural damages.

The evaluation of residential property along the shoreline was restricted to the major population areas. Existing stage damage relationships were updated to 1991 price levels by using ENR Building Cost Index Values. Commercial and industrial damages, centred around the City of Port Clinton were also updated in the same fashion.

Table 5.7 Expected Annual Inundation Damages ($1000) - Ottawa County

Plan Name	Residential	Commercial	Agricultural	Total	Difference From BOC
BOC	223.67	111.99	306.77	642.43	0
SEO Combined	73.51	37.92	33.20	144.63	497.80
58D / 28B MOD	223.67	111.99	306.77	642.43	0
1977A W/O C	223.67	111.99	306.77	642.43	0
58D MOD 35P	223.67	111.99	306.77	642.43	0
58D MOD 35Z	223.67	111.99	306.77	642.43	0
SO SUP -.5 Ft, 58D MOD 35P	206.06	104.25	204.14	514.45	127.98
1977A MOD, 58D MOD 35P	198.44	100.38	186.61	485.43	157.00
SEO Extended	47.91	24.52	12.56	84.99	557.44

To determine total annual crop damages to agriculture, the first step was to establish the gross revenue per acre of cropland. Land use maps were planimetered to determine the amount of cropland in the floodplain. The average yield per acre for each crop type was obtained from the Ohio Department of Natural Resources. Normalized prices for the crops grown were obtained from the U.S. Department of Agriculture. Maximum potential loss per acre was determined by multiplying the gross revenue per acre by a seasonal adjustment factor, which was based on the amount of time the crop is in the ground. Potential agricultural loss was determined by multiplying the maximum adjusted potential crop loss per acre by the amount of acres devoted to that crop at a particular stage.

Expected annual inundation damages for the residential, agricultural and commercial interests in Ottawa County are found in TABLE 5.7

From this table, it is clear that the SEO Extended and SEO Combined scenarios provide the greatest potential benefit in this study area, with potential average annual benefits of approximately $557,500. and $498,000 respectively.

A detailed analysis of possible changes in erosion damages under reduced water level range scenarios was undertaken for this site. Further details on the Ottawa County area can be found in the appropriate detailed site study report being prepared by the Detroit District Office of the U.S. Army Corps of Engineers and the Potential Damages Task Group Report.

Hoover Beach, New York

Land Use: Hoover Beach is located at the eastern end of Lake Erie, just south of the City of Buffalo, in the Town of Hamburg. The total length of shoreline within the study area is approximately 865 metres (2840 feet). The shoreline is composed primarily of a low, erodible bluff, ranging from 3-6 m (10-20 ft) in height. This bluff is fronted in spots by a small beach and is broken by a shale outcrop in the mid-portion of the study area.

The area is classified solely as a residential community with a wide variety of home styles. They are predominantly occupied year-round, with a small number of seasonal cottages. There are approximately 100 homes located in this area, ranging in value from $20,000 to $116,000. There are no commercial, industrial, agricultural, marina or recreational uses, either public or private, located within the area. There is a small amount of beach located lakeside of the privately constructed seawalls. This beach varies in width and is used solely by the individual property owners.

Past Flood, Erosion and Low Water Damages: Flood damage has occurred in this area due to a combination of wave overtopping of shore protection structures by up to 4-5 m (12-16 ft) of water during extreme storm surge events and poor interior drainage. Erosion damage is primarily limited to the small beachfront area in front of the private seawalls. The fact that these seawalls are vertical and not uniform along the shoreline also exacerbates the erosion problem, as wave energy is deflected downward and scours sand away from the base of these walls. This leads to failure of the shore protection structure.

Extreme wave activity during storm events, combined with the presence of ice has also created problems in the past, as waves carried large chunks of ice and other debris through and into buildings causing extensive damage. Proximity of development was also identified as a problem, as home are located directly in the run-up zone of some of the larger storm waves.

Comparison of Damage Estimates By Water Level Scenario: Stage-frequency relationships, for still water levels only, for the Basis of Comparison and 8 other regulation plans were provided for Hoover Beach (see TABLE 5.8). Historical information was used to develop a wave run-up factor to be applied to the frequency relationship. Using data on estimated damage, stillwater lake elevations, storm frequencies and wave run-up, final storm-induced frequency curves were produced and used to compute annual damages.

The development of these curves was supplemented by data collected during a limited damage survey of the area. Data was obtained on structure values, structure types, first floor elevations and lowest opening elevations. Value of contents was assumed to be 50% of the structure value. Damages were estimated at various flood depths and were based on the cost of repair, the depreciated value, or replacement cost. All values are expressed in 1991 dollars. Information was collected primarily on residential structures. Damages to public and other infrastructure would be minor and were only qualified in this analysis.

Expected annual damages for the various regulation plans and the base case were calculated and are presented in TABLE 5.8. This amount represents the damage that can be expected to occur during any given year.

It is clear from this table that the SEO Extended Plan provides the greatest reduction in potential flood damages to the Hoover Beach area, amounting to just under $30,000 per year. As erosion damage and low water damage are considered minor, or non-existent in this study are, they would essentially remain unaffected by implementation of any of the water level scenarios.

Oswego County, New York

Land Use: The Oswego County shoreline, which is approximately 55 km (34 mi) in length, consists of a variety of shoreline types, ranging from a series of drumlins and marshes west of the City of Oswego, New York, to high bluff shorelines just east of the City, and barrier beaches / dune complexes further to the east. Land use along the shoreline is as follows:

Table 5.8 Expected Annual Damages ($1000) - Hoover Beach

Plan Name	Residential EAD	Difference From BOC
BOC	49.15	0
SEO Combined	32.48	16.67
58D / 28B MOD	49.15	0
1977A W/O C	49.15	0
58D MOD 35P	49.15	0
58D MOD 35Z	49.15	0
SO SUP -.5 Ft, 58D MOD 35P	49.15	0
1977A MOD, 58D MOD 35P	49.15	0
SEO Extended	20.08	29.07

Low-density residential	37%
High-density residential	8%
Forest	34%
Ploughed	4%
Inland water, wetland, barren brushland, grassland	17%

There is s Federal deep-draft harbour at Oswego and a small boat harbour at Port Ontario that provides an entrance to the Salmon River. Selkirk Shores State Park is located in the vicinity of Port Ontario. There are marinas, launch ramps and yacht club facilities located in Oswego, Mexico Bay, Port Ontario and North Pond, as well as other locations along the shoreline. A large part of the frontage of Oswego County is considered natural wildlife habitat as large marsh areas are found in many places. Industrial use has increased in the county due to the construction of an aluminium plant and a nuclear power production facility near Oswego.

Past Flood and Erosion Damages: The shoreline of this county is subject to significant erosion where unprotected, except for a few short reaches where bedrock rises high enough above lake level to armour the toe of the bluff against wave attack. Approximately 4 km (2.5 mi) of shoreline is protected in the county. Over half of this total is accounted for behind the breakwaters of Oswego Harbour. Over 1.3 km (0.9 mi) of the shoreline of Selkirk Shores State Park is also protected.

Flooding does not appear to be a significant problem in the study area, as the commercial and industrial areas in Oswego are at elevations unaffected by high lake levels. Some flooding has occurred in low lying areas around bays, ponds and barrier beaches, but not to any significant extent.

Comparison of Damage Estimates By Water Level Scenario: Zero damage elevations for the commercial and industrial areas are higher than the 500 year lake level. The expected average annual damages are considered to be zero for base case and for all plans of improvements.

A detailed analysis of possible changes in erosion damages under reduced water level range scenarios was undertaken for this site. Further details on the Oswego County area can be found in the appropriate detailed site study report being prepared by the Detroit District Office of the U.S. Army Corps of Engineers and the Potential Damages Task Group Report.

Alexandria Bay, New York

Land Use: Alexandria Bay is located on the St. Lawrence River approximately 47 km (29 mi) downstream of Cape Vincent, New York. It's shoreline length is approximately 4 km (3 mi) and includes several small islands in the river. Most of the available coastline in the area has been developed, primarily with recreational facilities and summer cottages and resorts. Several inlets have been dredged and enlarged into marinas. The islands are mainly uninhabited with few structures.

Land ownership along the shoreline is privately held with minimal public ownership. Tourism is a major part of the economy, with the offshore islands being the prime attraction. Many lodging and business establishments are located along the shoreline, most of which have docks or boathouses available for rent.

The physical terrain in the study area is intermittently tree covered and slopes gently northward towards the river. The shoreline in Alexandria Bay is somewhat protected from the predominating westerly winds. East or northeast winds, however can generate sufficient enough wave activity to cause damage.

Past Flood, Erosion and Low Water Damage: The majority of Alexandria Bay is very high and on rock. Many businesses and marinas however, are located only a few feet above normal river levels, and can be subject to flooding from high water levels and wind-generated waves. Past damages however have been relatively minor.

Past problems have centred more on low water levels due to the large and important boating industry in the region. Low water levels have resulted in the grounding of boats, resulting in damage to hulls and motors, and the loss of boat use due to the inability to enter and leave boat slips. Marina and resort owners in the region have been forced to remove boats from the water earlier than they would like, and refund dock usage fees and / or refrain from accepting reservations. The degree of economic loss to the community is very much dependent upon the time of year that levels are too low to allow boating.

Comparison of Damage Estimates By Water Level Scenario: Stage-frequency relationships for the Basis of Comparison and 8 other regulation plans were provided for Alexandria Bay (see TABLE 5.9). Only the stage-frequency relations for the spring and summer were selected for use, as the focus of this site study was recreational boating, and it was felt that frequency results for the fall and winter periods would bias the results.

Damages due to loss of boat use by either high or low water levels are highly dependent upon the length of time the condition occurs. For this reason, elevation-duration relationships were developed for the plans being evaluated. These relationships were then combined with seasonal stage-damage information to compute the damages associated with each plan.

The development of these damage values was supplemented by recreational boating related data collected during a visit to the area. Data collected included the number of available docks, dock elevations, water depths at the docks, rental value of all docks, and types of boats utilizing the docks. An inventory of all available docks for each marina was also established. The docks were then ranked according to their elevation and then grouped in 15 cm (.5 ft) increments, representing rising water levels. It was determined that when a particular water level was reached, the associated group of docks became unusable to the owner. The value of a group of docks became the damage associated with the particular water level stage. Dock values were supplied by individual marina owners and were based on seasonal rental fees.

The same rationale was used for low water damages. For each dock a minimum required water depth was assigned according to the type of boat most likely to use the slip. Docks were considered damaged when boats would not be able to enter or depart the slip due to lack of draft.

Expected annual damages for both high and low water levels for each regulation plan were calculated by multiplying the computed duration of a particular stage with the damages associated with the stage to determine a weighted damage. This was done for the full range of river stages. This amount represents the damage that can be expected to occur in any one year. Values for this study area are found in TABLE 5.9.

For this study area, largest possible benefits would come from the implementation of the SEO Combined plan, which shows a decrease in damages of approximately $8,500 dollars relative to the BOC. This is followed closely by Plan 1958D 28B MOD, which shows decreases in damages of $8,150. The plan showing the worst benefit is "1977A without Criterion C", which actually shows an increase in damages occurring.

Table 5.9 Expected Annual Damages - Alexandria Bay

Plan Name	Recreational EAD	Difference From BOC
BOC	$27,418	0
SEO Combined	$18,913	-$8,505
58D / 28B MOD	$19,263	-$8,155
1977A W/O C	$27,700	+$ 282
58D MOD 35P	$25,709	-$2,339
58D MOD 35Z	$25,575	-$1,843
SO SUP -.5 Ft, 58D MOD 35P	$27,077	-$ 341
1977A MOD, 58D MOD 35P	$23,489	-$3,929
SEO Extended	$25,204	-$2,214

5.4 Recession - Damage Calculations

5.4.1 Introduction

As well as the concerns outlined earlier for the flood component of stage-damage curves, there was, and continues to be, concern with the manner in which potential erosion damages are calculated using these traditional stage-damage curves. Most of this concern stems from the relationships between stage and recession and between recession and damage. That is, it is known that as the shoreline recedes (whether by gullying, wave/water level erosion, slumps and failures, etc.), land and buildings are lost and threatened, and damages occur. Thus, there is a direct relationship between recession and damage. The relationship between stage (or water level) and recession however, is less clear. Arguments emanating from Phase I of the Reference Study indicated that, for many shore types, long-term recession is independent of water level changes. Results of Phase II studies on erosion processes indicate that changes in water level ranges have little or no effect on recession rates for some shore types, but significant effects on others. This leads to a degree of confusion and a lack of confidence in applying the traditional erosion stage-damage curves, as there is not yet a clear link between the effects of fluctuating stages on long-term recession rates for all shore types that exist in the Great Lakes basin.

In light of this uncertainty, the Potential Damages Task Group examined alternative approaches to the estimation of potential erosion or recession damages for the shoreline of the Great Lakes - St. Lawrence basin. The alternate approach taken here attempted to utilize: 1) known information on long-term recession rates for various shoreline areas; 2) relative changes in recession rates of these shore types with changes in water level (from the Erosion Processes Task group); and 3) the value of land and structures lost due to recession.

5.4.2 Methodology

It was recognized that it would be impossible within the timeframe and budget of the Reference Study to calculate "new" potential recession damages for the entire Great Lakes - St. Lawrence River shoreline. It was decided to apply the approach described here to selected areas of the shoreline - these being the detailed study areas already examined. For the U.S. shoreline, Berrien County, Ottawa County and Oswego County were used as examples. For Canada, Central Lake Erie was used. Results of these new damage calculations from Berrien County and Central Lake Erie are presented here. Ottawa County and Oswego County analyses were not complete as of this writing and are summarized in the appropriate site study reports, as well as in the Potential Damages Task Group Report.

The approach begins with the simple assumption that as the shoreline recedes, property and structures are lost and damages occur. Initially, no assessment is made as to the effect of water levels on this recession. This approach also initially assumes that, where available, long-term recession rates, measured over a period of 50 years or more, are indicative and representative of recession rates that would occur over the next 50 years or more, given that there are no changes in those factors that may influence the recession rate. To further clarify, long-term rates of this type will have, averaged within them, periods of high water and periods of low water (including the extreme highs of the 50's, 70's and 80's and the extreme lows of the 60's). If we do not change the frequencies of these occurrences of high or low water, or the magnitude of these events, then we can assume, that over the next 50 years or more, long-term recession rates will remain relatively unchanged.

The first step then was to calculate, using historic recession rates, the position of the 50-year recession line. This provided an area of land that is estimated to be lost over the next 50 years. The value of this land and the structures upon it was then calculated and totalled. This represents the potential future recession damage over the next 50 years (i.e. the "base case" situation).

Using data generated by the Erosion Processes Task Group (see Section 3) on the percentage reduction in recession of certain shore types with a reduction in water level range, the 50-year recession rates calculated for the site study areas were then modified to represent the recession that would be predicted to occur over the next 50 years if the range of water levels was reduced by 50%. These new values were then used to calculate a position of a modified 50-year recession line. Again, the value of land and structures in this area was calculated and subtracted from the value calculated previously. The difference between these two values represents the reduction in recession damage that is predicted to take place over that 50-year period, given a 50% reduction in the range of water levels that have historically occurred.

As mentioned above, calculations of this type were conducted for Berrien County, Michigan and the Central Lake Erie shoreline of Lake Ontario. Results are presented below.

5.4.3 Results

Berrien County, Michigan

Long-Term (50-Year) Recession Projections

Using historic recession data and the kilometre by kilometre reach designations utilized in the shoreline classification process, historical setback limits were calculated and encoded in the GIS database. Overlay analyses were performed to calculate the area of land (for each land use) found within the setback line. Assessor records and discussions with local real estate experts were used to estimate market value for the various properties. The total value of land expected to be lost was then divided by 50 to obtain an average annual recession "damage".

Results indicate that over the next 50 years, an average annual value of recession damage for Berrien County will be on the order of $4.89 million.

Modified Long-Term (50-Year) Recession Projections

The historical recession rates were then modified to incorporate the numerical output derived by the Erosion Processes Task Group. Again, the area defined by the modified recession line was calculated and the market value obtained. Results of the modified line found that average annual damages would now be on the order of $4.26 million. This translates into average annual benefits of approximately $636,000.

Comparison With Stage-Damage Curve Results

Basis-of-Comparison water levels when input into the updated CZSEVAL program yielded average annual erosion damages of approximately $3.04 million for Berrien County. A one-for-one comparison of the average annual damages computed above for the unmodified 50-year recession indicates that the stage-damage approach may underestimate damages by approximately 38% or a factor of 1.6.

To compare the benefits derived by the two approaches, comparisons were necessary between the benefits derived using the modified 50-year recession rate, and those derived by the stage damage curves for the water level scenario that provided a reduction in range as close as possible to 50%. A combination of the SMHEO-50 and SMHEO-30 scenarios were used for this purpose.

Under the SMHEO-50/SMHEO-30 combined scenario, the updated erosion stage-damage curves predict an average annual benefit for Berrien County of approximately $235,000. The modified

50-year recession approach found average annual benefits of $636,000. Thus, benefits derived from the stage-damage curve output could be underestimated by approximately 63%, or a factor of 2.7.

The aforementioned benefit analysis comparison, however, can be debated due to a number of technical considerations. The key technical considerations include: 1) inconsistent bases for the 50% reduction in water level range; and 2) irrelevance of these analyses when comparing 50% range reduction schemes to 3-lake regulation scenarios due to their non-linearity in potential benefits and due to reduced benefits caused by combined stillwater/stormwater frequencies for levels at this location. For more detailed explanation on these technical considerations, please see the Potential Damages Task Group Report.

Central Lake Erie, Ontario

Long-Term (50-Year) Recession Projections

Similar to the Berrien County Site, the 50-year erosion area was calculated. Market values of all property in that area were used to determine an average value per square kilometre. The value of expected erosion damage in the study area was determined by multiplying the average market value per square kilometre of each reach, by the total area expected to be lost in that reach. Results indicate that a total of $2.01 million in potential erosion damages could be expected over the next 50 years. This translates into average annual recession damages of approximately $40,300 for the entire study area.

Modified Long-Term (50-Year) Recession Projections

A similar procedure was utilized to calculate the amount of erosion damage under a modified water level regime by multiplying the market value per square kilometre by the modified shoreline recession area calculated. Results indicate that a total of $1.65 million in potential erosion damages over the next 50 years if the water level range is reduced by 50%. This translates into an average annual value of approximately $33,000 and results in benefits of approximately $367,000 for the total study area, or an average annual benefit of approximately $7,300.

Comparison With Stage-Damage Curve Results

The erosion-stage damage curve updated for this study area (Reach 10 in Marshall, Macklin, Monaghan, 1992) was run under the SMHEO-Optimized water level regulation scenario. The SMHEO-Optimized is the closest scenario in producing a 50% reduction in the range of water levels on Lake Erie (it reduces water level range by 48%).

The results indicate that the Basis of Comparison water levels yielded average annual erosion damages of approximately $120,000 for this study area. Average annual erosion damages predicted under the SMHEO-Optimized scenario were approximately $112,000. A one-for-one comparison of these values with those calculated in the recession-damage methodology ($40,300 and $33,000 respectively) indicate that the updated stage-damage curves predict much higher damages for this study area, than does the recession damage approach.

In comparing the differences in benefits derived by the two approaches however, it was found that for the SMHEO-Optimized scenario, benefits derived from the stage-damage model output ($6,900) were very similar to the benefits predicted using the recession-damage approach ($7,300), with the stage-damage approach predicting slightly lower average annual benefits.

5.5 A Basin-Wide Model For Potential Damage Estimation

In order to estimate basin-wide flood and erosion damage potential, the Task Group investigated developing it's own model. The intent of the model was to be able to evaluate flood and erosion impacts, management alternatives (including land use, lake regulation, and local area management plans) and future development conditions. Model development, begun in August 1991, proceeded into the conceptual stage. While the concept was extremely appealing for the purposes of the Reference Study, it was found that data limitations precluded complete development of the model within the Study's timeframe. Future study efforts may well wish to examine the concept further and develop the model.

The primary limitation to model development was the lack of sufficient and accurate digital elevation data which would allow basin wide quantitative estimates of damage by flood elevation. To obtain this data would have required a large contracting effort well beyond allocated budgets. A second limitation was the nature of data on historic flood damages. Examination of this data revealed that separation of coastal flooding data from inland flooding data would have been very problematic. It was also discovered that the amount of flood data for commercial, industrial, public infrastructure and agricultural interests was far less than anticipated.

Upon a clear examination of the basin-wide model's data requirements and subsequent limitations, the Task Group, upon agreement from the Study Board, focused their efforts on completing updates to existing stage-damage curves, and the conduction of reach and site studies as already documented in this section.

5.6 Past Expenditures on Shoreline Protection

5.6.1 Overview

The Potential Damages Task Group was interested in obtaining an estimate of Canadian private and public shore protection expenditures on the Great Lakes during the 1985-1987 period. De

Cooke (1988) estimated that U.S. riparian property owners spent over $68 million (1987 dollars) on shore protection during the 1985-87 high water period. Additionally, through the Advance Measures Program administered by the U.S. Army Corps of Engineers approximately $12.7 million of public funds (federal and non-federal) were expended on shore protection during the same period (U.S. Army Corps of Engineers, 1989).

De Cooke's (1988) estimates were based on a review of U.S, Army Corps of Engineers shore protection permits issued during the 1985 to 1987 period, and applying estimated average project costs per permit. All shore construction activities below a specified elevation on each lake require a Corps permit. Public shore protection costs were calculated only for the Corps' Advance Measures Program.

Previous estimates of private shore protection expenditure on the Canadian portion of the Great Lakes - St. Lawrence River Basin during the 1985 to 1988 period, should be acknowledged. Ibbott and Whittington (1990), in a study of shoreline expenditure in Canada, estimated that 50,000 shore property owners spent $66.5 million on shoreline protection in 1988 alone. The origin of this estimate is not entirely clear, but is based on Shoreline Property Assistance Program loans and possibly an earlier study by Sudar (1987). Sudar used random telephone interviews with 222 shore property owners on the lower Great Lakes (Port Severn on Lake Huron to Gananoque on the St. Lawrence River). Over 47% of respondents reported spending an average of about $5,000 per property on shore protection in 1985 and 1986 (Sudar, 1987). Sudar (1987) suggests that 1985-86 shore protection expenditure on the lower Great Lakes could exceed $100 million.

It must be stressed, however, that Sudar's study was undertaken at the end of 1986, during record high lake level conditions. At that time, respondents would be very sensitized to flood and erosion problems, and may have over-reported the level of shore protection activity. Moreover, neither Sudar nor Ibbott and Whittington had the benefit of the very extensive Riparian Survey database on over 14,000 shore property owners now available.

5.6.2 Methodology

To derive Canadian estimates, several sources of information were explored and analyzed. These included the shore protection permit arrangements of several agencies, files pertaining to the extensively used Ontario Shoreline Property Assistance Program, and Environment Canada's 1990 Riparian Survey database. Details on the use of this information can be found in Ecologistics Limited (1992).

Firm estimates of the cost of private shore protection supported by the Shoreline Property Assistance Program were obtained from Ontario Ministry of Municipal Affairs files, which specify, for each participating municipality, the number of loans and total loan amount for each fiscal year. Data was obtained for the period April 1985 to March 1988. The loan amounts were adjusted upwards to reflect the program requirements that loans not exceed 75% of the cost of the work undertaken. This information was cross-referenced with information from the 1990 Canadian riparian survey, described in Section 4, which provided data relevant to estimating recent private shore protection activity.

5.6.3 Private Shore Protection Expenditures, 1985-1987

Analysis of the Shore Property Assistance Program data and the Canadian Riparian Survey found that an estimated 20,150 riparian properties on the Great Lakes, and a further 3,517 properties on the connecting channels, have some form of shore protection. This represents 44.5 and 47.3 percent, respectively, of total private properties on the shores of the Lakes and connecting channels. Of protected riparian properties, an estimated 4,188 on the Great Lakes and 673 on the connecting channels were the site of some shore protection activity during the study period - an estimated $21,033,000 spent by private shore property owners on the Great Lakes shores and a further $3,278,000 estimated to have been spent along the connecting channels. This amounts to an estimated total of over $24 million of shore protection activity during the study period.

5.6.4 Public Shore Protection Expenditures, 1985-1987

Undoubtedly, considerable expenditures were incurred by a number of municipalities, Conservation Authorities and, to a lesser extent, provincial and federal agencies in protecting roads, public buildings and other public property. However, as noted in the methodology, no comprehensive data were available from which an estimate of public shore protection expenditures could be derived. Review of a number of documents (Cain et al., 1988; Shaw, 1988; and Stewart, 1988 for example) and discussions with various agencies and municipalities found that public expenditures exceeded $11 million, however, the very incomplete data available make it impossible to suggest the level of public shore protection expenditures during the study period.

5.6.5 Discussions and Conclusions

This task has estimated that shore protection was undertaken on over 4,100 properties on the Canadian shores of the Great Lakes during the 1985-1987 period, and on a further 700 properties on the connecting channels, including the St. Lawrence River to Cornwall. This represents shore protection activity on about 9.3 percent of the 45,253 Great Lakes riparian properties reported in the 1989 Census of Canadian Riparian Properties. This is very close to the level of private shore protection activity reported by De Cooke (1988) for the United States shores of the Great Lakes. De Cooke (1988) estimated that shore protection totalling over $68 million was undertaken on 10.2 percent of the 65,966 riparian properties in the United States.

Private shore protection expenditures, in 1991 dollars, during 1985-1987 can be considered to be in the range of $21 million to $29 million for the Canadian shores of the Great Lakes, and $25 million to $34 million including the connecting channels to Cornwall. This should be considered a conservative estimate. A documented $11 million in public shore protection costs also likely underestimates the total public investment in shore protection during the study period.

5.7 Avoided Costs of Shoreline Protection

5.7.1 Overview

An essential aspect of the Reference Study is to compare future conditions on the lakes, channels, and shorelines around the Great Lakes-St. Lawrence River Basin, with measures in place and without measures in place. A systematic review of the impacts of measures in reducing adverse consequences across the water use categories leads to a determination of how effective the measures are likely to be.

The determination of "future costs avoided" involves anticipating or projecting what actions might (or might not) need to be taken to reduce future damages depending on whether certain other measures are implemented. For example, if system-wide water level and flow regulation is accomplished, some types of shore protection works might not require construction to the same elevation when compared to conditions with no system-wide regulation. The difference in construction costs for the shore protection works would be considered a future cost avoided, and therefore a benefit of the system-wide regulation plan.

The purpose of this component of the work conducted by the Potential Damages Task Group is to determine the approximate future costs avoided for the construction of shore protection if certain regulation scenarios were adopted.

5.7.2 Methodology

The methodology used to develop these cost estimates has been described in detail in Baird and Associates (1993), however a summary of the important assumptions and inputs to the analyses is presented below.

First, the extent of existing protection is based on data provided by Geomatics International (1992) in Canada and the Detroit District Army Corps of Engineers in the United States. These data consist of classifying the extent of protection along a specific reach of shoreline into one of six categories (see Section 3). Four classes refer to structural shore protection, specifically high, moderate, low and no protection. For the purposes of our calculations, the mean value of each range was utilized to represent the extent of protection. Thus, high, moderate, low and no protection were quantified as 85, 55, 25 and 5 percent protection respectively along the lower and middle lakes, and 70, 40, 15 and 1 or 0 percent along the upper lakes. For example, a 10 km (6.21 miles) length of shoreline classified as moderately protected on the lower lakes would have 5.5 km (3.42 miles) of shore protection structures. No costs were estimated for non-structural protection or unclassified shorelines.

The breakdown in type of shore protection was based on the results of riparian surveys in Canada and the United States. Four types of protection were considered, namely rubblemound revetments, steel sheet pile seawalls, steel sheet pile groynes (with beach fill) and riprap flood dykes. Design details for each type of structure were estimated as a function of the design water level using standard design procedures. Typical designs were developed for each type of structure for each water level reach (as defined in reports produced by the Ontario Ministry of Natural Resources and the U.S. Army Corps of Engineers) on each lake. Construction costs per unit length of shoreline were estimated using typical unit costs provided by Public Works Canada and the Corps of Engineers, along with the consultant's own expertise in this area. These calculations were then repeated for each different lake level scenario. In this way, the structure geometries, material quantities and costs take into account variations in the design water level around each lake, as well as different lake levels associated with the three lake level scenarios. The cost per unit length within each water level reach was then multiplied by the length of protection in the reach (for each type of protection structure) to provide an estimate of the replacement cost of existing shore protection for each reach.

Annual maintenance costs were estimated as 1.5 percent of the initial construction cost for each type of structure. A 50 year planning horizon was utilized. Thus, maintenance costs over a 50 year period have been considered.

The extent of future protection was estimated by assuming that the growth rate for shore protection was equal to the growth rate for urban land use categories. Data on land use trends were available by Conservation Authority jurisdiction (or Ministry of Natural Resources District jurisdiction) in Canada. Ten year growth rates for urban land use categories were estimated from these data. Similar information was provided by the Corps of Engineers for each county along the U.S. shoreline. Where no data were available, growth rates were interpolated between those in adjacent areas. The ten year growth rate was then used to define the length of shore protection to be constructed in each of five decades over the 50 year planning horizon of the study. Simple growth was assumed, and growth was assumed to cease if the extent of urban land use reached 100 percent. Design details and unit costs for the new protection were identical to those estimated for existing protection within a particular reach.

Future expenditures (including annual maintenance costs and construction costs for new protection to be built in the future) were discounted using a present value approach. Discount rates of 6, 8, 10 and 12 percent were assumed.

To summarize, the shore protection costs estimated in this study represent well designed (ie. "engineered") structures, and include an allowance for maintenance costs over a 50 year period. It is important to note that many existing shore protection structures are not well designed, and would have significantly lower construction costs than those estimated in this study. In addition, maintenance procedures vary significantly, and many structures are not maintained at all. It is assumed that all existing protection would be replaced with new protection, at a uniform rate over the next 25 years, and that all unprotected buildings and new development would have shore protection built over the next 50 years at a uniform rate.

5.7.3 Results and Discussion

TABLE 5.10 presents the cost of replacement of existing and construction of future shore protection (including both construction and maintenance costs) for all lakes under each of the water level scenarios evaluated. Results are presented for a discount rate of 6% and for both the Canadian and United States shoreline. More detailed results, including results for each lake by country, as well as results for other discount rates, are found in Baird and Associates (1993) and the Potential Damages Task Group Report. The results presented in Baird and Associates (1993) were based on the assumption that all existing protection would be replaced immediately. This assumption has been modified to replacement occurring uniformly over the next 25 years. The results in Table 5.10 are based on this modified assumption, and therefore differ from the results in Baird and Associates (1993).

Results in TABLE 5.10 indicate that the replacement of existing protection over the next 25 years, plus the construction of new shore protection in the future (i.e. at presently unprotected developments and at undeveloped land that is anticipated to be developed over the next 50 years) along the Canadian and U.S. shoreline, represents a present value of approximately $1.51 billion (including construction and maintenance costs over 50 years). If the SMHEO-50 scenario were to be implemented, the present value of the cost would be reduced by $340 million, or 23%. Implementation of scenario 1.18 SEO would reduce the present value of costs by $330 million.

The cost savings under the SHMEO-50 and 1.2 SEO schemes are the direct result of reduced structure dimensions (and therefore material quantities) for the various types of shore protection. Specifically, due to lower design water levels under both schemes, lower crest elevations are possible for revetments, seawalls, groynes and dykes. In addition, steel sheet pile lengths are decreased for seawalls and groynes, and in some locations, armour stone sizes are reduced such that the unit cost for the stone decreases.

5.8 Summary

The Potential Damages Task group employed a number of techniques in order to develop estimates of damages to shoreline interests as a result of fluctuating water levels and as a result of measures that might be implemented to reduce ranges in these fluctuations. Existing and updated stage-damage curves, along with information gleaned from a series of detailed site studies were used to evaluate a series of water level scenarios. It was found that no one regulation plan proposed was able to eliminate all flood or erosion damages on all reaches of the Great Lakes - St. Lawrence River shoreline. In addition, all plans resulted in a shift or redistribution of benefits and impacts.

Table 5.10 Comparison of Shore Protection Costs For Various Lake Level Scenarios (Discount Rate 8%).

	Canada ($M, CDN)		**U.S. ($M, US)**		**Total ($M, U.S)***		**Grand Total Existing and Future**
Scenario **	**Existing Protection**	**Future Protection**	**Existing Protection**	**Future Protection**	**Existing Protection**	**Future Protection**	
All Lakes							
BOC	378.55	232.19	587.53	415.72	902.99	609.21	1512.21
SHMEO-50	339.58	215.58	412.75	295.03	695.73	474.68	1170.41
1.2 SEO	334.37	209.74	511.31	358.15	789.95	532.93	1322.88
1.18 SEO	311.95	195.36	444.68	313.35	704.63	476.15	1180.78
1.4 SO	380.23	233.23	588.96	416.81	905.81	611.17	1516.98
1.19 SO	367.73	223.64	572.67	405.31	879.11	600.01	1479.12
1.20 SO	372.39	228.66	571.48	404.81	881.80	595.36	1477.16
1.21 SO	374.95	229.82	575.08	407.04	887.54	598.36	1486.10
Lake Ontario Only							
BOC	113.20	89.17	32.24	23.08	126.58	97.39	223.97
1.6 (28B)	113.67	89.47	32.51	23.28	127.24	97.84	225.07
1.6a(35P)	114.83	90.43	32.93	23.57	128.62	98.93	227.55
1.6b(35z)	115.71	91.23	33.18	23.77	129.60	99.80	229.39

* $1.00 U.S. = $1.20 CDN assumed.
** For a full description of scenarios, refer to Working Committee 3 Report.
Note: Some errors may occur due to rounding.

REFERENCES

Argiroff, C.A., 1992. Analysis and Report On Stage Damage Relationships For Selected U.S. Shoreline Reaches. Report Submitted to the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 43pp., plus Appendices.

Baird and Associates Coastal Engineers, 1993. Future Avoided Costs of Shore Protection. Report Prepared For the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study.

Cain, K., G. Nelson and G. Priddle. 1989. "Fluctuating Great Lakes Water Levels and Ontario Provincial Parks: A Call for Management". In K.G. Cain et al. (eds.) Shoreline Resource Management and Ontario Provincial Parks, Occasional Paper 8. Waterloo: University of Waterloo, Heritage Resources Centre, pp. 40-54.

Day, J.C., J.A. Fraser and R.D. Kreutzwiser (1977). "Assessment of Flood and Erosion Assistance Programs, Rondeau Coastal Zone Experience, Lake Erie". Journal of Great Lakes Research. 3:38-45.

De Cooke, B.G. 1988. Situation Report Great Lakes 1985-1987 High Water Levels, U.S. Damage, Models and Mapping. Prepared for U.S. Army Corps of Engineers, North Central Division and the U.S. Section of the International Joint Commission.

De Cooke, B.G., 1990. Lake Superior Damage Assessment of Reaches 9001 and 9002 for High Water of 1985-1986. U.S. Army Corps of Engineers, North Central Division, 111pp., plus Appendices.

De Cooke, B.G., 1991. Great Lakes Shoreline United States Inundation and Erosion Stage Damage Relationships. Prepared For U.S. Army Corps of Engineers, North Central Division, 355p.

Ecologistics Limited, 1992. Private and Public Shore Protection Expenditures Along the Canadian Great Lakes - St. Lawrence River Shoreline 1985-1987. Report Prepared For the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study.

Fraser, J.A., J.C. Day, R.D. Kreutzwiser and R.J. Turkheim. 1977. "Residents' Utilization of Coastal Hazard Assistance Programs, the Long Point Area, Lake Erie". Canadian Water Resources Journal. 2:37-50.

Geomatics International, 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side. Report Prepared For the Erosion Processes Task Group, Working Committee 2, Phase II, IJC Levels Reference Study.

Haras, W.S. and Tsui, K.K. (eds.), 1976. Great Lakes Coastal Zone Atlas. Environment Canada and Ontario Ministry of Natural Resources, Canada Ontario Great Lakes Shore Damage Survey.

Ibbott, P. and M. Whittington (1990). Valuation of Shoreline Expenditure in Canada. Toronto: Acres International Limited.

Illinois State Geological Survey, 1989. "Final Report, High Water Damage Costs, Illinois Shore of Lake Michigan - 1986 Through 1988".

Illinois State Geological Survey, 1989. "Coastal Atlas, Illinois Shore of Lake Michigan, Revised 1987-88".

International Lake Erie Regulation Study Board, 1981. Lake Erie Water Level Study. Report Submitted to the International Joint Commission, 231pp.

Kreutzwiser, R.D. 1991. "Hazard Assistance to Great Lakes Shore Property Owners: An Evaluation of Ontario Programs". Paper presented to the Canadian Association of Geographers, Queen's University, Kingston.

Marshall, Macklin, Monaghan, 1988. Lake Superior Shore Property Damage Economic Evaluation and Social Impact Assessment. Report Prepared For Ontario Ministry of Natural Resources and Environment Canada, 30 pp., plus Appendices.

Marshall, Macklin, Monaghan, 1992. Great Lakes Flood and Erosion Stage-Damage Curves Update. Report Submitted to the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 43pp., plus Appendices.

Paragon Engineering Limited, 1984. Flood Damages, Volumes 1 and 2. Report Submitted to the Ontario Ministry of Natural Resources, Conservation Authority and Water Management Branch, 130pp.

Paragon Engineering Limited, 1993. Potential Damage Estimates for Site Specific Areas. Report Submitted to the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 14pp.

Philpott, K. and Associates, 1989. Kettle Creek Conservation Authority Shoreline Management Plan. Report Submitted to the Kettle Creek Conservation Authority.

Rasid, H., R.S. Dilley, D. Baker and P. Otterson. 1989. "Coping with the Effects of High Water Levels on Property Hazards: North Shore of Lake Superior". Journal of Great Lakes Research. 15:205-216.

Rasid, H., D. Baker and R. Kreutzwiser. 1992. "Coping with Great Lakes Flood and Erosion Hazards: Long Point, Lake Erie, vs. Minnesota Point, Lake Superior". Journal of Great Lakes Research. 18:29-42.

Reinders, F.J. and Associates Limited, 1989. Lake Huron Shoreline Processes Study. Report Prepared for the Ausable-Bayfield, Maitland Valley, St. Clair Region and Saugeen Valley Conservation Authorities, 102pp., plus Appendices.

Shaw, J. (ed.) 1988. Long-Term Shore Management Alternatives Point Pelee, Lake Erie. Government of Canada.

Stewart, C.J. 1988. A Report on 1987 Water Levels of the Great Lakes. Burlington: Great Lakes Water Level Communications Centre, Environment Canada.

Sudar, A. 1987. A Survey of Public Perceptions of Great Lakes Water Levels. Burlington: Environment Canada.

U.S. Army Corps of Engineers. 1989. After Action Report: Flood Response, Advance Measures and Other Activities as a Result of Record Great Lakes Water Levels, March 1985 through April 1989. Buffalo, Chicago, Detroit Districts: U.S. Army Corps of Engineers.

The Water Network, 1992. Impact Analysis and Assessment For: Recreation, Domestic Water Supply and Sanitation, Industrial and Commercial Water Supply and Agriculture. Report Submitted to the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 168pp., plus Appendices.

Yoe, C., 1992. A Critical Review of Existing and Updated U.S. and Canadian Stage-Damage Curves. Report Submitted to the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 96pp.

6.0 LAND USE AND SHORELINE MANAGEMENT TASK GROUP

6.1 Introduction

The Land Use and Shoreline Management Task Group was charged with two main responsibilities as per the Phase II Directive of the Study. These were to:

> *"examine past, present and potential future changes in land use and management practices along the shores of the Great Lakes, their connecting channels and the St. Lawrence River"; and to*
>
> *"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."*

Using these directives as a guideline, the Task Group developed a series of tasks to answer these charges. Generally, these tasks fell into three main categories:

1) to catalogue land uses, land use trends and shoreline management practices in order to provide information necessary for the correlation of damages to shoreline use, targeting of high risk areas, projection of potential high risk areas and evaluation of the effectiveness of response measures to lake level fluctuations;

2) to provide a detailed evaluation and assessment of the effectiveness of selected shoreline management practices, including the provision of comprehensive information on the merits and disbenefits of the various practices, estimates of their costs of implementation and the benefits (i.e. their success at alleviating adverse consequences of fluctuating water levels) that they have provided to the implementing agencies and municipalities (counties, cities, etc.); and

3) to develop a working definition of shoreline management, including a comprehensive listing of all relevant terminology for use throughout Phase II of the Reference Study.

It should be noted here that the evaluations discussed here simply provided a basis for evaluating shoreline management measures in the study process. What is presented here as an "evaluation and assessment" may not necessarily be what is recommended by the Study Board in their final report.

6.2 Great Lakes - St. Lawrence River Basin Land Use

6.2.1 *Land Use Inventory, Mapping and Trend Analysis Methods*

General

A wide range of data was used to carry out these tasks, including past reports, land use data, mapping and past inventory and survey work. New data were also collected through the use of a questionnaire that requested current information on land use trends, as well as shoreline management practices. In Canada, this questionnaire was forwarded to public agencies (Conservation Authorities, Ministry of Natural Resources District Offices), selected shoreline municipalities in the detailed study sites in Ontario and Quebec and Provincial authorities in Quebec (see Triton Engineering and Ecologistics Limited, 1992). In the United States, questionnaires were forwarded to approximately 32 Regional Planning Authorities throughout the eight states.

The questionnaire asked for a breakdown of existing land use as a percentage of shoreline length for selected land uses. The respondents were also asked to provide the changes in each land use over the past 10 years and what changes were anticipated over the next 10 years. This provided data on both present land use and past and future trends. The shoreline management questions asked for the current extent of application of the selected measures. The respondent was also asked to rank the effectiveness of each of the measures and provide any further comments regarding preferred management measures.

Current Land Use - Canadian Shoreline

1:25 000 National Topographic System (NTS) map sheets and 1:50 000 sheets, where 1:25 000 scale were not available, were used for base mapping of the Canadian Great Lakes-St. Lawrence River shoreline. Based on air photo interpretation from 1985 and 1988 and selected 1990 photo coverage, land use information was delineated onto the base maps. Of the 1544 reaches along the Canadian shoreline (Lac St. Pierre in Quebec to the U.S border west of Thunder Bay) there is land use information for 1266 of them. This amounts to approximately 82 percent coverage for the shoreline.

Inland Extent of Air Photo Coverage

The inland extent of land use information collected for the Canadian Coastal Zone Database was determined primarily by the availability of existing air photo coverage and was generally on the order of one kilometre (0.62 mile). For the majority of the shoreline, this more than covered the hazard area defined by the 100 year flood and erosion lines. For long term planning purposes, the 100 year flood line can be said to define the planning area. It was concluded that the inland extent of the Canadian land use mapping was adequate for management purposes under a reasonable planning horizon.

Geographic Information System (GIS) Capability and Utilization

The Canadian shoreline GIS data was assembled in 1989 during Phase I of the Levels Reference Study. Digitizing of shoreline reaches, land use, flood and erosion lines, bathymetry (2m and 5m), and buildings were completed for all of Lakes Erie, Ontario, St. Clair, the St. Clair and Detroit Rivers, and southern Lake Huron to just north of Sauble Beach on a NTS map sheet basis. Some land use and building coverages were digitized for approximately half of the NTS sheets which cover the shoreline of Lake Superior, but no reach or bathymetry data was included. No land use or other information was digitized for the remainder of Lake Huron or any of the St. Lawrence River.

Because of the incomplete nature of the Canadian shoreline GIS data, it was not possible to generate a description of land uses across the Basin using the GIS without additional work being completed. This would include the digitizing of undigitized data, processing of data into functional GIS files and performing data quality checks. As this work could not be completed within the timeframe of the Reference Study, basin-wide descriptions of land uses could not be obtained solely using the GIS.

Cataloguing of Current Land Use

In order to provide timely land use information to this Phase of the Reference Study an alternative approach was thus required to consolidate the information contained within the Canadian Coastal Zone Database. The methodology adopted utilized the reliable components of the GIS combined with a manual approach of tabulating land use information on existing base maps (see Triton Engineering and Ecologistics Limited, 1992).

Land use information contained on existing base mapping was tabulated manually for those portions of the shoreline for which useable GIS information was not readily available. Areas for land use polygons were manually calculated from the original mylar base maps using both electronic planimeter and scaled grid squares sheets. Land use areas were recorded in hectares (ha) and were rounded to one decimal. To the extent possible land use tabulations were cross-referenced according to reach and NTS base map sheet. Land use information by reach was recorded as the kilometre length of the land use along the shoreline. The GIS generated reach information according to area. This was not possible with the manual calculations. Geo-political boundaries were not included in the original base mapping. Therefore land use information could not be referenced to particular county or township units. NTS map sheets represented the extent of geo-referencing possible with the database in its present form, including those portions contained within the GIS. The raw data was entered into a Lotus 123 spreadsheet for tabulation and manipulation.

In Quebec, there is complete coverage based on mylar maps for the region up to and including the Dorval area on the island of Montreal. No original base mapping from the Phase I exercise exists beyond this point. In order to provide complete coverage of the Canadian Basin, supplemental land use information was extracted from a land uses series prepared by Lavalin Environment (1988). The Lavalin base mapping is not as detailed as the Phase I base mapping. Land use was classified according to the dominant land use type along shoreline reaches and not the actual use. In order to provide for continuous and consistent reporting of land use information, it was necessary to convert the Lavalin categories into Canadian Coastal Zone Database equivalents. Length of shoreline in a particular land use was the only information that was obtainable from this mapping. Area calculations were not possible.

Current Land Use - United States Shoreline

The U.S. shoreline database consists of data on the land cover / current use of a strip of shoreline from the water's edge to approximately 3 km (2 mi) inland. The land cover / current use data is subdivided into 52 categories, within major classes such as residential development, industrial and wetlands. For the purposes of this exercise, these classes have been further subdivided into five main categories: residential; commercial / industrial; public (which includes parkland, road networks, institutional facilities and airports); agricultural; and other (which includes extraction uses, wetlands, forested, nonforested, beaches, dunes and rock).

The data base was developed from source material at a scale of 1:24,000. The land cover / current use data for all states other than Michigan was interpreted primarily from 1:24,000 scale aerial photography taken in the fall of 1988. Michigan data was obtained from the Michigan Resources Information System, which uses base data from 1979 (see Functional Group 2, 1989 for further details).

All land use information was encoded into the INTERGRAPH GIS residing at the Detroit District, U.S. Army Corps of Engineers. Summary statistics were generated on a county-by-county basis, along with summaries on a lake wide basis.

Analysis of Land Use Trends - Canadian Shoreline

The land use information contained within the Canadian and U.S. data bases described above represent a snap-shot or static view. Land uses and land use patterns within the Great Lakes Basin are constantly changing in form and intensity. While the information contained within the databases provides excellent detailed information that will remain current for many years and will be a useful tool for large scale basin and lake wide analysis, it does not provide an indication of what future changes will, or would likely, occur along these shorelines.

In order to make sound and reliable evaluations of management options and their potential impacts on the shoreline, planners and decision makers need to have an understanding of what future land use patterns are likely to be in the Basin. In order to provide this information, an analysis of land use trends for the Great Lakes - St. Lawrence River shoreline has been undertaken.

Past Land Use Trends

Analysis of past land use trends was undertaken by examining previously published material. The main data sources for this component were the Great Lakes Coastal Zone Atlas (Haras and Tsui, 1976) and survey information published by the Task Force on Available Shore Erosion Information on the Great Lakes St. Lawrence System (1973).

Future Land Use Trends

A more important task of this study from a planning and water level management perspective was to determine what the future trends in land use would be. To answer this question a detailed questionnaire (described previously) was sent to individual Conservation Authorities and appropriate MNR districts along the Ontario shoreline and to Municipalitie Regionale de Comte (MRC) along the shoreline in Quebec. Individual municipalities were also served with a similar questionnaire for the representative study sites in Ontario and Quebec.

Respondents were asked to indicate what the past, present and future land use patterns have been and are projected to be. Percent change in land uses between present and projected shoreline land use were calculated to determine future land use trends.

Analysis of Land Use Trends - United States Shorelines

Past land use trends were not examined on the U.S. shoreline. Future trends were estimated in a number of ways, primarily through discussion with county planning representatives, but also by analysing recent trends in land use in some specific areas, and comparing recent aerial photography with that taken in 1988.

6.2.2 Current Land Use - Results

Canadian Shoreline

Basin Overview

Summary results of land use in 13 specific categories and organized by water body (and connecting channel) are found in TABLE 6.1 (from Triton Engineering and Ecologistics Limited, 1992). Forested land uses are the largest single category and represent 22.1 percent of the land use along the Canadian shoreline. Residential development is the next dominant land use type accounting for 18.6 percent of shoreline land uses. The barren/denuded category is the third largest and accounts for 14.2 percent of shoreline. Together these three uses account for approximately 55 percent of the shore.

There is approximately 14% of shoreline for which land use is not known. Unknown land uses have been delineated but have not been definitively interpreted from air photos. The remainder of the land uses classed each represent less that 10 percent each of the shoreline.

It should be noted in Table 6.1, that beaches compose a significant portion of the "Barren" category. Ownership of the beach has not been explicitly addressed and quantified. In many cases, areas classified as beaches may in fact be adjacent to private and commercial land uses, or be adjacent to undeveloped lands in public and private holdings. The land use figures presented only reflect the "beach" category. The adjacent land uses that might occur inland of the beach are not reflected in the totals.

Detailed Site Studies

The proceeding section has provided a brief overview of land use along the Canadian shore. As noted previously, a coordinated and focused effort of Phase II of the Levels Reference Study has been to focus on detailed site studies in both Canada and the U.S. The following section briefly describes existing land use patterns for the six representative sites in Canada (see Section 2.5 and 5.3). A more detailed presentation can be found in Triton Engineering and Ecologistics Limited (1992).

The **Montreal** site study covers approximately 80 km (50 miles) along the south shore of the Island of Montreal. The study area extends from the town of St. Anne de Bellevue eastward to the Champlain Bridge. It is not surprising that residential land uses occupy approximately 55 percent of the shoreline length. Other dominant land uses are forest (13.5 percent) and recreational (9.2 percent). As noted previously, land use information from the Coastal Zone Database was not complete for the entire area. A portion of the east end of this study area was incomplete.

Table 6.1 Great Lakes Shoreline Land Use Summary - Canadian Shoreline

	LAND USE CATEGORIES								REACH = length of shoreline						REACH
	Ac	As	D	C	I	TC	R	E	W	M	F	G	B	?	TOTAL
ST LAWRENCE RIVER															
TOTAL LAND USE (km)	90.4	2.4	217.8	5.0	10.1	12.1	42.1	1.0	2.5	45.3	88.8	78.7	1.6	20.3	618.1
% LAND USE OF WATERBODY	14.6	0.4	35.2	0.8	1.6	2.0	6.8	0.2	0.4	7.3	14.4	12.7	0.3	3.3	100.0
LAKE ONTARIO															
TOTAL LAND USE (km)	156.0	17.0	102.2	9.7	35.6	3.9	50.1	2.1	5.9	52.6	83.4	61.6	98.0	84.4	762.5
% LAND USE OF WATERBODY	20.5	2.2	13.4	1.3	4.7	0.5	6.6	0.3	0.8	6.9	10.9	8.1	12.9	11.1	100.0
NIAGARA RIVER															
TOTAL LAND USE (km)	3.1	0.0	2.3	0.9	0.6	0.0	3.9	0.0	0.2	0.0	10.8	11.1	2.1	0.9	35.9
% LAND USE OF WATERBODY	8.6	0.0	6.4	2.5	1.7	0.0	10.9	0.0	0.6	0.0	30.1	30.9	5.8	2.5	100.0
LAKE ERIE															
TOTAL LAND USE (km)	5.6	0.3	101.0	0.0	3.3	0.9	9.7	0.5	8.6	37.5	29.7	15.0	248.2	12.2	472.5
% LAND USE OF WATERBODY	1.2	0.1	21.4	0.0	0.7	0.2	2.1	0.1	1.8	7.9	6.3	3.2	52.5	2.6	100.0
DETROIT RIVER															
TOTAL LAND USE (km)	3.5	0.0	16.6	1.2	2.2	2.8	5.5	3.8	0.3	6.4	1.8	8.9	4.8	0.0	57.8
% LAND USE OF WATERBODY	6.1	0.0	28.7	2.1	3.8	4.8	9.5	6.6	0.5	11.1	3.1	15.4	8.3	0.0	100.0
LAKE ST. CLAIR															
TOTAL LAND USE (km)	10.8	2.1	51.4	0.0	1.0	0.0	2.4	0.0	2.3	40.8	0.2	14.5	0.8	2.2	128.5
% LAND USE OF WATERBODY	8.4	1.6	40.0	0.0	0.8	0.0	1.9	0.0	1.8	31.8	0.2	11.3	0.6	1.7	100.0
ST. CLAIR RIVER															
TOTAL LAND USE (km)	0.9	0.0	15.1	0.4	8.0	0.0	3.6	0.0	1.2	0.0	0.0	0.6	15.8	0.0	45.6
% LAND USE OF WATERBODY	2.0	0.0	33.1	0.9	17.5	0.0	7.9	0.0	2.6	0.0	0.0	1.3	34.6	0.0	100.0
LAKE HURON															
TOTAL LAND USE (km)	19.0	0.0	151.3	0.3	11.2	0.2	22.2	0.0	23.1	24.1	338.5	42.6	179.2	275.5	1087.2
% LAND USE OF WATERBODY	1.7	0.0	13.9	0.0	1.0	0.0	2.0	0.0	2.1	2.2	31.1	3.9	16.5	25.3	100.0
ST. MARY'S RIVER															
TOTAL LAND USE (km)	7.9	0.0	19.8	0.0	0.0	0.5	0.9	0.0	12.0	4.8	61.8	0.0	0.0	0.0	107.7
% LAND USE OF WATERBODY	7.3	0.0	18.4	0.0	0.0	0.5	0.8	0.0	11.1	4.5	57.4	0.0	0.0	0.0	100.0
LAKE SUPERIOR															
TOTAL LAND USE (km)	0.4	0.0	52.4	0.0	18.5	0.6	129.3	0.0	4.6	2.0	252.9	2.3	6.0	145.7	614.7
% LAND USE OF WATERBODY	0.1	0.0	8.5	0.0	3.0	0.1	21.0	0.0	0.7	0.3	41.1	0.4	1.0	23.7	100.0
GREAT LAKES TOTAL (km)	297.6	21.8	729.9	17.5	90.5	21.0	269.7	7.4	60.7	213.5	867.9	235.3	556.5	541.2	3930.5
% LAND USE OF GREAT LAKES	7.6	0.6	18.6	0.4	2.3	0.5	6.9	0.2	1.5	5.4	22.1	6.0	14.2	13.8	100.0

LEGEND

Ac = Agricultural Field Crop; As = Agricultural Specialty Crop; D = Residential; C = Commercial; I = Industrial; TC = Transportation & Communications; R = Recreation; E = Extraction; W = Water; M = Wetlands; F = Forestry; G = Grassland; B = Barren; ? = Unknown.

N.B. figures based on available data only

The **Toronto** detailed site study is located at the western end of the urban areas and encompasses approximately 36 km (22 miles) of the shorelines of the Cities of Mississauga and Etobicoke. While this portion of the shore is a populated area, recreational land uses comprise the major land use, covering 13.8 km (9 miles) or 38.1 percent of the area. Actual residential uses located immediately along the shore line account for 29.3 percent or 10.6 km (7 miles). The remaining dominant land use type is industrial which accounts for 14.6 percent or 5.3 km (3 miles) of shoreline in the study area.

The **agricultural** representative study site covers the portion of the central Lake Erie shoreline between **Port Burwell east to Clear Creek**. Data for this representative study site was available in the GIS, therefore land use is reported by square kilometre and not by length of shoreline. Agriculture, which accounts for 74 percent of the total area, is not surprisingly the dominant land use along this portion of the lake. Forests cover approximately 10 percent of the area. Extraction, transportation and communication and commercial use is virtually non-existent for these areas. There are no unknown land uses in the study site.

The **residential** detailed site study covers the portion of the shoreline of the Detroit River and Lake St. Clair encompassing the **City of Windsor** to the east boundary of the **Town of Belle River**. Residential land uses account for 60 percent or 30.9 km (19 miles) of shoreline within the study area. Recreational, Agricultural, Extraction and Grassland are the other primary land uses; each accounting for approximately 7 percent of shoreline length within the area.

The **recreational** study area covers the area of **Severn Sound, Georgian Bay** from Honey Harbor to Penetanguishene. Reach information for this area was not available for this study. Forests are the largest single land use and occupy approximately 60 percent of the study area. Field crops are the second largest use at 15.3 percent and residential land uses occupy 9.6 percent. While residential property accounts for just under 10 percent of land use, the majority of it is located along or close to the shoreline. There is extensive cottage lot development in this area.

The boundary for the **industrial** detailed site study corresponds to the municipal boundary of the **City of Thunder Bay**. Industrial land uses account for approximately a third of the shoreline (15.5 km (10 miles)) within the study area, while forest and residential account for an additional 25.3 and 17.4 percent, respectively. These data are somewhat skewed due to the size of the study area. The industrial portion is highly concentrated and forms large continuous blocks along the shore.

United States Shoreline

Basin Overview

Land use information from U.S. sources has been collated and tabulated on a lake-by-lake, county-by-county basis in a series of tables found in the Land Use and Shoreline Management Task Group Report. TABLE 6.2 presents summary data on a lake-by-lake basis for five main land use types: residential; commercial / industrial; public (which includes parkland, road networks, institutional facilities and airports); agricultural; and other (which includes extraction uses, wetlands, forested, nonforested, beaches, dunes and rock).

On a basin-wide scale, 55% of the U.S. shoreline falls into the "other" category. Residential land uses occupy the second largest component of the U.S. shoreline at 27%. Public lands occupy 11% of the shore, while commercial / industrial and agriculture occupy 7% and 2% respectively.

Residential development predominates along the shoreline of Lake St. Clair (53%) and Lake Ontario (42%), as well as along the St. Mary's and St. Clair Rivers (48% and 45% respectively). Commercial and industrial land use is heaviest along the shorelines of the St. Clair (24%) and Detroit (31%) Rivers reflecting the heavy concentration of industry south of Detroit. "Other" land uses predominate in the upper lakes - Superior, Michigan and Huron - with 68%, 54%, and 55% of their shorelines respectively, falling into this category. The St. Lawrence River also has a significant percentage of its shoreline (66%) in "other" land uses. Public land use is predominant along the St. Mary's River and Lake St. Clair, and agricultural uses are heaviest along the shorelines of the St. Clair River and Lake Ontario.

It should be noted in Table 6.2, that beaches compose a significant portion of the "Barren" category. Ownership of the beach has not been explicitly addressed and quantified. In many cases, areas classified as beaches may in fact be adjacent to private and commercial land uses, or be adjacent to undeveloped lands in public and private holdings. The land use figures presented only reflect the "beach" category. The adjacent land uses that might occur inland of the beach are not reflected in the totals.

Detailed Site Studies

Land use data is presented for the seven U.S. site study areas below. This data has been summarized from a series of detailed site study reports prepared by the Detroit and Buffalo District offices of the U.S. Army Corps of Engineers. More detailed information is also available in the Potential Damages and Land Use and Shoreline Management Task Group Reports.

Duluth/Superior is located at the western tip of Lake Superior and is the boundary between the states of Minnesota and Wisconsin. The two cities are separated by the St. Louis River. Land use in the area is predominantly commercial and industrial, composing almost 38% of the Duluth shoreline, and 45% of the Superior shoreline. "Other" uses, such as wetlands, forest, bedrock and other undeveloped lands, occupy 31% of the Duluth shoreline and 52% of the Superior shoreline.

Table 6.2 United States Land Use Classification Summary Table For Percentage of Shoreline by Lake or Connecting Channel.

Land Use	Percent Land Use by Lake or Connecting Channel - United States											
	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River
Total Shoreline Length (km)	2242.3	383.3	2387.0	1110.8	33.1	136.1	118.0	833.5	82.1	505.3	451.8	8283.3
1. Residential	14.9	48.0	27.7	27.3	45.3	53.3	16.2	32.6	34.0	42.1	20.7	26.5
2. Comm/Indust	5.0	18.0	5.6	5.0	24.1	2.6	31.2	11.3	14.1	3.3	3.7	6.7
3. Public	11.9	31.0	6.6	4.3	9.6	31.2	20.2	16.1	20.3	10.2	5.2	10.8
4. Agricultural	0.2	3.0	1.2	0.3	4.2	0	1.9	3.9	1.9	4.6	4.1	1.5
5. Other	67.9	0	58.9	63.2	16.8	13.0	30.5	36.1	29.6	39.9	66.2	54.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Total shoreline length figures do not reflect islands. Total shore length including islands is 10,511 km (6527 mi).

The **Chicago** study area occupied the entire Illinois shoreline of Lake Michigan (Cook and Lake Counties). The dominant land use in this area is "other" with 58 km (36 mi), or 44% of the shoreline falling into this category. The majority of these uses are outdoor recreation in Cook County (23 km (14 mi)) and beaches or woodlands in Lake County (18 km (11 mi)). Public infrastructure was the next largest land use, occupying 48 km (30 mi), or 37%, of the shoreline. Commercial and industrial uses occupied 13% of the shoreline, while residential uses accounted for 6%.

Not surprisingly, **residential** land use occupied the majority of the **Berrien County** shoreline, with over 38 km (24 mi), or 57%, in residential land use of some type. "Other" uses occupied 26 km (16 mi), or 39% of the shoreline, being predominantly beaches (13 km (8 mi)), sand dunes (8 km (5 mi)), woodlands (3 km (2 mi)), or outdoor recreation (2 km (1 mi)). Commercial and industrial, public infrastructure and agricultural uses were relatively minor.

Although selected as an **agricultural** site, agricultural land use occupies only 10 km (6 miles), or 8% of the **Ottawa County** study area shoreline. Dominant uses here include "other" with 45 km (28 mi), or 37% of shoreline, with wetlands (17 km (11 mi)) and outdoor recreation (10 km (6 mi)) being the most significant types. Residential land uses occupy 40 km (25 mi), or 33% of shoreline. Public infrastructure also occupies almost 24 km (15 mi), or 20% of the shoreline in this study area.

Hoover Beach is located at the eastern end of Lake Erie, just south of the City of Buffalo, in the Town of Hamburg. The total length of land within the study area is approximately 865 metres (2840 feet). The area is classified solely as a residential community with a wide variety of home styles. They are predominantly occupied year-round, with a small number of seasonal cottages. There are approximately 100 homes located in this area, ranging in value from $20,000 to $116,000. There are no commercial, industrial, agricultural, marina or recreational uses, either public or private, located within the area. There is a small amount of beach located lakeside of the privately constructed seawalls. This beach varies in width and is used solely by the individual property owners.

Similar to Ottawa County, dominant land use in **Oswego County** is "other", with 24 km (15 mi), or 42% of the shoreline, followed by residential, with 20 km (12 mi), or 34% of the shoreline. Beaches constitute 5 km (3 mi) of the shoreline under the "other" category. Commercial and Industrial uses occupy 6 km (4 mi), or 11% of the shore, most of which is focused in the Oswego Harbour area. Public infrastructure uses occupy another 8 km (5 mi), or 13% of the shore. There is no agricultural land use in this study area.

Alexandria Bay is located on the St. Lawrence River approximately 47 km (29 mi) downstream of Cape Vincent, New York. It's shoreline length is approximately 4 km (3 mi) and includes several small islands in the river. Most of the available coastline in the area has been developed, primarily with recreational facilities and summer cottages and resorts. Several inlets have been dredged and enlarged into marinas. The islands are mainly uninhabited with few structures.

Land ownership along the shoreline is privately held with minimal public ownership. Tourism is a major part of the economy, with the offshore islands being the prime attraction. Many lodging and business establishments are located along the shoreline, most of which have docks or boathouses available for rent.

6.2.3 Past Land Use Trends - Results

Canadian Shoreline

Land use information obtained from the Erosion Task Force was collected in 1966. Land use information obtained from the Coastal Zone Atlas was collected in 1973. Numerical analysis of trends was not undertaken on this data. Due to the great variation in the data collection methodologies and the land classification systems, the results of such analysis would be relatively meaningless. However, a qualitative analysis reveals a general decrease in natural shoreline and increases in developed portions of the shoreline.

Additional studies (Kreutzwiser 1988; LURA Group, 1989; Nelson et al., 1991; Lawrence and Nelson, 1992) were reviewed. The general trend in the basin over the last several decades has been a general and often rapid increase in shoreline development, (primarily residential) at the expense of natural areas; mainly forest and wetland. There has also been some additional loss of agricultural land to support residential shoreline development.

United States Shoreline

Detailed information on past land use trends along the U.S. shoreline was extremely limited. Analysis of the little data there was indicates a similar trend to that found for Canada - a general decrease in natural shoreline and increases in developed portions of the shoreline, particularly in the residential land use category.

6.2.4 Future Land Use Trends - Results

Canadian Shoreline

A more important task of this study from a planning and levels management perspective was to determine what the future trends in land use would be. Results from the questionnaire are presented by waterbody for those Conservation Authorities and MNR Districts reporting in TABLE 6.3 (from Triton Engineering and Ecologistics Limited, 1992). The reader should be cautious when interpreting these results, as they may not represent complete coverage of the water body. Jurisdiction of the Essex Region Conservation Authority, Niagara Peninsula Conservation Authority, and Sault Ste. Marie MNR District office encompass more than one waterbody. For

Table 6.3 Future Land Use Trends By Conservation Authority and MNR District.

		PRESENT									PAST								
Respondent	Shoreline (km)	AFC (%)	ASP (%)	RES (%)	C&I (%)	IND (%)	TRAN (%)	REC (%)	EXTR (%)	UNDEV (%)	AFC (%)	ASC (%)	RES (%)	C&I (%)	IND (%)	TRANS (%)	REC (%)	EXTR (%)	UNDEV (%)
LAKE ST. CLAIR																			
St. Clair Region CA	100.00	5.00	0.00	75.00	1.00	5.00	4.00	8.00	0.00	2.00	5.00	0.00	75.00	1.00	6.00	4.00	7.00	0.00	2.00
LAKE HURON (ENTIRE)																			
Ausable Bayfield CA	54.00	5.00	0.00	80.00	5.00	0.00	0.00	5.00	0.00	5.00	5.00	0.00	80.00	5.00	0.00	0.00	5.00	0.00	5.00
Espanola District MNR	1400.00	5.00	0.00	20.00	3.00	0.00	1.00	6.00	1.00	64.00	5.00	0.00	15.00	3.00	0.00	1.00	4.00	1.00	71.00
Grey Sauble CA	155.00	0.00	0.00	52.00	0.00	0.00	15.00	9.00	0.00	24.00	0.00	0.00	47.00	0.00	0.00	15.00	9.00	0.00	29.00
Maitland Valley CA	50.00	20.00	0.00	70.00	0.00	0.00	0.00	10.00	0.00	0.00	40.00	0.00	50.00	0.00	0.00	0.00	10.00	0.00	0.00
Saugeen Valley CA	82.00	0.00	0.00	45.00	0.00	5.00	0.00	20.00	0.00	30.00	0.00	0.00	35.00	0.00	5.00	0.00	20.00	0.00	40.00
Sudbury District MNR	170.00	0.00	0.00	30.00	4.00	0.00	10.00	5.00	5.00	50.00	0.00	0.00	20.00	1.00	0.00	8.00	2.00	5.00	65.00
LAKE ONTARIO (ENTIRE)																			
Cataraqui Region CA	245.00	1.00	1.00	50.00	15.00	5.00	5.00	10.00	1.00	20.00	1.00	1.00	45.00	15.00	5.00	5.00	10.00	1.00	20.00
Credit Valley CA	15.00	0.00	1.10	33.10	0.00	26.30	13.60	25.90	0.00	0.00	0.00	1.10	33.10	0.00	26.30	13.60	25.90	0.00	0.00
Ganaraska Region CA	45.00	65.00	5.00	5.00	5.00	5.00	0.00	5.00	0.00	10.00	65.00	5.00	5.00	5.00	5.00	0.00	5.00	0.00	10.00
Halton Region CA		0.00	0.00	90.00	0.00	2.00	0.00	8.00	0.00	0.00	0.00	0.00	93.00	0.00	2.00	0.00	5.00	0.00	0.00
Lower Trent CA	80.00																		
Metro Toronto Region CA	46.50																		
Napanee Region CA	21.60	0.00	0.00	3.00	5.00	7.00	0.00	0.00	0.00	85.00	0.00	0.00	2.00	5.00	7.00	0.00	0.00	0.00	86.00
Niagara Peninsula CA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Prince Edward CA	400.00	10.00	26.00	25.00	1.00	1.00	2.00	10.00	0.00	25.00	15.00	31.00	15.00	1.00	1.00	2.00	10.00	0.00	25.00
ST. LAWRENCE RIVER																			
Bas Richelieu MRC	84.00	0.00	0.00	20.20	1.20	4.10	2.10	3.10	0.00	69.30	0.00	0.00	19.60	3.10	4.10	2.10	1.20	0.00	69.90
Champlain MRC	20.00	0.00	0.00	0.00	0.00	0.00	0.00	80.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	50.00
Lajemmerais MRC	52.00	12.00	0.00	52.00	1.00	15.00	2.00	10.00	0.00	8.00	14.00	0.00	50.00	1.00	15.00	2.00	10.00	0.00	8.00
Nicolet-Yamaska MRC	39.00	5.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	85.00	5.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	85.00
Raisin Region CA	70.00	7.00	0.00	22.00	5.00	1.00	0.00	48.00	0.00	17.00	7.00	0.00	18.00	5.00	1.00	0.00	43.00	0.00	26.00
Roussillon MRC	48.00	0.00	0.00	78.00	0.00	2.00	0.00	20.00	0.00	0.00									
LAKE ERIE (ENTIRE)																			
Catfish Creek CA	15.00	57.91	0.59	3.33	0.00	0.03	0.01	0.24	0.00	36.81	58.91	0.59	2.33	0.00	0.03	0.01	0.24	0.00	36.81
Essex Region CA	160.00	25.00	10.00	35.00	5.00	6.00	4.00	7.00	3.00	5.00	20.00	10.00	30.00	5.00	5.00	5.00	10.00	5.00	10.00
Grand River CA	23.00																		
Kettle Creek CA	27.00	75.00	2.00	10.00	1.00	1.00	1.00	0.00	0.00	10.00	75.00	2.00	8.00	1.00	1.00	1.00	0.00	0.00	12.00
Long Point Region CA	170.00	11.00	15.00	60.00	0.00	4.00	0.00	5.00	0.00	5.00	11.00	15.00	60.00	0.00	4.00	0.00	5.00	0.00	5.00
Lower Thames Valley CA	136.00	65.00	2.00	10.00	1.00	0.00	2.00	10.00	2.00	8.00	65.00	2.00	10.00	1.00	0.00	2.00	10.00	2.00	8.00
Niagara Peninsula CA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LAKE SUPERIOR (ENTIRE)																			
Lakehead Region CA	210.00	0.00	0.00	21.00	0.00	6.00	0.00	0.10	0.00	72.90	0.00	0.00	20.50	0.00	6.00	0.00	0.10	0.00	73.40
MNR Nipigon		0.00	0.00	0.50	0.10	0.10	20.00	0.50	0.00	28.80	0.00	0.00	0.50	0.10	0.10	20.00	0.50	0.00	78.80
MNR Terrace Bay	248.50	0.00	0.00	2.00	0.50	1.00	0.10	0.80	0.00	95.60	0.00	0.00	1.80	0.40	1.00	0.10	0.60	0.00	96.10
Sault St. Marie CA	49.50	0.00	0.00	37.00	4.00	16.00	1.00	13.00	2.00	28.00	0.00	0.00	35.00	4.00	15.00	1.00	13.00	0.00	32.00
Thunder Bay District MNR	293.00	0.00	0.00	20.50	0.00	4.00	0.00	30.50	0.00	45.00	0.00	0.00	0.00	0.00	0.00	0.00	30.40	0.00	10.00
Wawa MNR		0.00	0.00	1.00	0.00	1.00	1.00	60.00	1.00	40.00	0.00	0.00	1.00	0.00	1.00	1.00	60.00	1.00	40.00
TOTAL (CA & MNR)	4509.10	368.91	62.69	1023.32	57.80	117.53	83.81	410.14	15.00	889.41	391.91	67.69	781.83	56.60	110.53	82.81	346.94	15.00	994.01

LEGEND: AFC = Agricultural Field Crop; ASP = Agricultural Specialty Crop; RES = Residential; C&I = Commercial and Industrial; TRAN = Transportation; EXTR = Extraction; UNDEV = Undeveloped.

Table 6.3 (continued) Future Land Use Trends By Conservation Authority and MNR District

		FUTURE									CHANGE																	
Respondent	Shoreline km	AFC (%)	ASC (%)	RES (%)	C&I (%)	IND (%)	TRANS (%)	REC (%)	EXTR (%)	UNDEV (%)	AFC % Change	AFC in km	ASC % Change	ASC in km	RES % Change	RES in km	C&I % Change	C&I in km	IND % Change	IND in km	TRANS % Change	TRANS in km	REC % Change	REC in km	EXTR % Change	EXTR in km	UNDEV % Change	UNDEV in km
LAKE ST. CLAIR																												
St. Clair Region CA	100.00	5.00	0.00	75.00	1.00	5.00	4.00	8.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE HURON (ENTIRE)																												
Ausable Bayfield CA	54.00	0.00	0.00	90.00	5.00	0.00	0.00	5.00	0.00	0.00	-5.00	-2.70	0.00	0.00	10.00	5.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-5.00	-2.70
Espanola District MNR	1400.00	5.00	0.00	30.00	5.00	0.00	1.00	10.00	1.00	48.00	0.00	0.00	0.00	0.00	10.00	140.00	2.00	28.00	0.00	0.00	0.00	0.00	4.00	56.00	0.00	0.00	-12.00	-168.00
Grey Sauble CA	155.00	0.00	0.00	57.00	0.00	0.00	15.00	10.00	0.00	18.00	0.00	0.00	0.00	0.00	5.00	7.75	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.55	0.00	0.00	-6.00	-9.30
Maitland Valley CA	50.00	15.00	0.00	75.00	0.00	0.00	0.00	10.00	0.00	0.00	-5.00	-2.50	0.00	0.00	5.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saugeen Valley CA	82.00	0.00	0.00	55.00	0.00	5.00	0.00	20.00	0.00	20.00	0.00	0.00	0.00	0.00	10.00	8.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.00	-8.20
Sudbury District MNR	170.00	0.00	0.00	50.00	1.00	0.00	10.00	15.00	5.00	20.00	0.00	0.00	0.00	0.00	10.00	17.00	-3.00	-5.10	0.00	0.00	0.00	0.00	10.00	17.00	0.00	0.00	-30.00	-51.00
LAKE ONTARIO (ENTIRE)																												
Cataraqui Region CA	245.00	1.00	1.00	50.00	15.00	5.00	5.00	10.00	1.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-5.00	-12.25
Credit Valley CA	15.00	0.00	0.00	33.10	0.00	24.30	13.60	29.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.00	-0.30	0.00	0.00	3.10	0.47	0.00	0.00	0.00	0.00
Ganaraska Region CA	45.00	60.00	5.00	10.00	5.00	5.00	0.00	10.00	0.00	5.00	-5.00	-2.25	0.00	0.00	5.00	2.25	0.00	0.00	0.00	0.00	0.00	0.00	5.00	2.25	0.00	0.00	-5.00	-2.25
Halton Region CA		0.00	0.00	90.00	0.00	2.00	0.00	8.00	0.00	0.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
Lower Trent CA	80.00											0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
Metro Toronto Region CA	46.50											0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
Napanee Region CA	21.60	0.00	0.00	5.00	5.00	7.00	0.00	0.00	0.00	83.00	0.00	0.00	0.00	0.00	2.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.00	-0.43
Niagara Peninsula CA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Prince Edward CA	400.00	6.00	20.00	40.00	1.00	1.00	2.00	10.00	0.00	20.00	-4.00	-16.00	-6.00	-24.00	15.00	60.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-5.00	-20.00
ST. LAWRENCE RIVER																												
Bas Richelieu MRC	84.00	0.00	0.00	20.00	1.00	4.10	2.10	3.80	0.00	68.00	0.00	0.00	0.00	0.00	-0.20	-0.17	-0.20	-0.17	0.00	0.00	0.00	0.00	0.70	0.59	0.00	0.00	-0.30	-0.25
Champlain MRC	20.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	4.00	0.00	0.00	-20.00	-4.00
Lajemmerais MRC	52.00	8.00	0.00	54.00	1.00	18.00	2.00	10.00	0.00	8.00	-3.00	-1.56	0.00	0.00	2.00	1.04	0.00	0.00	1.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nicolet-Yamaska MRC	39.00	5.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	85.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Raisin Region CA	70.00	2.00	0.00	30.00	5.00	1.00	0.00	48.00	0.00	14.00	-5.00	-3.50	0.00	0.00	8.00	5.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.00	-2.10
Roussillon MRC	48.00	0.00	0.00	75.00	0.00	2.00	0.00	23.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.00	-1.44	0.00	0.00	0.00	0.00	0.00	0.00	3.00	1.44	0.00	0.00	0.00	0.00
LAKE ERIE (ENTIRE)																												
Catfish Creek CA	15.00	58.91	0.59	4.33	0.00	0.03	0.01	0.24	0.00	36.81	2.00	0.30	0.00	0.00	1.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Essex Region CA	160.00	15.00	15.00	40.00	4.00	3.00	4.00	10.00	4.00	5.00	-10.00	-16.00	-5.00	-8.00	6.00	9.60	-1.00	-1.60	-3.00	-4.80	0.00	0.00	3.00	4.80	1.00	1.60	0.00	0.00
Grand River CA	23.00											0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
Kettle Creek CA	27.00	75.00	2.00	10.00	1.00	1.00	1.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Point Region CA	170.00	10.00	10.00	66.00	0.00	4.00	0.00	5.00	0.00	5.00	-1.00	-1.70	-5.00	-8.50	6.00	10.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Thames Valley CA	138.00	65.00	2.00	10.00	1.00	0.00	2.00	10.00	2.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Niagara Peninsula CA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LAKE SUPERIOR (ENTIRE)																												
Lakehead Region CA	210.00	0.00	0.00	21.50	6.00	0.00	0.00	0.00	0.05	72.45	0.00	0.00	0.00	0.00	0.00	0.00	6.00	12.60	-6.00	-12.60	0.00	0.00	0.10	0.05	0.05	0.11	0.45	0.95
MNR Nipigon		0.00	0.00	0.50	0.10	0.10	20.00	0.50	0.00	78.80	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		50.00	
MNR Terrace Bay	248.50											0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
Sault St. Marie CA	49.50	0.00	0.00	43.00	4.00	15.00	1.00	14.00	2.00	21.00	0.00	0.00	0.00	0.00	6.00	2.97	0.00	0.00	-1.00	-0.50	0.00	0.00	1.00	0.50	0.00	0.00	-7.00	-3.47
Thunder Bay District MNR	293.00							30.50		10.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00		0.00	-35.00	-102.55
Wawa MNR		0.00	0.00	1.00	0.00	1.00	1.00	60.00	1.00	40.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
TOTAL (CA & MNR)	4509.10	329.91	55.59	1045.43	61.10	101.53	83.71	460.04	16.05	694.06	-38.00	-45.91	-16.00	-40.50	97.80	271.48	3.80	33.73	-11.00	-17.68	0.00	0.00	50.90	88.64	1.05	1.71	-94.85	-385.55

LEGEND: AFC = Agricultural Field Crop; ASP = Agricultural Specialty Crop; RES = Residential; C&I = Commercial and Industrial; TRAN = Transportation; EXTR = Extraction; UNDEV = Undeveloped data analysis purposes, these agencies have been grouped under one waterbody only.

Basin Overview

The results indicate that the general trend for the future will be a rather large increase in residential development along the shore and a smaller, but significant, increase in recreational development at the expense primarily of natural (undeveloped) shores and agricultural land.

The single largest percent increase in residential (15%) over the next 10 years affecting 60km (37 miles) of shoreline is expected by Prince Edward Region CA on Lake Ontario. Lake Huron, as a water body, will experience the largest percentage increase as a percentage of shoreline. Most of this development is likely to come from cottage lot development and is estimated to impact 180km (112 miles) of shoreline. The Lake Huron development will come with a corresponding loss of primarily undeveloped shoreline.

Land Use Change By Category

With the exception of the undeveloped category, **agriculture** as a whole is expected to experience the largest decline. The areas covered by the Essex Region Conservation Authority will lose the most agricultural land as a percentage of shoreline with expectations of 10 and 5 percent declines in field and speciality crops, respectively. The largest proportion of speciality crop loss was reported in the area covered by the Prince Edward Region Conservation Authority (primarily orchard land, where approximately 45km (28 miles) of agricultural shoreline will be lost).

Residential land use is expected to increase dramatically along the Canadian shoreline. Largest expected increases were reported by the Prince Edward Region Conservation Authority (15% or 60km (37 miles) of shoreline in this jurisdiction). MRC Roussillion, located along the south shore of Lac St. Louis in Quebec reported an expected decrease in residential development of 3%. This land use change will occur to create recreational parks along the river, however, the exact nature of residential loss remains unclear. Lake Huron will experience the largest per kilometre increase in residential shoreline use (180km (112 miles)).

Throughout the basin, respondents predicted a relatively small overall decline (3.7km (2.3 miles) in the amount of shoreline used for **commercial and institutional** purposes. The largest expected decline was reported by Sudbury District MNR who anticipate losing 3.5%, or 5km (3.1 miles) of commercial/institutional shoreline land use within their jurisdiction. Conversely, the Lakehead Region Conservation Authority anticipates a net gain of approximately 6%, or 13 km (8.1 miles) of commercial/institutional land use along the shoreline. It is postulated that the majority of this will be within the Thunder Bay representative site, where a recently completed waterfront tourism and recreation plan calls for increased recreation and tourism activity along the shoreline, including commercial operations. Espanola District MNR has projected a 2% increase in commercial/institutional land use affecting 28km (17.4 miles) of shoreline.

Throughout the basin, there was an estimated net loss of 18km (11.2 miles) of **industrial** use shoreline. The majority of loss (3%) was predicted to occur within the area of the Lakehead Region Conservation Authority. This loss likely reflects the general economic downturn being experienced by the country, combined with shoreline redevelopment plans within the region. The Essex Region and the Credit Valley Conservation Authorities predict losses of industrial land of 3% and 2% respectively. The largest net loss of industrial shoreline in kilometres (miles) will be experienced by the Lakehead Region CA (12.6km (7.8 miles)). MRC Lajemmeraus in Quebec is the only region to report a net increase in industrial land use in the next ten years. The projected 1% increase is likely tied to a specific development, although this could not be confirmed.

All respondents reported that there would be no change (net gain or loss) in **transportation and communication** land uses. It is hypothesized that this in part reflects a possible recognition by government agencies that the construction of infrastructure along the shoreline is not a desirable undertaking.

The ten year projection for **recreation** land use along the Canadian shoreline is for a general increase of 137km (85.1 miles). The majority of this increase was predicted by the Espanola District MNR (56km (34.8 miles) or approximately 4% of the shoreline in their jurisdiction). MRC Champlain, located along the south shore of the eastern portion of Montreal, reported an estimated 20% increase in recreation shoreline land use over the next decade, affecting 4km (2.5 miles) of the shore. Similarly, Sudbury District MNR reports an estimated recreational land use increase of approximately 10%, or 17km (10.6 miles) of shoreline. Excluding the Quebec site, the majority of recreation increases are anticipated to occur on Lake Superior. It is hypothesized that present land use for the shoreline on the lower lakes is more regulated and options for development and redevelopment are more restricted based on market and economic factors.

Similar to the projected trend for transportation and communication, very little change in **extractive** land uses was forecast for the basin. This is not surprising given the relatively low amount of this activity along the shoreline. The Essex Region Conservation Authority and Lakehead Region Conservation Authority projected extraction land use increases of 1% and 0.05%, respectively. Given the characteristics of aggregate resource deposits, these increases will be very site specific in nature.

Second only to residential land uses on a percentage basis, **undeveloped** land uses (water, wetland, grass land and barren/denuded) are projected to have the largest net change over the coming decade. For the shoreline as a whole, this change is estimated to be a net loss accounting for a total of 198 kilometres (123 miles) of shoreline. The majority of this natural shoreline will likely be lost to residential uses. In ranked order, largest percentage losses are anticipated to occur within the jurisdiction of Thunder Bay District MNR (35%), Sudbury District MNR (30%) and MRC Champlain in Quebec (20%). Only Lakehead Conservation Authority and Nipigon District MNR are projecting net increases in the amount of undeveloped land within their jurisdiction. Espanola District MNR reports the largest per kilometre decrease of 168km (104.3 miles), or 12% of their shoreline.

United States Shoreline

Basin Overview

Future land use trend information for each lake and connecting channel is summarized in TABLE 6.4. These numbers are summarized from more detailed county-by-county statistics presented in the Land Use and Shore Management Task Group Report. The numbers reflect a combination of the residential, commercial / industrial and public infrastructure categories. Land use trends presented herin are exclusively "new" development. Redevelopment of existing properties has not been explicitly addressed. "Average Development" refers to the current percentage of shoreline on a particular waterbody that falls into these three land use categories. The "10 Year Development Trend" is the increase in percentage of shoreline that is expected to be developed into any of these three categories. The "Average Total Possible Development" is the maximum percentage of shoreline on the waterbody that could possibly be developed into any of these three categories. Limitations to development that are factored in to this number are public land ownership, wetlands, dune environments and lack of transportation networks. For example, on Lake Superior, residential, commercial / industrial and public infrastructure currently occupy 20% of the shoreline. Over the next ten years, it is anticipated that there will be a 1% growth in these types of land uses and that the total possible growth of these three land uses will be restricted to 40% of the total shoreline length.

From this table, it is clear that growth in these three categories will continue on all lakes and connecting channels, except for Lake St. Clair, which is already at its maximum limit of development. On a basin-wide scale, it is anticipated that there will be a 3% increase in development over the next ten years. For individual waterbodies, the largest increase in development is anticipated on the St. Clair River (7%) followed by Lake Ontario (6%) and Lake Erie (5%).

Detailed Site Studies

A detailed breakdown in future trends by land use category was not possible for the U.S. shoreline. However, data is available for each of the site studies. For the counties of St. Louis, Minnesota and Douglas, Wisconsin (which encompass the **Duluth / Superior** study site, a 2% and 1% increase in development respectively, is expected. For the **Chicago** site study area, it is anticipated that there will be no increase in development over the next ten years. In **Berrien**

Table 6.4 United States Development Trend Summary Table By Lake or Connecting Channel

1988-89 Land Use Development and Trends	Lake or Connecting Channel - United States											
	Lake Superior	St. Marys River	Lake Michigan	Lake Huron	St. Clair River	Lake St. Clair	Detroit River	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Great Lakes St. Lawrence River
Total Shoreline Length (km)	2564.0	389.7	2711.7	1784.7	34.0	464.6	126.9	999.2	111.5	678.3	646.4	10511.0
Average Development (%)	20	41	41	35	86	90	70	57	68	53	33	40
10-Year development Trend (%)	1	1	2	3	7	0	2	5	2	6	2	3
Average Total Possible Development (%)	40	50	70	70	100	90	90	80	95	80	80	65

County, a 5% increase in development is expected, while **Ottawa County** on Lake Erie could see a 10% increase in development. Erie County on Lake Erie (which contains the **Hoover Beach** study site) anticipates little or no growth over the next ten years, while **Oswego County** on Lake Ontario, may experience a 4% increase. Finally, the area around **Alexandria Bay**, New York, is anticipated to have a 2% increase in development over the next ten years.

6.3 Great Lakes - St. Lawrence River Shoreline Management Practices

6.3.1 Shoreline Management Definition

The development of a shoreline management definition for the purposes of this study recognizes that the consideration of shoreline management measures is being focused. It therefore considers the need for management given the fact that lake level fluctuations do exist and the resulting land use conflicts are influenced by shoreline processes. The definition developed is as follows:

> *"Shoreline management is the approach taken or actions adopted in order to direct existing and future land and water use activities along the shoreline in a fashion that will reduce the adverse consequences of the interaction between human activity and the physical environment. These consequences or conflicts are generally viewed as primary (e.g. loss of land or structures), or secondary (e.g. impact on shipping and subsequent impact on industry relying on shipping). The approach to shoreline management is wide ranging. It can include: control of human activities to reduce conflict (i.e. regulations); provision of financial incentives to encourage changes to human activities and to reduce conflict (e.g. loans, tax incentives); and direct manipulation of shoreline form or process (e.g. structural and non-structural shore protection) (Triton Engineering and Ecologistics Limited, 1992).*

6.3.2 Shoreline Management Measures To Be Examined

The measures to be examined by the Land Use Task Group were introduced in Section 2. They are repeated below, along with a brief definition of each.

Land Use Regulatory Practices

Setback Requirements would require new buildings to be set back to a predetermined erosion or flood control line. These could also require existing dwellings lakeward of this line to relocate landward. Construction lakeward of the control line could be permitted if structures are portable or moveable. These measures are supported by hazard mapping.

Elevation requirements would require new buildings to be elevated above a predetermined 1:100 year flood level. These could also require retrofit flood proofing or raising of buildings above the flood elevation. These measures are also supported by hazard mapping.

Habitat protection would include public acquisition of barrier beaches, wetlands, dunes and other shore habitat, and the development of regulations to protect habitats located on private land from the impact of land development.

Shoreline alteration requirements would include the regulation of privately or publicly constructed shore protection and navigation structures; extraction of beach and nearshore deposits; and land filling to protect adjacent land uses and the environment from any adverse effects of shoreline alteration.

Deed restrictions/regulations would require notice of shoreline hazards in property deeds or the requirement for disclosure of hazards in real estate transactions, to alert prospective purchasers of shore property. This could include deed restrictions on the type and location of development permitted on hazard susceptible property.

Development controls for public infrastructure would ensure that the design or location of roads, public buildings, water supply and sewage lines, and other infrastructure would take place outside of recognized hazard areas, or ranges of water level fluctuations.

Non-structural land use practices would include the public acquisition of hazard land and buildings, or publicly financed relocation of structures outside of hazard areas. Public agencies could convert acquired land to recreation uses or resell for private development with conditions to minimize hazard susceptibility.

Land Use Incentive - Based Practices

Tax incentives/disincentives might include a variety of incentives to encourage maintenance of shoreline habitat or relocation of structures landward of a hazard setback line, and tax penalties to discourage development of hazard land or to fund coordinated shore protection in designated shore reaches.

Loans to property owners could encourage various nonstructural and structural measures, including flood proofing or relocation of buildings, or shore protection. This could also include the elimination of loans that encourage new development in hazard susceptible shore areas.

Grants to property owners could also encourage various nonstructural and structural measures, including floodproofing or relocation of buildings, or shore protection. This could include the elimination of grants that encourage new development in hazard susceptible shore areas.

Insurance (either subsidized or actuarial rate insurance) for properties located in recognized hazard areas could be provided. Such insurance could be conditional on municipal or property owner actions to reduce hazard susceptibility.

Shore Protection Alternatives

Structural shore protection to prevent erosion would include public agency design and construction of various large-scale shore protection works, including seawalls, breakwaters, groynes, revetments, artificial headlands or artificial barrier islands.

Structural shore protection to prevent flooding would include public agency design and construction of large-scale shore protection work, including temporary or permanent dykes.

Non-structural shore protection would include public agency implementation of various non-structural shore protection measures, including beach nourishment, landfilling, bluff grading, bluff drainage, or vegetation planting.

6.3.3 Inventory and Extent of Shoreline Management Practices - Methods

The current use of the shoreline management measures listed above was assessed primarily through available information as well as current data collected by means of the questionnaire described previously (for Canada) and through an ad hoc "Interstate Committee on Land Use and Shoreline Management" (ISCLUSM) (United States). The Canadian questionnaire was developed to determine the extent of current use of the various shoreline management measures. The measures included in the listing are those currently in common use by Canadian municipalities, Conservation Authorities, and other public agencies. In addition, the respondents were asked to judge the effectiveness of the measures, as well as to provide an indication of any further measures that should be included for shoreline management.

The ISCLUSM consisted of a series of state representatives knowledgeable in the areas of shoreline management, as well as Task Group members and consultants. Several workshops were held to solicit information from these individuals and to present the needs and progress of the Task Group. Through these workshops and follow up activity, a large amount of information on U.S. shoreline management practices was obtained. A detailed literature review was also undertaken, including visits to the library of the National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean and Coastal Resource Management in Washington D.C.

Information regarding shoreline management measures from a riparian survey conducted by Environment Canada and the U.S. Army Corps of Engineers in 1989 (see Section 4) was also analyzed and summarized. This survey provided insight into the types of shoreline management practices that riparians have employed in the past, and provided details on future preferences for these types of measures.

6.3.4 Inventory and Extent of Shoreline Management Practices - Results

The purpose of this section is to further define the various shoreline management measures under consideration and to highlight their spatial distribution and extent of application throughout the Great Lakes - St. Lawrence River Basin. This information is provided below on a measure-by-measure basis with a discussion of both Canadian and U.S. distribution. Evaluation of the effectiveness, costs, benefits, compatibility and implementability of each measure will be discussed in Section 6.4. Further details on the overview and extent of these measures can also be found in Ecologistics Limited (1992 a and b).

Setbacks

Overview of Measure

Setbacks consist of regulations specifying that new development (or redevelopment) along the Great Lakes-St. Lawrence River shoreline take place landward of a predetermined erosion and/or flood control line. Setbacks can be divided into two general categories called *fixed* and *floating*. *Fixed setbacks* are those where the setback distance is established prior to a permit application. Under *floating setbacks*, the setback distance is determined when a permit is requested and is based on a multiple of the average.

Setback lines are generally defined based on the 100 year flood elevation, or based on a 30 to 100 year erosion limit. The 100 year flood elevation is defined as the water level due to the combined occurrences of mean monthly lake levels and wind setups having a total probability of being equalled or exceeded during one year of one percent. The 100 year erosion limit is defined as the average annual recession rate extended 100 years from the shore, plus an allowance to achieve a stable slope in bluff areas.

Administering agencies implement setbacks in a variety of ways. Some use a standard distance from a determined line, while others employ equations which may account for local site specific conditions. Municipal zoning bylaws which restrict the use of land as outlined in official plans can be used to specify building setbacks from the shoreline.

Extent of Application

In a 1991 survey administered to Conservation Authorities in Ontario, Law et al. (1992) found that of 100 municipalities along the shoreline with a physical flood hazard, 82 recognized the hazard in an Official Plan or zoning by-law. Similarly, of 86 municipalities with an erosion hazard, 74 recognized it in Official Plans or by-laws. While these hazards were recognized, they were not always appropriate. Only 27 of the 82 flood hazard designations were correctly referred to as "hazard land", "floodplain", or "flood prone." Similarly, only 23 of the 74 erosion hazard designations were appropriately referred to as "hazard land" or "erosion prone." The remainder were either classed as a "close" designation, were inappropriate, or were not referred to at all in the Official Plan. Setback "reference points" for flood and erosion hazards were recorded for 66 and 63 municipalities/townships, respectively.

In a 1983 study of twenty shoreline municipalities that had introduced or amended shoreline hazard policies, Kreutzwiser (1988) determined that only six municipalities had specific requirements for building elevations in flood-prone areas, building setbacks, and shore protection. A further eight municipalities had a setback requirement and one specified a building elevation. Four of the fifteen municipalities specifying a setback used the variable 100 year requirement based on local recession rates.

In the United States, reports by Houlahan (1989) and Saunders et al.(1990) indicate that seven of the eight Great Lakes states (Indiana being the only exception) have formal setback regulations in place. The majority of these are floating setbacks, utilizing a certain number of years, multiplied by the average annual recession rate, plus the addition of a stable slope allowance, or other fixed "buffer" limit. The extent of setbacks application between the Great Lakes states varies according to whether the state relied on its participation in the NFIP for coastal flooding purposes or for coastal management as a whole; thus addressing shoreline erosion and storm damages. New York, Michigan and Wisconsin acknowledged the limitations of the NFIP in addressing all the necessary coastal management issues and consequently took steps to ensure that all aspects of coastal zone management were addressed. These three states have more vigorous setback requirements than other Great Lakes states.

Relocating structures behind newly designated setback lines is not a widely applied type of measure along the Great Lakes shoreline, however it has been carried out in many of the coastal states.

Flood Elevations / Floodproofing

Overview of Measure

Flood elevations would ensure that any new structures built in a hazard area would be constructed above a specified elevation, (e.g., the 1:100 year flood level). Existing dwellings would be retrofitted by raising the structures above the 1:100 year flood level or alternatively raising the elevation of the first opening of the house.

Buildings can be raised above the flood level either by the application of fill in low lying areas or by raising the foundation through the use of posts, piles, piers, walls, etc. Flood damages would be minimized, but residential use of the shoreline would still be permitted.

The 1:100-year flood level in the United States is also known as the base flood elevation (BFE) as determined by the Federal Emergency Management Agency (FEMA). Once the BFE has been established, it is published on a Flood Insurance Rate Map, which is used to delineate areas of a specific community that are subject to the base flood.

In communities participating in the NFIP, certain regulations apply to elevating structures prone to flooding, depending on whether the retrofitting project can be classified as a substantial improvement. In A-Zones (coastal flood-prone areas subject to storm surges with velocity waves of less than 3 ft (0.9m)), regulations are set that the top of a building's lowest floor (including the basement) be elevated to or above the Base Flood Elevation (Federal Emergency Management Agency, 1986).

Regulations for structures located in the V-Zone (coastal flood-prone areas subject to storm surges with velocity waves of 3 ft (0.9m) or more) require that the lowest portion of the horizontal structural members supporting the lowest floor be elevated on pilings or columns above or to the BFE. (Federal Emergency Management Agency, 1986). Construction of new buildings must also comply with a number of strict requirements.

Floodproofing and elevation requirements are often contained in building codes as standards that builders must follow when designing or building structures in hazard prone areas. These standards establish minimum construction elevations consistent with flooding potential.

Extent of Application

In the Ontario experience, flood elevations are one of the most widely applied and most effective measures (Triton Engineering and Ecologistics Limited, 1992). They are commonly specified in planning guidelines established by Conservation Authorities and use the 1:100 year flood line with a wave uprush limit, a standard derived from the Canada-Ontario Great Lakes Flood and Erosion-Prone Areas Mapping Program.

In a 1988 study of 10 U.S. cities that had implemented land use measures, Burby et al. (1988) determined that of the flood damage mitigation adjustments employed by developers, adding fill to the site and elevating individual buildings were the predominant methods employed.

Under the National Flood Insurance Program (NFIP) in the United States, a wave run-up provision is given which specifies flood elevation criteria that participating states must adhere to. Although no detailed information of the measure's application at the state level was available, states participating in the NFIP must meet these flood elevation requirements.

Results of the Canadian Riparian Survey indicated that only approximately 9% of Ontario respondents and 1% of Quebec respondents raised their dwellings to protect their property against the adverse consequence of fluctuating water levels.

Land Acquisition

Overview of Measure

Public acquisition of shoreline property is the most direct approach local governments can use to prevent development along flood-prone portions of the shoreline. In addition to potential damage reduction from flooding and erosion, land acquisition programs have also been undertaken in pursuit of other goals including wetland habitat preservation, provision of open space recreational areas and the maintenance of water quality and groundwater recharge capabilities (Burby et al., 1988).

Outright purchasing of the land is a capital intensive venture. As a result of the financial requirements, municipalities embark on acquisition programs over a period of time or in phases, often with the support and cooperation of regional or other levels of government.

Shoreline properties may also be obtained through a variety of other means such as mandatory dedication provisions in subdivision regulation (5% open space in Ontario), conservation easements or purchase of development rights, private landowner bequests, donations from private landowners and landowner sales of property to the public at a bargain price in return for classification of the difference between the market price and sale price as a charitable deduction for tax purposes (Burby et al., 1988).

Extent of Application

Land acquisition programs have been carried out throughout Canada and the U.S. by municipalities, Conservation Authorities and other levels of government. Acquisition programs for the purposes of shoreline management or waterfront preservation have been carried out by the majority of Conservation Authorities whose jurisdiction includes portions of the Great Lakes - St. Lawrence River shorelines. In Ontario, notable programs include Frenchman's Bay, Hamilton Beach and Burlington Beach. Additionally, Royal Commission on the Future of the Toronto Waterfront (1992) has recommended the acquisition of a strip of land along the Lake Ontario shoreline (for a waterfront trail and other public access activities) and has established the Waterfront Regeneration Trust to investigate this further.

Habitat Protection Measures and Regulations

Overview of Measure

There are many pieces of legislation affecting all or part of the Great Lakes - St. Lawrence River coastal zones. Many of these deal with planning and development issues. Habitat regulations are intended to ensure the protection of areas which provide specialized habitat requirements to aquatic or terrestrial life. Examples of such areas would be colonial waterbird nesting sites, waterfowl concentration areas, and fish spawning and nursery habitat.

Canadian legislation pertinent to protective management in the Great Lakes would include (from McKeen and Law, 1991 and Smith, 1987): the National Parks Act (Parks Canada Policy); the Migratory Birds Convention Act; the Canada Wildlife Act; and the Fisheries Act. Ontario legislation includes: Ontario Fishery Regulations; the Provincial Parks Act; the Wilderness Areas Act; the Game and Fish Act; the Public Lands Act; the Mining Act; the Beach Protection Act; the Lakes and Rivers Improvement Act; the Ontario Heritage Act; the Conservation Authority Act; and the Planning Act.

Quebec legislation and policies broadly applicable to shoreline habitat regulations include: a series of laws, usually enforced by the Quebec Ministry of the Environment, for the protection of endangered species, trees, environmental quality, water systems and nature reserves; a number of regulations or directives on drinking water, groundwater, oil refinery effluent, sewers, sewage, water treatment, and toxic waste, all of which may be applicable in shore zones; and policies for the protection of shorelines, coastlines and floodplains.

At the federal level in the United States, the most predominant regulatory influences are the Coastal Barrier Resources Act, under which coastal wetlands are protected, and the National Estuarine Sanctuary Program which attempts to forestall ecological degradation of estuaries. Under the Coastal Barrier Resources Act, over 167 coastal barriers along the Great Lakes shoreline have been identified and delineated by the Department of the Interior's Coastal Barrier Study Group.

As part of the Coastal Zone Management program, the National Estuarine Sanctuary Program currently protects eighteen Reserves, with a number of new sites being proposed, including one in the Lake Ontario/St. Lawrence River Basin in New York (5,000 acres (2025 ha)). The Old Woman Creek Estuary in Ohio, which covers an area of 543 acres (220 ha), was designated in 1980.

Extent of Application

Smith (1987) provides a comprehensive inventory of "natural heritage areas" regulated or protected along the Canadian shores of the Great Lakes. This study provides detailed information on the location and aerial extent of the protected natural areas, including heritage sites. Information on the length of shoreline protected is not presented.

The following represents a summary of these findings for individual waterbodies.

Along the shores of **Lake Ontario**, approximately 7,265 hectares (17,945 acres) of land are protected, a portion of which is directly associated with the shoreline. Protected areas include a segment of a national park, three national wildlife areas and six provincial parks. Areas protected along **Lake Erie and Lake St. Clair** include one national park, four national wildlife areas, fifteen provincial parks and four provincial wildlife management areas (two of which are within provincial parks). This totals approximately 12,345 ha (30,492 acres), 8066 ha (19,923 acres) of which is comprised of Rondeau and Long Point Provincial Parks. A total of 113,406 ha (280,113 acres)) are protected along the **Lake Huron** shore. Of this, approximately half of the protected area (60,750 ha (150,053 acres)) is comprised of Killarney and the proposed Blackstone Harbour Provincial Parks. Other protected areas include three national parks, two migratory bird sanctuaries, twenty-two provincial parks and three provincial wildlife management areas. Approximately 419,578 ha (1,036,358 acres) of the **Lake Superior** shoreline are protected, the majority of which (343,459 ha (848,344 acres)) is comprised of Pukaskwa National Park and Lake Superior Provincial Park.

In the United States, at the state level, all of the states contacted to date (6 of 8) have protection regulations in place along the Great Lakes shoreline.

The **New York** Department of Environmental Conservation has long implemented wetland restoration and enhancement programs on state owned wetlands, and wildlife management areas. Currently, under the Freshwater Wetlands Act, wetlands 5 ha (12.4 acres) in size or greater are protected by state law. Under the Coastal Resource and Waterfront Revitalization Act, New York has also identified and protected over 100 significant fish and wildlife habitat areas. **Minnesota** has enacted the Wetland Conservation Act which specifies that all activities have a "no net loss" to all state wetlands. Local wetland protection programs will be developed and adapted in the near future (Personal communication, D. Retka, Minnesota DNR). In **Ohio**, the state's significant coastal habitat (1215-1620 ha (3000-4000 acres) of wetland and estuaries) is regulated by the Division of Wildlife of the Department of Natural Resources and the Division of Natural Areas and Preserves. The state's one significant dune complex, Headland Dune State Nature Preserve, which is approximately 12-16 ha (30-40 acres) in size, is protected by the Division of Natural Areas and Preserves.

In **Michigan**, wetlands and other natural shoreline features such as beaches and dunes are protected from destruction under three state statutes: the Goemaere-Anderson Wetland Protection Act; the Sand Dunes Protection and Management Act; and the Shorelands Protection and Management Act. State acquisition of wetlands is made possible by The Michigan Natural Resources Trust Fund and also through a number of programs including funds raised indirectly thought he sale of waterfowl hunting licenses and by a percentage of the sales tax on firearms.

Trust fund monies are acquired by payments to the state for oil and gas leases and used to acquire property or rights in land for environmental protection on recreational use. Two large wetland complexes acquired partially in this manner are the St. Johns Marsh project on Lake St. Clair (810 ha (2,000 acres)) and the Harsen Smith Marsh on Saginaw Bay (405 ha (1,000 acres)). State acquisition of development rights, but not direct purchase, of the land determined unique or critical that should be preserved, is also authorized through the Farmland and Open Space Preservation Program. Criteria for defining lands eligible for acquisition under this program has recently been developed by the Real Estate Division and Land and Water Management Division and three areas are currently being considered for acquisition through this program: a 58 ha (142 acre) parcel with coastal wetland along Saginaw Bay in Bay County and over 73 ha (180 acres) of wetland on Marquette Island in northern Lake Huron.

Shoreline Alteration Requirements and Regulations

Overview of Measure

There are a number of regulations in place in both Canada and the United States that govern alterations to the shoreline. In Canada, Conservation Authorities (C.A.'s) are given provincial jurisdiction to apply regulations to control fill, construction and alterations to waterways, under Section 28 of the Conservation Authorities Act. Fill Regulations can prohibit the dumping or removal of fill in regulated shoreline areas without C.A. permission. Construction Regulations can prohibit the construction of any building on the regulated shoreline areas without prior C.A. permission. Alteration to Waterways Regulations can prohibit the change to or interference with the existing shoreline without prior C.A. permission.

Property owners are required to apply for a permit from a C.A. prior to initiating any work in regulated shoreline areas. To obtain a permit, an application, accompanied by site plans and a permit fee, is submitted to the C.A. To minimize the length of time required to obtain approval, the administrative review process is preceded by consultation with C.A. technical staff before the application is submitted. A site visit with the applicant and other agencies involved in the proposed works is arranged.

In the United States, the U.S. Army Corps of Engineers and individual state agencies have jurisdiction to apply regulations to control fill, construction and alteration of waterways. Under Section 10 of the Rivers and Harbors Act of 1899, the Corps issues a permit program for the deposition of fill material, dredging, excavation, construction (on natural water bottoms as well as fill) and all obstructions, alterations and modifications of navigable waterways (Holmes, 1980). The Corps also issues permits under Section 404 of the Clean Water Act (CWA) for discharges of dredged and fill material at specified disposal sites in navigable waters that do not fall under jurisdiction of Section 10 of the Rivers and Harbors Act, in compliance with the site selection of those sites with EPA guidelines (Holmes, 1980).

Property owners are required to apply for a permit prior to initiating any work in regulated shoreline areas. To obtain a permit, an application accompanied by site plans and a permit fee is submitted to the State Department of Natural Resources. To minimize the length of time required to obtain approval, several states have been given authority to approve the applications under the Corp's regulations if the State program complies with federal standards. This *"joint approval or review process"* is preceded by consultation with Department staff before the application is submitted. A site visit with the applicant and other state of local agencies involved in the proposed work is also encouraged.

Extent of Application

Since 1991, six Conservation Authorities in Ontario have implemented various shoreline development regulations. Two other Authorities are in the process of developing shoreline regulations to implement in the next few years. At the state level, shoreline alteration requirements appear similar, although those states which administer joint permit applications have been identified as more efficient.

Pennsylvania issues a joint permit program under their Dam Safety and Encroachment Act whereby the applicant submits one application to the Department of Environmental Resources and the Corps. Under the Encroachment Permit Process, the state regulates all waters and reviews environmental and engineering aspects of each application in conjunction with comments received from the Pennsylvania Fish and Boat Commission. Permits can be denied for encroaching on a wetland and an applicant must prove that the proposal facility or activity is water dependent (personal communication J. Hoffman, Pennsylvania DER).

In the State of Minnesota, shoreline alteration requirements are regulated under the Shoreland Management Act and implemented in rural areas under the North Shore Management Plan (North Shore Management Board, 1988) and through city ordinances within the urban area of Duluth. The State permit program regulates all shoreline development or activities that might potentially impact shoreline vegetation and wetlands (personal communication, D. Retka, Minnesota Department of Natural Resources).

The Illinois State Permit Program regulates activities under The Rivers Lakes and Streams Act to ensure that structures do not have adverse impacts on navigation or adjacent properties. State officials conduct site inspections to make sure that a structure conforms to the approved proposed structure (personal communication, D. Injerd, Illinois Division of Water Resources).

New York State regulates shoreline alteration requirements under four statutes: the Freshwater Wetlands Act, the Coastal Erosion Hazard Area Act, the State Environmental Quality Review Act, and the Waterfront Revitalization and Coastal Resources Act.

Deed Restrictions / Regulations and Disclosures

Overview of Measure

Deed restrictions would consist of restriction notices placed on property deeds so that future buyers of shoreline property are aware of the potential hazard of flood or erosion. Ideally, deed restrictions would also encourage future property owners to use the land for compatible shoreline uses such as open space or recreation.

Buyers of vacant shoreline could be notified in their deed that residential development would not be permitted or would be restricted in some way, so as to prevent potential hazardous development. If the property owner decides to proceed with residential development, despite the deed restrictions, the deed could potentially be considered null and void and the buyer could possibly lose the property.

Disclosure would consist of mandatory warnings being included on property deeds so that potential buyers are aware of the associated risks. Real estate agents or land owners would then be required by law to inform prospective buyers of the potential hazard of the property. Similarly, property owners would also be responsible for disclosing any past damage or repair costs associated with flooding or erosion problems on the property. If they refuse to disclose problems, they could legally be held responsible for any future damages incurred by the new buyers.

Extent of Application

There is currently little use of these types of mechanisms in Ontario. According to the responses received by Triton Engineering and Ecologistics Limited (1992), only four Conservation Authorities have used deed restrictions in isolated instances.

Deed restrictions and disclosures have been more widely implemented as implementation mechanisms in the United States. Several American states require or have recently proposed deed restrictions and disclosures in their real estate transactions.

For example, legislation of the state on Ohio requires that:

> *"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 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 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."*

Wisconsin real estate "Offer To Purchase" forms include the following clauses:

> *"(Seller warrants/Map dated __________ indicates) (none, part, all) of the property is located in a flood plain."*
>
> *"Seller warrants and represents to Buyer that Seller has no notice of any shoreland or special land use regulations affecting the property."*

Deed restrictions and disclosures are also recommended in the New York Governor's Task Force on Coastal Resources and legislation on disclosures is currently being drafted.

The Task Force recommends:

> *"Property in coastal hazard areas should have that designation recorded on the maps and official records in municipal clerk's offices".*

Deed restrictions are also set out in the sand dune statutes enacted in the State of Michigan. In Minnesota, disclosures are alluded to in the North Shore Plan where the Location of Erosion Prone Areas are defined, but the mechanism has not been implemented yet.

Development Controls for Public Infrastructure

Overview of Measure

The placement of public infrastructure (i.e., roads, bridges, sewers, water supply and government buildings and installations) has the potential to impact on shoreline development. These fundamental decisions, by implication, direct or redirect development to specific areas. This has major implications for shoreline management in the long term. Development controls for public infrastructure as a measure, would consist of designing and locating public infrastructure outside of recognized hazard areas, to reduce the potential for future losses. Examples of actions that could be undertaken under this measure include: during initial development (or rehabilitation after substantial damage), elevate water supply or wastewater lines and roads; floodproof buildings that must be in a hazard area; incorporate water saving devices and procedures; and avoid infrastructure in shoreline hazard areas.

Zoning regulations can also be used as a measure to control development or influence the location of development. Zoning regulations can be used to prohibit certain uses, such as high density housing in flood hazard areas or prohibit virtually all urban uses.

Extent of Application

Public infrastructure in and of itself does not necessarily impact on shoreline development, but the subsequent development that it promotes does. This impact has led to the creation of various pieces of legislation in the U.S. For example, past decisions to construct roads, bridges and causeways to barrier islands on the east coast have had major implications in hazard prone development and potential hazard related development. Partially as a response to this situation, the U.S. has enacted the Coastal Barrier Resources Act and more recently the Coastal Barrier Protection Act. Under these Acts, federal subsidies for the construction of access (causeway, bridges, etc.) are prohibited. In this manner, public funds are not facilitating future hazard development.

Tax Incentives / Disincentives

Overview of Measure

Tax incentives are designed to affect floodplain development indirectly by influencing individuals and firms to calculate the advantages and disadvantages of building on a particular site. These consist of various tax related arrangements to provide property tax relief, tax abatements, tax penalties or tax collection for a specified purpose.

One such tax policy applied primarily in the U.S. is to provide property owners tax relief if they purchase property and maintain it as flood storage or wetland areas. Development is therefore precluded and the potential hazard associated with shoreline location is reduced or eliminated. These areas may also provide valuable fish and wildlife habitat.

Another type of incentive is to provide tax abatement to shoreline property owners to relocate existing structures behind a setback line designated as a flood or erosion hazard zone. Conversely, tax penalties can be assigned to any property owner who builds in a designated hazard area. Taxes collected from these developers can be used to cover municipality costs incurred in preparing for the impacts of flooding, such as emergency response plans. Alternatively, these monies could be used to design and construct structural shoreline protection measures where needed.

Extent of Application

There is little documentation presently available that describes how tax incentives and disincentives have been applied to shoreline management. These types of incentives are more widely in place in the U.S. In Canada, under the Flood Damage Reduction Program (FDRP) homes located in flood-prone areas are not eligible for mortgage insurance granted to guarantee repayment of non-conventional mortgages (i.e., low equity) available through the Canada Mortgage and Housing Corporation (CMHC).

There are several other incentives in place that have been initiated by the provincial government to encourage/discourage certain land owners, which have some relevance to shoreline property owners. Under the Property Assessment Act, the value of a property can be reassessed based on a reduction of the size of a property due to erosion. If erosion damage is more severe than just diminishing the size of property, and the dwelling is damaged or lost, then the reassessed value of the property would be even lower (Personal communication, R. Kreutzwiser,University of Guelph).

A second type of incentive is applicable under the Income Tax Act, to businesses only , but has some application to lakeshore property owners who derive income from their properties (e.g., a tourist cabin operator at a recreational campground or a farmer whose property is adjacent to the shoreline). Costs of maintaining this shoreline or implementing shoreline management measures can be deducted from income reported on income tax returns as an allowable business expense (personal communication, R. Kreutzwiser, University of Guelph).

Four other programs provide some tax incentive for property owners to keep their land undeveloped, but are not specific to floodplain hazard zones. Under the Management Forest Tax Rebate Program, landowners enter an agreement with MNR to manage their woodlot. They are then given a rebate up to 100% on property taxes. Similarly, under MNR's Ontario Conservation Land Tax Reduction Program, property owners can enter agreements with MNR to maintain wetlands and are then given rebates up to 100% of eligible property taxes. Only property owners who have Class 1, 2 or 3 wetlands are eligible under the Program. Under the Property Assessment Act, agricultural land is taxed at a lower rate than the residence, encouraging the land owner to maintain his land in agricultural production. Finally, under the Land Stewardship II Program, farmers could receive grants to take land unsuitable for cropping out of production and to restore a permanent vegetative cover such as grass or trees. Grants would cover the cost of establishing the permanent cover. Indirectly, such a program could be applied to erosion-prone shore zone load best left permanently vegetated rather than cropped.

In the U.S., Michigan and New York have or have had specific programs in place that provide communities or property owners with tax incentives. Michigan's ongoing program of wetland acquisition was first instigated through historical acquisition by the state through tax reversion. Through tax reversion, property owners are exempt from property taxes on designed lands. Thousands of acres were acquired by the state in this way during the 1920's and 1930's. Tax reversion still facilitates an important opportunity for acquisition of Michigan's wetlands.

New York state has established Local Waterfront Revitalization Programs (LWRPs) to facilitate the Coastal Management Program addressing of the problems and issues of coastal development and protection in cooperation with coastal municipalities. To date, 105 coastal municipalities out of 250 are preparing or implementing LWRPs in full partnership with the state. Ideally, LWRPs analyze waterfront conditions and allocate land and water uses consistent with state coastal policy and propose capital improvement programs which forecast needs for infrastructure and services. By providing a detailed analysis of local conditions and waterfront objectives, they provide an opportunity for the state to enhance its ability to plan for coastal activities consistently with coastal policies.

Loans

Overview of Measure

In Ontario, the provincial government introduced a number of shoreline property assistance programs following the November 1972 and March 1973 floods. Many of these programs provide grants or ad hoc assistance to property owners. One of these programs, the Shoreline Property Assistance Program, provided loans to lakeshore residents through the local municipality.

Shoreline property owners requiring a loan would apply to the municipality who would appoint an official to investigate the property and recommend what measures were required. Loans are provided to a maximum of $20,000 or 75% of the cost of the work, except for shore protection, where the program allows for a maximum $500 per metre, or 75% of costs. Loans are presently recovered through property taxes by the municipality over a 10 year period, however, the program was originally implemented allowing repayment over 20 years at an interest rate of 8% (Kreutzwiser, 1990). This loan program was amended in 1986 to include relocation of buildings or raising structures as eligible expenses. The Program was also extended to Great Lakes shore areas outside of organized municipal boundaries.

In the United States, the use of loan programs has been limited. One of the only known examples was in the state of Illinois, where the Department of Transportation - Division of Water Resources, in collaboration with the Illinois Housing Development Authority, introduced a low interest floodproofing loan program to enable low to moderate income victims of August 1987 flooding to take steps to protect themselves from possible future damage.

Extent of Application

Participation in Ontario's Shoreline Property Assistance Program has been high with 111 municipalities of the 212 eligible municipalities in the Province taking part. Loan use has been concentrated in southwestern Ontario in municipalities such as Essex County, Niagara Region, Lambton County, and Haldimand-Norfolk Region (Day et al., 1977).

In the Illinois program highlighted above, nineteen communities passed resolutions to participate in the program and fourteen were able to prepare mitigation plans that gained approval. Program funding was allocated to communities based on the number of individuals helped at Disaster Assistance Centers following the 1987 flood. Each community received $20,000 on average. One community distributed all their monies to participants and required additional funds, however a majority of communities did not distribute any loans. A total of twelve floodproofing projects were conducted, primarily the installation of overhead sewers, or sump pumps and enclosure of basement windows.

Grants

Overview of Measure

Grants could be used to encourage proper use of coastal areas by: eliminating all grant programs which provide incentives for any type of floodplain development; providing government grants as an incentive to implement non-structural shoreline protection measures; or removing existing structures which have been destroyed, are in immediate danger of substantial damage or are contributing to potential for loss. Grants could also be provided to property owners for shoreline protection construction assistance.

In Ontario, in the past, grants have only been provided as relief funding and not generally as an incentive for Conservation Authorities to implement shoreline protection measures. Currently, the Essex Region Conservation Authority has a grant program available as part of its Floodproofing Assistance Program. The Upper Thames Conservation Authority also receives grant monies from the MNR for property owners wishing to implement shoreline protection.

Under the federal Coastal Zone Management Act in the United States, states receive grant funding for their state run coastal zone management programs. Under the State Match Program, the U.S. Army Corps of Engineers covers half of the 30% of local match requirement for projects undertaken through the Advance Measures Program.

Extent of Application

In the early 1970's there were a variety of shore property assessment programs that made grants available to municipalities in Ontario that experienced flood and erosion damage. The Agricultural Rehabilitation and Department Administration (ARDA) used to provide up to 90% federal-provincial subsidies for drainage and flood protection. The Special Emergency Assistance Program provided 80% provincial funding to municipalities for temporary access roads, for repairing flood and erosion damaged roads and dykes or for temporary protective works or pumping off of flood water on property which the municipality is directly responsible (Day et al., 1977). Neither of these two programs remain in operation.

However, the Ontario Disaster Relief Assistance Program provides matching of provincial funds to contributions made to local disaster funds established in municipalities severely affected by a national disaster (Day et al., 1977). This program is administered on an ad hoc basis and only if the provincial government declares the area a disaster zone. Relief assistance under this program was provided for the Grand River flood in 1972, the Woodstock tornado in 1980 and the tornado that hit Barrie and Grand Valley in 1985.

In the United States, New York has established Local Waterfront Revitalization Programs (LWRPs) to facilitate the Coastal Management Program addressing the problems and issues of coastal development and protection in cooperation with coastal municipalities. To date, 105 coastal municipalities out of 250 have received grants to prepare or implement LWRPs in full partnership with the state.

Insurance

Overview of Measure

This measure would use insurance as an implementation mechanism to encourage municipalities to adopt floodplain management programs. The following are types of methods that could be included in this measure.

- The National Flood Insurance Program in the United States could be modified to preclude damage claims on a property when the aggregate of such claims exceed 50% of the fair market value of the insured property.
- Requirements that all owners of shoreline property within the recognized hazard area purchase full actuarial rate (unsubsidized) insurance to cover the property against the hazards inherent at that location.
- Providing the option for all owners of shoreline property within the recognized hazard area to purchase full actuarial rate (unsubsidized) insurance to cover the property against the hazards inherent at that location.
- Eliminating or reducing the availability of hazard insurance to shoreline property owners putting them "on their own" rather than subsidizing them through insurance availability.
- Requirements that all shoreline property owners purchase subsidized rate hazard insurance with certain conditions as a requirement for community or individual floodproofing.
- Requirements that all shoreline property owners purchase subsidized rate hazard insurance within recognized hazard areas.

Extent of Application

Flood insurance as an implementation mechanism for shoreline protection has only been applied in the United States. It has not been applied in Canada.

The U.S. National Flood Insurance Program (NFIP) was established as a federal program through the National Flood Insurance Act in 1968 to provide affordable insurance coverage and reduce further flood losses. The federal government had been providing money through the 1960's as disaster relief and began to use the Flood Insurance Program as leverage to encourage municipalities to put into place flood management policies. The program requires local governments to regulate floodplain land use in order to reduce the exposure of property to flood damages and resulting insurance losses. The premise of the program is that if communities act to limit future flood losses by instituting sound floodplain management, then the government will take responsibility financially for covering the risk to existing structures. The program provides insurance coverage for *"damage and loss which may result from erosion and undermining of shorelines by waves or currents in lakes or other bodies of water exceeding anticipated cyclic levels"* (Committee on Coastal Erosion Zone Management et al., 1990).

The Upton-Jones Amendment to the National Flood Insurance Program was adopted in 1987 in response to Congressional concern about the damage to structures along the Great Lakes and the impact that substantial damage costs were having on the financial viability of the NFIP. Rising Great Lakes levels and shoreline erosion caused significant shoreline damage and many houses literally fell over eroding bluffs into the lakes. Under the Amendment, payment of a flood insurance claim could occur prior to the actual damage. Flood insurance loss payments were to be made after threatened structures were condemned, but before they collapsed. Costs were also covered to relocate endangered structures. Structures had to be moved landward at least 30 times the average annual erosion rate in order to be insured. Payment for demolition prior to collapse of a structure would be 100% of the value of the structure; the additional 10% being used to cover demolition costs. Payment for relocation of a structure would be the actual cost of relocation up to 40% of the value of the structure (Committee on Coastal Erosion Zone Management et al., 1990).

Structural Shore Protection For Flooding

Overview of Measure

Flooding of property adjacent to the lakeshore can result either from a gradual rise in lake water levels or from temporary storm conditions causing increases in water level known as wind set-up. High winds passing over a lake surface for a number of hours push a sufficient volume of water downward to produce these temporary high water levels along the lakeshore. Lake Erie is particularly susceptible to wind set-up conditions for its is shallow and its axis is oriented parallel to the direction of spring and fall storms. Measures to reduce flood damage along lakeshores include the following:

- dyking

- floodproofing
- raising susceptible areas using landfill

Floodproofing and filling have been discussed previously. Dykes are essentially impermeable barriers, normally constructed of earth but sometimes of the materials such as concrete, which are placed along a lakeshore to prevent water from inundating the land behind. Depending on the application, dykes often require an erosion resistant facing on the structure's lake side in order to protect the dyke face and bank. As well, dyke design must take into consideration techniques for draining the developed land to the lee of the dyke. This may include the installation of sluice gates, and/or drainage ditch pumping systems in order to discharge surface and tile drainage runoff water to the lake.

Extent of Application

Dykes have been installed along the lakeshore in the Essex and Kent County regions of southern Ontario, usually in conjunction with road construction, or agricultural drainage works, often through the Ontario Drainage Act which provides a mechanism for implementing agricultural drainage works. Dykes have also been used in inland applications such as along river courses to control river flooding. If applicable, river dyking works also take into consideration the lake rise affect. Dyking however, is an expensive endeavour often requiring higher level government funding, as well as a co-ordinated effort among affected landowners. Projects are also administered by regional Conservation Authorities to help justify the cost of constructing the dykes.

A total of 8% of respondents to the 1990 Ontario Riparian Survey indicated that they had built dykes to protect their property from flooding, with the majority of these being located on Lake St. Clair, the St. Clair River and the Detroit River.

A review of the projects implemented under the U.S. Federal Government's Advance Measures Program, which was initiated in 1985 by the Corps of Engineers in response to high water levels, found that only 12 flood protection projects were ultimately undertaken. Others were rejected due to poor benefit-cost ratios, uncooperative landowners, or insufficient matching funds. Of the 12 measures implemented, rubblemound or clay dike structures were a component of all the projects.

The high cost of dyke construction may explain why only six percent of the sites visited under the Advance Measures program saw implementation. A review of the locations of the Advance Measures projects implemented indicates that the projects built were almost exclusively in urbanized settings where transportation corridors or high-valued properties were in jeopardy.

Structural Shore Protection For Erosion

Overview of Measure

While many structural shore protection devices utilized around the Great Lakes - St. Lawrence River Basin are used to control flooding (see above), the vast majority are installed to prevent or minimize erosion (loss of land) of property due to the influence of wave activity. To say that the types of shore protection structures that have been utilized by property owners and other shoreline interests is varied is an understatement. Erosion protection devices have ranged from the inexpensive, non-engineered dumping of rubble and fill, to the multi-million dollar, well-engineered construction of harbour breakwaters, or shoreline revetments. Many property owners have also attempted "unique" forms of protection, including the use of junked automobiles, oil drums, and rubber tractor and automobile tires.

For the purposes of this study, and under the strict definition of shoreline management, as referred to in this report, shoreline erosion structures being considered refer only to large-scale, community based structures. Community based structures are designed to protect an entire reach of shoreline, or a series of shoreline properties, and thus are acceptable as a shoreline management measure.

There are five classes of large scale structures that have been examined in this study: revetments; seawalls; breakwaters; groynes and groyne fields; and headland embayment structures. Each of these is defined briefly below. More complete descriptions can be found in the full evaluation report (Ecologistics Limited, 1992a and b) and the Land Use Task Group Report.

Revetments are sloped structures placed on banks or bluffs in such a way as to absorb the energy of incoming waves. They are normally made of large rocks (armourstone) and incorporate carefully placed layers of different sizes of rock (rip-rap), excavated foundations or keyways, and/or filter cloth. Seawalls or bulkheads are vertical structures which provide protection to banks and bluffs by completely separating land from water. They are usually constructed of steel sheet piling, concrete, gabions, grout filled fabric bags, or treated timber. Bulkheads tend to be distinguished from seawalls in that they primarily lend structural support of the retained fill, while seawalls are generally constructed to protect the backshore from wave attack.

A breakwater is an erosion resistant structure that is designed to provide protection from wave action to an area or shoreline located to the leeward side of the structure. There are two general types of breakwaters - offshore and shore-connected. Offshore breakwaters are normally constructed parallel to the shoreline, while shore-protected breakwaters are positioned in a manner which will produce a harbour area with minimum wave and surge action over the greatest period of time during the year. Rubble mound (armourstone) construction is the most common form of breakwater construction in the Great Lakes.

Groynes are shore protection structures built out at an angle from a shore to trap sand and to protect the shore from erosion by currents and waves by making a beach. Generally constructed in groups, or "groyne fields", they are commonly constructed of sheetpiles of treated timber, steel, or aluminum, often with timber brace piles or mounds of rubble as reinforcement on the offshore end.

Headland - bays occur naturally all over the world, wherever rock outcrops or other hardpoints exist on shorelines in unconsolidated deposits. The shoreline between the headlands or hard points take on a distinctive, stable, shape which, when looking from the air, resemble a half heart. It is through observing these natural shoreline formation that coastal engineers have developed the concept of creating artificial headlands or hardpoints, using armoured mounds of stone to initiate the stabilization of the shoreline between the hard points. If erosion proof artificial headlands are provided, and the dominant wave direction is known, the ultimate shape of the headland bay can be predicted through geometric relationships. A stable equilibrium occurs when the shoreline has adjusted so that the dominant waves arrive at right angles to the entire periphery with the result that there is no net littoral drift within the bay.

Extent of Application

Shore protection structures for erosion have been utilized extensively throughout the Great Lakes - St. Lawrence River Basin. For the Ontario and Quebec Riparian survey conducted for this study, almost half (16 out of 34) of the respondents indicated that shoreline protective measures had been carried out. Extent of the five individual measures outlined above is presented below.

Historically, revetments are one of the most common shore protection measures employed in both Canada and the United States. They are used extensively along the coastal shores as well as along the Great Lakes shoreline. Based on the results of the Canadian Riparian Surveys, generally one-half to two-thirds of residential riparian respondents on any water body in Ontario have installed some form of revetment. The degree to which these are engineered or non-engineered structures is unknown. Percentages are generally higher for a small representative sample of Quebec riparians surveyed.

The most recent comprehensive data source, to our knowledge, that identifies the extent of seawall installation along the shoreline is in the Canada/Ontario Great Lakes Shore Damage Survey Technical Report (Boulden, 1975). This report expresses the percentage of shoreline protection by bulkheads and seawalls. These figures for individual lakes are: Lake Ontario (5.43%), Lake Erie (7.90%), Lake St. Clair (29.73%), and Lake Huron (1.70%). Only a portion of Lake Huron and none of Lake Superior were inventoried. In a recent study, Lawrence (1989), inventoried shoreline protection structures along the shoreline administered by the Maitland Valley C.A. on Lake Huron and determined that there were 96 seawall and similar structures installed, representing approximately 32% of all shore protection in the study area.

Breakwaters are used extensively around the Great Lakes, often in conjunction with other measures, for harbour protection. The cost of these structures, particularly along certain shoreline conditions is what limits their use beyond harbour sites. Information from the 1990 Canadian Riparian Survey indicated that approximately 30% of shoreline property owners in Ontario have constructed breakwaters.

Historically, groynes have been widely applied in erosion hazard-prone areas in both Canada and the United States (on ocean coasts and inner lakes) for shore protection. Davidson-Arnott and Keizer (1982) reported that groynes and seawalls have historically been the dominant type of sore protection used in the Stoney Creek, southwest Lake Ontario area. Groynes and seawalls were also found to be the predominant type of shore protection structures along the Ohio shoreline of Lake Erie (Carter et al., 1986). Similarly, in an exhaustive inventory of shoreline protection structures along the Maitland Valley Conservation Authority, Lake Huron Shoreline, Lawrence (1989) determined that groynes comprised approximately 63% of all structures. The Canadian riparian survey also indicated that while not widely applied over the basin, groynes have been used extensively in erosion-prone situations (e.g. Lakes Erie, Huron, and St. Clair). The Canada/Ontario Great Lake Shore Damage Survey (Boulden, 1975) reported that the following percentage of shorelines were protected with groynes or jetties; Lake Ontario (0.28%), Lake Erie (1.90%), Lake St. Clair (2.01%), and Lake Huron (2.20%).

Shore stabilization by means of headland control is a relatively new concept. Field experience in design and implementation is sparse, but increasing. A section of Lake Ontario shoreline within the jurisdiction of the City of Toronto has been protected with headlands. The artificial hardpoints were constructed simply of material from excavation and demolition sites in the city, consisting mostly of rubble concrete, reinforced concrete and bricks (Bishop, 1983). Bronte Beach Park located west of Toronto was one of these sites. Bluffers Park, also near Toronto is another example of headland implementation. The concept is also being applied near Burlington, Ontario to protect a portion of a lakeshore highway.

Non-Structural Shore Protection

Overview of Measure

Non-structural shore protection measures consist of a variety of methods to afford protection or stabilization of the shoreline. Methods include beach nourishment or shoreline stabilization using vegetation to stabilize bluffs and to build and maintain protective sand dunes. Another non-structural measure, although one which may lead to structural protection being put in place, is the provision of technical assistance to property owners.

Beach or artificial nourishment involves importing a suitable volume of unconsolidated material within the shore zone to maintain or develop recreation beaches, to supply material for shore protection at the site, or by natural transport by wave actions and currents to other locations to fill groynes or for other purposes. For beach development, the quantity of nourishment material supplied needs to be sufficient to restore the beach to an adequate pre-erosion profile. The intended result is an increase in the size of both the onshore and offshore beach areas. The artificial nourishment technique is most suited to shoreline sites where a permanent beach is required or where the shore ecosystem demands natural solutions to erosion. Beach nourishment will not prevent a shoreline from eroding. It often simply substitutes for the eroding material. The reasons for nourishing a shoreline include: controlling erosive forces by providing a sacrificial slope; supplementing littoral drift to offset particular actions or works; and replenishing reserves of littoral material normally available in sand dunes.

Some minor shoreline and bluff erosion problems can be remedied by establishing vegetation to stabilize the shoreline. Establishing vegetation cover can also be used as a non-structural shoreline stabilization technique on barren slopes, sand dunes, along denuded shoreline areas, or in conjunction with structural protection measures, to provide a more complete solution to specific shoreline erosion problems. Indirect benefits of shoreline vegetation such as improved visual quality and wildlife habitat enhancement can also be derived. Shoreline vegetation will not control erosion problems due to wave-erosion or where groundwater seepage is occurring.

Technical assistance, in the form of advice concerning the design of structural, or non-structural shore protection or bluff stabilization methods, is another non-structural measure that could be implemented. Such assistance would usually take the form of a site visit by a staff person from the government agency dealing with shoreline erosion problems (e.g. Ontario Conservation Authorities, or State DNR's). This site visit would involve discussions with the property owner about relevant history of the site, a survey to locate any structures that may be at risk, an examination of the shoreline to determine the extent of the erosion / flooding hazard and the photographing of the property. A written evaluation would then be prepared, outlining the nature of the hazard, the degree of risk for that property and a series of recommended solutions, both structural and non-structural, are presented. The property owner is then encouraged to follow up on the site visit recommendations by contacting a consultant or contractor to carry out the recommended work.

Extent of Application

Within the global context, artificial beach nourishment is increasingly being seen as an effective way of combatting coastal erosion problems (Nelson and Pullen 1985). Application of this technique however is rare along the Canadian side of the Great Lakes shoreline. A large beach nourishment/groyne project was completed along the Lake Huron shoreline near the Port of Goderich in 1987. After construction of a curved groyne in 1986, material dredged from the Goderich harbour was used to supply the accretion material effectively providing additional beach area at the site. There are also cases of similar large-scale beach nourishment projects being applied with success on the American side. These include: Presque Isle Beach, Lake Erie; Lexington Harbour, Michigan, Lake Huron; St. Joseph Harbour, Michigan, Lake Michigan; New

Buffalo Harbour, Michigan, Lake Michigan; and Illinois Beach State Park, Chicago, Lake Michigan.

Shoreline work of this type is normally large-scale in nature. Shoreline specialists contacted during this study were not aware of any individual landowners intentionally addressing a shoreline problem with beach nourishment techniques. For the private landowner, a solid wall or revetment is seen as providing a much more secure defence from the lakes than is the idea of placing beach sand along the eroded shoreline.

Shoreline stabilization using vegetation has been applied extensively by shoreline property owners experiencing slope failure and erosion problems. Vegetation planting has also be used in sand dune stabilization projects such as a research program implemented at Long Point Provincial Park in 1978 (Ralph and Heffernan, 1978). Dai et al. (1977) outline vegetation communities best suited to particular slope conditions along the north shores of Lakes Ontario and Erie and discusses environmental factors that influence successful vegetation establishment for shoreline stabilization.

6.4 Detailed Evaluation and Assessment of Shoreline Management Practices

6.4.1 Measures for Evaluation

Shoreline management measures were categorized as either First Order, Second Order or Third Order based on an assessment of data quality and availability . The following measures and implementation mechanisms representing Regulatory, Incentive, and Protection Based Practices, formed the First Order group.

- Setback Requirements,
- Elevation Requirements,
- Loans, and
- Local, Large Scale, Structural Community Protection Projects

These measures are quite widespread in their use and have been in place for many years along the shoreline. This length of experience provided an extensive database for evaluation. Consequently, estimates of cost, benefits and potential impacts are based largely on real-world experience and not hypothetical situations or extrapolations. A good quantitative assessment of the measures in this group was accomplished with a high level of confidence.

The following measures formed the Second Order group:

- Habitat Protection Measures and Regulations,
- Shore Alteration Requirements and Regulations, and
- Non-structural Land Use Practices.

These practices incorporate examples from Regulatory Based and Shore Protection practices. While relatively common in their use, these practices did not have the same quality database available for analysis as the First Order practices. Second Order measures have generally been applied on an ad hoc basis. The results of the evaluation of these measures have a somewhat reduced level of confidence than is expected for First Order measures and are comprised of a mix of qualitative and quantitative analyses.

Remaining measures for evaluation and assessment comprised the Third Order group. These measures are:

- Deed Restrictions and Regulations,
- Development Controls for Public Infrastructure,
- Tax Incentives/Disincentives,
- Grants,
- Insurance, and
- Local Large Scale, Non-structural Community Protection Projects.

Generally, these measures have been employed infrequently along the shoreline of the Great Lakes - St. Lawrence Basin. Consequently, the evaluation of the majority of these measures consisted almost exclusively of qualitative data from secondary sources supplemented with data collected from key informant interviews. An exception to this general trend was found with local large-scale, non-structural Community Protection Projects.

6.4.2 Evaluation Framework and Methodology

In any evaluation exercise, there must be criteria against which measures or treatments are to be evaluated against. The shoreline management measures described were evaluated with respect to three broad sets of evaluation criteria: effectiveness, compatibility and implementability.

The effectiveness criterion was designed to assess the broad effectiveness of individual measures and mechanisms in meeting the shoreline management objective of damage reductions. It includes subcomponents addressing the cost of the measure (capital / maintenance / administrative), damages avoided (where determinable) and the net benefit of the measure. Net benefits are measured as the cost of the measure minus the damage avoided due to its installation. To the degree possible, numerical information was used to compute these values.

The compatibility criterion sought to identify and evaluate the potential impacts (positive and negative) of the various shoreline management practices on both the natural environment, and on various land and water related uses and users (interest groups) within the basin. The application of the compatibility criterion is qualitative in nature, but attempted to the maximum extent possible to provide a relative assessment of the direction (positive or negative) and magnitude (weak, moderate or strong) of the impact.

Finally, the implementability criterion sought to identify and evaluate the constraints and facilitators to shoreline management practices. This criterion was broken down into four subcomponents: technical feasibility, social acceptability, institutional compatibility and jurisdictional issues. Technical feasibility addresses the degree of difficulty involved in the physical implementation of a measure. Social acceptability considers the degree to which individual measures are likely to be perceived by the public. Institutional compatibility is the degree to which certain shoreline management measures may conflict with mandates of shoreline institutions. Lastly, jurisdictional issues address compatibility and conflicts between government ministries and agencies in administering shoreline management measures.

Generic Evaluation and Assessment

The generic evaluation was used to produce general assessments of the costs and benefits of individual practices and mechanisms in achieving shoreline management objectives. These objectives included, for specific riparian interests affected, reducing the susceptibility of the shoreline hazard for specific combinations of shore type and land uses. Generic information was collected over a range of geographical regions, some of which were external to the Great Lakes. To the extent possible, this information has been extrapolated for relevance to the Great Lakes - St. Lawrence River Basin.

The generic evaluation provided the primary source of information for identifying the barriers and facilitators to implementing specific measures and mechanisms. The use of the opinion/perception portion of the Riparian Survey and analysis of the institutional setting affecting shoreline jurisdictions and decision making through key informants interviews also provided information useful in determining the existing and, where possible, the intensity of implementation barriers and facilitators.

The generic portion of the evaluation and assessment relied heavily on secondary data sources. To the extent possible, attention was given to integrating and utilizing information and data being generated by other portions of the Levels Reference Study.

Site-Specific Evaluations and Assessment

The site-specific evaluation focused on detailed qualitative and quantitative evaluation of the effectiveness and appropriateness of selected shoreline management practices.

In order to maximize the quality of data used in the evaluation, measures were targeted to the most appropriate detailed study site area. The term "appropriate" in this context is not related to individual measures specifically, but to data quality and availability. By matching measures with sites, study resources were targeted to collect the highest quality data possible within the limits of the study.

For full details on the evaluation methodology the reader is referred to Ecologistics Limited (1992a and b).

6.4.3 Results of Detailed Evaluation of Practices

The following is a summary of results based on the evaluation of shoreline management practices and implementation mechanisms. The bulk of the results are presented in a series of evaluation tables and matrices contained in the full evaluation report (Ecologistics Limited, 1992 a and b).

Setbacks and Flood Elevations / Floodproofing

Setback and/or floodproofing requirements have been readily implemented and have been shown to be very effective in reducing damage, particularly for currently undeveloped areas. This observation is particularly salient given the results contained in Triton Engineering and Ecologistics Limited (1992) which indicate a projected doubling of residential riparian development over the next ten years, largely at the expense of undeveloped portions of the shoreline.

Setbacks and elevations may also be applied in areas which are currently developed. Developed areas are not static. Setback and elevations can often be effectively applied to redevelopment of lots or in combination with other measures, e.g., dwelling relocation. However, in most cases, a setback or elevation requirement for new development will do little to alleviate damages in existing developed areas in the short term. Retroactive requirements in existing developed areas are also usually costly and disruptive. Often there is insufficient room for relocation on the same lot, which can dramatically increase the cost and disruption. In these areas where a retroactive setback or elevation is implemented, shoreline property owners should be offered other incentives to relocate or raise their dwellings. In areas of relatively shallow flooding, or where wave damage or erosion is limited or can be readily overcome, the raising of existing buildings in usually a cost effective measure which can be accomplished with minimal disruption.

Areas which are presently zoned and/or serviced for development along the shore, but in which construction has not yet occurred present a difficult situation. This also applies to "infilling" of vacant lots, or redevelopment of lots, in areas of existing development. Should a retroactive setback be required, there may be instances in which a setback significantly reduces or eliminates the economic development potential of an individual parcel of land. In these instances, the property owner may have the right to compensation. Common law private property rights and government imposed land use planning restrictions are evolving. At present, the full implication (i.e., costs and benefits) of the setback option cannot be fully assessed for areas already designated for development.

The typical cost of implementing these practices is minimal in undeveloped areas. In areas of existing development, the cost is variable. The average cost of raising dwellings was found to be about $10,000 per dwelling in the case study investigated. The cost of relocating homes was found to be about $20,000 per dwelling if relocation is possible on the same lot (about 25% of cases in the sample area). It was estimated that in 50% to 75% of cases, a retroactive setback would require relocation to a new lot, with a cost of $70,000 to $100,000 or more, per dwelling. These situations would essentially be acquisitions as further discussed below.

Impacts of setbacks on land and water related uses are both positive and negative. The most significant positive impact is lower expected flood and erosion losses. Strong positive impacts can also be realized by recreational interests resulting from potential increases in recreational opportunities afforded by a less developed shoreline. Negative impacts are felt primarily by individuals or companies owning or wishing to purchase and develop shore property. For floodproofing and flood elevation measures, net positive impacts are directed to the riparian interests from potential damage reduction to property and structures. There would be a negligible effect on the natural environment, other than possible changes to drainage if the grade differentials of the floodproofed home were much different than that of adjacent properties. Construction impacts would be minimal provided proper mitigation measures were implemented to reduce the likelihood of soil compaction from construction equipment. Aesthetics might also be a concern for neighbouring property owners.

Acquisitions and Relocations

Areas that are currently developed and which have experienced repeated damage due to flooding are candidates for a dedicated land acquisition or dwelling relocation program. Acquisition, however, is likely to only be justifiable in areas where public money has been repeatedly expended to compensate property owners for damages or in instances where significant public buildings and infrastructure are at risk. Results of a site specific modelling exercise carried out in the evaluation process indicated that acquisition was not economically feasible in the erosion prone area modelled. The cost of acquisition was estimated at $25,000 to $50,000 per vacant lot, depending on degree of servicing and zoning; and well over $100,000 per dwelling for relocation in developed areas.

With acquisition, land is reverted back to passive, non-hazardous use, such as recreation, environmental protection or for education purposes. Where municipalities are unable to afford the purchase price of the entire parcel of land, the acquisition of the immediately threatened area as an easement would achieve a certain amount of setback from the waterline and reduce hazard threat. This measure would afford the community recreational benefits as well as shoreline protection. Financial support or partnership with regional or provincial levels of government would facilitate municipal land acquisition of hazard-prone areas.

In developed areas susceptible to severe damage, in the form of either long-term recession or short-term wave damage, acquisition should be seriously considered as an alternative to government assistance for other measures such as structural protection. This is particularly true for most bluff situations where the cost of effective structural protection and bank stabilization can be prohibitive in the long-term. Further studies should also be undertaken to determine the feasibility of acquiring shoreline areas or coastal barriers that exhibit unique shoreline characteristics or habitat for protection under provincial or federal statutes as provincial or national parks.

Acquisition and relocation programs have generally strong, positive impacts on the natural environment. Acquired land is either returned to or maintained in a natural state compatible with natural processes. Terrestrial and aquatic habitat created or maintained provides benefits to fish and wildlife species. Access to this habitat is particularly important in urban ecosystems in which such sites are often limited. Acquisition of land makes the waterfront more accessible to the public and provides opportunities for open space, recreational activities as well as water related activities such as fishing. Visual attractiveness and aesthetics may also be positively affected.

Land acquisition programs can be implemented when economically and administratively feasible and when parcels of land meeting certain criteria become available. Private landowner bequests and donations from private landowners can also be encouraged.

Costs associated with undertaking and administering shoreline acquisition programs may present a significant obstacle to municipalities, or other agencies wishing to undertake this type of program. Actual land acquisition costs are capital intensive. Ancillary costs associated with building demolition, site decommissioning, landscaping, real estate fees, taxes, and maintenance are not generally factored into program budgets.

A second barrier to the implementation of acquisition programs is the availability of waterfront parcels of land for acquisition. Landowner sales of property are generally infrequent, however, over an extended period of time in conjunction with a dedicated plan, this type of piecemeal acquisition can be an effective means of obtaining hazard prone shoreline areas. However, given current administrative costs, the length of time and required long-term commitment of resources necessary to acquire contiguous blocks of hazard property remains an impediment.

Deed Restrictions / Disclosures

Deed restrictions or disclosure are both highly feasible in the Canadian and U.S. context, although they have not been widely required or adopted along the shoreline. Much remains to be explored regarding the potential impact of this mechanism on property values, perception of prospective buyers, decision of buyers, effects on appropriate redevelopment of shoreline lots, effectiveness of shoreline management actions taken by a vendor, etc.

In their limited application to Ontario and U.S. shoreline situations, deed restrictions are not considered a very effective mechanism because of the possibility that the restrictions would become invalid when the property was taken over by a new owner. The Sauble Valley Conservation Authority initiated their deed restrictions as a last resort. A more preferable type of agreement and more binding are development agreements under Section 50(6) and Section 52(1) and (2) of the Ontario Planning Act.

Deed restrictions would be drawn up and signed by the property owner in consultation with a legal advisor. Real estate agents, investors and municipal planning departments would be provided with hazard land maps. Real estate agents or land owners would then be required by law to reveal to the prospective buyer that there are potential hazards associated with the property. There should be no compatibility problems associated with this.

Although being aware of potential property hazards would not have altered some owners decisions to purchase, they would appreciate disclosures so they could be aware of the potential risks associated with the property and weigh that in the decision to purchase. Real estate transactions should also have a mandatory "cooling-off" period, a time in which the purchaser can investigate the potential existence of flood and erosion hazards and other such risks that are not apparent at the time of the offer to purchase.

Tax Incentives

Tax incentives for shoreline management are generally not well organized in Canada or the United States. Improvements to tax incentive programs such as more sophisticated tax abatement opportunities are required to encourage property owners to maintain natural shoreline features/wetlands and flood storage areas.

Tax abatements as an incentive for shoreline property owners to relocate existing structures could be widely applied along developed portions of the shoreline, thereby reducing the potential of flood related property damages in built up areas. Property tax relief to owners who maintain flood storage or wetland areas is unlikely to have much of an impact considering the dramatic decline of remaining shoreline wetland habitat.

Other tax incentives could be applied where shoreline parcels of land remain undeveloped, however, this mechanism would be either inapplicable or difficult to implement in well established areas. They might provide some incentive on an individual property basis.

Similarly, capital improvement policies and floodplain building and subdivision regulations would not have wide application in built up shoreline areas but could be implemented in areas undergoing initial development. Many of the incentives seem to be "after the fact" types of mechanisms in terms of application along the lower Great Lakes shoreline.

Some incentives/disincentives have the potential to work at cross-purposes. Particularly noteworthy is the income tax laws in the U.S. For example, residential riparian property owners are able to deduct shoreline damage costs from their income tax, if supported by damage repair receipts.

Further research on the feasibility of expanded tax incentives should be undertaken.

Loans

The Ontario Shoreline Property Assistance Program might attract property owners to take steps before a crisis situation occurs. Property owners also have more leeway in terms of what types of proposed projects are considered eligible under the Assistance Program. In this manner, it is a proactive, rather than reactive mechanism. As such, there is greater potential to protect property and therefore avoid damages. The loan program could facilitate more effective implementation of some shoreline measures if there was an administrative framework that required technical consultation prior to completion of works and a formalized inspection following completion of the work. If a municipality or Conservation Authority provided more technical direction to property owners, implementation of measures might be more effective. Without any sort of required inspection, the potential exists for this type of implementation mechanism to promote the use of inappropriate measures.

Kreutzwiser (1990) determined through his interviews with property owners that despite several complaints about "red tape", the loan program was evaluated favourably by participating property owners. The majority of loan applications (93% in Kreutzwiser's study) are approved, no doubt making application to the Program attractive. Evidence also suggests that loan funds are distributed in a timely manner. Seventy-nine percent reported receiving funds within a month of the completion of the work. The most appealing aspect of the Program's setup to the property owner is that loans are paid back as taxes to the municipality at a fixed preferred rate over a ten year period. This type of financial arrangement is more attractive than a loan negotiated through a bank or other accredited lending institution. However, 10% of the surveyed property owners commented on how they disliked the fact that the loan was actually a lien on their property.

The Provincial government, specifically the Ministry of Municipal Affairs administers funding to municipalities to make loans to property owners. From what can be discerned from the available literature, the Shoreline Property Assistance Program is operated smoothly with various government levels interacting in a successful and efficient manner.

There do not appear to be any major jurisdictional issues, however, if pre and post-construction inspection becomes a more rigorous requirement of the Program, there will have to be a decision made as to who will administer and enforce this component of the Program. To ensure a higher conformity of measures actually implemented to those proposed, loan applications should require a detailed description of the proposed work, and the municipality impose some sort of financial penalty or disincentive to those property owners who deviate from the proposed work plan for whatever reason.

Loans as implementation mechanisms made available by municipalities serve as a type of facilitator in themselves because they provide a means for property owners who might otherwise not be able to afford to take steps to address potential shoreline problems. This is a cost saving step in that it reduces or eliminates the potential need for even more costly post-crisis financial assistance.

In the United States, the Illinois Low Interest Floodproofing Loan Program was not very effective. Program staff felt that the program did not receive enough publicity and that the income limitations were set too low. Also, many property owners who suffered damage were already in debt, or financially constrained by other factors, and were unable to take on another loan.

Delays were also experienced in getting the loan program started. As a result, the window of opportunity that occurs after a flood was missed. Due to the level of coordination needed between agencies and financial institutions and the requirements placed on communities before they could access funds, loans were not available until a year after the flood.

Grants

To promote the use of appropriate shoreline management practices, grants could be made available through a variety of other programs conducted by government and other regulatory agencies to encourage shoreline property owners to take steps to reduce the potential of flood and erosion related damages to their property. Grants could be used to implement any of the shoreline management measures. In 1989, the Ontario Shoreline Management Advisory Council reported that municipalities recommended to Council a need for either a grant or a low interest loan program funded by the province to help pay the cost of new shore protection projects (Shoreline Management Advisory Council, 1989).

Results of the riparian survey indicate that tax incentives and grants are well perceived by residential property owners in Ontario and Quebec. Respondents in Ontario (64.2%), Quebec (69.4%) and the U.S. (60%) are in favour of the use of tax credits or grants for the purpose of subsidizing the construction of shore protection devices.

The availability of grants to implement shoreline management measures has the potential to increase the effectiveness and the extent of use of each type of measure. Financial assistance will make implementing shoreline management measures more affordable and encourages more property owners to participate. Grants will decrease the cost of the measure to the property owner, but increase the financial responsibilities of the agency authorizing the work. Grants do not have much potential to promote bad measures as long as they are applied to implement measures that have been approved and will be supervised and/or inspected during construction.

Receiving a grant with which to implement shoreline management measures would be highly favourable from the property owner's perspective. Essentially, it would be free to him except for the cost of labour. On the other hand, the source of funding for these grants would have to be evaluated and arranged.

If provincial or state grants are obtained by an agency, the agency should be responsible for the distribution of funding on approved shore protection works or non-structural measures. This responsibility and allocation of funds should be done in consultation with the municipality.

Grants would be made available from an overseeing agency, which should not pose any problems between agencies or create conflicts between other programs being operated, provided works constructed with grants meet legislated specifications and proper work permits, etc., are obtained.

The most significant barrier to implementing grant programs is availability constraints on funding.

Insurance

In the United States, over 16 500 US communities have adopted full regular program status and floodplain ordinances that meet minimum federal standards. Although over 90% of the approximately 20 000 flood-prone communities have joined the NFIP, only 25% of eligible homeowners carry flood insurance (Committee on Coastal Erosion Zone Management et al., 1990).

One goal of Congress in adopting the NFIP Program was to discourage or end increases in floodplain occupancy. Communities facing other erosion problems were also encouraged to direct future development to non-eroding areas; to reserve erosion prone areas for open space; to co-ordinate planning with neighbouring communities and to adopt preventative measure for E-Zones, including setbacks, shore protection work and relocating structures in the path of flood-related erosion properties (Committee on Coastal Erosion Zone Management et al., 1990). Measures also include the acquisition of frequently damaged properties for open space. As of 1990, many of these measures had not been implemented (Committee on Coastal Erosion Zone Management et al., 1990).

Flood insurance has been implemented in the United States as a means to encourage municipalities to put into place flood management policies and therefore reduce potential flood losses. Insurance has never been implemented in Ontario to encourage similar types of floodplain management policies.

The application of flood insurance in Ontario is not particularly appropriate for several reasons. Ontario does not have a history of providing extensive federal or provincial disaster relief to property owners. In U.S. communities affected by natural disaster, there is a strong reliance on federal relief programs, whereas Ontario has never had this type of fiscal responsibility.

Second, Ontario has traditionally had a much more aggressive land use planning process, where development controls and policies have been applied to effect the same sort of floodplain management objectives achieved through the U.S. Flood Insurance Program.

Structural Protection

Shore protection, for flooding and erosion, has been shown to be an effective means of avoiding future property damages when structures have been designed, implemented and maintained in accordance with good engineering practices and in a manner that considers potential negative impacts on adjacent and downdrift property. However, it has been demonstrated that the majority of privately constructed shore protection structures fail within 10 years of construction. Any government incentive program (i.e. loans, grants, tax incentives, etc.) that encourage the construction or upgrading of shore protection structures must include provision for technical inspection and approval of plans including enforcement powers.

Subsidies/fund matching programs should be established to encourage/enable property owners to undertake community-based structural shore protection measures where no alternative non-structural measures are feasible.

For floodprone areas with existing development, while structures such as dykes are appropriate in some cases, it is often more cost effective to raise the individual dwellings, particularly in areas of shallow flooding. In areas of very deep flooding potential, the cost effectiveness of dyking, including the long-term maintenance costs, should be weighed against alternatives such as acquisitions, and/or relocations.

For areas susceptible to erosion and/or direct wave attack, community based structural protection projects should be weighed against alternatives such as relocations or acquisitions which may be more cost-effective in the long-term, particularly where the hazard is difficult to overcome by structural means, or where structural protection would seriously interfere with natural coastal processes.

Aside from the question of investment of public funds in community based projects, it should be recognized that private shore protection proposals are inevitable. In many cases, private projects are appropriate and effective, particularly if proper engineering is involved as outlined above. Protective works often have several functions beside protection from damage, and also improve the value of shoreline properties. Sometimes private structural protection can be combined with programs such as raising and/or relocation of dwellings to provide added protection.

However, in some areas protective works interfere with natural processes, and can also aggravate problems on neighbouring properties. It should be recognized that structural protection is not feasible or appropriate in such cases. If existing development is threatened in a situation where shore protection is not appropriate, consideration should be given to incentives or compensation to assist in relocation, and possible acquisition in extreme cases. The option of short-term interim maintenance or improvements may also be warranted to extend the lifetime of protective works to match the lifetime expectancy of the home.

The cost of installing and maintaining structural protection on a basin-wide perspective has been addressed in detail by the "Potential Damages Task Group". The initial construction cost reported by the Consultant to our task group was about $2,000/metre ($600/foot) for either dyking or erosion protection. For a 20 metre (65 foot) lot, this would translate to about $40,000 per lot, although long-term maintenance and replacement costs would be much higher.

Non-Structural Protection

A thorough knowledge and understanding of the shoreline processes dominating a problem site is needed in order to determine the suitability and predict the success of a beach nourishment solution. There are more uncertainties associated with this control measure as the variables involved are complex and not fully understood. Beach nourishment projects implemented which have been thoroughly studied and designed based on existing site conditions appear to be quite effective in improving beach and shoreline conditions. The Goderich Harbour project, for example, has stabilized and yielded additional recreational beach area for the town and facilitated improved navigation in the Goderich Harbour through the removal of sediment. Because such a measure does not arrest shoreline erosion, implementors need to be aware that losses of imported material will occur and that replenishment of lost material particularly in severe storm or water level conditions, can result in high maintenance costs. It is not possible to estimate a general life expectancy of a beach nourishment project for it is dependant upon the nature, frequency and magnitude of the storms that act upon it.

The consequences of placing nourishment materials along beach areas can be far reaching if the materials used are highly susceptible to erosion or if they contain toxic contaminants giving rise to water quality problems and aquatic habitat degradation. On the other hand, effects of beach nourishment projects can be negligible if they are designed to closely imitate natural nourishment conditions such as is the case with creating artificial sand dunes along the beach which are available for littoral drift supply only if needed. To help gain a better understanding of the potential environmental impacts of beach nourishment, it is essential to have an accurate description of the environmental conditions at the borrow and replenishment sites prior to work starting.

If the beach nourishment material is to be dredged from an offshore location, suspended sediment load and water turbidity will increase in the vicinity of the borrow area. If large borrow pits are dug offshore, the bottom morphology of the lake may change in the borrow areas. Regardless of how deep the sand is extracted, virtually all the organisms inhabiting the upper bottom layer dredged will disappear. Care is needed in the extraction process to encourage a re-establishment of these species after dredging is complete. If the borrow materials silt and fine particle fraction is high, high turbidity will also result. Turbidity in turn has an adverse affect on many biological processes. Fish gills for example can become clogged or blocked if subjected to high turbidity levels for long periods of time. Because of their mobility, however, adult fish are less likely to be affected by the sand extraction operation than other aquatic creatures and could return following the nourishment work.

Land-based borrow sources can also create adverse impacts, if not addressed. Vegetation and possibly habitat sites will be lost and disruption of wildlife and vegetation will be expressed in transporting the material to the nourishment site.

At the beach replenishment site, benthic communities may be lost when the imported material is spread over the lake bottom. It is beneficial to plan a beach nourishment undertaking during times of the year in which most species affected are not reproductive.

As with all construction activity, beach nourishment will have some negative impact on the areas involved in the work. Beach nourishment, however, is generally regarded as a positive approach to shoreline erosion control when environmental factors are considered. This is because they closely imitate natural erosion control barriers. Natural beaches are flexible buffers to storm wave forces. Sand displaced by large storms and deposited on the nearshore slopes, forming bars, are later returned to the beach during more normal wave conditions. At the same time, recreational and aesthetic components of a site are all improved with beach nourishment undertakings.

Beach nourishment projects are best applied to sites which require both shoreline erosion protection and an improved beach. The implementation of a beach nourishment project should be based on a thorough analysis of the shoreline site conditions and processes.

Schemes which encourage capital intensive, short duration, minimum maintenance solutions are not well suited to beach nourishment implementation. If construction and maintenance costs however are spread over the project life, beach nourishment is seen as quite favourable.

Public perception of a beach nourishment scheme can also be a barrier to its implementation. Psychologically, a solid wall or revetment is seen as providing a firm line of defence against the lake water. Adding sand to the beach, especially if it is dumped offshore, is not seen to be a satisfactory solution at the time. The long term results of such work, if properly developed normally turn out positive as recreational and aesthetic benefits are realized.

6.5 Shoreline Management Practices and Lake Level Regulation

Another task that the Land Use and Shoreline Management Task Group undertook was to determine and assess the broad impacts of proposed lake regulation on land use and shoreline management practices for both Canadian and United States Great Lakes - St. Lawrence River shoreline areas. To do this, two sub-tasks were conducted:

1) To the extent possible, the landward implications of future lake level regulation for land use and shoreline management practices was determined, with specific reference to the Canadian detailed study sites; and

2) Changes to shoreline management practices and/or land uses that may be required if five lake regulation were implemented were examined, also with specific reference to the Canadian detailed study sites.

Results of these sub-tasks are summarized below. A more complete discussion can be found in Ecologistics Limited (1992c).

6.5.1 Sensitivity of Detailed Study Sites To Lake Level Regulation

Lake level regulation of all five Great lakes will likely alter shoreline conditions in some way. Impacts of extreme high and low levels may be mitigated by a reduction in range of fluctuation. To determine the sensitivity of the shoreline to such a reduction, the five detailed study sites from the Canadian side (see Section 5) were examined in terms of regulation impact on erosion. The existing land use and shoreline management measures along the shoreline were analyzed in relation to the potential changes in shoreline recession predicted by the Erosion Processes Task Group (see Section 3), assuming a 50% reduction in the historic range of water levels.

Assessing the future landside impacts of lake level regulation requires that assumptions be made. Of particular concern is the issue of regulatory standards and requirements'(e.g. setback lines, flood elevations, shore protection design standards). Would these requirements be kept as they are today or would they be recalculated to be consistent with new flood probability data resulting from regulation? If standards were changed, would they apply only to areas of new development, or would areas of existing and redevelopment be included as well?

For the purposes of this task, it was assumed that standards would generally remain as they are today. It is logical to assume that following implementation of full regulation that there may be a phased approach to altering regulatory requirements once the dynamics of the "new" system are accurately measured and evaluated.

Shoreline planning based on existing conditions has the advantage of maximizing protection and future damage avoided. It cannot be assumed that future regulated levels will not be subject to change or that deviations to the plans of regulation will not be exercised.

Montreal (St. Lawrence River)

The land use on this study site is primarily residential, with some recreational shoreline. Due to extensive structural protection over half (58%) of the shoreline length (18.1 km (11.2 miles)), this area is not presently erosion prone, and almost 70% of the shore would experience no recession under a 50% reduction in water level range scenario. Approximately 9.5 km (5.9 miles) of shoreline presently with moderate to minor shore protection would see a significant reduction in recession (20-50% of their historic rates) with reduced water levels. It is however, presently unclear as to the degree to which levels can successfully be maintained in the St. Lawrence channel from a five lake regulated system.

Toronto (Mississauga and Etobicoke)(Lake Ontario)

Residential and industrial land uses, combined with occasional recreational areas, characterize the 56.2 km (35 miles) of shoreline in this study area. Heavy shore protection structures along 81.5% (45.8km (28.4 miles)) of the shore have reduced or eliminated shoreline recession with current lake levels, and would likely prevent or reduce erosion even further along 88% (48.7 km (30.2 miles)) of this shore if the current range of levels were reduced by 50%. It is predicted that a water level reduction of this nature would completely eliminate recession along 3.7 km (2.3 miles) of this shoreline, as well as providing erosion related benefits to parts of the Port Credit and Toronto Islands shoreline.

Port Burwell to Clear Creek (Lake Erie)

This predominantly high bluff shoreline is backed by a mainly agricultural land base. Over three-quarters of the shoreline (76.8% or 23.5 km (14.5 miles)) is predicted to experience a moderate reduction (5-20%) in recession with a reduction in the range of water level of 50%. Since 20.5 km (12.7 miles) (67%) of this shoreline lacks shore protection, the regulation of water levels would not necessarily eliminate erosion; it would likely continue at a moderately reduced rate, with continued loss of agricultural land. Only the heavily protected entrance to the Port Burwell harbour would experience no recession under a regulation scenario of this nature.

Windsor to Belle River (Lake St. Clair)

The heavy concentration of residential land use along the length of this study area has brought about the installation of numerous shore protection structures. Due to the low elevation of land along Lake St. Clair, industrial, agricultural and recreational properties have also been protected.

As a result, recession is currently well under control. If water levels ranges were reduced by 50%, it is predicted that over 90% of this shoreline would have no further recession. The remaining 10% of shoreline, currently protected to minor degrees, could experience a significant reduction (20-50%) in recession rates that currently occur.

Thunder Bay (Lake Superior)

The primary land uses in this study area are industrial, forested and residential. The shoreline has been protected to varying degrees, from no protection (29%), to minor protection (14.5%), to moderate protection (29.7%), to heavily protected (26.8%). The longest reach in the study area (6.9km (4.3 miles)) is characterized by an unprotected, undeveloped bedrock shoreline that is stable and would remain so under reduced ranges of water levels. Minor to moderately protected shorelines, representing 18.6 km (11.6 miles) (44.2%) of the shoreline, tend to be sandy or coarse beach shores, and would experience a reduction in the active beach zone under lower water level ranges (i.e. the maximum inshore extent of wave activity would be reduced). The 26% of the shoreline that is heavily protected would not experience any recession with further regulation of the levels and unprotected areas near the mouths of the Kaministikwia and Neebing Rivers could benefit from water level range reductions by experiencing significant reductions (20-50%) in current recession rates.

6.5.2 Implications of Lake Level Regulation For Shoreline Management Measures

Further lake level regulation has the potential to alter shoreline conditions on Lake Erie, Huron and Michigan, which have not been previously regulated. In the above section, it was assumed that the range of lake level fluctuations would be reduced by 50%. This section describes the impacts of such a 50% reduction on individual shoreline management measures. A more complete description of these potential changes can be found in Ecologistics (1992c).

Setbacks

Setbacks consist of regulations which specify that new development takes place landward of a predetermined erosion and / or flood control line. The cost of this shoreline management measure would not likely be affected by a reduction in water level range. However, in terms of damages avoided, the effectiveness of setbacks would likely increase. A reduction in the frequency and magnitude of high water levels has the potential to increase the margin of safety provided by setbacks. However, if setbacks were changed in the future to reflect a new hazard definition resulting from regulation, the implication would be to reduce the extent of the hazard zone.

The natural environment could be enhanced through the application of setbacks along regulated lakes, as a natural buffer between new development and the lakes would be preserved. This buffer would likely be less susceptible to flood and erosion damages. In areas where erosion is reduced or eliminated, the natural environment would also be enhanced.

The impact of setbacks on land and water related uses and interests would not change if all Great Lakes were regulated, provided that the position of the setback line be determined as if the lakes were not regulated. Implementing setback lines on this basis could pose problems, as riparian interests could argue for a relaxed setback line, thus development closer to the water. Shore property owners generally perceive that regulation of water levels would reduce or eliminate most flooding and erosion and that setbacks impinge too much on private property rights. These opinions may constrain future setback implementation, despite their effectiveness in reducing damages.

Flood Elevation Requirements

Flood elevation requirements specify that new developments in hazard areas be constructed above a minimum elevation, or that existing structures be raised or retrofitted to ensure that windows and other openings fall above the flood level. The cost of this measure would not necessarily be affected by water level reductions, provided that the flood elevation requirements do not change. In this situation, a higher freeboard between flood elevations and floodproofed structures would be achieved, which could reduce flood damage potential.

Flood elevation requirements along regulated lakes would not impact the environment differently than such requirements on unregulated lakes. Flood elevations, if left unchanged after lake level regulation, would not impact shoreline interests and users any differently. However, flood elevation implementation could prove controversial if interests demand a lowering of the elevations once lake levels became regulated. Some interests would likely question the necessity of high flood elevation requirements if there were a 50% reduction in the range of levels.

Land Acquisition

This shoreline management measure is capital intensive and, with a reduction in lake level range, costs could rise due to an increase in real estate values. Waterfront real estate could become more desirable as potential owners perceive flood and erosion problems diminished or eliminated as a result of regulation. Values could also rise if waterfront property became more scarce as a result of a successful land acquisition program. If the program were implemented through subdivision regulations, then cost effectiveness should not change with regulation. If water levels are reduced, land acquired should suffer fewer damages from flooding and erosion, thereby increasing its effectiveness in damage reduction. For the same reason, the natural environment would be enhanced. Shorelands could be retained in, or returned to, a natural state. As more property is acquired, a continuous natural shoreline environment could be reestablished.

In terms of land acquisition's compatibility with water and land related users or interests, lake level regulation would not change an acquisition program's impact. However, the riparian survey indicated that land acquisition is not a favoured government action. A higher percentage of U.S. respondents on regulated lakes were opposed to acquisition of hazard prone property than on unregulated lakes. This may indicate that a reduction in lake level fluctuation would increase riparians opposition to this measure. Implementation of such a program could, therefore be constrained.

Relocation of Dwellings

Structures built in hazard areas and faced with impending destruction are, if technically feasible, often relocated on the same lot (farther inland), or to a different location. Cost effectiveness would generally be unaffected by lake level regulation. The value of a dwelling must be above the cost of relocation for this measure to be cost effective. If lake level regulation brings about a reduction in flood and erosion damage, then the damages avoided by relocations could increase. A relocated dwelling would likely be exposed to reduced damage potentials if flood frequencies and erosion rates were reduced.

Structural Shore Protection (Flooding)

In addition to flood elevation requirements, flood damages can also be mitigated through the construction of dykes. Dykes of earth or concrete placed along or around flood prone property or section of shoreline can prevent water from inundating the land behind. A reduction in flood elevations due to lake level regulation could reduce the costs of dyking as lower dykes may prove to be sufficient protection from flood waters, and reduced maintenance cost may be afforded as well. However, the cost savings would likely be small as dyking remains an expensive endeavour.

In terms of damages avoided, the effectiveness of damages avoided would likely increase with lower high water levels due to lake level regulation. The probability of dyke overtopping or breaching would be reduced for dykes already constructed, therefore, lowering damage potentials. However, lower water level fluctuations may incur increased maintenance responsibilities.

Dykes have several environmental impacts and they also provide incentive for intensified land use behind the dyke such as agricultural, residential or industrial. The nature of these impacts would not necessarily change with a regulated lake level scenario, nor would the compatibility with water and land related interests be changed. Implementation of dyking systems could be constrained as their high installation costs ($1,600/m to $2,300/m in 1991 dollars) could exceed the benefits (Ecologistics, 1992a). Water level regulation could reduce the need for dyking, particularly as emergency measures.

Structural Shore Protection (Erosion)

A variety of erosion protection structures are used on the Great Lakes. They include: revetments, seawalls or bulkheads, groynes and groyne fields, and headland embayment structures. As with most shoreline management measures, these structural protection methods have advantages and drawbacks. While the methods provide erosion protection, many privately constructed measures are damaged or destroyed by poor design or construction, lack of cooperation between property owners and physical stress on the structures (Davidson-Arnott and Keizer, 1982). A detailed quantitative discussion of the shore protection costs that could be avoided under various water level scenarios can be found in Baird and Associates (1993) and in Section 5 of this report. This section will present a more generic and qualitative discussion of the impacts of water level regulation on various shore protection structures.

Revetments

Large rocks placed along an eroding shoreline to absorb the energy of incoming waves are known as revetments. The cost effectiveness of revetments could improve as lower expenses would be necessary in a regulated lake level environment. The maintenance cost should also decrease. Erosion reduction qualities of revetments should improve with regulated lake levels, thereby increasing the damages avoided. The positive and negative environmental impacts, described in the report on Task 15.2 (Ecologistics, 1992 a and b) would not likely be subject to change in a regulated lake scenario.

The compatibility of revetments with land related interests may be enhanced. Riparians could find revetment life spans to be longer due to a reduction in high lake levels with regulation. Only where lower levels reduce erosion would effectiveness be enhanced. However, the protection could still suffer damages from storms with strong wave action. The implementability of revetments could be facilitated as structurally lowered standards could prove effective in a regulated lake level environment. These reductions could only be calculated by an engineered modelling of anticipated water levels and design quality.

Seawalls and Bulkheads

Seawalls or bulkheads are usually constructed of steel sheet piling, concrete, gabions, grout filled fabric bags, or treated timber to separate land from water. The structures provide erosion protection to loose fill, sand or weak bedrock. With a regulation of lake level fluctuations, the costs of seawalls and their maintenance could be reduced. Similarly, the degree of erosion protection offered by seawalls could increase, in turn lowering damage potential.

Positive environmental impacts (erosion control and lower turbidity levels) and negative environmental impacts (potential aquatic habitat loss, impacts during construction and a reduction in natural shoreline characteristics) would not likely change when lake level fluctuations are reduced. Shore property owners would likely increase their benefits from seawalls along regulated lakes. Seawall life spans could improve, affording a longer period of erosion protection. Implementability should not change.

Breakwaters

Breakwaters reduce wave actions to protect leeward waters, such as harbours, from destructive wave forces. The structures can be built parallel or at some angel to the shore to protect harbour sites. In terms of their effectiveness in reducing erosion damages and their compatibility with the environment are similar to that of seawalls. Lower lake level fluctuations likely reduce breakwater installation and maintenance costs, yet increase damages avoided. Environmental impacts and compatibility with land and water related interests should not be different under regulated lake levels.

Smaller breakwaters could become effective in regulated lake level environment, thereby facilitating implementability.

Groynes

A groyne is a shore protection structure built out at an angle from the shore to trap sand and to protect the shore from erosion by currents and waves by making a beach (Strelchuk, 1981). Constructed in groups, groyne fields attempt to trap sand along eroding shore line reaches. Again, a reduction in lake level fluctuations could decrease the installation and maintenance cost of groynes as their structural standards could be reduced. Subsequently, depending on site conditions, increased damage avoidance may materialize.

As high lake levels are reduced with lake level regulation, there would likely be a shift lakeward to sediment transport in longshore drift. This shift could restore natural littoral drift conditions which would benefit the environment. Sediment deficient shore reaches could revert to depositional environments.

The sediment that has been trapped by groynes in the past would likely remain in place once lake levels were regulated. This would benefit riparians and enhance the measure's compatibility. Implementability of groynes should not be affected by lake level regulation.

Headland Embayment Structures

Coastal engineers, through the observation of natural headlands, have developed artificial headlands using armoured mounds of stone to stabilize the shoreline between the hard points.

An embayment develops, often with sediments remaining trapped to create beaches. Two types of headlands are used: those constructed as small offshore islands or breakwaters and those placed on shore. The former induces tombolos to form in the lee of the headlands, provided that sufficient sediment can be provided by littoral drift. The latter contributes to littoral drift until a stable embayment has developed.

Similar to the other erosion protection measures, costs would likely be lower for headlands in a regulated lake level environment. The damages avoided would likely be increased as the probability of failure of headlands would be reduced assuming design standards do not change. As lake levels fluctuation regulation will reduce water quality in the Great Lakes in general, the pooling of water in embayments could further impair the natural environment. Related to this, the land and water users and interests would experience impaired recreational opportunity thereby reducing compatibility. Conversely, erosion would be reduced providing enhanced compatibility. The implementation of headlands on shore would be facilitated by lake level regulation as these structures would likely produce stable shoreline embayments more rapidly than in an unregulated lake environment. The impact of headland embankment structures on shoreline processes would not be altered as a result of lake level regulation.

Non-structural Shore Protection (Flood and Erosion)

Two shore protection measures can potentially reduce flooding and erosion. Beach nourishment and shore stabilization using vegetation can maintain protective sand dunes and stabilize bluffs, respectively.

Beach Nourishment

Beach nourishment is a technique of supplying sediment to the shore zone in order to create beaches or substitute eroding material. In does not prevent erosion. The maintenance cost of beach nourishment projects should decrease with controlled lake levels. As wave action or high water levels potentially incorporate the nourished sediment into the littoral drift stream, a period replenishment of sediment may be necessary, especially along eroding shorelines. When lake level regulation reduces high water levels, the periods between replenishment may be lengthened; thus reducing maintenance cost. In addition, a given amount of beach nourishment should become more effective in reducing flood or erosion damages in a regulated lake level environment.

Beach nourishment would still impair the natural environment, however. Dredging of sediment supplies off-shore to nourish beaches could increase turbidity and further impair water quality in a regulated lake environment. These are inherent factors in the nature of the measure, and are not influenced by lake levels to a great degree.

Vegetative Shore Stabilization

Vegetation plantings on barren shores, sand dunes and exposed bluffs can effectively reduce erosion. The relatively inexpensive measure should not be influenced by lake level regulation in terms of cost effectiveness. Damage potentials should be reduced as a result of lake level control as bluff shores would be less susceptible to erosion by high lake levels. Vegetation would then more effectively anchor soil layers.

The natural environment would be enhanced as vegetation can provide habitat for wildlife. In addition, shoreline users would appreciate the improved aesthetic quality of vegetation. The recreational opportunities could be enhanced if wildlife are attracted to the vegetated shoreline. Implementability of vegetative shore stabilization would be facilitated if reduced high water levels on regulated lakes slowed bluff recession rates. These benefits would occur as inherent characteristics of the measure, and are unaffected by lake level regulations.

Shore Alteration Requirements

Shore alteration requirements include regulations which prohibit unlicensed filling, construction or alternation of shorelines. The cost effectiveness of regulations should not be affected by controlled water levels. However, the damage reduction potential could increase if standards are maintained and policies remain unchanged with regard to shoreline development on water level regulated lakes. The natural environment should not be influenced differently by shore alteration requirements on regulated lakes.

As with setbacks and elevation requirements, the dangers exist of a relaxation in regulatory requirements.

The compatibility of this measure may be impaired as shoreline property owners could regard the requirements too stringent or limiting. In the face of reduced lake level fluctuations, riparians could reject shore alteration requirements, creating difficulties for the Conservation Authority implementation program.

Habitat Regulations

Habitat regulations are intended to protect special habitat for aquatic or terrestrial life. Waterbird nesting or congregation sites or fish spawning and nursery habitat are often protected natural areas. Many government legislative acts have been implemented to manage these habitats.

Habitat regulations would remain unaffected by lake level controls in most cases. However, lake level fluctuation reduction could impair or enhance habitat areas, depending on the natural qualities protected. Some environments would be negatively impacted (such as wetlands), while others would be positively impacted (for example, an increase in nesting opportunities for specific birds in water-intolerant vegetation types).

Development Controls for Public Infrastructure

Public infrastructure (i.e., roads, bridges, sewers, water supply and government facilities) can influence shoreline development to a significant degree. A road that provides access to the shoreline increases the development potential of that shoreline. Damages to infrastructure could be reduced as a result of controlled lake levels. However, a greater damage avoidance occurs when infrastructure is located outside shoreline hazard areas. The implementability of development controls could only be constrained by a tendency to release the controls in light of regulated lake levels. The compatibility with the environment or with land and water related interests should not be affected by lake level regulation.

6.6 A Discussion of Findings and Recommendations

Unlike lake level regulation, which has direct impact along the entire shoreline, shoreline management alternatives must be evaluated and undertaken in concert and harmony with unique site specific conditions. Many of the results that have been presented in this document are based on the experience with specific measures and mechanisms at unique locations along the shoreline. Lake-wide or basin-wide extrapolation of these results should be undertaken with caution and with an understanding of the limits on the data.

Setback and/or floodproofing requirements have been shown to be very effective in reducing damage. These measures can be readily implemented in shoreline areas that are currently undeveloped. This observation is particularly salient given the results contained in the Task 15.1 (Triton Engineering and Ecologistics Limited, 1992) report which indicated a projected doubling of residential riparian development over the next ten years; largely at the expense of undeveloped portions of the shoreline. Setbacks may also be equally applied in areas which are currently developed. Developed areas are not static, setback can be effectively applied to redevelopment of lots or in combination with other measures, e.g., dwelling relocation.

Areas which are presently zoned for development along the shore, but in which construction has not yet occurred present a unique situation. Should a retroactive setback be required there may be instances in which a setback significantly reduces or eliminates the economic development potential of an individual parcel of land. In these instances, the property owner may have the right to compensation. Common law private property rights and government imposed land use planning restrictions in evolving. At present, the full implication (i.e., costs and benefits) of the setback option cannot be fully assessed for areas already designated for development.

Areas that are currently developed and which have experienced repeated damage due to flooding are candidates for a dedicated land acquisition or dwelling relocation program. Acquisition, however, is likely to only be justifiable in areas where public money has been repeatedly expended to compensate property owners for damages or in instances where significant public buildings and infrastructure are at risk. Results of the site specific modelling in this report indicate that acquisition was not economically feasible in the erosion prone area modelled.

With acquisition, land is reverted back to passive, non-hazardous use, such as recreation, environmental protection or for education purposes. Where municipalities are unable to afford the purchase price of the entire parcel of land, the acquisition of the immediately threatened area as an easement would achieve a certain amount of setback from the waterline and reduce hazard threat. This measure would afford the community recreational benefits as well as shoreline protection. Financial support or partnership with regional or provincial levels of government would facilitate municipal land acquisition of hazard-prone areas.

It is quite acceptable to collect a user fee to cover all or a portion of administrative costs from shoreline property owners participating in government sponsored programs or subjected to shore alteration permitting process. Given the popularity of some programs around the basin that already require fees, there may be room to offset the full cost of administration. By increasing the fees further, service in the areas of enforcement and technical advise could be undertaken or expanded.

Further studies should be undertaken to determine the feasibility of acquiring shoreline areas or coastal barriers that exhibit unique shoreline characteristics or habitat under provincial or federal statutes for protection as provincial parks, etc. Funding would be required from federal and provincial levels of government.

Tax incentives for shoreline management are not well organized in Canada. Improvements to tax incentive programs such as more sophisticated tax abatement opportunities are required to encourage property owners to maintain natural shoreline features/wetlands and flood storage areas. Further research on the feasibility of expanded tax incentives should be undertaken.

Property owners should be provided access to technical assistance from Conservation Authority staff to undertake shoreline management in hazard-prone areas. This advice could include, for example, guidance with respect to the best shoreline management alternative or guidance as to design requirements for structural shore protection. Effective technical assistance programs would require additional full time staff responsible for the program's implementation and administration as well as increased financial resources subsidized by local or provincial government sources.

Subsidies/fund matching programs should be established to encourage/enable property owners to undertake community-based structural shore protection measures where no alternative non-structural measures are feasible.

In shoreline areas where a retro-active setback is implemented, shoreline property owners should be provided attractive incentives to relocate their dwellings. Fundamental decisions about roads, water supply, and sewers have long-term impact on patterns of shoreline development.

Municipalities and other governments should be encouraged to restrict shoreline development in hazard-prone areas by enforcing development controls on public infrastructure.

Shore protection, for flooding and erosion, has been shown to be an effective means of avoiding future property damages when structures have been designed, implemented and maintained in accordance with good engineering practices and in a manner that considers potential negative impacts on adjacent and downdrift property. However, it has been demonstrated that the majority of privately constructed shore protection structures fail within 10 years of construction. Any government incentive program (i.e. loans, grants, tax incentives, etc.) that encourage the construction or upgrading of shore protection structures must include provision for technical inspection and approval of plans including enforcement powers.

The greatest use of implementation mechanisms historically has been for shore protection. Shore protection is only one component of a comprehensive approach to shoreline management. Many riparians have not been exposed to the variety of shoreline management options available. When applying for assistance in undertaking action to reduce the hazard susceptibility of their property, riparians should be required to consider the feasibility of alternatives to shore protection.

Deed restrictions or disclosure have not been widely required or adopted along the Canadian shoreline. Much remains to be explored regarding the potential impact of this mechanism on property values, perception of prospective buyers decision of buyers, affects on appropriate redevelopment of shoreline lots, effectiveness of shoreline management actions taken by a vendor, etc. The Ontario Shoreline Management Advisory Council recommended that a disclosure requirement be implemented.

Flood and erosion damage insurance is not available in Canada. The historic development of shoreline management measures and government assistance in Canada has evolved towards utilizing other measures to assist property owners. In particular, generally well established land use planning procedures have reduced somewhat the need for a government insurance scheme as an incentive for the development and application of these procedures.

The extent of application and effectiveness of many measures, especially those that require property owners to undertake substantial works and investment can be enhanced when combined with incentives and other forms of assistance.

6.7 Summary

The installation or application of any measure can not be done in isolation. A water level regulation measure which alters the water level regime will not eliminate damage due to storms. Other land use remedial and preventative measures will still be necessary. Land use measures themselves should be implemented in a coordinated fashion according to the local situation. Remedial measures might be best suited for developed areas where the shoreline or existing structure needs to be altered or modified to alleviate problems. Preventative measures are more appropriate for undeveloped areas, where it is still possible to prevent future damages by controlling the type and degree of development along the shoreline.

It must be realized that no single land use measure will be appropriate in every situation around the Basin. The measures highlighted here, must be applied according to the individual situation and problems of the local area. These measures should be considered as a set of "tools" available to shoreline agencies for use in their management of the Great Lakes - St. Lawrence River shoreline.

REFERENCES

Baird and Associates Coastal Engineers, 1993. Future Avoided Costs of Shore Protection. Report Prepared For the Potential Damages Task Group, Working Committee 2, Phase II, IJC Levels Reference Study.

Bishop, C.T., 1983. A Shore Protection Alternative: Artificial Headlands. Proceedings of the Canadian Coastal Conference 1983, National Research Council of Canada, p.305-319.

Boulden, R.S.(ed.), 1975. Canada-Ontario Great Lakes Shore Damage Survey Technical Report. Environment Canada and Ontario Ministry of Natural Resources, 97pp.

Burby, et al., 1988. Cities Under Water. A Comparative Evaluation of Ten Cities Efforts to Manage Floodplain Land Use. University of Colorado, Institute of Behavioral Science, Program on Environment and Behaviour, Monograph No.47.

Carter, C.H., Munroe, C.B. and Gray, D.E. Jr., 1986. Lake Erie Shore Erosion: The Effect of Beach Width and Shore Protection Structures. Journal of Coastal Research, Vol. 2 (1): 17-23.

Committee on Coastal Erosion Zone Management, Water Science and Technology Board, Marine Board, Commission on Engineering and Technical Systems and the National Research Council, 1990. Managing Coastal Erosion. National Academy of Sciences Press, Washington D.C., 182pp.

Dai, T.S., Hill, I.K. and Smith, D.W., 1977. The Role of Vegetation in Stabilizing the Lower Great Lakes Canadian Shoreline. Journal of Great Lakes Research, Vol. 3 (1-2): 45-56.

Day, J.C., Fraser, J.A., and Kreutzwiser, R.D., 1977. Assessment of Flood and Erosion Assistance Programs, Rondeau Coastal Zone Experience, Lake Erie. Journal of Great Lakes Research, 3(1-2): 38-45.

Davidson-Arnott, R.G.D. and Keizer, H.I., 1982. Shore Protection in the Town of Stoney Creek, Southwest Lake Ontario, 1934-1979: Historical Changes and Durability of Structures. Journal of Great Lakes Research, Vol. 8 (4): 635-647.

Ecologistics Limited, 1992a. Evaluation of Shoreline Management Practices - Canadian Shoreline. Report Submitted To The Land Use and Shoreline Management Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 198pp. plus Appendices.

Ecologistics Limited, 1992b. Evaluation of Shoreline Management Practices - United States Shoreline. Report Submitted To The Land Use and Shoreline Management Task Group, Working Committee 2, Phase II, IJC Levels Reference Study.

Ecologistics Limited, 1992c. Lake Level Regulation and Shoreline Management. Report Submitted To The Land Use and Shoreline Management Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 198pp.

Federal Emergency Management Agency, 1986. Design Manual for Retrofitting Flood Prone Residential Structures.

Haras, W.S. and Tsui, K.K. (eds.), 1976. Great Lakes Coastal Zone Atlas. Environment Canada and Ontario Ministry of Natural Resources, Canada Ontario Great Lakes Shore Damage Survey.

Houlahan, J.M., 1989. Comparison of State Construction Setbacks to Manage Development in Coastal Hazard Areas. Coastal Management, Vol. 17: 219-228.

Kreutzwiser, R.D., 1988. Municipal Land Use Regulations and the Great Lakes Shoreline Hazard in Ontario. Journal of Great Lakes Research, 14(2): 142-147.

Kreutzwiser, R.D., 1990. Evaluation of Loan and Advice Programs Responding to Great Lakes Shoreline Flooding and Erosion. A Report to the Social Sciences and Humanities Research Council.

Lavalin Environment, 1988. Projet des Mise en Valeur du Saint-Laurent, Rapport Preliminaire. Pour Ministere de L'Environnement du Quebec, Centre Saint - Laurent.

Law, M.N., McKeen, P, Thoenley, D and Davidson-Arnott, R., 1992. Municipal Flood and Erosion Land Use Regulations Along The Great Lakes Shoreline in Ontario. Unpublished Report, Lands and Water Policy Branch, Ontario Ministry of Natural Resources.

Lawrence, P.L., 1989. Inventory of Shoreline Protection Structures on Lake Huron. Maitland Valley Conservation Authority Internal Report.

Lawrence, P.L. and Nelson, J.T., 1992. Preparing For a Shoreline Management Plan For the Saugeen Valley Conservation Authority: An Initial Survey and Assessment of Relevant Information. Heritage Resources Centre, University of Waterloo.

LURA Group, 1989. Trends in Shoreline land Use and Land Values in Selected Growth Centre in The Great Lakes - St. Lawrence River Basin.

McKeen, P.L. and Law, M.N., 1991. Provincial Legislation and Regulatory Controls Along The Shorelines of the Great Lakes - St. Lawrence River. Ontario Ministry of Natural Resources, Toronto.

Nelson, D.A. and Pullen, E.J., 1985. Environmental Considerations in Using Beach Nourishment for Erosion Protection. Proceedings of the Second Water Quality and Wetlands Management Conference, New Orleans.

Nelson, J.G., Skibicki, A.J., Stenson, A.J., and Yeung, C.L., 1991. Urbanization, Conservation and Sustainable Development: The Case of Frenchman's Bay, Toronto, Ontario. Heritage Resources Centre, University of Waterloo.

North Shore Management Board, 1988. North Shore Management Plan - A Shoreland Management Plan for Lake Superior's North Shore. Minnesota Department of Natural Resources, 50pp.

Ontario Shoreline Management Advisory Council, 1989. Second Annual Report (1988-1989) To The Minister of Natural Resources. Government of Ontario, 39pp.

Ralph, B. and Heffernan, S., 1978. An Environmental Management Study - Long Point Provincial Park. Ministry of Natural Resources, Simcoe District.

Royal Commission on the Future of The Toronto Waterfront, 1992. Regeneration - Toronto's Waterfront and The Sustainable City: Final Report. Governments of Canada and the Province of Ontario, 530pp.

Saunders, K.E., Law, M.N., MacKinnon-Burwell, D., Abel, M.J. and Mauriello, M.N. (eds.), 1990. Delineation of Erosion Hazard Shorelines - Workshop Summary. Great Lakes Shoreline Management Workshop Series, Cleveland, Ohio, June 1990. Ontario Ministry of Natural Resources, 52pp.

Smith, P.G.R., 1987. Towards the Protection of Great Lakes Natural Heritage Areas. Heritage Resources Centre, University of Waterloo, Technical Paper 2, 164pp.

Strelchuk, D.(ed.), 1981. Great Lakes Shore Management Guide. Fisheries and Oceans - Environment Canada and Ontario Ministry of Natural Resources,212pp.

Task Force on Available Shore Erosion Information on the Great Lakes - St. Lawrence System, 1973. Shore Erosion on the Great Lakes - St. Lawrence System.

Triton Engineering and Ecologistics Limited, 1992. Inventory and Assessment of Land Uses and Shoreline Management Practices. Report Submitted to the Land Use and Shoreline Management Task Group, Working Committee 2, Phase II, IJC Levels Reference Study, 48pp. plus Appendices.

7.0 NATURAL RESOURCES TASK GROUP

7.1 Introduction

7.1.1 The Resources

The natural resources addressed in the Reference Study are the ecosystems of the Great Lakes, their connecting channels, and the St. Lawrence River. The water resource issues under discussion in this study concern large parts of the United States and Canada. The specific environmental resources in this span of geography are so vast that it is difficult to comprehend their extent. As such, estimating effects upon these resources is a complex task. Further, the environmental consequences of water level fluctuations have not been studied thoroughly enough to provide an understanding of many of their qualitative effects, much less their quantitative effects. While it is fortunate for the overall study that, since the turn of the century, water level and flow data have been monitored, it is equally as unfortunate that monitoring data for the ecosystem components do not exist. As a result, the Natural Resources Task Group has sought to improve knowledge of the environmental impacts of water level regulation schemes on the Great Lakes and St. Lawrence River by obtaining information on impacts without the benefit of monitoring data.

7.1.2 The Approach

One means of understanding impacts at this scale is by using wetlands as a primary indicator of ecological productivity in the Great Lakes - St. Lawrence River basin. The decision to use wetlands in this way has been made for two reasons. First, because wetlands serve as habitat for a great number of waterfowl, fish, mammals, and other animals, and have numerous other "functions and values" that are important to aquatic ecosystems (e.g., see Jaworski and Raphael, 1978; Stephenson, 1988). Second, information has been accumulated on wetland responses to water levels so that a little further work on this component of the ecosystem greatly increases our understanding of ecological effects of water level changes. Hence Task Group studies have primarily acquired data that improve the ability to predict the effects of regulatory measures on Great Lakes coastal wetlands.

The techniques employed to estimate wetland effects have included: 1) using information on past wetland characteristics at different water levels determined from historical aerial photographs; 2) examining existing distribution patterns of wetland communities along offshore/onshore profiles which reflect the influence of past water level changes; and 3) estimating the influence of changing water levels on wetlands through the use of conceptual modeling, which combines information from various sources on how wetlands respond to water level changes. Conceptual modeling provides an indication of how regulatory changes will affect the extent and diversity of coastal wetlands on the Great Lakes and St. Lawrence River.

On the other hand, it is well understood that wetland communities form only parts of the ecosystems of the Great Lakes-St. Lawrence system. A number of fish species, for example, are directly dependent upon wetlands for parts of their life cycles, but fish also live in deepwater communities throughout these large bodies of fresh water. To best deal with the rest of the ecosystem components, given time and resource limitations, the results of previous water level studies have been used and additional information has been sought on water quality effects and fish community effects through the review of the existing scientific literature.

7.1.3 The Issues

The Phase I findings concerning wetlands can best be summarized in a single sentence from Annex B: "Significant compression of the range of fluctuation would have systemwide impacts on plant species diversity, and wetland area." These findings follow from a characteristic of Great Lakes/St. Lawrence River wetlands known as "pulse stabilization" (Harris et al., 1977; Lyon, 1981; Lyon et al., 1986). Historic fluctuations in the Great Lakes and St. Lawrence River have sustained wetland communities that are more extensive, more diverse, and more productive than those that would have existed without fluctuations. Reducing the fluctuations would reduce wetland extent, diversity, and productivity wherever the reductions took place. The Phase II wetland studies described below, confirmed and extended these findings as they relate to wetland area, wetland complexity, and wetland plant diversity, so that the effects of regulation scenarios could be better understood and addressed.

The Phase II studies have also brought into focus the distinct differences between the Great Lakes wetlands and the St. Lawrence River Lakes wetlands. While coastal marshes are the predominant wetland resources on the Great Lakes, floodplain forests, generally silver maple forests, are the predominant resource on the St. Lawrence River. Because forested wetlands take so long to regenerate, there is a strong concern about the potential of destroying them because of inappropriate regulation changes.

The fluctuation regime along the St. Lawrence is also artificial. It is partly a product of the regulation of Lake Ontario and the lakes above it, and the effects of the navigation and power generation structures of the St. Lawrence Seaway. Because regulation for the Great Lakes can create large changes in the levels and flows in the St. Lawrence, there is a strong potential for damage to St. Lawrence River wetlands from extensive regulation schemes.

Historic Wetland Changes (Great Lakes)

To further investigate findings that historic changes in water levels correlate with changes in the extent of different wetland plant communities on the Great Lakes, a study using historic aerial photographs of wetlands was conducted on Lakes St. Clair, Erie, and Ontario. Plant communities in six Great Lakes coastal wetlands were mapped for five or more years between 1958 and 1991 at various water levels. The community distributions were digitized and placed in a Geographic Information System (GIS) for detailed assessment of changes in wetland landscape, for statistical analysis, and for future comparisons.

Impact of Water Level Changes on Wetland Plant Diversity (Great Lakes)

The diversity and integrity issues were studied on the Great Lakes. In contrast to the St. Lawrence River, where extensive forested wetlands are found, Great Lakes shorelines sustain extensive coastal marshes. Previous IJC studies have shown that fluctuations of water levels in the Great Lakes are necessary to perpetuate cycling of successional processes in wetlands (Wilcox, 1988). High lake levels periodically eliminate competitively dominant emergent 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 through competitive interactions. This maintains plant diversity and through plant diversity, habitat diversity in coastal wetlands is also maintained.

Previous studies also showed that each wetland responds differently to water level fluctuations as a result of differences in basin morphology and topographic positioning of plant communities within a basin (Wilcox, 1988). Therefore, site-specific data from a few locations cannot be used to generalize across a whole lake or the entire Great Lakes system. Instead, data are necessary from a number of sites in a lake to describe typical basin morphology and identify critical water levels to which wetland plant communities respond. In Phase II, numerous wetlands were assessed to collect the data necessary to identify the range of fluctuations that must be maintained to protect wetland integrity and habitat diversity. Water level regulation scenarios were then assessed according to whether or not they would sustain wetland integrity and diversity.

Conceptual Model of Coastal Wetland Area (Great Lakes/St. Lawrence)

The issue of changes in areal extent of coastal wetlands was addressed by development of a "conceptual model" of wetland area. The mechanisms which apparently are responsible for changes in wetland area, essentially the water level fluctuations acting upon the geometry of the offshore/onshore profile, were simulated in the computer-based numerical model. The water level regulation scenarios were then run through the model to assess how they would affect marsh or emergent wetland area in each lake.

St. Lawrence River Water Level Effects

Because the St. Lawrence River is downstream of the Great Lakes, water level regulation on the Great Lakes affects the hydrological conditions, and consequently wetlands, along the St. Lawrence River. Water level regulation affects large geographic areas, so wetland resources are affected at a large scale. The St. Lawrence River, which has a length of 3,060 km (1900 miles), a watershed of 1,344,000 km^2 (518,918 square miles)(without Gulf of St. Lawrence), and a mean discharge of 10,100 m^3 (356,631 ft^3)/s , is one of the largest rivers on the planet. Along the shore of its fluvial section (from Cornwall to Grondines), 63,000 ha (155,610 acres) of wetlands are encountered. Because water level fluctuations play an important role in the maintenance and the diversity of these wetlands, a separate study of three St. Lawrence River wetlands was undertaken. Although it was conducted on a very small sample of St. Lawrence River wetlands, this project was conducted to look at historical data and see how these wetlands, and specific plant communities within these wetlands, have reacted to past water level fluctuations.

Effects on Fish Habitat

Predicting the effects of water level changes on fish habitat and fish populations is exceedingly difficult not only because of the number of different fish species and the complexities of their life cycles, but also because of the lack of suitable information. In an attempt to gather this type of data, the following tasks were completed by the Task Group:

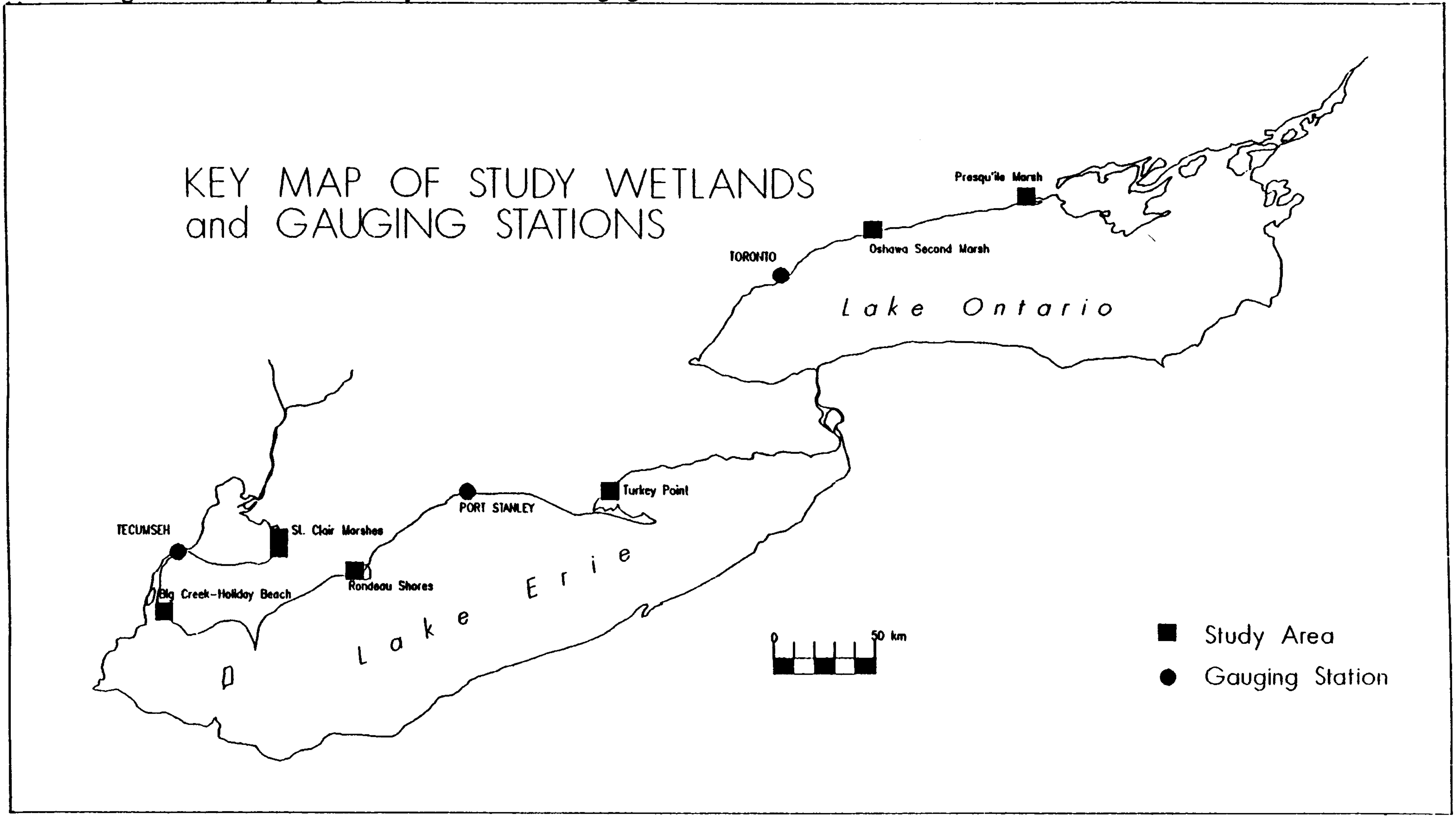
- a review of past studies conclusion about the potential effects of alterations of Great Lakes water levels on fisheries;
- a discussion of the significance of nearshore habitats, and mechanisms by which fish resource impacts could occur;
- a review of the scientific literature examining the relationship between water levels and reproduction of Great Lakes fish species;
- an examination of the effects of water level fluctuations at two sites in Saginaw Bay, Lake Michigan on bathymetry and spawning habitat;
- an examination of the potential impact of the proposed water level regulation scenarios on yellow perch (Perca flavescens) recruitment in South Bay, Lake Huron; and
- an example GIS map of nearshore habitat from the Bay of Quinte.

7.2 Impact Assessment Methods

7.2.1 Historic Wetland Changes in the Great Lakes

The Historic Wetland Mapping Project developed and implemented a method to analyze the change in wetland quality, quantity, value and function due to water level fluctuations, using historic water level, vegetation and land use information.

Figure 7.1 Key Map of Study Wetlands and Gauging Stations



Methods

Six Lower Great Lakes wetlands (FIGURE 7.1) were selected from three Great Lakes based on location, wetland type, and known biological significance. The six wetlands chosen for study were:

Lake St. Clair	Lake Erie	Lake Ontario
St. Clair Marshes	Big Creek-Holiday Beach	Oshawa Second Marsh
	Rondeau Shores	Presqu'ile Marsh.
	Turkey Point	

Vegetation and Land Use Information

For each site, maps of wetland vegetation communities and adjacent land use were created by photo interpretation using aerial photographs of at least 6 different years for each site. The air photos provided historical records of vegetation and land use from 1954 to 1989. The vegetation and land use maps were digitized and entered into a Geographic Information System (GIS).

Initial classification of wetland vegetation was based on the finest detail possible from photo interpretation. These classes were aggregated into fourteen different wetland vegetation classes which were then used for analysis (TABLE 7.1). The vegetation classes were chosen to reflect distinct habitat and successional differences, a range of water presence, and categories that were feasible for reasonably consistent interpretation at a variety of scales and seasons.

Wetland Attributes

A number of wetland attributes were analyzed for changes over the study periods. For each wetland, these attributes describe: 1) the wetland as a whole; 2) the individual vegetation communities (and abiotic units) comprising the wetland; and 3) the internal dynamics of the wetland over time.

The Wetland As A Whole. Changes in the wetland as a whole are important in terms of understanding the dynamics of the spatial and physical characteristics of these ecosystems. Attributes used to measure total wetland changes in this study include total wetland area, total wetland perimeter, and area to perimeter ratio.

Table 7.1 Wetland Communities

Open Water	Managed Emergents*
Flat/Wet Emergents	Wet Meadow*
Emergents	Meadow
Cattail Interspersed	Sphagnum*
Taller/Denser/Drier Emergents	Trees/Shrubs in Water
Solid Cattail	Trees/Shrubs
Grass/Sedge Hummocks*	Sandbar/Remnant Dike

*Turkey Point only

<u>Individual Wetland Communities (TABLE 7.1)</u>. The following attributes were selected to serve as indicators of wetland community dynamics in response to lake level change: total area per wetland community; percentage of total wetland area occupied by each wetland community; number of patches per wetland community; and average patch size per wetland community. Each of these attributes also reflects a wetland value function because the greater the diversity and interspersion of vegetation communities, the higher a wetland's habitat value.

Average edge is an index of wetland structural complexity for a given, constant area. If the average edge increases over time, the wetland becomes more complex (i.e., either there are a greater number of smaller wetland community units or the units have more complex shapes). Many marsh nesting birds such as the Virginia rail prefer marsh vegetation interspersed with open water (Cadman et al., 1987). In this study, a more complex wetland (i.e. greater total edge) was considered to provide more habitat than one having less complexity.

<u>Internal Wetland Dynamics</u>. Changes in the spatial distribution of wetland communities were determined by overlaying each consecutive pair of years and calculating the total area of wetland communities that changed and remained unchanged. This represents one component of the internal dynamics of a wetland. Certain organisms are favoured by stable wetlands (e.g., wild rice)(Thomas and Stewart, 1969), while others benefit from highly dynamic ones (Keddy and Reznicek, 1982).

A Geographic Information System (GIS) was used as an analytical tool. The software provided rapid analysis of change in wetland attributes from one year to another so that trends could be identified and quantified and related to water level. The quantities generated by the GIS were exported to a tabular format for further analysis.

Lake Level Attributes

The present distribution and abundance of shoreline plant species is determined by past as well as present water levels. However, the rates and magnitudes of the effects of water level change on wetland vegetation are unknown (Functional Group 2, 1989). Nor is it known how rate and magnitude vary from wetland to wetland, nor from wetland community to wetland community. Because lake levels are in a continuous state of flux, and because the exact nature of the wetland/lake level relationship is unclear, the analysis was based on several lake level attributes which can be expected to have some influence on wetlands. Lake level attributes measured included: mean, median, level that was exceeded 10% of the time, level that was exceeded 90% of the time, minimum, maximum, and amplitude (range). Each of these attributes was calculated for the short term (2 years previous to the aerial photo) and the long term (10 years previous to the photo). The water level information was captured at three water level gauging stations: Tecumseh (Lake St. Clair); Port Stanley (Lake Erie); and Toronto (Lake Ontario). These were the closest stations to the individual wetlands which had water level data for all the years of photo coverage.

Correlation Analysis of Water Levels and Wetland Change

Correlations between selected lake level variables (mean lake level, mean spring lake level, mean summer lake level, minimum lake level and maximum lake levels) and wetland attributes were performed using SYSTAT statistical software.

7.2.2 Impact of Water Level Changes on Wetland Plant Diversity

This study was initiated to obtain necessary data from a number of sites in Lakes Ontario and Superior to describe typical basin morphology and identify critical water levels to which the wetland plant communities in those lakes have responded. The data would help identify the range of fluctuations that must be maintained to protect wetland integrity and habitat diversity. Water level regulation scenarios were then assessed according to whether or not they would sustain wetland integrity and diversity.

Inventory and Site Selection

Existing inventories of wetlands of lakes Superior, Ontario, and Michigan were reviewed to identify wetlands that could serve as study sites. Video recordings from a helicopter flight along the shore of Lake Ontario (Buffalo District, U.S. Army, Corps of Engineers), and aerial photograph archives (Detroit District, U.S. Army, Corps of Engineers, and Michigan Department of Natural Resources) were used to upgrade the wetland inventories. Photographic enlargements were made of wetland areas under consideration as study sites along the shores of lakes Superior and Ontario.

Wetlands affected by disturbance factors (e.g., marinas and shoreline protection structures) were eliminated from consideration as study sites because they would not accurately reflect responses to water level change. Wetlands not reasonably accessible by foot or by boat were also eliminated. The study sites were then selected as a random sample drawn from each stratum and were considered representative of the wetlands in the respective lakes. Seventeen sites on Lake Ontario and eighteen sites on Lake Superior were selected for sampling (FIGURE 7.2).

Field Work

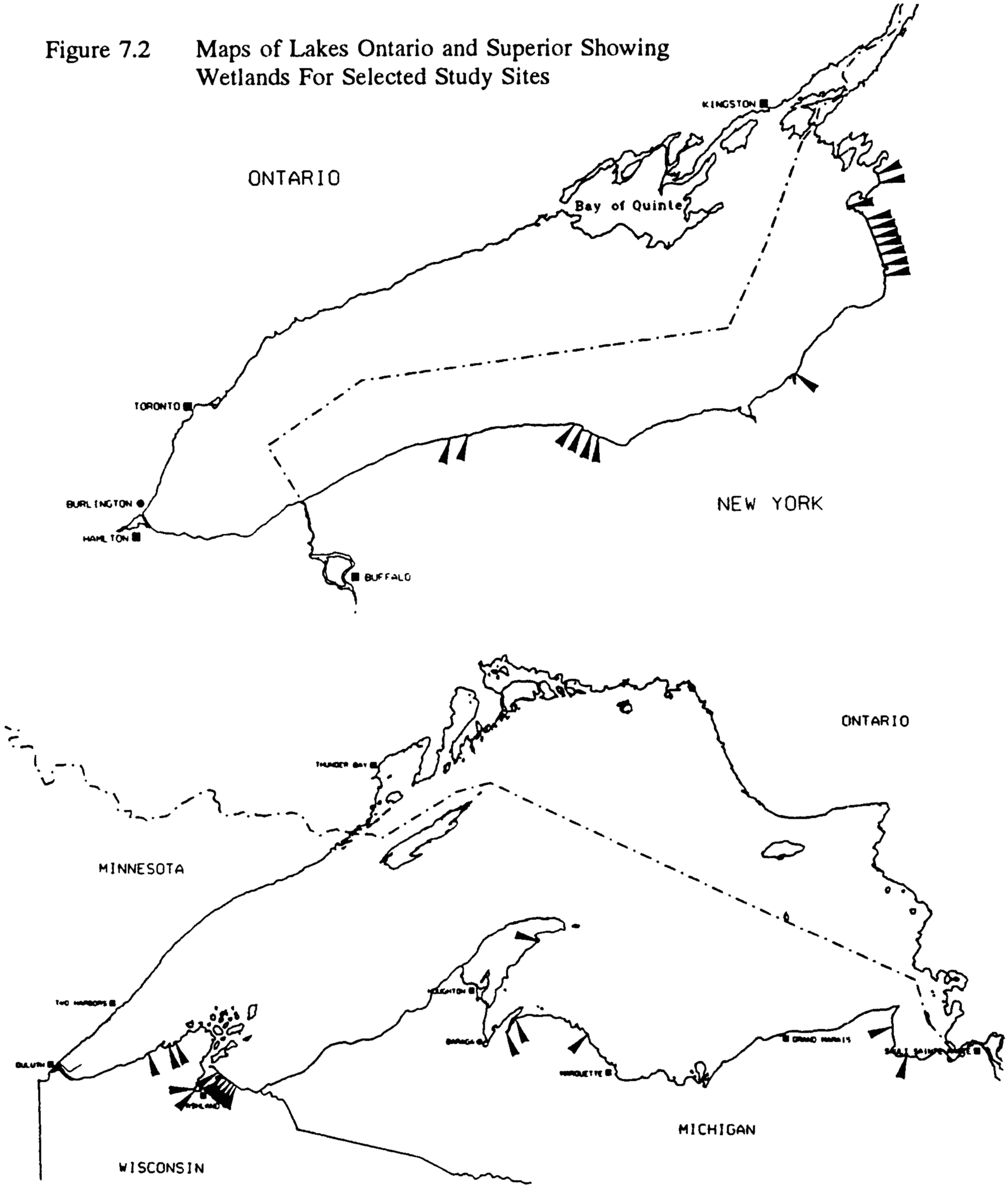
Field work was conducted at the Lake Ontario sites in July 1991. Work at the Lake Superior sites was conducted in August and early September 1991. The aerial photograph enlargements for each study site were used to map the wetlands.

Two transects perpendicular to the shore were established 50 m (164 ft) apart at each site and surveyed using a laser transit. The current lake level was used to establish elevations. Specific elevations with ecological significance were located by surveying, marked with flags, and their distances from the water line measured and recorded. These elevations were used for vegetation sampling. Since the existing wetland vegetation in each lake developed in response to the history of high lake levels and low lake levels, the selected elevations were based on lake level history. Hence they differ for each lake.

The amplitude of lake-level changes in Lake Ontario has varied according to several successive time periods. Before 1955, the amplitude varied widely and frequently. From 1955 until the late 1970s, the amplitude and frequency of highs and lows was reduced. Further reductions have occurred since the 1970s, and the amplitude has been further reduced since 1989. The composition of wetland plant communities should correspond to the highest highs and lowest lows that delineate these periods because those lake levels represent the times that vegetation at high elevations was flooded and vegetation at low elevations was dewatered. The range of fluctuations in recorded water levels in Lake Superior has shown no historic variation as has Lake Ontario; however, certain landmark highs and lows have occurred that have determined the character of the present vegetation. Key elevations and dates to note are shown for each lake in TABLE 7.2.

Along the contours for each specific elevation chosen (parallel to the shoreline), sampling for the vegetation survey was conducted in 1m (3.28 ft) wide belt transects. In each transect, the plant species present were identified and assigned to one of 4 cover classes and 4 frequency classes according to the following scheme: 1 = 0-5%, 2 = 6-20%, 3 = 21-50%, 4 = 51-100%. Substrate types were also noted and recorded. Plant identification for Lake Ontario sites is according to Mitchell (1986). For Lake Superior sites it is according to Voss (1972, 1985) whenever possible, otherwise Gleason and Cronquist (1963).

Figure 7.2 Maps of Lakes Ontario and Superior Showing Wetlands For Selected Study Sites



Data Analysis

Vegetation survey data were analyzed using summary statistics and detrended correspondence analysis (DECORANA) ordination procedures. For each lake the ordination arranged each transect at each site according to similarity of wetland vegetation. Importance Values (IV) were calculated for each plant on each transect as the sum of frequency and cover ratings; these values were used in the ordinations. Correlations between specific elevations and accompanying plant communities were assessed across all wetlands sampled in each lake to determine the range of elevations in which the most diverse plant communities occur and to identify any specific habitat requirements of individual plant species.

Vegetation maps were created for each site using aerial photographs and ground-truth information. Generalized topographic maps were created for each study site using the laser survey information, line transects on aerial photographs, and zonation patterns shown in vegetation maps. The topographic maps were used during generation of topographic models for scenario evaluation. GIS maps of all lake-affected wetlands on lakes Ontario, Superior, and Michigan were supplied by the Detroit District of the U.S. Army Corps of Engineers and used to complete the mapping portion of the study. Wetland area was determined by planimetry, and the data were applied to the full complement of wetlands on a lake to estimate the total area of wetland that might be affected by each regulation plan.

7.2.3 St. Lawrence River Wetland Studies

This study was conducted to: 1) determine how wetlands have reacted to past water level fluctuations by examining past wetland distributions mapped from historical aerial photography; and 2) specify how wetland plant communities develop in relation to external factors including water level and elevation.

Description of Study Area

Because the St. Lawrence River, from Lake Ontario to the Gulf of St. Lawrence, is so diverse, a study area was chosen knowing that it would not represent the whole St. Lawrence River system. Lake Saint-Louis, near Montreal, was chosen based on its proximity to a major urban area, the importance of its diverse wetlands, which are important wildlife habitats, and the availability of considerable data on its wetlands.

Three sites within the study area were selected to better cover the broad variability of the lake's wetlands. Dowker Island is a rock outcrop located in the northwest part of the lake. Its vegetation is mainly composed of tree communities adapted to mesic conditions. Riparian forests are present on a narrow strip of the island shoreline; silver maple (Acer sccharinum) and red ash (Fraxinum pennsylvanica) are the dominant species. Saint Bernard Island is a

Table 7.2 Transects, elevations, data collected, and vegetation sampling rationale, Lakes Ontario and Superior

Transect #	Elevation m ft	Data Collection	Rationale
Lake Ontario			
1	75.4 247.38	sample just above	highest high, post-regulation (not flooded since 1952)
2	75.1 246.39	sample just above	highest high, last decade & last two yrs (not flooded since 1976)
3	75.0 246.06	sample just below	lowest high lake level, last 2 years (summer peak shoreline, last 2 years)
4	74.5 244.42	sample just below	always flooded since end of 1988
5	74.2 243.44	sample just below	always flooded since 1964
Lake Superior			
1	183.46 601.90	sample just above	not flooded since 1985
2	183.28 601.31	sample just above	not flooded since 1987
3	183.12 600.79	sample just above	not flooded since 1990
4	182.92 600.13	sample just above	flooded in growing season since 1988
5	182.77 599.64	sample just below	always flooded since 1926
6	182.42 598.49	sample just below	always flooded, out of disturbance zone

low-lying area at the mouth of the Chateauguay River. Wetlands are found in the middle of the island; forested wetlands (with silver maple), large marshes (of cattails and giant bur-reed) and wet meadows form the dominant landscapes. Iles de la Paix National Wildlife Area is a protected wetland area owned by the Canadian Wildlife Service, on the southwest shore, near the St. Lawrence Seaway. It is composed of many small low lying islands surrounded by marshes which are considered essential for the large population of mirgratory birds that annually visit the waters of Lake Saint-Louis.

Data Collection and Analysis: Level Effects

Data were available on the wetland vegetation of the three sites from previous studies. Vegetation maps were produced from aerial photographs taken in 1958, 1969, 1972, 1975, and 1981. Data from 1991 photographs were added for this study. The vegetation data were incorporated into a grid-based Geographic Information System (GIS), MAP II for the MacIntosh, with a grid cell size of 0.25 ha (0.62 acres). Using the GIS, digital maps of wetland vegetation structure and health (healthy tree stands, disturbed tree stands, dead tree stands, shrubs, wet meadows, and marshes) were produced for each of the three study areas, for each year. Year to year comparisons were then made to determine areas of vegetation change. Tables of change were then constructed for each vegetation class, for each successive pair of years (e.g., areas which became disturbed tree stands between 1969 and 1972). Each class area was tabulated and tested (with the McNemar test) to determine which changes were significant.

A method was then developed to determine if the changes observed on the maps could be explained by changes in water levels. For example, from the water level records it was determined that a high water level occurred between 1972 and 1976 on Lake Saint Louis. Since vegetation and water levels do not vary in a perfectly synchronized way, water level records could not be directly related to vegetation changes. Usually, there is a natural delay for vegetation to respond to an extreme water level (in time and / or amplitude), particularly if forested wetlands are considered. A conceptual model that describes the response of vegetation to this event was constructed. In this model, water levels alone, explained changes in wetland vegetation. For all pairs of years, the consequences to the vegetation of the time span and the occurrence of the high water level period were tabulated (see table 7.3).

The model described the evolution of cells that composed maps. Hence, a cell with a given vegetation class (e.g. healthy tree stand), did not change to another class before 1969, since this time period is prior to a high water period. By 1972, high water levels started to disturb vegetation, and by 1976, all cells had changed to a different vegetation class (e.g. disturbed or dead tree stand). After 1976, cells slowly changed to other classes, while rémaining different from their original state of 1958 (e.g. shifting from dead tree stand to herbaceous cover).

Values in TABLE 7.3 were transformed into "dissimilarity measures" (minimum = 0: both years are identical; maximum = 1: both years totally different). Pairs of years that experienced no changes between them received 0, pairs of years with few changes received 0.5, and pairs of years experiencing major changes received 1.

A similar table, which shows the observed evolution of the wetland vegetation, was constructed with maps. The dissimilarity of maps can be calculated and placed in each entry of the map table. A statistical test (the Mantel test) was used to compare the conceptual table (above) and the map table. A high correlation was found if high and low values of one table occurred at the same places in the other table.

Table 7.3 Matrix of the expected response of Wetland Vegetation to the 1971-1976 High Water Levels: Lake St. Louis, St. Lawrence River.

Year of Photography	1958	1969	1972	1975	1981
1969	No changes				
1972	Few changes	Few changes			
1975	Major changes	Major changes	Few changes		
1981	Major changes	Major changes	Few changes	Few changes	
1991	Major changes	Major changes	Major changes	Major changes (recovery)	Few changes (recovery)

Data Collection and Analysis: Derivation of Communities

The second part of this study was the analysis of the zonation of wetland plant communities of Lake Saint-Louis. Vegetation surveys were done on the three study sites and the results analyzed quantitatively. A total of 163 vegetation samples was taken and 137 species were found. Elevation, water level, wave and wind exposure, and soil texture of the sediment were recorded at each site. A clustering algorithm was used to create groups of stands forming 15 community types. Two methods were used to relate community types to external factors: 1) a canonical ordination technique that creates graphs representing the relation between vegetation composition and external factors; and 2) contingency tables, which identify the range of each external factor in which each of the 15 community types exists.

Constraints and Assumptions

The historical approach is limited by the availability, scale, and quality of aerial photographs. Because of the limits of the range of fluctuations of water levels during the time span of the available photographs, it was not possible to investigate the effect of low water levels. Although GIS analysis is powerful, a comparison of tables with the Mantel test can be done only with a database of reasonable size (<1,000 cells that change). On the other hand, the strength of the Mantel test rises with the number of photo surveys.

7.2.4 Conceptual Model of Wetlands and Lake Levels

The conceptual model focuses on changes in area of emergent wetland, or marsh, in response to fluctuating water levels. It was developed to incorporate current information on generic plant community response to seasonal and previous years' water levels. Emergent plants respond both to water level events and to competitive forces of other plant communities: trees and shrubs which are upslope, and submerged aquatic plants which are downslope.

The landward upper edge of the marsh is determined by high water events. The average water level for the three months surrounding the peak of the growing season was chosen as the critical time period which would move the woody-plant/marsh transition upslope. For example, in Lake Ontario, the peak of the growing season normally occurs in June so the average water level from May, June and July was determined. The upper edge moves inland in response to a single season of high water but is forced back downslope slowly by the re-invading trees and shrubs when lower water levels return. The competitive exclusion of marsh by trees and shrubs begins slowly and escalates over time as the marsh plants are excluded by shading from the tree canopy. The model also scans back in time to ensure that the new location for the landward edge is sensitive to minor high water events.

The lakeward lower edge of the marsh is determined by low water events. The lower edge moves lakeward in response to a single season of low water as muds become exposed and annual marsh plant seeds sprout. The mean water level for September was chosen as the critical time period which would determine the transition between emergent marsh plants and submergent plants. When high water returns, the lower edge moves upslope after a few years of flooding.

Various time delays were tried to determine the sensitivity of the model. For the landward transition, 15, 18, and 20 year delays, and for the lakeward transition, 2, 3, and 4 year delays were examined. The predicted marsh response varied by +/- 10% between the various combinations (i.e., 15/2 vs 20/4, FIGURE 7.3). An 18/3 delay combination was chosen.

7.2.5 Fish Habitat Evaluation

Evaluation of Spawning Habitat Area in Two Sites in Saginaw Bay at Three Different Water Levels

To examine effects of changing water levels on fish species, two areas of Saginaw Bay, one on the northwest side, in the vicinity of Pine River, and the other on the northeast side, in the vicinity of Wildfowl Bay (FIGURE 7.4), were examined using existing information on bathymetry and fish spawning areas.

Figure 7.3 Upper and Lower Emergent Plant Extent - Sensitivity Analysis To Lag Times

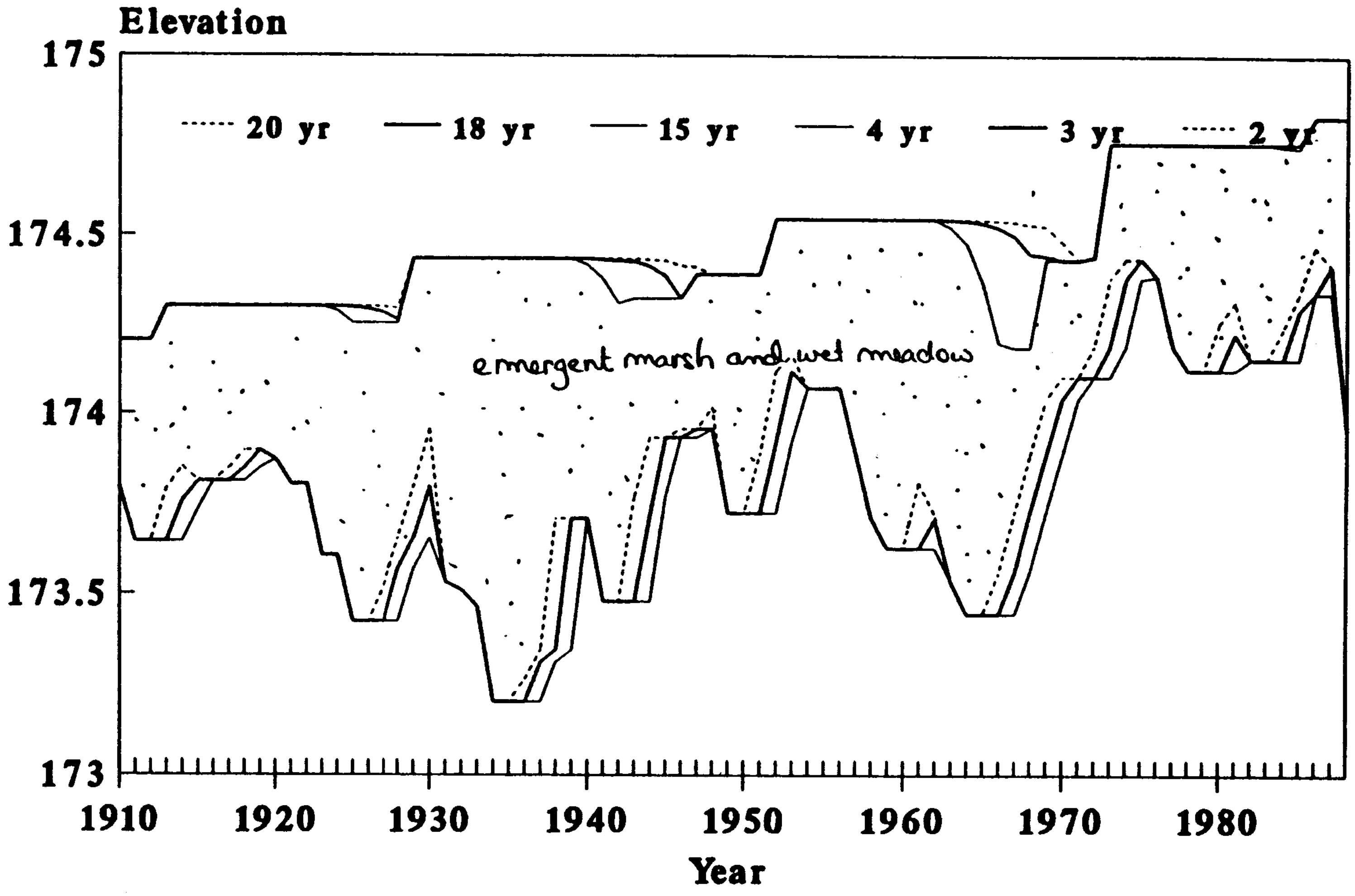
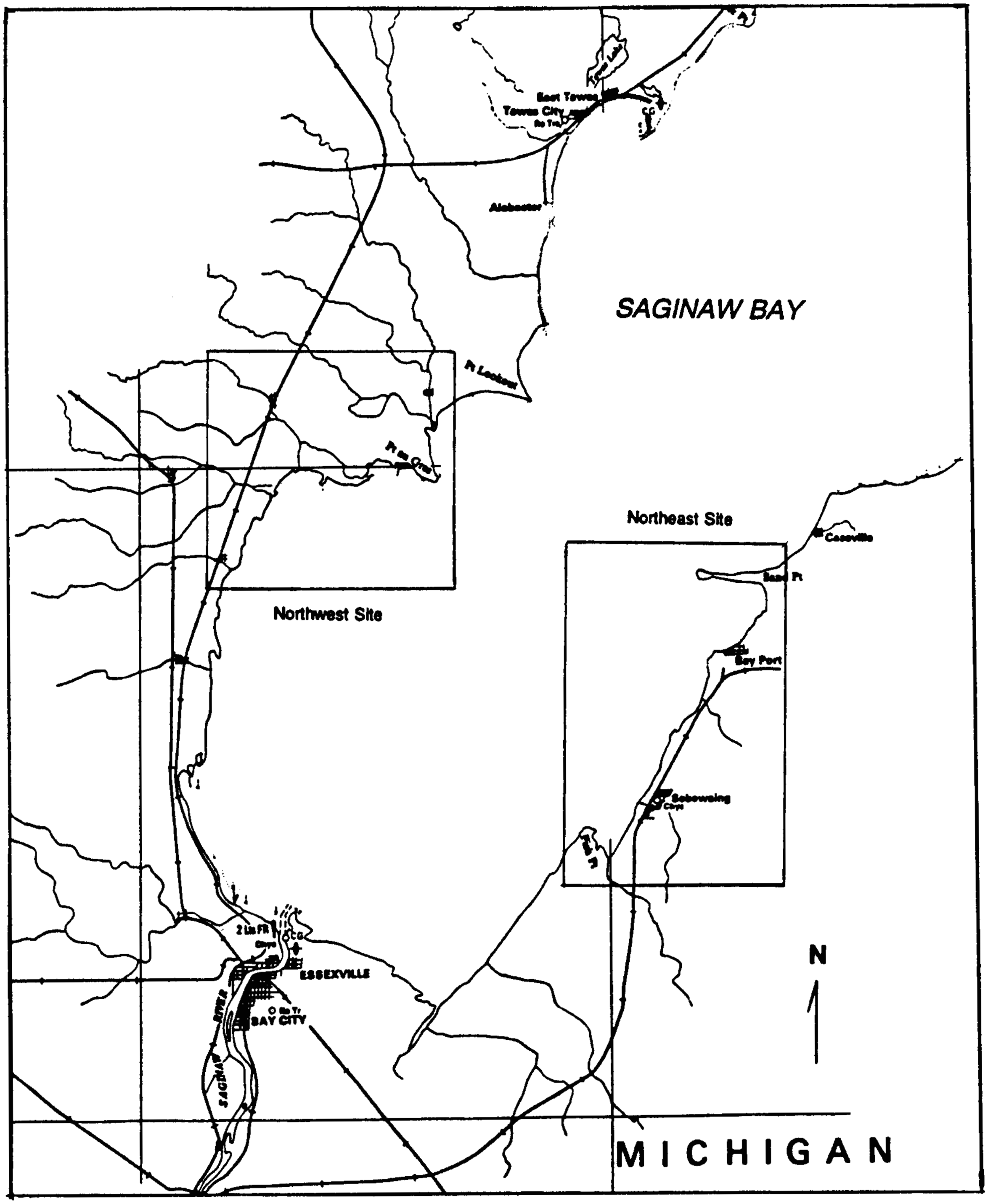


Figure 7.4 Fish Habitat Evaluation Study Areas - Saginaw Bay



Bathymetric maps which identified the location of the 100-year floodline (1.5 m (5 ft) higher than the shoreline at Chart Datum (Intertational Great Lakes Datum, 1955)), the shoreline, and the 0.9 m, 1.5 m, 2.4 m, 3.0 m, and 4.6 m (3, 5, 8, 10, and 15 foot) isobaths, relative to Chart Datum, were digitized for each area (TABLE 7.4). The spawning areas identified for ten fish species (TABLE 7.5) in Goodyear et al. (1982) were also digitized, and overlaid on the bathymetric data to determine the area of reported spawning habitat within each isopleth, for each species.

Table 7.4. Surface area, in km^{2*}, of each isopleth, and the cumulative surface area for two areas of Saginaw
^U^R^R^U
+^*ths are relative to Chart Datum (IGLD)

Isopleth	Northwest		Northeast	
	Area	Cumulative Area	Area	Cumulative Area
+1.5 - 0.0 m	87.6	264.6	44.0	439.9
0.0 - -0.9 m	40.6	177.0	108.2	395.9
-0.9 - -1.5 m	19.9	136.3	14.9	287.7
-1.5 - -2.4 m	28.5	116.4	47.2	272.8
-2.4 - -3.0 m	14.0	87.9	58.9	225.6
-3.0 - -4.6 m	34.4	73.9	115.3	166.7
> -4.6 m	39.6	39.6	51.4	51.4

*km^2 x 0.386 = miles^2

The bathymetric data were used to calculate the area within various isopleths for two other water level scenarios, 1.5 m (5 ft) above Chart Datum and 1.5 m (5 ft) below Chart Datum (IGLD'55). The assumption was made that the proportion of the area within each isopleth which was used for spawning would remain constant, regardless of the water level. Therefore the area of spawning habitat for each species was calculated by multiplying the total area within each isopleth by the proportion of the area within that isopleth which was reported to be spawning habitat at Chart Datum (IGLD).

Table 7.5. Fish species for which the area of spawning habitat in two sites on Saginaw Bay was examined.

Common Name	Scientific Name
lake herring (cisco)	Coregonus artedii
lake whitefish	Coregonus clupeaformis
round whitefish (menominee)	Prosopium cylindraceum
lake sturgeon	Acipencer fulvescens
burbot	Lota lota
northern pike	Esox lucius
walleye	Stizostedion vitreum vitreum
yellow perch	Perca flavescens
largemouth bass	Micropterus salmoides
smallmouth bass	Micropterus dolomieui

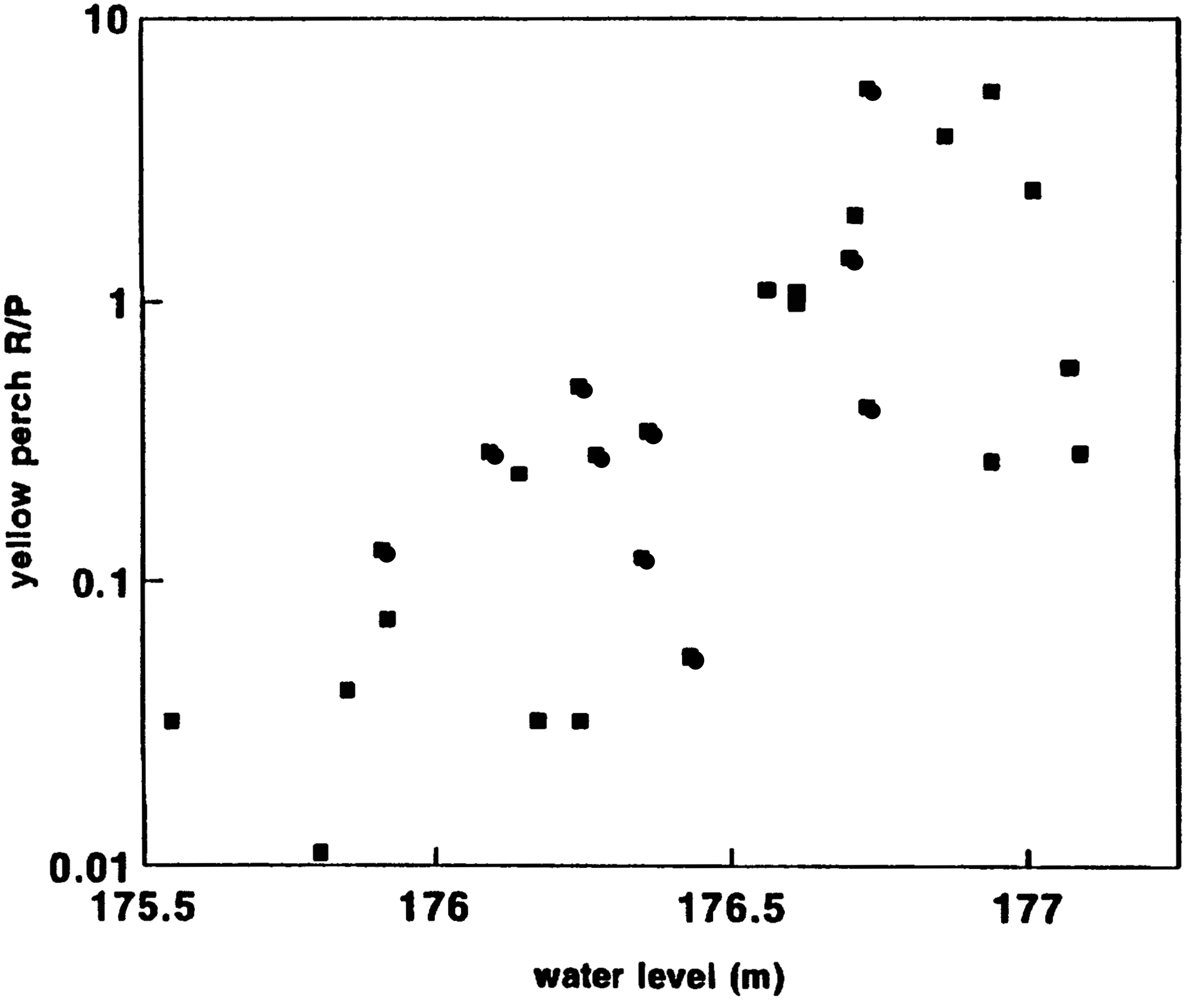
Yellow Perch Reproduction in South Bay, Lake Huron

Henderson (1985) calculated an index of yellow perch spawning stock and recruitment from pound net catches in South Bay, Lake Huron, for the years 1951-1977. He found a highly significant positive correlation ($P<0.001$) between the ratio of recruits:spawning stock (R/P) and the June water levels in the year of spawning (FIGURE 7.5). His data suggested that a June water level in excess of 176.5 m (579.1 ft) was necessary in order for a $R/P > 0.6$ to occur. In order to investigate the potential impact of the various proposed water level regulation scenarios on the yellow perch R/P ratio, the regression of the logarithm of R/P versus the mean June Lake Huron water levels (WL) using Henderson's R/P data was calculated. The resulting regression, which is highly significant ($P<0.001$), takes the form:

$$\log R/P=-229.807 + 1.3(WL),$$

and has an r^2 of 0.56 and a standard error of 0.504. The predicted June water levels which have been hindcast for the proposed regulation scenarios for the same years under the various water level regulation scenarios were substituted into this regression equation to predict R/P under regulated conditions.

Figure 7.5 Relationship Between June Water Levels and the Ratio Of Yellow Perch Recruits: Parental Stock for South Bay, Lake Huron (From Henderson, 1985).



7.3 Wetland Impact Assessments

7.3.1 Results and Discussion: Historic Changes in Wetlands

Specific Site Results

The sites provided a cross section of Great Lakes coastal wetland size, location and type. Based on a percentage of study area analysis, only one site (Rondeau Shores) may have been significantly influenced by development or encroachment of land use over the study period.

St. Clair Marshes, Lake St. Clair

Some changes in the size, vegetation communities and structure of the St. Clair Marshes can be attributed to changing water levels in Lake St. Clair. The following relationships for the St. Clair marshes are supported by the data and analysis conducted for this study.

- higher lake levels tend to reduce the area and increase the patchiness of emergent vegetation communities
- emergents tend to reestablish during low water
- fluctuating lake levels act to maintain the structural diversity of the marsh through the periodic breakup and reestablishment of emergent vegetation
- reduced lake level fluctuations might favour the formation of solid stands of cattail with a resulting loss of habitat diversity and wetland value

Big Creek, Lake Erie

Some changes in the size, vegetation communities and structure of the Big Creek-Holiday Beach Marsh can be attributed to changing water levels in Lake Erie. Apparently because this wetland is located behind a barrier beach, total wetland area is less sensitive to lake level fluctuations than is the case in the St. Clair marshes. However, the internal composition of the wetland changes in response to water levels in similar fashion. The following relationships for Big Creek - Holiday Beach Marsh are supported by the data and analysis conducted for this study.

- higher lake levels tend to slightly increase total wetland area by inland expansion as the surrounding forested area is flooded
- higher lake levels also tend to result in reduced area of emergent vegetation and increased area of open water

- with a return to lower water levels emergent vegetation reestablishes.

Rondeau Shores, Lake Erie

Changes in the total wetland area and plant community structure of the Rondeau Shores wetland may be attributed to changing water levels in Lake Erie. The patterns observed are very similar to those for St. Clair marshes and demonstrate the important relationship between fluctuating lake levels and community structure in these exposed shoreline marshes. The following relationships for Rondeau Shores are supported by the data and analysis conducted for this study.

- higher lake levels tend to reduce the area and increase the patchiness of emergent vegetation

- the 1978 recovery of emergent vegetation after the 1972 decline of emergents shows the resiliency of the wetland system and gives some indication of the time required for recovery, emergents can be expected to recover after the 1985 decline as well.

Turkey Point, Lake Erie

The strongest statistical correlations between lake levels and wetland communities were found in the Turkey Point data set. The statistical analysis also indicates that wetland responses to water level changes are highly correlated with water level attributes from two years preceding wetland attribute measurements. The following relationships for Turkey Point are supported by the data and analysis conducted for this study.

- the total area of the wetland appears to decrease slightly with increasing lake levels

- the greatest influence of lake levels is on the internal community structure

- there appears to be a threshold at which prolonged periods of high lake levels result in greatly reduced emergent vegetation

- recovery of emergent vegetation after lake levels recede is relatively quicker in this wetland than those at the other study sites.

Oshawa Second Marsh, Lake Ontario

The statistical measures showed that Oshawa Second Marsh and Presqu'ile Marsh exhibited the least response to lake levels of any of the six wetlands. The following observations are drawn from visual inspection of the data and were not supported by the statistical analysis.

- the area of cattails and other emergent vegetation varied inversely with water levels
- the area of open water varied directly with lake levels.

Because Oshawa Second Marsh is behind a barrier beach, it could be expected to be less responsive to lake level fluctuations than wetlands open to the lake. The lack of statistical support suggests that there are compounding and interacting factors such as land use and stream flow regimes which are also affecting the marsh.

Presqu'ile Marsh, Lake Ontario

Wetland changes in the Presqu'ile Marsh are not primarily influenced by water level fluctuations in Lake Ontario. The size of the wetland at Presqu'ile has remained relatively constant from 1953 to 1986. The changes in wetland vegetation community composition indicate a healthy, dynamic ecosystem responding to environmental conditions. However, these internal dynamics appear to be controlled primarily by factors other than lake level.

Summary

Table 7.6 indicates which water level effects are statistically significant. Similar patterns and directions of change occurred in all the wetlands, although the effects were not always statistically significant, and the magnitude of the effects and rates of change appeared to differ from wetland to wetland.

Discussion

Impacts of Lake Levels on Coastal Wetlands

The data and analysis presented in this study indicate that changing water levels have affected the vegetation community dynamics of all the wetlands studied. The six wetlands can be placed along a gradient of the apparent degree to which changes in the wetland can be attributed to changing water levels. The degree of apparent sensitivity to water level change can then be compared to the physical position and the lake on which the wetland is located. This is summarised in Table 7.7.

This table suggests that the wetlands with similar physical positions in the landscape share similar degrees of response to changing lake levels. The more exposed the wetland to lake waters, the more apparent the impact of changing water levels (St. Clair and Rondeau). The more protected the wetland the less the apparent response to changing lake levels (Big Creek and Oshawa). The wetlands on a spit in a bay (Turkey Point and Presqu'ile) do not share a similar type of response to lake levels. Turkey Point is clearly influenced by lake levels while the influence of lake level changes on Presqu'ile is less apparent. Either there is insufficient information (years of aerial photography) to reflect water level influences or much of the wetland community dynamics in Presqu'ile is due to other processes.

Table 7.6. Significant Wetland/Water Level Correlations [(-) = negative correlation; (+) = positive correlation]

Wetland	Total Wetland	Wetland Communities
St. Clair	total area (-)	solid cattail (-) emergents (-) t/d/d emergents (-)
Big Creek		solid cattail (-) cattail/water (-) meadow (-)
Rondeau Shores		solid cattail (-) meadows (-) trees/shrubs (+)
Turkey Point		open water (+) t/d/d emergents (-) wet/man. meadow (-) meadow/shrubs (-)
Oshawa Second	perimeter (+) area/peri. (-)	
Presqu'isle		

Table 7.7 Summary of Wetland Types & Level Influences

Physical Location	Greatest Lake Level Influence	Moderate Lake Level Influence	Least Lake Level Influence
Open to Lake	St. Clair	Rondeau	none
Spit in Bay	Turkey Point	none	Presqu'ile
Behind Barrier	none	Big Creek	Oshawa
Totals:	**2**	**2**	**2**
Lake Location			
Regulated lake	none	none	Presqu'ile, Oshawa
Unregulated lake	St. Clair, Turkey Point	Rondeau Big Creek	none
Totals:	**2**	**2**	**2**

Vegetation community changes in the two Lake Ontario wetlands cannot be linked to water level changes as strongly as the changes on wetlands on unregulated lakes. This suggests that the regulation of Lake Ontario levels may be disrupting wetland dynamics. The small sample size and the absence of an unprotected marsh (similar to St. Clair or Rondeau) on Lake Ontario limits the strength of this conclusion. Presqu'ile Marsh and Turkey Point, however, are exposed to significant lake level influence despite their location on spits in bays. The fact that Presqu'ile appeared to be one of the more stable wetlands, while Turkey Point one of the most responsive to water level changes, supports the hypothesis that regulation of Lake Ontario is reducing wetland dynamics.

All the wetlands exhibit some response to lake level fluctuations. The changing water levels appear to sustain wetland diversity and vegetation community dynamics. The coastal wetlands could decrease in size, decrease in community diversity, and lose some of their dynamic nature if fluctuation patterns in Great Lakes water levels were changed.

7.3.2 Impacts of Water Level Change on Great Lakes Wetland Diversity

Ordinations

The ordinations of all transects at all sites on each lake showed a general pattern of grouping by elevation. Transects at the same elevation had similar coordinates, thus they had similar plant communities. Transects at different elevations had different coordinates, thus different plant communities. For both Lake Ontario and Lake Superior, the transects at the highest elevation (1) grouped together on one side of the ordination, those at the lowest elevation (5) grouped on the other side, and the others sorted out in the middle. Good separation of unlike transects in the ordinations suggests that different plant communities have developed at different elevations in both lakes. Like transects grouped more closely at extreme elevations than at middle elevations, indicating that lakewide differences in vegetation between sites are greater at middle elevations, where flooding and dewatering alternate more frequently.

Floristics

Lake Ontario

A total of 260 plant taxa were recorded in samples from 17 wetlands along the U.S. shore of Lake Ontario. Of these, 151 (58%) are considered either obligate or facultative wetland species (Reed 1988a). Many upland species were found at higher elevations that have not been flooded in recent years (FIGURE 7.6). The greatest total species richness was found along transect 1, which was 0.5 m (1.64 ft) above water level at the time of sampling (74.9 m; 245.73 ft) and was last flooded in 1952. However, over half of the taxa were upland species (FIGURE 7.6). Across all sites, the plant communities at this elevation were dominated by grasses (Phalaris arundinacea, Calamagrostis canadensis), old field plants (Solidago spp.), and shrubs (mainly Cornus amomum).

Transects 2 and 3 had the greatest diversity of wetland taxa (FIGURE 7.6). Transect 2 was 0.2 m (0.66 ft) above water level and was last flooded in 1976. Dominant plants included grasses (C. canadensis, P. arundinacea), purple loosestrife (Lythrum salicaria), forbs (Impatiens capensis, Lycopus americanus), shrubs (C. amomum, Alnus incana ssp. rugosa), and cattail (Typha hybrid). Transect 3 was 0.1 m (0.33 ft) above water level and was last flooded through the growing season in 1986. Dominant plants included hybrid cattail, purple loosestrife, grasses, forbs, and short emergent plants such as Sagittaria latifolia.

Transects 4 and 5 were below water level in 1991. Transect 4 was at a depth of 0.4 m (1.31 ft) and was last dewatered during the growing season in 1964. Dominant plants were submersed (Ceratophyllum demersum, Elodea canadensis, Myriophyllum spicatum) and floating species (Spirodela polyrhiza, Nymphaea odorata). Transect 5 was at a depth of 0.7 m (2.3 ft) and has not been dewatered since 1935. Many of the submersed species found on transect 4 were also dominant on transect 5, although species richness was reduced. Two additions of note were Vallisneria americana and Heteranthera dubia.

Transects 1, 2, and 3 supported certain unique species that were not found at the other elevations. Transect 1 had the greatest number of unique species (FIGURE 7.7), but most of them were upland plants. Transects 2 and 3 had the greatest number of unique wetland species and may represent critical wetland plant habitat.

Many of the dominant taxa are introduced species (exotics) or otherwise considered undesirable because of weed-like habits. Examples include Lythrum salicaria (purple loosestrife), Myriophyllum spicatum (Eurasian watermilfoil), Phalaris arundinacea (reed canary grass), and Typha hybrid (cattail). Dominance of Lythrum, Phalaris, and Typha can be attributed to the lack

Figure 7.6 Numbers of Plant Taxa Recorded Along Transects in Wetlands of Lakes Ontario and Superior

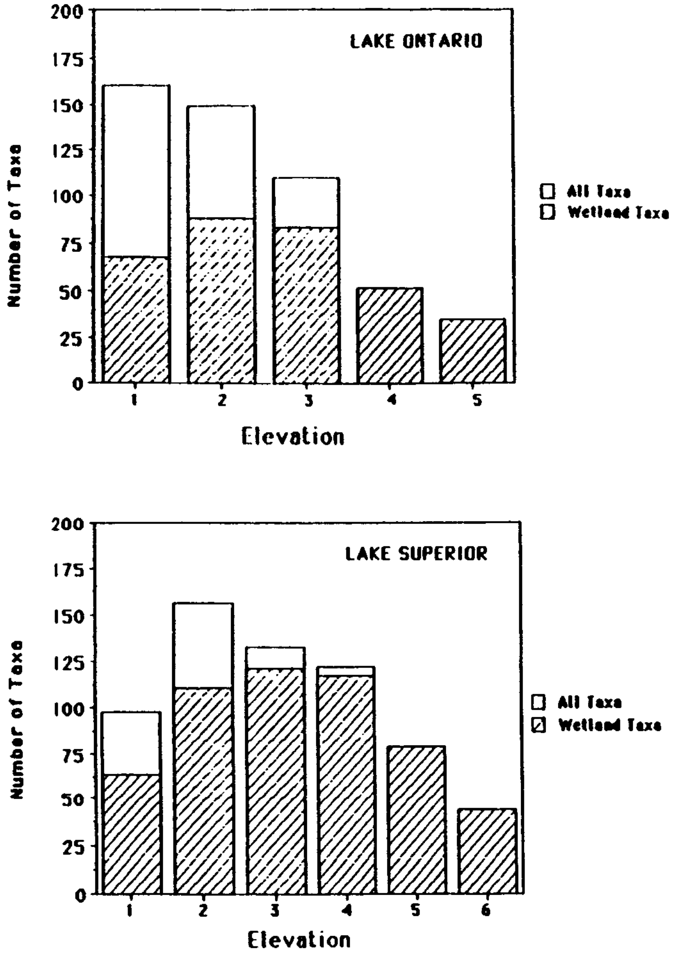
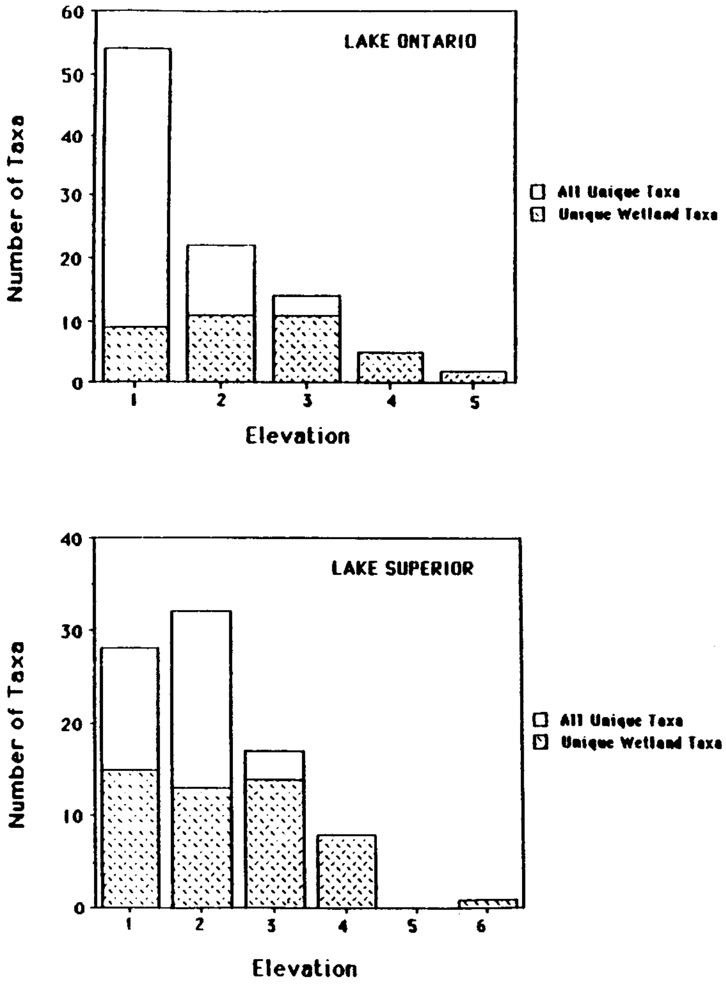


Figure 7.7 Numbers of Plant Taxa Unique To Individual Transects in Wetlands of Lakes Ontario and Superior



of high lake levels since the mid-1970s. These plants cannot tolerate deep waters for prolonged periods; Typha can be killed by flooding during winter. They can be competitive dominants under favorable conditions, however, and are often favored by disturbance or a disruption of the natural ecosystem that stresses or eliminates native vegetation. Alteration of natural water level regimes is an example of such a disruption. In addition, cattails can form floating mats that buffer plants from the effects of water level change. High lake levels, combined with wave action can periodically destroy cattail mats. In Lake Ontario, where high lake levels have not occurred since the mid-1970s, floating cattail mats are quite prevalent.

Lake Superior

A total of 278 species (taxa) were recorded in samples from 18 wetlands along the U.S. shore of Lake Superior. A greater number of taxa (216; 78%) in Lake Superior were obligate and facultative wetland species (Reed 1988b) than in Lake Ontario (FIGURE 7.6). Most of the upland species were found on transects 1 and 2 at higher elevations that had not been flooded recently. Transect 1, which was 0.34 m (1.12 ft) above water level at the time of sampling (183.12 m; 600.79 ft), was last flooded in 1985 and was dominated by shrubs (Alnus rugosa, Myrica gale, Spiraea alba), sedges (Carex lacustris, C. rostrata), and blue-joint grass (Calamagrostis canadensis). Transect 2 had the greatest species richness, although many upland taxa were represented. This transect was 0.16 m (0.52 ft) above water level and was last flooded in 1987. Dominant plants included blue-joint grass, shrubs (A. rugosa, M. gale), and sedges (Carex stricta, C. lasiocarpa).

The greatest number of wetland species (taxa) were found on transects 3 and 4, which were at the 1991 shoreline or in shallow water. Transect 3 at the shoreline was last flooded during the 1990 growing season. Dominant taxa included short emergent plants (Sagittaria latifolia, Dulichium arundinaceum, Sparganium eurycarpum, Eleocharis smallii), sedges (Carex stricta, C. lasiocarpa), and rushes (Juncus canadensis, J. effusus). Transect 4 at a depth of 0.2 m (0.66 ft) has been flooded during the growing season since 1988. Dominant taxa included the short emergents of transect 3, sedges, rushes, and submersed aquatic plants (Utricularia vulgaris, Elodea canadensis, Bidens beckii, Ceratophyllum demersum).

Transects 5 and 6 were below water in 1991. Transect 5, at a depth of 0.35 m (1.15 ft), has been flooded since 1926, and was dominated by many of the submersed species of transect 4, some short emergents, and the floating Nuphar variegatum. Transect 6, at a depth of 0.7 m (2.3 ft), has not been dewatered since water level recording began, and was out of the disturbance zone. Submersed species (Bidens beckii, Elodea canadensis, Vallisneria americana) and floating species (Nuphar variegata, Sparganium fluctuans, Nyphaea odorata) dominated. Species richness was less than at the other transects (FIGURE 7.6).

As in Lake Ontario, transects 1, 2, and 3 supported certain unique species not found at the other elevations. Many of them were upland plants that were most common in transects 1 and 2 (FIGURE 7.7).

Wetland Areas

The areas of wetland along the U.S. shores of lakes Ontario, Superior, and Michigan that could be affected by water levels were determined by planimetry from GIS maps. The totals were over 3400 ha (8400 ac) for Lake Ontario, over 4200 ha (10,500 ac) for Lake Superior, and over 5400 ha (13,400 ac) for Lake Michigan (TABLE 7.8).

Table 7.8. Area of lake-affected wetlands along U.S. shores of lakes Ontario, Superior, and Michigan as determined from available wetland inventories and grouped according to Michigan Department of Natural Resources classification scheme.

Lake	Scrub-Shrub	Aquatic Bed	Emergent	Flats	Total
Ontario					
ha	488	465	2461	1	3415
acres	1209	1152	6103	2	8466
Superior					
ha	2343	186	1714	0	4243
acres	5804	461	4246	0	10511
Michigan					
ha	1997	29	29	28	5426
acres	4947	72	69	69	13440

General

The ordinations and floristic studies indicate that in both lakes Ontario and Superior, wetland plant communities differed at different elevations. The plant communities developed as a result of the water level history of each elevation that was sampled; these elevations were selected to define different water level histories. In general, plant communities at elevations that had not been flooded for many years were dominated by shrubs, grasses, and old-field plants. If flooding was more recent, small shrubs that became established after flooding were present, as were grasses, sedges, and forbs. The plant communities at elevations that are flooded periodically each ten to twenty years and dewatered for successive years between floods had the greatest diversity of wetland vegetation. The plant communities contained the most wetland species and the most diversity of plant types. Dominants included grasses, forbs, sedges, rushes, short emergent plants, and submersed aquatic vegetation. At elevations that are rarely or never dewatered, submersed and floating plants are dominant, with emergent plants also occurring at some sites. In Lake Ontario, floating mats of cattail are present in many locations, and purple loosestrife is widespread.

Application to Regulation Scenarios

Results of the above studies were used to perform an evaluation of the impacts of a number of water level regulation scenarios under consideration by the Study Board. The following measures and conditions were evaluated: Basis of Comparison (BOC); historical (what actually occurred); environment (pre-regulation); BOC Wet/Dry; Lake Ontario 58D/28B; Lake Superior 77a Modified; SO-Environment; SEO Optimized; SHMEO-Optimized; SHMEO-50; Lake Ontario 58D/35Z; Lake Ontario 58D/35P; Lake Superior 1977a without Criterion C; SO Two Lake Combined with Superior 15 cm (1/2 foot); SO Lake Ontario Combined; SEO Combined; and SEO Extended (see Working Committee 3 Report for full descriptions). A summary of the results of these evaluations can be found below. Further detail can be found in the Natural Resources Task Group Report.

Lake Ontario

The regulation scenarios developed by Working Committee 3 for Lake Ontario offered few choices that would protect wetlands. All scenarios evaluated extend the moderation of fluctuations that has existed since the mid-1970s. The lack of high lake levels has allowed floating cattail mats to form, purple loosestrife and other exotics to thrive, and shrub and old field communities to take over higher elevations. The lack of multi-year fluctuations in these regulation scenarios makes them unacceptable from the standpoint of wetlands protection. If these measures are enacted or continued, the species richness of the wetlands will probably decline as competitive dominants eliminate more and more species and are themselves unchecked by environmental conditions. SMHEO-50 has the same major fault as the other regulation scenarios - it lacks a long-term cyclic pattern of peak summertime high lake levels with intermittent low summertime highs. Short-term variability under this scenario would result in changes in vegetation, but those changes would not have the desired effect. The Environment Case, or some modification of it that provides periodic high lake levels followed by low lake levels, would promote the cyclic, regenerative processes that maintain wetland diversity.

Lake Superior

The Basis of Comparison and similar scenarios for Lake Superior (Wet/Dry, 1977a MOD2, and SMHEO-50) do not have the dire environmental consequences posed by those for Lake Ontario.

However, the lowest summertime highs are not frequent enough to allow cyclic, regenerative wetland processes to occur over a large enough elevation range. As a result, the area occupied by the most diverse plant communities is restricted. The amplitude of the peak summertime highs also restricts development of these plant communities. A scenario similar to the Environment Case initially described for Working Committee 3, that provides an increased range of elevation between the highest and lowest summertime highs, would increase the diversity of plant communities and consequently the diversity of faunal habitats. Achieving the reduced summertime peaks in paired years is most critical. The 3-Lake Optimized and 5-Lake Optimized scenarios counter the requirements to maximize wetland diversity; they reduce the range of fluctuations. If they were implemented, the chances would increase for developing stable uniform plant communities consisting of competitive dominants.

The 1977a without Criterion C-1958D Scenario differs little from the Basis of Comparison. SEO Combined and SEO Extended scenarios would generate the benefit of decreasing the stable vegetation characteristics of transects 1 and 5 but would increase the stable vegetation of transect 6. Although some decreases in transect 3 or 4 vegetation would occur under these scenarios, there would be a net gain in the total transect 2-4 vegetation. The relative benefits and drawbacks of these scenarios are difficult to weigh. Although the Lake Superior -15 cm (-1/2 foot)-1958D/35P scenario would increase overall wetland diversity, increase in stable, shrub-dominated communities along the shore and potential loss of access to wetlands by spawning fish make the scenario undesirable.

Lakes Michigan and Huron

The Basis of Comparison and similar scenarios for lakes Michigan and Huron (Environment Case, 1977a MOD2) are quite similar to the actual record of lake levels for the period 1900-1990, with summertime highs approximately each 21 years and lower summertime levels in most intervening periods. As with the other lakes, high water levels followed by multiple years of lower lake levels would result in diverse wetland communities. Introduction of more intervening low lake levels, as originally proposed to WC3 for the Environment Case, would probably increase the prevalence of shoreline plant communities and increase the diversity of wetlands. The Wet/Dry scenario reduces the summertime highs in the mid-60s and increases those in the mid-80s. These changes would have modest effects in decreasing the area dominated by old field, tree, shrub, and submersed aquatic communities and increasing the area dominated by emergent marsh communities. If the lower and higher lake levels had been introduced into the scenario near the beginning of the 90-year period, however, they would have affected plant dominance in wetlands for many more years. SMHEO 50 allows no multi-year variability across the 90-year period of record; the likely result would be substantially reduced wetland diversity, development of stable plant communities and floating cattail mats, and invasion of purple loosestrife. The 3-Lake Optimized and 5-Lake Optimized scenarios maintain the periodicity of high and low lake levels but reduce their amplitude. The likely result would be a substantial reduction in wetland area occupied by emergent marsh communities as more wetland area along the shoreline is eliminated by trees, shrubs, and other competitive dominants, such as cattails and purple loosestrife, and more submersed aquatic communities dominate the lakeward edge of wetlands. The 1977a without Criterion C and Lake Superior -15 cm (-1/2 foot) - 1958D/35P scenarios are nearly identical to the BOC and would create little change in the nature of present wetlands. The SEO Combined scenario follows the general pattern of the BOC, but summertime highs differ through several periods of years, resulting in potential changes in wetland vegetation. These changes can range from decreases in stable shoreline vegetation and an increase in emergent marsh in some years, to a decrease in emergent vegetation in others. Generally, any wetland losses seem to be countered by gains. The SEO Extended scenario maintains the year-to-year variability in the BOC, but reduces the range of fluctuations. This would result in a decrease in the area of diverse wetland and an increase in area dominated by less diverse, stable plant communities, especially the shrub and cattail dominated communities.

Lake St. Clair

The Basis of Comparison case for Lake St. Clair provides peak summertime highs of various magnitudes approximately each 10 to 13 years. Lower summertime highs occur in paired years between most peaks. The Environment Case, Wet/Dry, 1977a Modified and without Criterion C and the Lake Superior -15 cm (-1/2 foot)- 1958D/35P scenarios differ little from the Basis of Comparison and would create little wetland change. SMHEO-50, SEO Extended, SEO Combined, the 3-Lake Optimized, and the 5-Lake Optimized scenarios allow little or no multi-year variability across the 90-year period of record. The likely result would be substantially reduced wetland diversity, development of stable uniform plant communities and floating cattail mats, and invasion of purple loosestrife.

Lake Erie

The last 45 years of the Basis of Comparison case for Lake Erie are very similar to recorded lake levels for 1945 to 1990; however, water levels under the Basis of Comparison would be about 0.15 m (0.5 ft) higher than actual for years 0-44. Peak lake levels would be reached approximately each 12 years, and low waters would generally occur in some intervening years. In wetlands hydrologically connected to the lake, this scenario would likely result in diverse wetland plant communities. Reduced summertime highs would not be reached during several periods of high water, however. Introduction of more low water years, as originally proposed for the Environment Case would likely result in an increase in the prevalence of shoreline plant communities and increased wetland diversity. The current Environment Case, Wet/Dry, 1977 a without Criterion C-1958D, Lake Superior -15 cm (-1/2 foot)- 1958D/35P and 1977a Modified scenarios differ little from the Basis of Comparison. SMHEO-50, SEO Combined, SEO Extended, the 3-Lake Optimized, and the 5-Lake Optimized scenarios have no multi-year variability across the 90-year period of record. The likely result would be substantially reduced wetland diversity, development of stable uniform plant communities and floating cattail mats, and invasion of purple loosestrife.

7.3.3 St. Lawrence River Wetland Study

Between 1958 and 1991, major changes occurred along the St. Lawrence in the wetlands of Lake Saint Louis. Vegetation in all three study sites (Dowker Island, Saint Bernard Island, and Iles de la Paix National Wildlife Area), changed during that period. The loss of silver maple forests, a characteristic feature of the St. Lawrence River's landscape, was an important transformation. The study showed a direct relationship between wetland landscape changes and the 1972-1976 high water level period. This is true for disturbed tree stands, dead tree stands, shrubs, and herbaceous cover. For marshes, there is direct agreement of the observed data with the conceptual model (see Section 7.3.4). Silver maple forests died because of the high water levels. They are replaced today by herbaceous or shrub vegetation.

Dowker Island showed no loss of wetlands. However, 26% of the original wetlands of 1958, most of which were forests, was transformed to vegetation dominated by herbs. On Saint Bernard Island, 41% or 96 ha (237 acres) of silver maple forests died. At Isle de al Paix National Wildlife Area, high water levels transformed almost all forests into open spaces. In addition, about 100 ha (247 acres) of marsh were lost due to erosion caused by the proximity of the St. Lawrence River Seaway. The effect of erosion could be permanent because natural sediment supplies are no longer available to reconstruct wetland area.

The analysis of the distribution of wetland plant communities showed that the vegetation is mainly controlled by elevation, water level, and exposure to wave or wind action. Wetland vegetation communities ranged from aquatic beds, dominated by submerged plants and by magnolia water lily, to silver maple swamps. Forested swamps were found between 21.40 and 22.17 m (70.21 and 72.74 ft) above sea level. Forests disturbed by the 1972-1976 high water levels were at the lower end of this range. At the other extreme, marsh and aquatic plant communities were found between 21.40 and 20.03 m (70.21 and 65.72 ft) above sea level.

These silver maple forests are typical habitat of the St. Lawrence River floodplains. However, among all plant communities studied, only silver maple swamps showed major degradations. Some of these forests died, and these sites are today dominated by purple loosestrife (Lythrum salicaria), reed-canary grass (Phalaris arundinacea), cattails (Typha angustifolia and Typha latifolia) and rice-cutgrass (Leersia oryzoides). These species, particularly reed-canary grass, invade dead forests forming dense monospecific (single species) communities, which compete with tree seedlings. In such situations, the reestablishment of silver maple is very difficult. In some cases, trees will never come back. Further, in an urban environment, these habitats are more subject to displacement by other land uses. Thus, by causing a loss of forested wetland areas, the 1972-1976 high water period created a degradation in habitat quality.

The high water levels recorded between 1972 and 1976 caused a major negative impact on the wetlands of Lake Saint Louis. Although water level fluctuations are a natural phenomena, intensity, frequency, and timing of fluctuations have important effects on wetlands. High water periods (where water level is above 21.3 m (69.89 ft) year-round) occurring too often at other times of the year (e.g., in winter) will have detrimental effects on the Lake Saint Louis wetlands, and on other wetland areas of the St. Lawrence River. Based on tree ring data, it takes at least 65 years to create a mature silver maple forest. If the future management of Great Lakes water levels produces high water levels similar to the ones observed, and at frequency higher than 65 years, more degradation is foreseeable. Even more destruction could result if erratic fluctuations in the levels and flows of the St. Lawrence were produced to accomodate regulation of the lakes upstream.

7.3.4 Conceptual Modeling of Wetlands Impacts: With and Without Measures

Results of Scenario Analysis

The model analysis to predict the emergent marsh landward and lakeward extents was performed on the following scenarios: Basis of Comparison (BOC); historical (what actually occurred); environment (pre-regulation); BOC Wet/Dry; Lake Ontario 58D/28B; Lake Superior 77a Modified; SEO Optimized; SHMEO-Optimized; and SHMEO-50.

The present regulation plans (the basis of the BOC) for both Lakes Superior and Ontario are having serious negative impacts on emergent marsh area in Lakes Superior and Ontario, and minor impacts on Lakes Michigan, Huron, St. Clair, and Lake St. Louis on the St. Lawrence River (FIGURE 7.8A). In Lake Superior, the model predicts a loss of 26% of wetland area compared to pre-regulation water levels; in Lake Ontario, the loss is predicted to be 31%.

The regulation plan for Lake Superior is under review (77A modified). Emergent marsh area in Lake Superior under 77A Mod. would be 82% of pre-regulation area, an 18% loss, which is a slightly smaller loss than the present regulation plan (FIGURE 7.8B). However, losses are higher on Lakes Michigan and Huron under 77A Mod. (6%) than BOC (2%). There is still a 31% loss in emergent marsh area on Lake Ontario under 77A mod. There are minor impacts on Lakes St. Clair, Erie, and St. Louis (St. Lawrence River) from the modification to plan 77A.

The regulation plan for Lake Ontario is also under review (58D-28B mod.). There would be a 35% loss of emergent marsh area on Lake Ontario under the modified plan (FIGURE 7.8C). The modification to the plan would be even more detrimental to wetlands than the present plan. The same small losses would continue to occur on the St. Lawrence River as under the current plan.

The 3 lake optimized plan would result in similar or greater losses in emergent marsh area in Lakes Superior (22%) and Ontario (36%) when compared to the BOC, 77A Mod. or the 58D-28B Mod. plans (FIGURE 7.8D). There are serious losses on Lakes Michigan/Huron (11%), St. Clair

Figure 7.8 (A-C) Predicted Emergent Marsh Response (A = BOC; B = 77A MOD; C = 58D-28B MOD)

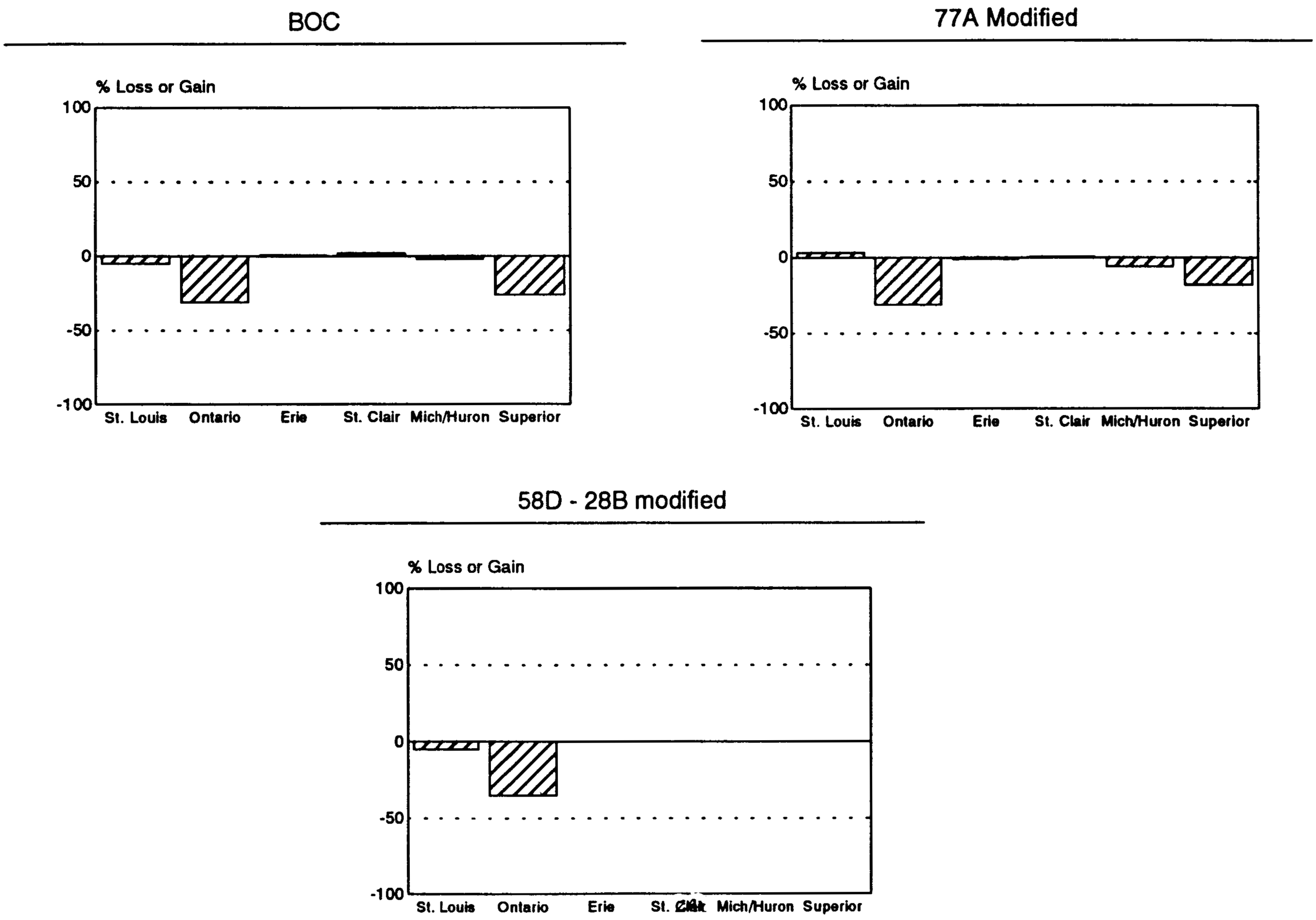
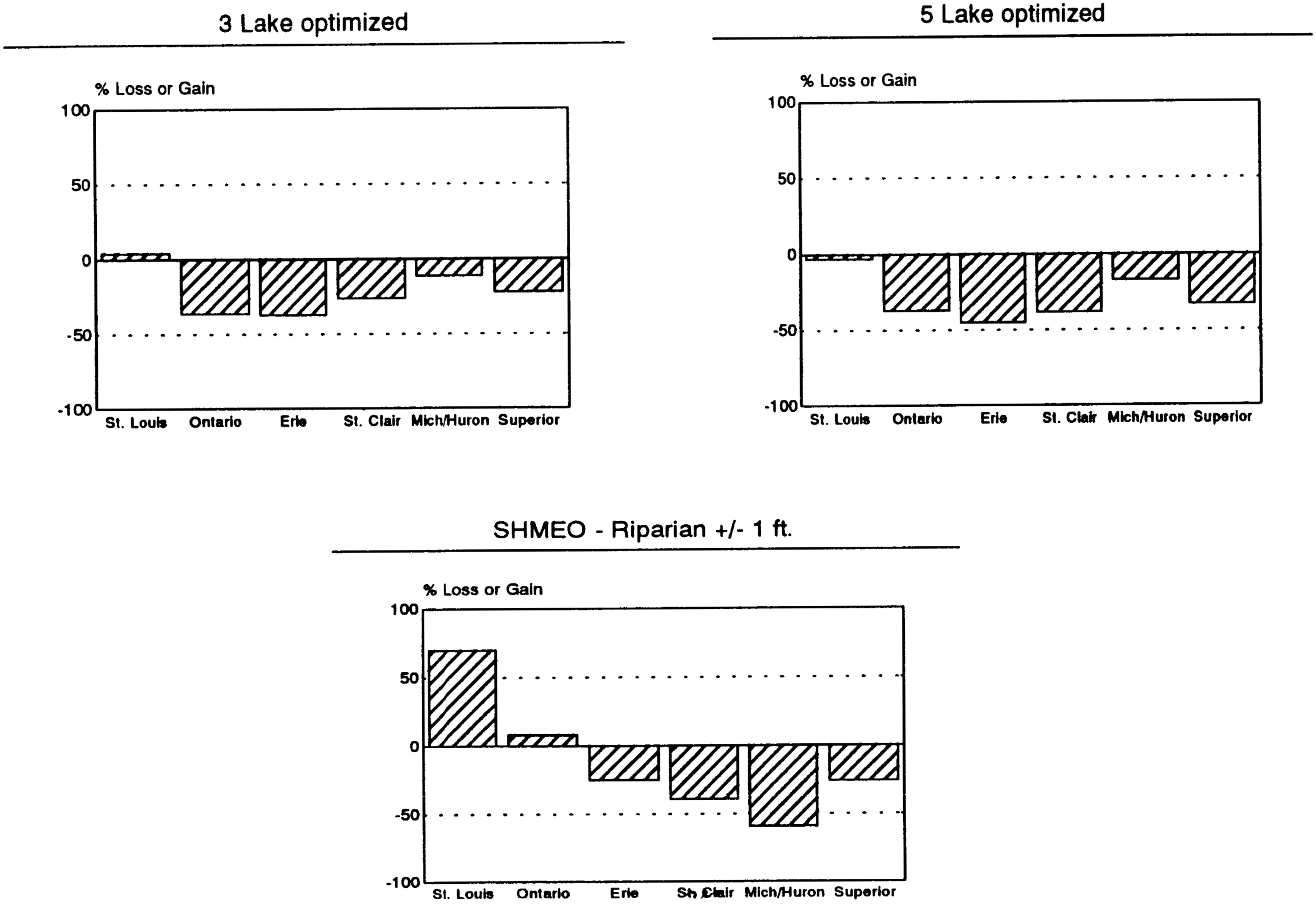


Figure 7.8 (D-F) Predicted Emergent Marsh Response (D = 3Lake; E = 5Lake; F = SMHEO-50)



3 Lake optimized

5 Lake optimized

SHMEO - Riparian +/- 1 ft.

(26%) and Erie (37%) with the 3 lake optimized plan. There were no losses of this magnitude with the present regulation plans or their modifications on these middle lakes. The Lake St. Louis emergent marsh community is not significantly impacted by the 3 lake optimized plan.

The 5 lake optimized plan results in serious losses on all lakes (FIGURE 7.8E). There would be a 33% loss on Lake Superior; the present plan results in a 26% loss by comparison. There would be a 17% loss on Lakes Michigan and Huron compared to only a 2% loss under BOC. Lakes St. Clair and Erie would be the most impacted lakes, losses would be 38% and 45%, respectively. There would continue to be a serious loss on Lake Ontario (37%) which is similar to the loss with 58D-28B and worse than the present loss due to BOC (33%). The Lake St. Louis emergent marsh community would be minimally impacted.

The SHMEO riparian +/- 1 foot plan would result in 26%, 59%, 39%, and 25% losses in emergent marsh area in Lakes Superior, Michigan/Huron, St. Clair and Erie, respectively (FIGURE 7.8F). Emergent marsh area in Lake Ontario would increase by 8% compared to pre-regulation or 39% compared to BOC. However, this gain would occur on the landward margin of the emergent marsh community in response only to high water levels when compared to the BOC.

Unfortunately, a mix of high and low water levels would have been more desirable to maximize emergent marsh. On Lake St. Louis in the St. Lawrence River there would be a 70% increase in the emergent marsh area in response to high and low water levels compared to BOC and pre-regulation. Approximately half of the gain in emergent marsh area would occur inland as a result of very high water events and half would occur lakeward due to low water. The emergent marsh area gain inland, however, is made possible by the high water events killing the silver maple trees in environmentally sensitive areas in the Quebec portion of the St. Lawrence. The Quebec Ministry of the Environment has expressed serious concern over the loss of these trees and the impact on the environmentally sensitive areas. Some islands have been permanently lost due to erosion during previous high water events (see Section 7.3.3).

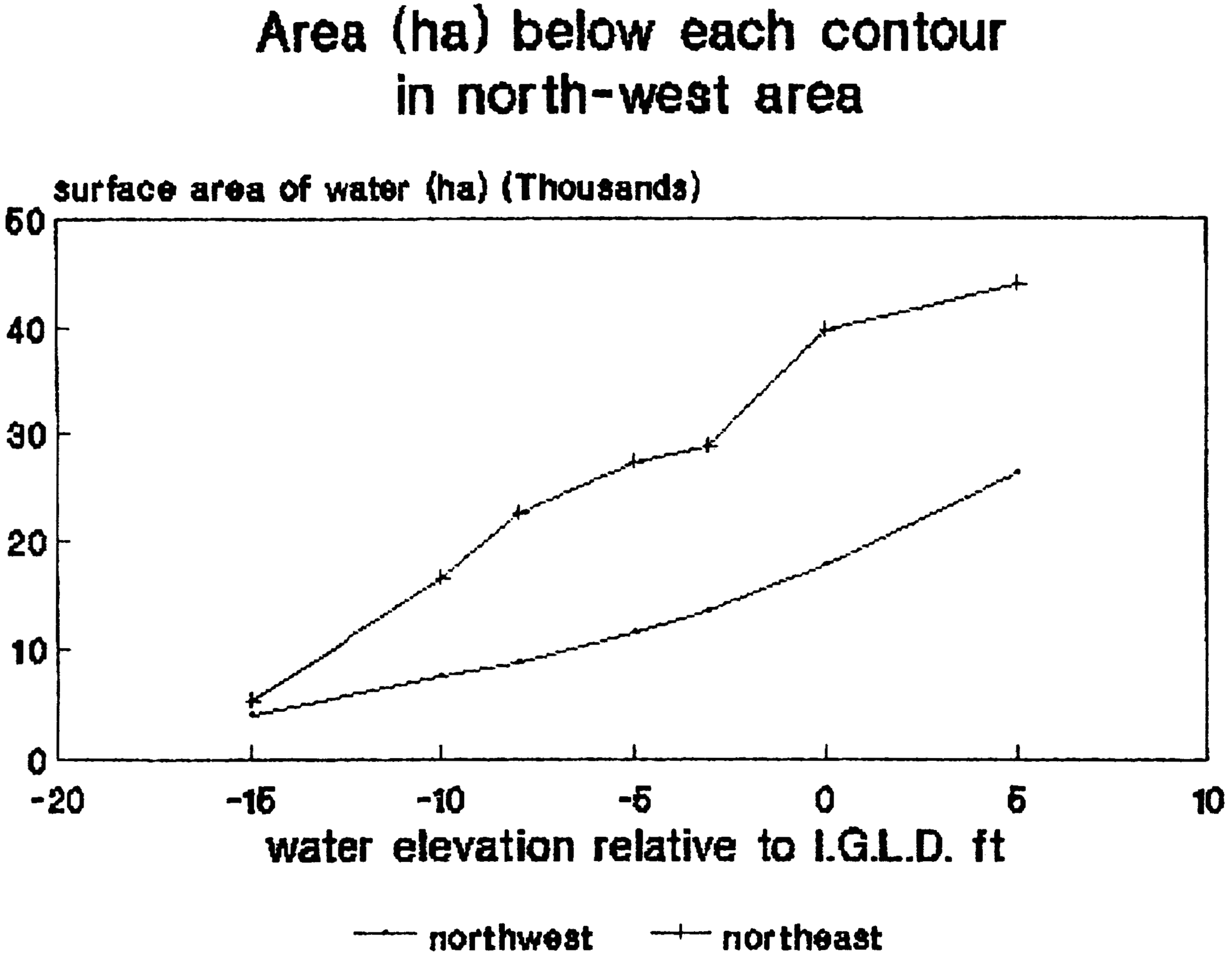
7.4 Fish Habitat Impact Assessment

7.4.1 Evaluation of Spawning Habitat Area in Two Sites in Saginaw Bay at Three Different Water Levels

Relationships Between Water Surface Area and Water Elevation

At Chart Datum the area of the northwest study site is 177 km^2 (68.3 mi^2) and the area of the northeast study site is 396 km^2 (152.9 mi^2). Approximately 22% of the northwest site is deeper than 4.6 m (15.1 ft), compared to only 13% of the northeast site. In the northwest site the slope of the water level versus surface area curve increases at a nearly constant rate as water elevation increases (FIGURE 7.9). In contrast, in the northeast site the rate of increase in the level/surface area curve varies with depth/elevation. In the northeast site the rate of change in area is much

Figure 7.9 Surface Areas of The Two Study Sites At Various Water Levels



greater between Chart Datum and -0.9 m (-2.95 ft) than at other depths. A water level increaseof 1.5 m (5 ft) from Chart Datum would cause the total surface area of the northwest site to increase by nearly 50%, but would only result in an 11% increase in surface area at the northeast site. A 1.5 m (5 ft) reduction in water level from IGLD would result in a 34% reduction in the area of the northwest site and a 31% reduction in the area of the northeast site. At the northeast site most of the habitat lost would be in the 0 to -0.9 m (0 to -2.95 ft) isopleth, whereas at the northeast site it would be more uniformly distributed.

The percentage change in area within each isopleth which would result from a 1.5 m (5 ft) increase in water levels is presented in TABLE 7.9. The area in all isopleths would increase in the northwest site. In the northeast the areas in the 0 - 1.5 m (0 - 5 ft) and the 2.4 - 3.0 m (8-10 ft) isopleths would decrease markedly, but the area in the 1.5 - 2.4 m (5 - 8 ft) isopleth would be more than doubled. The greatest percentage increase would occur for the area deeper than 4.6 m (15 ft) at both sites, because this area, which was within the 4.6-3.1 m (15-10 ft) isopleth at chart datum (see Table 7.4), is simply added to the area which was deeper than 4.6 m (15 ft) at chart datum.

A decrease in the water levels to 1.5 m (5 ft) below Chart Datum causes a decrease in the area of all isopleths in the northwest site (TABLE 7.10). The area in the 0 - 0.9 m (0-3 ft) isopleth, and the area deeper than 3.0 m (10 ft) decreased in the northeast site, but the area in the 0.9 - 1.5 m (3-5 ft) isopleth was nearly 4 times what it was at Chart Datum.

Area and Distribution of Spawning Habitat at Chart Datum

The proportion of each site reported to be spawning habitat varies widely between species. In the northwest site yellow perch and walleye are both reported to spawn over more than 70% of the site, lake sturgeon over 60% (FIGURE 7.10A). In contrast, reported spawning areas for largemouth bass and round whitefish are restricted to 1.5% and 6.2% of the total area, respectively. In the northeast, yellow perch are reported to use nearly 70% of the total area for spawning, but walleye only use 36% and lake sturgeon 32% (FIGURE 7.10B). Largemouth bass spawning habitat is reported to be more widespread in the northeast site (37% of the total area) than in the northwest, and the same is true for northern pike and smallmouth bass.

Differences between sites in spawning habitat depth distributions occurred for several species. In the northwest the rate of use of the various depth isopleths by lake sturgeon is roughly equal, whereas in the northeast a disproportionately large percentage of the spawning habitat occurs at depths of less than 1.5 m (5 ft). Lake herring apparently use a range of depths in the northwest but mainly areas deeper than 2.4 m (8 ft) in the northeast. Round whitefish spawning habitat is only reported from areas shallower than 2.4 m (8 ft) in the northwest, but in the northeast nearly all of the spawning habitat is at depths greater than 2.4 m (8 ft). The depth distribution of spawning habitat also differs markedly between sites for largemouth bass, northern pike, and burbot.

Table 7.9 Percentage change in area of each isopleth as a result of a 1.5 m increase in water levels relative to IGLD '55		
Isopleth	Northwest	Northeast
0.0 - 1.5 m	44.7	-64.3
1.5 - 2.4 m	42.5	129.3
2.4 - 3.0 m	42.7	-74.7
3.0 - 4.6 m	23.6	8.0
> -4.6 m	86.8	224.2
Total	49.5	11.1

Note: metres x 3.28 = feet

Table 7.10 Percentage change in area of each isopleth as a result of a 1.5 m decrease in water levels, relative to I.G.L.D.		
Isopleth	Northwest	Northeast
0.0 - -0.9 m	-29.8	-56.4
-0.9 - -1.5 m	-29.9	294.7
-1.5 - -3.0 m	-19.1	8.6
> -3.0 m	-46.5	-69.2
Total	-34.2	-31.1

Note: metres x 3.28 = feet

Changes in Available Spawning Habitat with Changed Water Levels

Because it was assumed that the proportion of the habitat at a given depth used for spawning will not change as a result of changes in water levels, the predicted change in area of spawning habitat in any given isopleth will be proportional to the change in area of that isopleth. In other words, if the area in the 0 - 1.5 m (0-5 ft) isopleth increases by 50%, then the spawning area in that isopleth will increase by 50% for each species.

Figure 7.10a Percentage of Total Spawning Habitat Within Each Isopleth For Ten Species in the Northwest Site, Saginaw Bay

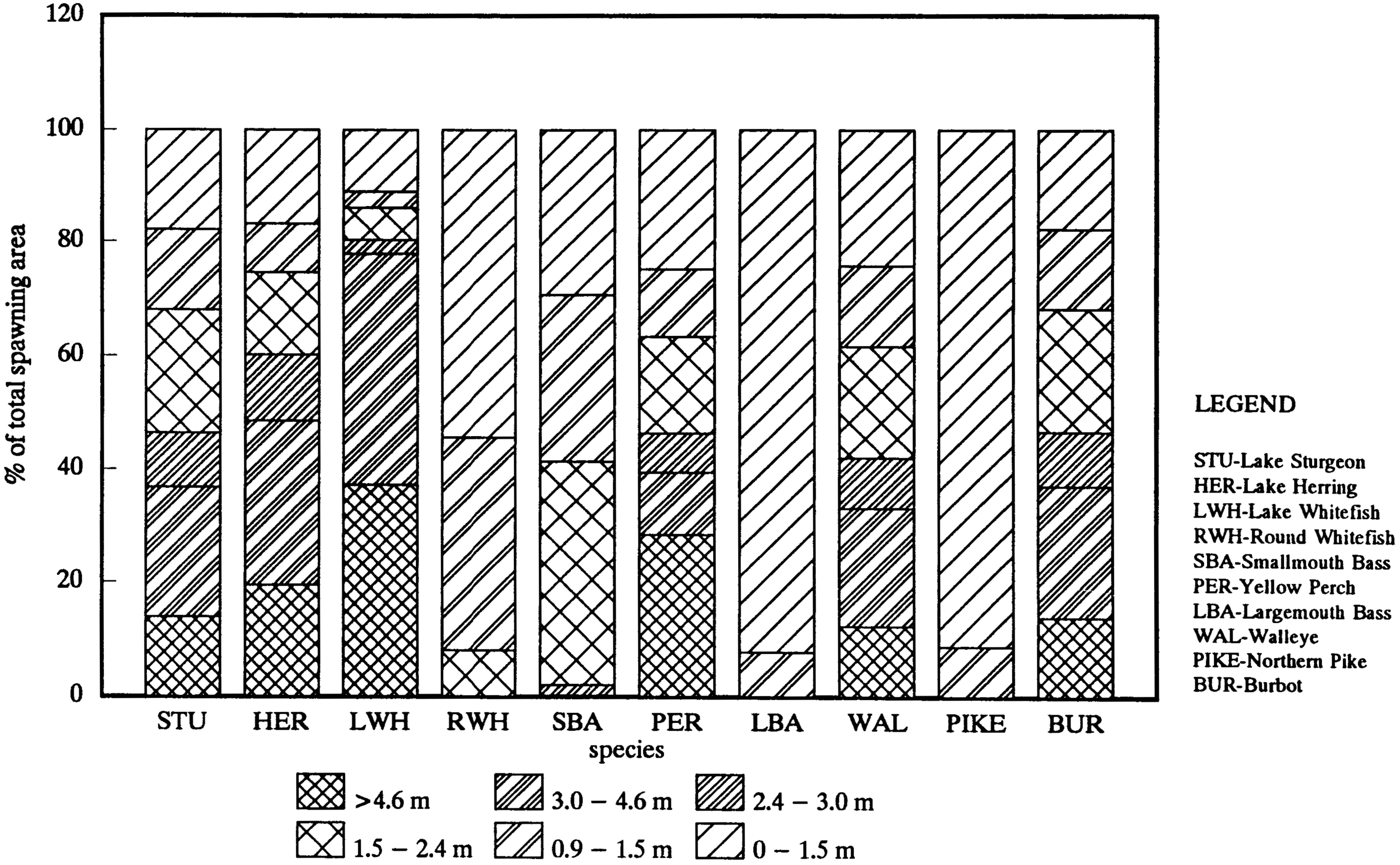
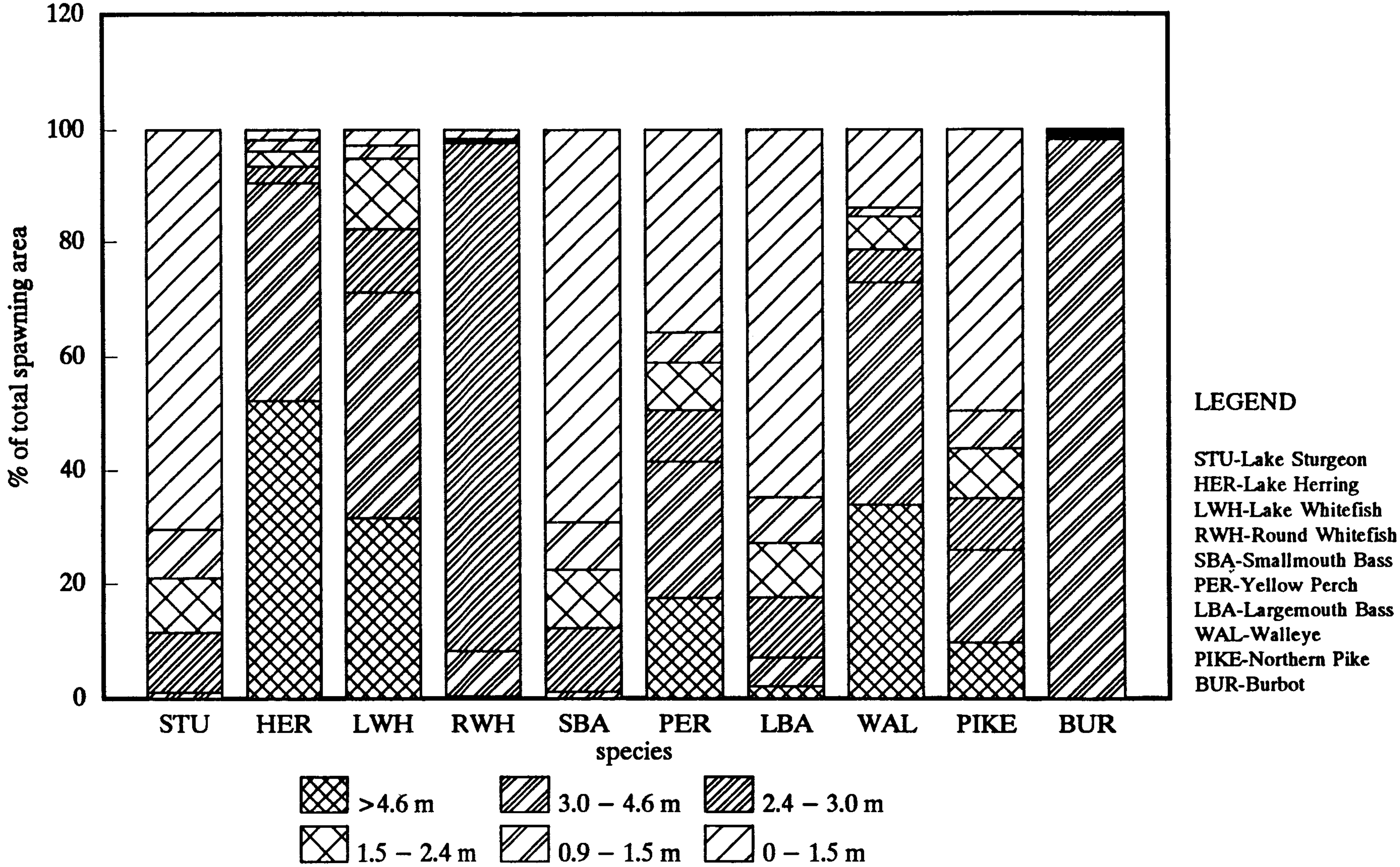


Figure 7.10B Percentage of Total Spawning Habitat Within Each Isopleth For Ten Species in the Northeast Site, Saginaw Bay



In the northwest, where the area in all isopleths increases with a 1.5 m (5 ft) increase in water levels, the model predicts that the spawning habitat for all species would increase (FIGURE 7.11). This increase ranges from 44% to 54%, which is comparable to the increase in total area (49.5%). The changes in the area of spawning habitat which are predicted to result from a 1.5 m (5 ft) increase in water levels vary widely between species in the northeast site. The area of lake herring spawning habitat, for example, is predicted to more than double, but the area of round whitefish spawning habitat would be reduced by 67%. As would be expected, an overall reduction in spawning habitat is predicted for species for which a large portion of the total spawning habitat occurs within the 0.0 - 1.5 m (0-5 ft) and the 2.4 - 3.0 m (8-10 ft) isopleths, which areas decrease when water levels are increased. The largest increases in spawning habitat are predicted for species reported to spawn primarily at depths of 3.0 m (10 ft) or deeper. A 1.5 m (5 ft) decrease in water levels is predicted to reduce the spawning habitat for all species in the northwest site (FIGURE 7.11). The reduction ranges from 25% for smallmouth bass to 42% for lake whitefish. In the northeast, the situation is, once again, more variable (FIGURE 7.11). The spawning area of round whitefish would increase by 2%, while the spawning area of burbot would decrease by 67%. As for increasing water levels, the predicted change depends upon the spawning habitat depth distribution.

7.4.2 Yellow Perch Reproduction in South Bay, Lake Huron

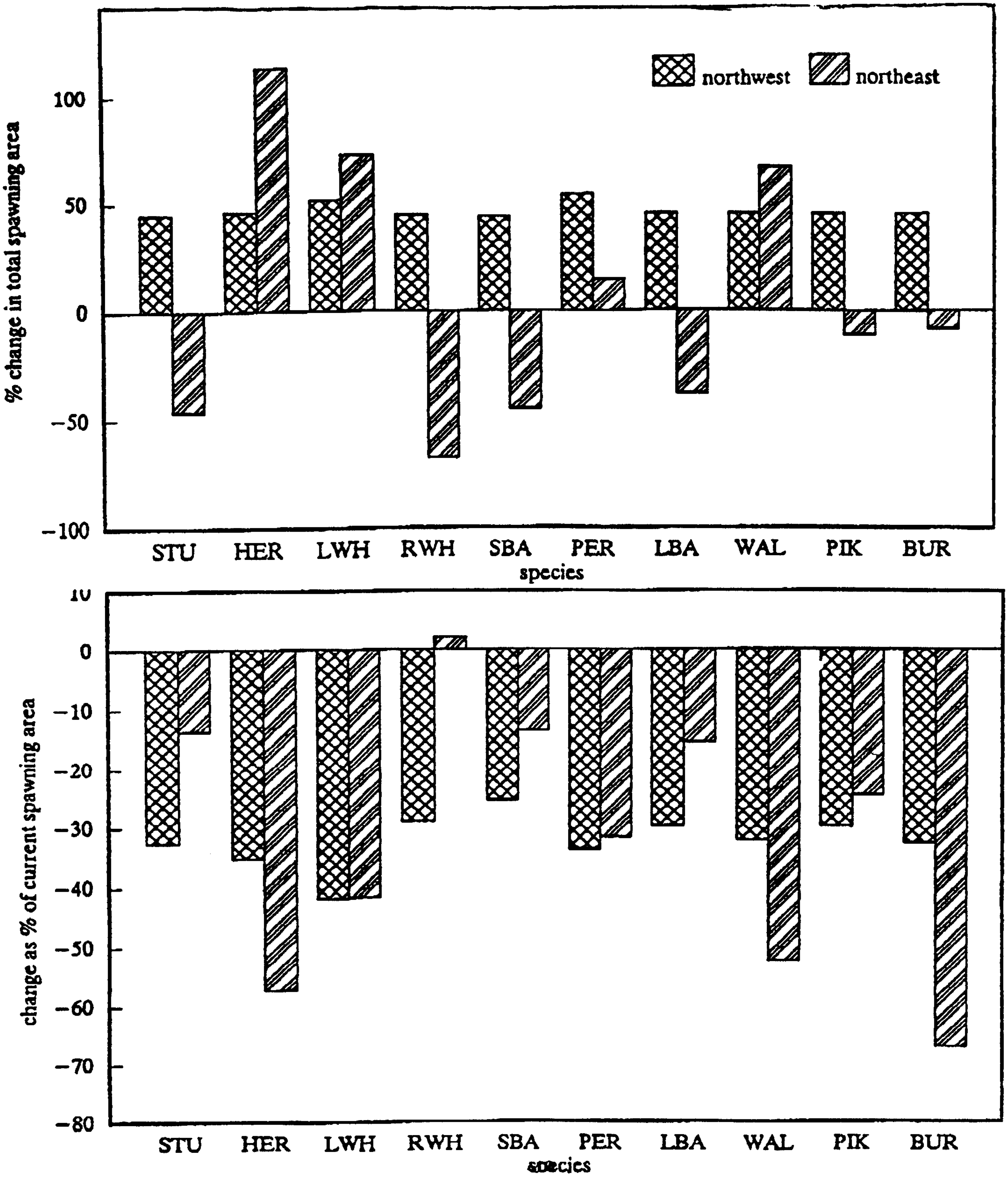
TABLE 7.11 summarizes the results, with the regulation scenarios arranged in order of decreasing geometric mean R/P. Both the geometric and arithmetic mean R/P, and the number of years in which R/P was predicted to exceed 1, were highest when the actual water levels were substituted into the equation. There was little difference between means of predicted R/P for the actual water levels and the Environmental, 77a, and Basis Of Comparison (BOC) scenarios. Both of the means, and the maximum R/P, were markedly lower for the other four scenarios. The number of years in which R/P was predicted to exceed one was lowest for the SHMEO-50 and 3Huron scenarios. The predicted maximum R/P for the SHMEO-50 scenario was 0.50, approximately one fifth of the maximum predicted under actual water level conditions.

7.4.3 Discussion

It is unlikely that the rate of change in Great Lakes water levels could occur quickly enough to de-water the spawning areas of spring spawning fish species during their relatively short period of incubation, with the exception of spawning areas in the connecting channels, where rapid changes in water levels could occur if control structures were put in place. The spawning areas of fall spawning species such as lake trout, lake whitefish, and other coregonids would be more susceptible to dewatering, as the embryos spend several months in the substrate.

Several studies have demonstrated a positive correlation between water levels and the reproductive success of northern pike and yellow perch. The increased reproductive success

Figure 7.11 Changes in Area of Spawning Habitat Predicted To Occur as a Result of a 1.5 Metre (5 Foot) Increase (Top Graph) and a 1.5 Metre (5 Foot) Decrease in Water Level From Chart Datum



resulting from high water levels has often been attributed to the increase in flooded vegetation which resulted from rising water levels, rather than to the high water levels per se. Data from newly created reservoirs support the conclusion that rising water levels are the critical condition leading to strong year classes of northern pike (Nelson, 1978; Hassler, 1970; Bodaly and Lesack, 1984) and yellow perch (Nelson, 1978). Indeed, water level manipulations in some reservoirs managed for fisheries have been modified to increase the area of flooded vegetation during the spring and summer (Groen and Schroeder, 1978; Beam, 1983). Seeding of exposed mud flats following late-summer drawdown has also been used to achieve this goal (Strange et al, 1982).

Table 7.11 The geometric and arithmetic means and the maximum of the predicted ratio of yellow perch recruits to spawners, and the number of years when this ratio is predicted to exceed 1, for the years 1951-1977 under various water level scenarios.

Regulation Scenario	Mean R/P		Maximum R/P	Years R/P>1
	Geometric	Arithmetic		
original data	0.32	1.03	5.62	8
predicted				
actual	0.36	0.68	2.47	6
enviro	0.31	0.64	2.68	5
77a	0.31	0.59	2.32	5
BOC	0.30	0.61	2.57	5
SEO optimized	0.28	0.46	1.70	4
3huron	0.24	0.39	1.38	2
SHMEO-50	0.23	0.24	0.50	0
BOC wet/dry		0.51	1.93	5

This analysis demonstrates three important principles. The first is that changes in the area of spawning habitat in response to changes in water levels will vary between species. The second principle is that changes in the area of spawning habitat for individual species will vary between locations. This is an important consideration because it indicates that generalizations drawn for large areas are inappropriate. In fact, the responses will vary on an even finer scale than the summary data presented here indicate, especially in the northeast site where the bottom contours are quite irregular. Here individual, discrete spawning areas might be completely eliminated, and others created, as water levels fluctuate.

The analysis also indicates that responses will vary the least between species where the slope of the bottom is constant. Where the bottom profile is irregular, variation between species is greater, and prediction of response becomes more difficult.

A positive exponential relationship existed between mean June water level and yellow perch ratio of recruits:spawning stock (R/P ratio) ($R/P=10^{(-229.807+1.3WL)}$) in South Bay, Lake Huron, during the years 1951-1977 (Figure 7.4). This model predicts that the R/P ratio will change by an order of magnitude in response to a 0.77 m (2.5 ft) change in water levels. Henderson's (1985) hypothesis stated that the positive correlation between June water levels and yellow perch R/P was related to the greater amount of vegetated spawning habitat which is available at higher water levels. This hypothesis is consistent with the observations of other investigators, who have found large year-classes of yellow perch in years of rising (Nelson, 1978) or high (Martin et al, 1981) water levels.

One consequence of a high R/P can be the "strong year-class" phenomenon, which is familiar to Great Lakes fisheries managers. When parental numbers are low, a high R/P can facilitate the recovery of the stock. The recovery of walleye populations in the Bay of Quinte, Lake Ontario, appears to have been due in large part to the production of an exceptionally large year-class in 1978, which was produced by a relatively small parental stock (Hurley, 1986).

Although a high R/P can bring about the recovery of stocks which have been reduced to low levels, a high R/P in a single year, or perhaps in several years, does not guarantee that stock size will increase dramatically. The high R/P for yellow perch in South Bay in 1975 did not result in parental stocks increasing to the levels observed in the 1950's and early 1960's (Henderson, 1985). It is clear, however, that eliminating, or reducing the frequency of occurrence of the conditions which permit a high R/P to occur will reduce the likelihood of stock recovery.

Analyses which examine the inter-relationships between habitat variables will permit us to increase our understanding of aquatic ecosystems, but data collected at a single point in time do not provide us with much further insight into the effects of water level fluctuations on the physical and biotic habitat characteristics which respond to water level fluctuations. Time-series data are necessary to further our understanding of such relationships.

7.4.4 Conclusions

Although the relationship between water levels and reproductive success has been examined for a few species, there is little or nothing known about the effect of water level fluctuations on most of the fishes in the Great Lakes. For yellow perch and northern pike, the available data suggest that strong year-classes can be produced during years when water levels are high, but reservoir studies indicate that these strong year-classes are not produced by continuously high water levels. Fluctuating water levels are essential to create the conditions which permit the higher reproductive success.

The exponential relationship which Henderson (1985) demonstrated between the ratio of yellow perch offspring/parents and June water levels shows that large biological responses can result from seemingly minor changes in water elevation. The offspring/parent ratio varied by nearly four orders of magnitude, while water levels varied by less than two metres. The analysis of the proposed regulation scenarios predicts that some of these scenarios would eliminate the potential for the production of large year-classes from small parental stocks of these species.

The Saginaw Bay data suggest that the response to regulation will vary between species, and between different populations or stocks of the same species. The role of fluctuating water levels in maintaining fish community diversity is largely uninvestigated. There is evidence that periodic disturbance maintains the diversity of algal communities in the marine inter-tidal (Sousa, 1979, 1980). Water level fluctuations may play a similar role for Great Lakes fish communities.

The potential consequences of changes in the near-shore areas of the Great Lakes are enormous. These areas are utilized by nearly all of the fish species present during some period of their lives, and changes in habitat conditions will therefore effect the deepwater communities as well as those commonly thought of as inhabiting the nearshore. Furthermore, any changes which might be incurred would be expected to alter other components of the ecosystem, including water quality. At present, the knowledge required to anticipate the effects of reducing water level fluctuations is not available, but there is increasing evidence that water level fluctuations, while incurring short-term variability, may help to maintain the resilience of the ecosystem, permitting it to recover from periodic stresses. Thus water level fluctuations may be essential for long-term stability.

Time-series data would provide a means of gaining the knowledge necessary to predict the impacts of water level regulation on the Great Lakes ecosystem. Both physical and biotic components is necessary. Examinations of biological parameters should go beyond simple indices of abundance to include metrics such as the number of offspring per parent. Fish population levels fluctuate over time, and conditions which permit stock recovery from low extremes are critical.

It is predictable that the fish communities will respond to changes in water level regulation, that the responses will vary between species and between locations for the same species, and, based on the yellow perch model analysis, that some of the responses will be undesirable. We cannot predict what the effect will be on parameters such as yield of yellow perch or lake trout to commercial or recreational fisheries. It is generally accepted that climatic change will bring about changes in natural ecosystems, that some of these changes will not be predicted, and that some would be undesirable. Regulation of Great Lakes water levels is an attempt to control the effects of short to medium-term climatic variation; the same conclusions apply.

7.6 Discussion and Analysis

7.6.1 Confidence in Findings and Their Application

Wetlands

There appears to be little doubt that water level fluctuations affect the amount and diversity of coastal wetlands that exist in the Great Lakes and St. Lawrence River. The Phase II study findings are consistent with previous findings and the Phase II findings are themselves consistent. However we lack a method which will, with a high level of confidence, provide quantitative predictions of changes in wetland area and diversity caused by specific changes in regulation. The historic study has indicated that there is a considerable range of difference in how specific wetlands respond to water level changes. The topographic study used generalized profiles to model effects on plant diversity; the conceptual model used general assumptions about rates of wetland change. How much error has been introduced into estimates based on these valid generalizations is unknown. Improvements must be made through quantification.

Historic Wetland Change Project

The fact that areas of certain emergent wetland communities showed consistent statistically significant dependence on water levels in several Great Lakes basins attests to the correctness of findings that wetland area and diversity are dependent upon water level changes. There is a growing amount of literature on findings that support the conclusion that wetland area and diversity changes are induced by water level changes (e.g., Harris, et al., 1977; Payne et al., 1985; Lyon et al.,1986; Greene, 1987; Bukata et al., 1988; Williams and Lyon, 1991). The lack of statistical validation of some of the findings is not reason to dismiss them. The historic wetland photographs are only five to six "snapshots" of wetland conditions within a span of about 40 years. Additional data, and more thorough treatment of water level conditions should improve the statistics and show more consistent findings. Differences in response from wetland to wetland could be partly explained not only by relative isolation from the lakes, but also by differences in topography/bathymetry and the particular plant species that are found in each wetland.

Impact of Water Level Changes on Wetland Plant Diversity

These studies have demonstrated the necessity of water level fluctuations in the Great Lakes to maintain wetland diversity. However, the studies were conducted using available data or data collected during a very short time period. More accurate information would be obtained by gathering data on wetland response to water level changes as they occur, rather than after the fact. In this way, changes could be "witnessed" and documented and not have to be estimated from changes in the offshore/onshore profiles. This process of information gathering could not only improve confidence in the findings, but also provide a fine-tuning mechanism to improve models and guide regulation decisions in the future.

St. Lawrence River Wetland Studies

The limitations of the St. Lawrence River wetland study are due primarily to the confined area of study; one site is not representative of the entire river. The findings, however, are in accord with the other studies. It is the resource concerns that differ. The resource concern in this area is about adverse effects on downstream wetlands from regulation plans designed to benefit interests on the Great Lakes. Past water level changes have had a sometimes dramatic effect on the large areas of forested wetlands in floodplain forest. Another concern is that the presence of dams limits the passage of sediments. The combination of high water levels, high current rates, and low sediment supply have caused erosion of wetland areas in the study areas. The question remains as to how extensive a problem sediment starvation may be in the rest of the St. Lawrence River.

Conceptual Model of Wetlands and Lake Levels

While insufficient information exits to allow the model to be subjected to a rigorous calibration/verification process, the model does utilize rates of wetland change derived from the literature, and the results appear to generally agree with the findings from the Phase I and Phase II studies on water level impacts on wetlands (Painter and Keddy, 1992). The historic aerial photography study indicates that reactions of wetlands to water level regimes may vary according to such factors as relative isolation from the lakes and specific topography. It might be difficult to predict exactly what will happen to a specific wetland with a given water level changed. Nonetheless, the model provides a good indication of what, on the whole, will occur to Great Lakes and St. Lawrence River wetlands. While a higher level of confidence in the numerical findings would be welcome, the model appears to provide a general indication of what the effects of changes in the fluctuation patterns on Great Lakes and St. Lawrence River'emergent wetlands (marshes) will be.

Fish Habitat

Our ability to predict the effects of water level regulation on Great Lakes fish communities is very limited. It can be predicted that the fish community will respond, that the responses will vary between species and between locations for the same species, and, based the analysis using the yellow perch model, that some of the responses will be undesirable. The effect on parameters such as yield of yellow perch or lake trout to commercial or recreational fisheries cannot be predicted. It is predictable, however, that some proposed regulation scenarios would eliminate the potential for the production of large year classes from small parental stocks allowing stock recovery. Fish population levels fluctuate over time, and it is vital that conditions periodically arise which permit stock recover from low population levels.

7.6.2 Basin-Wide Extrapolations

Wetlands

Historic Wetland Change Project

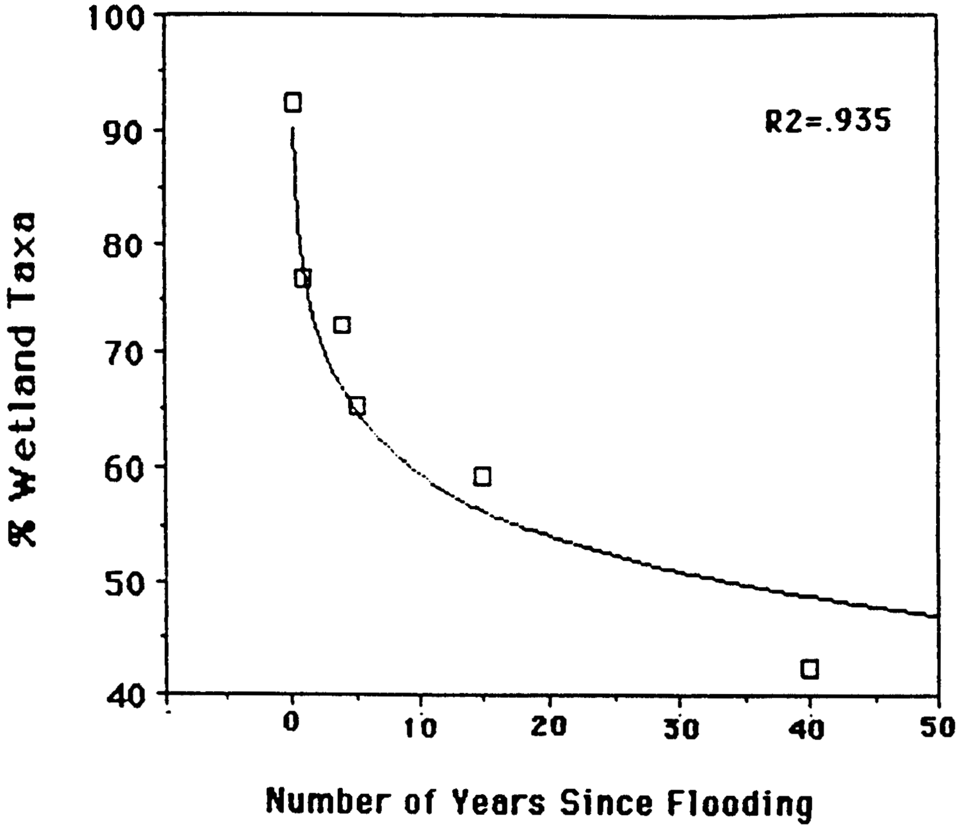
Because the historic wetland study was conducted on six sites on three different Great Lakes, the findings can be considered general. Because the St. Lawrence River study also used historic aerial photography, the results are further underscored. Clearly water level fluctuations have had, and will continue to have, a major influence on wetland area, wetland complexity, and wetland diversity. The magnitude of this influence varies from wetland to wetland, but with the possible exception of woody plants, is consistent in direction.

Impact of Water Level Changes on Wetland Plant Diversity

Studies of numerous wetlands in lakes Ontario and Superior during Phase II and previous studies of individual wetlands in Lakes Michigan, Huron, and St. Clair supported a clear general conclusion. Cyclic water level fluctuations in the Great Lakes are necessary to periodically stress competitively dominant plants both on the shore and in the water, thereby perpetuating cyclic successional processes and maintaining wetland diversity. An analysis of data across all sites on lakes Ontario and Superior showed a strong correlation between flooding history and the percentage of wetland species (FIGURE 7.12). Flooding history differs from lake to lake due to differences in supplies, basin and tributary characteristics, and position in the downstream flow of the Great Lakes system. The lake-specific cycles of flooding and dewatering are responsible for evolution of wetlands within each lake and represent the models upon which any lake-level regulation should be based. A long-term water level history (4000 years) is available only from Lake Michigan, however, where detailed sedimentological studies have been conducted (Thompson et al. 1991). Water level history on the remaining lakes comes from recording stations generally in operation for only 150 years. Although this snapshot can be used to examine short-term fluctuations cycles of 10 to 30 years, it cannot identify longer-term cycles that likely are greater in amplitude.

The areas of lake-affected wetland along the U.S. shores of Lakes Ontario, Superior, and Michigan was determined to be over 3400 ha (8400 ac), over 4200 ha (10,500 ac), and over 5400 ha (13,400 ac) respectively (Table 7.8). Coastal wetland diversity in all these lakes as well as the other Great Lakes is affected by past and current water level fluctuation patterns.

Figure 7.12 Percent Wetland Taxa vs Number of Years Since Flood As Determined For Both Lakes Ontario and Superior



St. Lawrence River Wetland Studies

The results of the St. Lawrence River study indicate both that the same influences on wetlands occur in a riverine environments and lake environments, and that resource concerns in the St. Lawrence are different. The wetland processes that occurred with changes in water levels are similar to those in the Great Lakes. Wetland plant communities changed in response to long term level fluctuations in the order of 1 to 30 years. Findings along the St. Marys River, the Lake Superior/Lake Huron connecting channel are also in accord with the Task Group's Great Lakes findings (Williams and Lyon, 1991).

The St. Lawrence and the Great Lakes situations differ in that the St. Lawrence wetland resources include large areas of floodplain forest, and that the existence of dams has reduced the supply of sediments to the forested and other classes of wetlands. Flooding has caused, and in the future will cause, losses of the floodplain forests, i.e., forested wetlands, and losses of other wetland types through erosion. Therefore, understanding the impacts of regulatory changes on the St. Lawrence requires emphasis on effects on woody wetlands, and the potential for effects from flooding and erosion.

Conceptual Model of Wetlands and Lake Levels

The basic mechanisms reflected in the conceptual model are those related to the topography/bathymetry of the onshore/offshore wetland profile. Within the limits of the assumptions of the model, the results are applicable throughout the Great Lakes/St. Lawrence basin. The model clearly does not attempt to take into account differences in plant species, nor can it account for erosion; both of these are site-specific characteristics. Its usefulness is primarily due to its generality.

Fish Habitat

The study of water level effects on spawning areas indicates that effects on a species may vary from one area to the next because of differences in bathymetry. It would therefore be difficult to extrapolate from the study findings to basin-wide effects without better knowledge of the basin-wide bathymetry. It is clear that the potential consequences of changes in the near-shore areas of the Great Lakes are very great. These areas are used by nearly all of the fish species during some part of their life cyccle, and changes in habitat conditions will therefore effect the deepwater fish as well as nearshore fish. Because the consequences of regulatory changes are unknown but could be far reaching, fisheries effects require some attention if we are to understand the consequences of future regulation proposals, or the secondary effects of global warming.

7.6.3 Natural Resource Impacts and the Study Planning Objectives

The study planning objectives relevant to the Natural Resources Task Group are the following:

- A5. Avoid Adverse Impacts to Water Quality Under Extreme Lake Level and River Flow Conditions
- G1. Avoid Adverse Impacts to Wetlands in the Basin Resulting From Changes in Fluctuating Water Levels and Flows and their Extremes
- G2. Reduce/Avoid Detrimental Effects on Water Quality in Basin Waters as the result of Fluctuating Water Levels and Flows and and their Extremes
- G3. Avoid Adverse Impacts to Fish and Wildlife as the Result of Fluctuating Water Levels and Flows and their Extremes
- H1. Avoid Adverse Impacts to Commercial fish Stocks as the Result of Fluctuating Water Levels and Flows and their Extremes

Restrictions on time and funding caused limitations on the extent to which the Task Group could address how different water level scenarios met these objectives. The "with" measure was addressed only for changes to lake level regulation scenarios, not for the effects of land use and shoreline management practices, although the Task Group provided comments on these effects to the Land Use and Shoreline Management Task Group. The Natural Resources Task Group was directed by the Study Board to use wetlands as indicators of the effects of water level fluctuations. In most instances, it was concluded that the water level scenarios did not meet Study Planning Objective G1. This can be readily concluded from the analyses provided above, and from the Task Group input to the "Impacts of Measures For Evaluation Summary," Working Committee 4, (August 1992). Conclusions concerning Study Planning Objective G3, effects on fish and wildlife, generally follow those concerning wetlands, because: 1) wetlands serve as habitat for numerous fish and wildlife species; and 2) although there is insufficient information to provide a definitive analysis, there appears to be the potential to greatly damage fish populations through water level regulation. The Task Group was not expected to address effects on commercial fishing.

7.6.4 Data Gaps, Limitations and Assumptions Behind the Findings: Future Information Needs and Research Requirements.

General

Individual studies conducted under the Levels Reference Study made use of available data or collected new data during a very short time period. Short-term studies that attempt to assess long-term processes cannot provide complete insight into the interactions between water level changes and the various aspects of the Great Lakes and 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. The Water level Reference Study has made clear the need for **long-term** evaluation, e.g. monitoring studies, of the effects of lake-level changes on many features of the Great Lakes community.

Wetlands

To understand diversity and area issues, long-term evaluations are needed on individual representative wetlands on each of the Great Lakes and at sites along the St. Lawrence River through at least one cycle of high lake levels, low lake levels, and return to high levels. Because wetland changes are closely related to topography and bathymetry, a better understanding of how water level changes affect bathymetry through erosion and accretion in wetland areas is important. There should be an area of overlap between erosional studies and wetland studies.

The conceptual model has proven to be a valuable tool for analysing the effects of water level regulation scenarios. Means need to be developed to better calibrate and verify rates of change in wetland community types at sites throughout the Great Lakes-St. Lawrence Basin. This would provide more confidence in the accuracy of the predictions provided by the model. Such a model could also be modified to account for wetland community types besides emergents, and for other wetland attributes such as those discussed in the historic wetlands study.

To gain an understanding of the natural cycles in water level change to which wetland evolution has responded, sedimentological studies are needed on all lakes to provide lake level histories of several thousand years, similar to that which has been produced for Lake Michigan. Coupled with continuous studies of the many features of the Great Lakes system, including wetlands, this information could result in a more realistic view of the options available for management of the shoreline of the Great Lakes.

Fish Habitat

Methods are still being developed to study the effects of water level fluctuations on fish populations. Because of the importance of this issue it is hoped that resources will continue to be devoted to determine these effects so that it can be addressed responsibly.

7.7 Summary

The habitats and populations of the Great Lakes and St. Lawrence River have been established, and are maintained by the dynamics of water level fluctuations caused by variations in the climate. The processes maintaining productivity and diversity are most readily tracked in the coastal wetland communities along the shores of the Great Lakes and St. Lawrence. The changes that occur have been identified in the historic wetlands study and in the St. Lawrence River wetlands study. Changes in wetland and wetland plant community characteristics are directly correlated with long term water level fluctuations on the Great Lakes, their connecting channels, and on the St. Lawrence River.

These same processes are reflected in the distribution and diversity of wetland plants and plant communities along the offshore-onshore profiles. For example, plant communities in Lake Superior and Lake Ontario wetlands at elevations that are flooded periodically each ten to twenty years and dewatered for successive years, between floods have the greatest diversity of wetland vegetation. These plant communities contain the most wetland taxa and the most diversity of plant types.

A model of wetland area changes that occur in response to level changes indicates that fluctuations are indeed important to the maintenance of the current extent of coastal marshes on the Great Lakes and St. Lawrence River, and of course the waterfowl, fish, mammals, and other animals that they support. Without water level fluctuations, there would be less wetland; the less the fluctuation, the less the wetland.

Our understanding of the effects of water level fluctuations on fish is in its infancy. The information that does exist suggests that water level is a critical element in fish reproduction and maintenance of populations. Minor differences in elevation at critical times of the year can have major influences on reproductive success. Because water level changes occur throughout a basin, their effects on natural resources are felt throughout the basin. Fish reproduction is also apparently dependent upon the existence of dynamic processes. Northern pike spawning success is not so dependent upon high water levels as upon rising water levels. For rising levels to occur, low levels have to occur beforehand.

Besides providing information with which to evaluate proposed regulation scenarios, the studies undertaken by the Task Group have provided information on how past regulation regimes have affected wetlands on Lake Ontario and the St. Lawrence River. It is probable that reduction of the water level fluctuation ranges on Lake Ontario has had a significant effect on the extent, diversity, and integrity of wetlands on its shores, and that water level regulation has caused losses of floodplain forests along the St. Lawrence from flooding and erosion. The work accomplished has provided a starting point for defining these losses and determining if there are reasonable means to redress them.

REFERENCES

Beam, J.H., 1983. The effect of water level management on population trends of white crappie in Elk City Reservoir, Kansas. N. Amer. J. Fish. Mgmt.3:34-40.

Bodaly, R.A. and L.F.W. Lesack, 1984. Response of a boreal northern pike (*Esox lucius*) population to lake impoundment: Wupaw Bay, Southern Indian Lake, Manitoba. Can. J. Fish. Aquat. Sci. 41: 706-714.

Bukata, R.P., J.E. Bruton, J.H. Jerome & W.S. Haras, 1988. A mathematical description of the effects of prolonged water level fluctuations on the areal extent of wetlands.

Cadman, M.D., P.F.J. Eagles, and F.M. Helleiner, 1987. Programs for the Analysis of Ecological Data on the IBM/PC Microcomputer. Toronto: University of Toronto, Faculty of Forestry and Department of Botany.

Ecological Services for Planning Ltd., 1992. Historical coastal wetland mapping study: Phase 2. Prepared for International Joint Commission Levels Reference Study, Working Committee 2, Natural Resources Task Group. 172 pp. plus appendices.

Gleason, H. A., and Cronquist, A., 1963. Manual of vascular plants of northeastern United States and adjacent Canada. Van Nostrand Reinhold Co., New York.

Goodyear, C.D., T.A. Edsall, D.M. Ormsby Dempsey, G.D. Moss and P.E. Polanski, 1982. Atlas of spawning and nursery areas of Great Lakes fishes. Volume thirteen: Reproductive characteristics of Great Lakes fishes. U.S. Fish and Wildlife Service, Washington, D.C. FWS/OBS-82/52.

Greene, R.G., 1987. Effects of Lake Erie water levels on wetlands as measured from aerial photographs: Pointe Mouillee, Michigan, M.S. Thesis. Ohio State Univ., Dept. Civil Engin. 70 pp.

Groen, C.L. and T.A. Schroeder, 1978. Effects of water level management on walleye and other coolwater fishes in Kansas reservoirs. Am Fish. Soc. Spec. Publ. 11: 278-283.

Harris, H.J., T.R. Bosley & F.D. Roznik, 1977. Green Bay's coastal wetlands: a picture of dynamic changes. In: C.B.Dewitt & E. Solway (eds.), Wetlands Ecology, Values and Impacts. pp. 337-358. Proc. Waubesa Conf. Wetlands, Madison, Wisconsin, June 2-5, 1977.

Hassler, T.J., 1970. Environmental influences on early development and year-class strength of northern pike in Lakes Oahe and Sharpe, South Dakota. Trans. Amer. Fish. Soc. 99: 369-375.

Henderson, B.A., 1985. Factors affecting growth and recruitment of yellow perch, *Perca flavescens* Mitchill, in South Bay, Lake Huron. J. Fish Biol. 26: 449-458.

Hurley, D.A., 1986. Fish populations of the Bay of Quinte, Lake Ontario, before and after phosphorus control, p. 201-214. In: C.K. Minns, D.A. Hurley, and K.H. Nicholls [ed.] Project Quinte: point-source phosphorus control and ecosystem response in the Bay of Quinte, Lake Ontario. Can. Spec. Publ. Fish. Aquat. Sci. 86: 270 p.

Jaworski, E. and C.N. Raphael, 1978. Fish, Wildlife, and Recreational Values of Michigan's Coastal Wetlands. Michigan Department of Natural Resources, Lansing, MI. 209 pp.

Keddy, P.A. and A.A. Reznicek, 1982. The role of seed banks in the persistence of Ontario's coastal plain flora. American Journal of Botany. 69:13-22.

Lyon, J.G., 1981. The influence of Lake Michigan water levels on wetland soils and distribution of plants in the Straits of Mackinac, Michigan. Doc. Diss., Univ. Michigan, Ann Arbor, Michigan.

Lyon, J.G., R.D. Drobney and C.E. Olson, Jr., 1986. Effects of Lake Michigan water levels on wetland soil chemistry and distribution of plants in the Straits of Mackinac. J. Great Lakes Res. 12:175-183.

Martin, D.B., L.J. Mengel, J.F. Novotny and C.H. Walburg, 1981. Spring and summer water levels in a Missouri River reservoir: effects on age-0 fish and zooplankton. Trans. Amer. Fish. Soc. 110: 370-381.

Mitchell, R.S. 1986. A Check List of New York State Plants. Bulletin No. 458, New York State Museum, Albany, N.Y. 272pp.

Nelson, W.R., 1978. Implications of water management in Lake Oahe for the spawning success of coolwater fishes. Am. Fish. Soc. Spe. Publ. 11: 154-158.

Painter, S. and P. Keddy, 1992. Effects of water level regulation on shoreline marshes: a predictive model applied to the Great Lakes. NWRI, Environment Canada, July 1992. 15 pp.

Payne, F.C., J.L. Schuette, J.E. Schaeffer, J.B. Lisiecki, D.P. Regalbuto, & P.S. Rogers, 1985. Evaluation of marsh losses: Maisou Island complex. Prep for: Wildl. Div., Michigan Dep. Ntrl. Resources. 67 pp plus appendices.

Stephenson, T.D., 1988. Fish utilization of Toronto area coastal marshes. M.Sc. thesis, Dept. of Zoology, University of Toronto, Toronto, Ontario.

Reed, P. B., Jr., 1988a. National list of plant species that occur in wetlands: North East (Region 1). U.S. Fish and Wildlife Service Biological Report 88(26.1).

Reed, P. B., Jr., 1988b. National list of plant species that occur in wetlands: North Central (Region 3). U.S. Fish and Wildlife Service Biological Report 88(26.3).

Scott, W.B. and E.J. Crossman, 1973. Freshwater fishes of Canada. Bulletin 184, Fish. Res. Board Can. xi + 966 pp.

Sousa, W.P., 1979. Disturbance in Marine Intertidal boulder fields: the non-equilibrium maintenance of species diversity. Ecology, Vol. 66: 1225-1239.

Sousa, W.P., 1980. The responses of a community to disturbance: the importance of successional age and species life histories. Oceologia, Vol. 45: 72-81.

Strange, R.J., W.B. Kittrell, and T.D. Broadbent, 1982. Effects of seeding reservoir fluctuation zones on young-of-the-year black bass and associated species. N. Amer. J. Fish. Mgmt. 2: 307-315.

Thomas, A.G. and J.M. Stewart, 1969. The effect of different water depths on the growth of wild rice. Can.J.Bot. 47:1525-1531

Thompson, T. A., Fraser, G. S. and Hester, N. C., 1991. Lake-level variation in southern Lake Michigan: magnitude and timing of fluctuations over the past 4,000 years. Illinois-Indiana Sea Grant Program IL-IN-SG-R-91-2.

Voss, E. G., 1972. Michigan flora, part I gymnosperms and monocots. Cranbrook Institute of Science Bulletin 55. Bloomfield Hills, MI.

Voss, E. G., 1985. Michigan flora, part II dicots. Cranbrook Institute of Science Bulletin 59. Bloomfield Hills, MI.

Wilcox, D. A., 1988. Responses of selected Great Lakes wetlands to water level fluctuations. Appendix B in Busch, W.-D. N., Kavetsky, R., and McCullough, G. Water level Criteria for Great Lakes wetlands. IJC Water Levels Reference Functional Group 2.

Williams, D. and J.G. Lyon, 1991. Use of a geographic information system data base to measure and evaluate wetland changes in the St. Marys River, Michigan. Hydrobiologia 219: 83-95.

8.0 CRISES CONDITION TASK GROUP (WC2 AND WC3)

8.1 Introduction

The Crisis Condition Task Group (a joint Task Group of Working Committee 2 and Working Committee 3) was responsible for developing an overall crises response plan for the Great Lakes - St. Lawrence River Basin, which would see implementation of a number of short-term measures to alleviate extreme water level situations. The development of this plan involved a number of tasks, including the determination of "threshold" water levels at which shoreline interests would begin to suffer major adverse impacts, and the examination of a series of both engineering measures, as well as "land based" responses, such as emergency evacuation and flood protection plans. Members of Working Committee 2 had key responsibility for carrying out a number of these tasks. These responsibilities are summarized very briefly below. For a more complete description of the tasks carried out and their results, the reader is referred to the reports of Working Committee 3 and the Crisis Conditions Task Group, both of which are available under separate cover.

8.2 Determination of Threshold Limits For A Crisis

8.2.1 Overview

The Task Group was assigned the mission of developing a set of crisis "threshold limits" (both high and low) for the Great Lakes - St. Lawrence River system; that is, threshold water levels which could signify crisis conditions for which effective emergency measures should be considered and implemented. Crisis threshold limits are defined as those water levels (either high or low) beyond which major damages begin to occur as a result of the magnitude of levels or flows. As major impacts are predicted at these levels, they are extremes that are not wanted to be reached or exceeded. Damages however, could start occurring prior to these levels being reached.

8.2.2 Static Water Levels

In the determination of static water level thresholds, consideration was given to defining high and low water values for each interest. It was quickly discovered however, that there was not enough information presently available to do this. As such, the Task Group decided to have one high and low threshold per lake, with such thresholds taking into consideration the possible impacts on all interest groups.

To determine the static threshold limits, a number of information sources were used. These included the International Joint Commission Orders of Approval, reports of damage elevations of past storm and extreme water level events, low water datum, or chart datum levels, the Basis of Comparison's 5% and 95% exceedence probability net basin supply condition levels, knowledge of the needs of the various interest groups and overall knowledge of the Great Lakes - St. Lawrence River system. The threshold limits determined for each lake and the St. Lawrence River are found in Table 8.1.

Table 8.1 Static Water Level Threshold Limits - Great Lakes - St. Lawrence River (All Levels in Feet (IGLD 1955)

LAKE	HIGH THRESHOLD	LOW THRESHOLD
Lake Superior	601.5	599.0
Lake Michigan-Huron	580.5	576.8
Lake St. Clair	576.2	572.6
Lake Erie	572.5	569.0
Lake Ontario	246.7	242.7
St. Lawrence River		
Ogdensburg	246.8	241.8
Cardinal	246.8	240.3
Iroquois (Above)	246.3	239.5
Morrisburg	244.7	238.2
Long Sault Dam	244.4	237.5
Point Claire	73.0	66.5
Montreal	27.9	18.0
Sorel	18.0 (May to October) 18.7 Nov. to April	12.2

Notes: -Feet x 0.305 = Metres
-Please Refer to Crisis Conditions Task Group Report For Rationale Behind Level Selections.

8.2.3 Storm Threshold Levels

The derivation of storm threshold limits was less straightforward. Local shoreline conditions, weather patterns and other site specific conditions can cause great variations in the level of water required to cause damage along even small sections of shoreline. In light of this, it was not possible to generate new storm threshold levels for the lakes. Instead, the Task Group conducted a review of previously determined storm "critical levels" for the Canadian shoreline. These levels were established by Environment Canada and took into account the physiography of the shoreline, as well as wind speeds and directions that would be needed to usually produce the given level. Using these critical levels as a starting point, along with previously collected storm water level and damage data, a very crude analysis was conducted to determine where, relative to these threshold limits, damage began to be reported. Results, which should be interpreted cautiously, indicate that the majority of damages seem to occur when critical water levels were exceeded by 15 cm (6 inches) or more. On Lake Erie, damages seem to become serious when critical levels are exceeded by 25 cm (9.8 inches), and on Lakes Huron (including Georgian Bay) and Lake St. Clair, by 10 cm (4 inches) (Note: For a listing of the critical levels, refer to the Crisis Condition Task Group Report).

To investigate the adequacy of these critical levels further, a more thorough analysis of threshold limits was undertaken by correlating newspaper reports of flood events between 1847-1991 with the recorded peak, maximum instantaneous water level (where available) for the date of the flood event (see The Water Network, 1991; Gabriel and Kreutzwiser, 1992; and Kreutzwiser and Gabriel, 1992). Using this data, threshold limits were calculated for each of the water level gauges examined. These limits were found to be somewhat conservative when compared to the critical levels set by Environment Canada, being much lower than the established values.

As a result of the above, it was felt that the critical water levels established by Environment Canada are adequate at this point for use as storm threshold limits. Further research should be undertaken to determine more precise storm threshold limits along these areas of the Canadian shoreline.

There was no analysis of storm thresholds for the United States shoreline. There was also a lack of information available on short-term, or "storm" low water level (i.e. set-down or seiche) damage and frequency. The Task Group was thus unable to set any threshold limits for this category of water level change.

8.3 Inventory and Evaluation of Extreme Water Level Crisis Condition Response Measures

8.3.1 Overview

A wide variety of short-term actions that could alleviate the consequences of extreme high or low water levels in the Great Lakes - St. Lawrence River system were reviewed for possible incorporation into an "Emergency Operations Plan" for responding to crisis conditions. These measures included hydraulic measures, which moderate water levels, and land side measures that provide protection and allow people to deal with the adverse impacts of extreme levels. The types of actions and measures considered were those which could be implemented quickly in order to have maximum effect during the crisis, and then be discontinued when the crisis is over.

8.3.2 Hydraulic Responses

A total of 29 potential hydraulic crisis measures were reviewed. These included such measures as modification of the existing regulation plans during extreme high or low conditions, manipulation of the diversions into, out of, and between the lakes, increases and decreases in the capacity of the connecting channels, weather modification and possible new diversions. Of these 29 potential measures, a smaller group of more promising measures was selected for detailed review. These were then evaluated and a set of measures selected for consideration and implementation.

The hydraulic measures selected for consideration in an overall Emergency Operations Plan were:

- A series of controlled changes from the flows generated by the Lake Superior and Lake Ontario Regulation Plans to respond to extreme water levels;
- Manipulation of three major Great Lakes diversions.
    - Decrease Long Lac and Ogoki diversion into Lake Superior
    - Increase Lake Michigan diversion at Chicago
    - Vary the Welland Canal flows from Lake Erie;
- Placement of an ice boom at the head of the St. Clair River; and
- Increase Niagara River flows through the Black Rock Lock.

Details on the hydrologic and hydraulic impacts, the costs to implement and the institutional considerations for each of these measures can be found in the Crisis Condition Task Group Report.

8.3.3 Land Based Responses

A total of 23 land based measures were chosen by the Task Group for evaluation. Of these short-term measures, twelve were identified as high water response measures, nine as low water response measures and two applicable to both high and low water. These land side measures are not designed to alleviate the actual crisis water levels, but are designed to help shoreline interests alleviate any adverse consequence of the crisis levels. In many cases, communities or various levels of government already have these measures, or at least the mechanisms for them in place. The land based measures considered for evaluation included emergency sandbagging, development of emergency response plans, storm forecasting, consumptive use regulations, disaster assistance, technical assistance and financial assistance programs for shore protection, temporary land and water use restrictions, temporary relocation, emergency dredging, power demand management and public education to name a few. Information was then collected on interest's past experiences with these measures (see Leadlay, 1992 for example) and this information was then used in the evaluation process.

The land based measures selected for consideration in an overall Emergency Operations Plan included:

High Water

- Development of Emergency Preparedness Plans;
- Monitoring of storm and water level conditions;
- Construction of community based shore protection structures;
- Technical and financial assistance for community based shore protection;
- Emergency sandbagging;
- Emergency beach nourishment; and
- Public information and the education of shoreline interests.

Low Water

- Emergency dredging procedures;
- Extension and adaptation of water intakes;
- Provision of emergency water supplies; and
- Public information and the education of shoreline interests.

Details on the impacts, the costs to implement and the institutional considerations for each of these measures can be found in the Crisis Condition Task Group Report.

Of the 23 land based measures examined, there are a number that would not be particularly suited to a crisis response situation. These are primarily the "regulatory" measures of "temporary relocation of buildings", "acquisition of hazard land and property", and "structural relocation and removal." While these may apply to a limited degree in a crisis (e.g. trailers could be moved), they are viewed more as long-term planning measures and should be utilized as such. "Drought assistance programs" for agriculture are another measure not suited to crisis conditions, as there is no direct relationship between a crisis low water level and crop losses to agriculture. Finally, "power demand management" should not be considered, as it may be difficult to draft and reach agreement on appropriate regulations to be implemented in times of a crisis.

8.4 Formulation of A Great Lakes - St. Lawrence River Crisis Condition Management Plan

The measures recommended above were then packaged into an overall "Action Plan" which provided a "stand-alone" discussion of the benefits, disbenefits, costs, impacts and institutional facilitators and barriers of each measure. A recommended series of "alert" water levels and "action" or trigger levels were also provided for each measure in the Action Plan. These are the water levels that, if reached, would initiate the implementation of specific crisis response measures. The alert level would serve notice that a crisis condition is impending and that preparations should be made to implement a crisis response. The action level is the level at which the measure would actually be initiated.

It should be noted that while equity in treatment of interests and regions was a guiding principle, the crises actions included in the Action Plan will not necessarily be considered acceptable to all of the interests affected. This may especially be the case for the hydraulic measures, which, to moderate extreme levels, re-distribute water within and out of the system in ways that re-distribute benefits.

Further details on the Crisis Condition Action Plan can be found in the Crisis Condition Task group Report.

REFERENCES

Gabriel, A. and Kreutzwiser, R., 1992. Identification of High Water Storm Thresholds For Property Damage. Report Prepared For the Crisis Conditions Task Group, Working Committee 2 and 3, Phase II, IJC Levels Reference Study.

Kreutzwiser, R. and Gabriel, A., 1992. Ontario's Great Lakes Flood History. Journal of Great Lakes Research, Vol.18, No.1:194-198.

Leadlay, H., 1992. A Study of High and Low Water Emergency Contingency Plans in the Great lakes Basin. Co-Op Work Term Report, University of Waterloo, Department of Geography, Prepared For the Crisis Condition Task Group, Working Committee 2 and 3, Phase II, IJC Levels Reference Study.

The Water Network, 1991. A Report on Ontario Flood History. Report Prepared For The Ontario Ministry of Natural Resources.

9.0 A SUMMARY OF KEY FINDINGS

9.1 Introduction

The tasks carried out by Working Committee 2 over the course of this Reference Study were very comprehensive in nature. The preceding sections have describeD these tasks and their results. The following section will provide a concise summary of this work, the results and key findings. To fully appreciate and understand the tasks that were conducted, the reader is also encouraged to review the final reports of the various task groups and the consulting reports that were prepared.

9.2 Erosion Processes Task Group

The Erosion Processes Task Group developed a comprehensive mapping and classification scheme and characterized Great Lake-St. Lawrence River shorelines according to a number of criteria, including: the geomorphic origin; the composition of the sub-aqueous (underwater) portion of the shoreline profile; and the extent to which shorelines are protected by structures. For the overall Great Lakes - St. Lawrence River basin, results indicate that bedrock shorelines predominate, comprising over 45% of the Canadian and over 30% of the U.S. shoreline. Sandy shorelines are next, making up over 18% of the Canadian and 28% of the U.S. shoreline. Wetlands occupy approximately 10% of the Canadian and 15% of the U.S. shoreline, while cohesive shorelines comprise approximately 6% of the Canadian and 10% of the U.S. shoreline. The majority of both shorelines (over 70% in both cases) is not protected. Only 7.2% of the Canadian and 8.4% of the U.S. shoreline was classed as heavily protected, primarily in highly developed residential or industrial areas. The remainder of the shoreline was protected primarily with minor amounts of protection (9% in Canada and 15% in the U.S.). The nearshore classification tended to parallel that of the geomorphic classification with bedrock predominating, followed closely by sandy areas. However, a large amount of the shoreline could not be classified for this criterion, as data was not available.

The classification results, combined with an evaluation of the impact of water level changes on erosion rates of specific shore types, and the development of an erosion sensitivity index and expert system, helped in predicting the impacts of long-term and short-term water level fluctuations on erosion rates and processes. Generally, it was predicted that approximately 32% of the Canadian and 29% of the U.S. Great Lakes shoreline (excluding connecting channels and the St. Lawrence River) would experience some type of erosion reduction, or benefit, as a result of compressing the range of water levels, with the remainder of the shore either experiencing no erosion, or no reduction in erosion. In general, these benefits would be greatest on Lake Erie, where over 70% of the Canadian shoreline and 32% of the U.S shoreline would experience an erosion benefit, and on Lake Michigan, where over 42% of the shoreline would experience a benefit.

All of the studies undertaken on erosion utilized existing historic recession rate data which was available for a limited number of shore types. This information was not consistent between states and provinces and was only rarely based on long-term monitoring of the shoreline. Although the recession rate data was adequate to complete the tasks required, a comprehensive recession rate database that included periodic (monthly, yearly) investigations and measurements of recession rates and profiles for all shore types would have permitted a more thorough evaluation of the relationship between water levels and erosion.

Similarly, a more comprehensive database on the nearshore composition of the Great Lakes shoreline would have allowed more precise definitions to be put forth in that level of the classification scheme. Given the importance of nearshore erosion in the overall process of shoreline retreat, efforts should be put forth to gather this information, particularly for the upper lakes where very little data currently exists.

The erosion studies determined that a portion of recession for some shoreline types is affected by water level changes. While recession is reduced for some shore types as a result of a compressed water level range, it is not reduced for others. This has significant implications for the use of traditional erosion stage-damage curves, which imply a direct relationship between water levels and erosion damage. It is possible that the stage-damage curve approach may not adequately estimate the impact of still water level changes on erosion damage. Further work, such as that conducted by the Potential Damages Task Group for three sites, is clearly needed to compare these two approaches and to determine the most accurate way of reporting potential erosion damages.

Information generated in the erosion evaluation studies was stored in a Geographic Information System database. This will allow easy identification of the most "erosion susceptible" shorelines of the Great Lakes - St. Lawrence River basin and will allow shoreline managers easy access to comprehensive shore classification and recession information. Every effort should be made to keep the GIS database up to date, to integrate it with other relevant databases (such as land use) and to share it with other government and private sector shoreline researchers.

9.3 Social Impacts Task Group

The Social Impacts Task Group completed a survey of riparians along the shorelines of the Great Lakes and the Ontario and Quebec portions of the St. Lawrence River, as well as a survey of Native North Americans who live along the shoreline. The task group undertook a thorough analysis of these survey results and has developed and tested a number of different hypotheses. The task group has also reviewed and analyzed Phase I reports on the commercial/industrial, agriculture, commercial fishing, and municipal interest groups to extract relevant information for use in impact and measures evaluation.

The surveys indicate that erosion is the most common problem reported by all riparians on the shoreline of the Great Lakes and the St. Lawrence River (59%-U.S; 57%-Canada; 66%-Natives), while considerably fewer have experienced flooding (20%-U.S.; 28%-Canada; 44%-Natives). Storms combined with high water were seen as the main cause of both flooding and erosion by Ontario and U.S. respondents. In Quebec, high water levels only and ship wake were identified as the main cause of flood and erosion, while Native communities felt storms were the main cause. It was also found that there was only a relatively small difference in reported incidence of damage between riparians living on regulated lakes and those living on unregulated lakes.

High water levels and erosion were the primary reasons given by respondents for actions taken. The most frequently reported actions were the protection of property with some form of shore protection device.

No single measure stands out as being the most preferred among respondents. The most preferred by U.S. respondents was to provide tax credits for building shoreline protection followed by the construction of dams to regulate water levels. Construction of dams was also most preferred by Ontario respondents, as well as both Canadian and U.S. respondents living along Lake Erie and Lake St. Clair. Native communities in the United States preferred that governments provide grants to individuals for shore protection, while most Quebec respondents preferred that the government construct shoreline protection to save their property.

Previous studies indicate that municipalities view erosion as a major problem, that commercial and industrial facilities have some degree of tolerance to level changes, that agricultural lands are primarily impacted when dykes are overtopped, and that commercial fishing suffers primarily from low water problems such as restricted access to docking and unloading facilities.

9.4 Potential Damages Task Group

The Potential Damage Task Group employed a number of techniques in order to develop estimates of damages to shoreline interests as a result of fluctuating water levels and as a result of measures that might be implemented to reduce the ranges in these fluctuations. Existing stage-damage curves for flooding and erosion were updated for inflation and to incorporate other data that may have changed between 1979-1992. In addition, a risk analysis approach that defined upper and lower thresholds for flood damage was undertaken. This gave a range of water levels within which researchers could be confident damages would occur.

A series of detailed site studies were also undertaken to obtain site specific information on damages. Thirteen site studies were initiated and the information gathered provided a substantial increase in the understanding of specific problems for specific interests. In addition, information at three sites provided data to compare and contrast results of existing stage-damage curves with new information gathered by the Erosion Processes Task Group on the erosion sensitivity of shorelines to a reduced water level range.

In applying these updated curves and the data collected from the site studies, to both existing and possible future water level scenarios, it was found that no one regulation plan proposed was able to eliminate all flood damages on all reaches of the Great Lakes - St. Lawrence River shoreline. In addition, all of the seven 5-Lake and four 3-Lake plans evaluated resulted in a partial shift or redistribution of the benefits and impacts of fluctuating levels and flows. The 5-Lake plan that provided the greatest compression in water level range, "SMHEO-50", was found to decrease average annual flood and erosion damages by 25% on Lakes Michigan, Huron, St. Clair and Erie, but would increase Lake Ontario and St. Lawrence River damages by 45%.

Similarly, the 3-Lake plan that provided the greatest reduction in water levels, SEO Extended, resulted in flooding and erosion damage reduction on Lakes Superior, Michigan, Huron, St. Clair and Erie, but flooding and erosion increases on Lake Ontario and the St. Lawrence River and increased costs of shore protection on Lake Superior.

The Task Group also explored issues related to shoreline protection and found that expenditures for protection of riparian properties between 1985-1987 amounted to over $68 million on the U.S. shoreline and between $25-$34 million on the Canadian shoreline. Examinations were also undertaken to determine the future shore protection costs that could be avoided with reduced water level range scenarios in place. Initial results indicate that savings under a number of the regulation plans may be significant, for example, over $340 million in savings being associated with the SMHEO-50 regulation plan and $330 million associated with the 1.18 SEO 3-Lake regulation plan.

9.5 Land Use and Shoreline Management Task Group

The Land Use and Shoreline Management Task Group reviewed and assessed a number of shoreline management practices in place throughout the Great Lakes - St. Lawrence River basin to determine those that have been successful in preventing and minimizing flooding and erosion damages. Included here was a review of practices such as land acquisition, infrastructure adaptation and regulation of property use in hazard areas. Part of this effort involved developing common terminology, and a working definition for Great Lakes "shoreline management."

Of the measures examined, setback and floodproofing requirements were shown to be very effective in reducing damages, particularly in undeveloped areas. They can also be effectively applied in developed areas, usually when lots are redeveloped, or in combination with other measures such as dwelling relocation. Acquisition or relocation of properties and structures was also considered as an effective measure, but would only be justifiable in areas where significant infrastructure is at risk, or where shoreline areas exhibit unique shoreline characteristics or habitat. Further investigation should be undertaken to determine the feasibility of acquiring such areas.

Shore protection was also an effective measure, but only when it has been properly designed and built in a manner that considers potential negative impacts on adjacent and downdrift property. Tax incentives and deed disclosure measures were found to be limited in their extent, and where applied, not very effective. Similarly, implementation mechanisms, such as loans and grants, have had limited effectiveness as they have been primarily used for the construction of protection and not for other possible measures like relocation.

It should be stressed that, unlike lake level regulation, which has direct impact along the entire shoreline, shoreline management alternatives must be evaluated and undertaken in concert and harmony with unique site specific conditions. Many of the results that have been presented in this document are based on experience with specific measures and mechanisms at unique locations along the shoreline. Lake-wide or basin-wide extrapolation of these results should be undertaken with caution and with an understanding of the limits on the data.

It should also be emphasized that the installation or application of any measure can not be done in isolation. A water level regulation measure which alters the water level regime will not eliminate damage due to storms. Other land use remedial and preventative measures will still be necessary. Land use measures themselves should be implemented in a coordinated fashion according to the local situation. Remedial measures might be best suited for developed areas where the shoreline or existing structure needs to be altered or modified to alleviate problems. Preventative measures are more appropriate for undeveloped areas, where it is still possible to prevent future damages by controlling the type and degree of development along the shoreline.

It must be realized that no single land use measure will be appropriate in every situation around the Basin. The measures highlighted here, must be applied according to the individual situation and problems of the local area. These measures should be considered as a set of "tools" available to shoreline agencies for use in their management of the Great Lakes - St. Lawrence River shoreline.

Analysis of land use by the Land Use Task Group found that the general trend in the basin over the last several decades has been a general and often rapid increase in shoreline development (primarily residential) at the expense of natural areas (forests and wetlands). Loss of agricultural land to support this development has also occurred. Examinations of future trends found that this increase in development will continue, but that some land will be converted into recreational, as opposed to residential uses.

The land use database produced in this Reference Study is extensive but not fully integrated. The land use information for the U.S. shoreline has been fully digitized in a GIS. The land use for the Canadian shoreline is in a mix of GIS and spreadsheet formats, which in its present form provides useful static land use information. The land use data contained in the Canadian Coastal Zone Database and GIS has not been standardized or integrated. A fully operational GIS database would allow 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. Combinations of a land use database with others identifying erosion or flood hazard zones will allow rapid identification of present and potential hazard areas, allowing a better estimation of potential flood or erosion damages.

9.6 Natural Resources Task Group

The Natural Resources Task Group conducted a number of studies to determine the impacts of fluctuating water levels on wetlands, fish and water quality in the Great Lakes - St. Lawrence River basin. Wetlands were documented and mapped and the impacts of reduced ranges in water level fluctuations on selected wetlands were assesses. It was also determined how fluctuations in the flows of the St. Lawrence River affected wetland vegetation. Results of these studies found that changes in wetland and wetland plant community characteristics are directly correlated with long term water level fluctuations on the Great Lakes, their connecting channels, and on the St. Lawrence River. Plant communities at elevations that are flooded periodically each ten to twenty years and dewatered for two successive years between floods have the greatest diversity of wetland vegetation. A model of wetland area changes that occur in response to level changes also indicated that fluctuations are indeed important to the maintenance of the current extent of coastal marshes, which support waterfowl, fish, mammals, and other animals.

The studies on how past regulation regimes have affected wetlands on Lake Ontario and the St. Lawrence River indicate that reduction of the water level fluctuation ranges on Lake Ontario have had a significant negative effect on the extent, diversity, and integrity of wetlands on its shores, and that water level regulation has caused losses of floodplain forests along the St. Lawrence from flooding and erosion.

Analysis of the majority of water level regulation scenarios put forth for evaluation found that it would be impossible to avoid adverse impacts to wetlands should the scenarios be implemented. In most cases the negative impacts would be a reduction in the diversity of wetland plant types and decreases in the area of wetland vegetation.

Studies of the effects of water level fluctuations on fish suggest that water level is a critical element in fish reproduction and maintenance of populations. Minor differences in elevation at critical times of the year can have major influences on reproductive success. Fish reproduction is also apparently dependent upon the existence of dynamic processes. Northern pike spawning success is improved by rising water levels.

Individual studies conducted by the Natural Resources Task Group made use of available data or collected new data during a very short time period. Short-term studies that attempt to assess long-term processes cannot provide complete insight into the interactions between water level changes and the various aspects of the Great Lakes and St. Lawrence River system. Natural and human resource management and protection strategies based on short-term studies risk error because data taken during fluctuation events are not available. The Reference Study has made clear the need for **long-term** evaluation, e.g. monitoring studies, of the effects of lake-level changes on many features of the Great Lakes community.

Long-term evaluations are needed on individual representative wetlands on each of the Great Lakes and at sites along the St. Lawrence River through at least one cycle of high lake levels, low lake levels, and return to high levels, in order to better understand diversity and area issues.

A better understanding of how water level changes affect bathymetry through erosion and accretion in wetland areas will also be important. A comprehensive wetland inventory for the entire basin needs to be completed so that accurate estimations can be made of the total area of wetlands at risk to future changes in natural water level regimes. Finally, means need to be developed to better calibrate and verify rates of change in wetland community types at sites throughout the Great Lakes-St. Lawrence Basin. This would provide more confidence in the accuracy of the predictions provided by conceptual modelling exercises.

To gain an understanding of the natural cycles in water level change to which wetland evolution has responded, sedimentological studies are needed on all lakes to provide lake level histories of several thousand years, similar to that which has been produced for Lake Michigan. Coupled with continuous studies of the many features of the Great Lakes system, including wetlands, this information could result in a more realistic view of the options available for management of the shoreline of the Great Lakes.

9.7 Crisis Conditions Task Group

The Crisis Condition Task Group developed an overall crises response plan for the Great Lakes - St. Lawrence River Basin, which would see implementation of a number of short-term measures to alleviate extreme water level situations. As a component of this plan, the Task Group determined a series of "threshold" water levels at which shoreline interests would begin to suffer major adverse impacts and examined both engineering measures, as well as "land based" responses, such as emergency evacuation and flood protection plans.

The hydraulic and land-based measures recommended were then packaged into an overall "Action Plan" which provided a "stand-alone" discussion of the benefits, disbenefits, costs, impacts and institutional facilitators and barriers of each measure. A recommended series of "alert" water levels and "action" or trigger levels were also provided for each measure in the Action Plan. These are the water levels that, if reached, would initiate the implementation of specific crisis response measures. The alert level would serve notice that a crisis condition is impending and that preparations should be made to implement a crisis response. The action level is the level at which the measure would actually be initiated.

It should be noted that while equity in treatment of interests and regions was a guiding principle, the crises actions included in the Action Plan will not necessarily be considered acceptable to all of the interests affected. This may especially be the case for the hydraulic measures, which, to moderate extreme levels, re-distribute water within and out of the system in ways that re-distribute impacts. Further investigation into the short-term impacts of these actions should be a priority before the action is put in place.

There are also a number of institutional considerations that need to be addressed to implement the crisis response measures recommended. Examples include obtaining the necessary authority to deviate flows from Lake Superior or Ontario, or to flow more water through the Chicago diversion or the Welland Canal. These considerations need to be adequately addressed before the crisis response recommended can be of benefit.

APPENDIX I

LIST OF WORKING COMMITTEE 2 AND TASK GROUP MEMBERS

WORKING COMMITTEE 2

Canadian Section

Co-Chair

Ralph Moulton
Water Planning & Management Branch
Environment Canada
867 Lakeshore Road, P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4580
FAX (416) 336-6250

Members:

Stan Taylor
Essex Region Conservation Authority
360 Fairview Ave., W.
Essex, ON N8M 1Y6
(519) 776-5209
FAX (519) 776-8688

Janet Planck
Great Lakes Environment Office
867 Lakeshore Rd.,P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-6284
FAX (416) 336-6250

Daniel Waltz
Ministère de l"Environnement
5199 Sherbrooke Street East
Office 3860
Montréal, QC H1T 3X2
(514) 873-2899
FAX (514) 873-7501

Laurie Maynard
Canadian Wildlife Service
70 Fountain Street East
Guelph, ON N1H 3N6
(519) 766-1593
FAX (519) 766-1750

United States Section

Co-Chair

Donald L. Hey
Wetlands Research, Inc.
53 W. Jackson Boulevard, Suite 1401
Chicago, IL 60604
(312) 922-0777
FAX (312) 922-1823

Joan Pope, Chief
Coastal Structures and Evaluation ranch
Coastal Engineering Research Center
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199
(601) 634-3034
FAX (601) 634-3080

Terry Yonker
Great Lakes United Inc.
State University College at Buffalo
Cassety Hall, 1300 Elmwood Ave.,
Buffalo, NY 14222
(716) 886-0142
FAX (716) 886-0303

William Wiesmueller
N2455 Cardinal Lane
P.O. Box 558
Oostburg, WI 53070-0558
(414) 564-3759
FAX (414) 564-2737

Roger Gauthier
U.S. Army Corps of Engineers-Detroit District
477 Michigan Avenue, Box 1027
Detroit, MI 48231-1027
(313) 226-3054
FAX (313) 226-2398

Chris Stewart
Water Planning & Management Branch
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4582
FAX (416) 336-6250

Wes MacLeod
Fisheries and Habitat Mgmt.
Bayfield Institute
Department of Fisheries and Oceans
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4522
FAX (416) 336-4819

Scott Painter
Rivers Research Br., N.W.R.I.
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4641
FAX (416) 336-6430

Michelle Nicolson
Water Planning & Managment
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4551
FAX (416) 336-6250

Senator William VanRegenmorter
Michigan State Senate
Farnum Bldg. Room 405
P.O. Box 30036
Lansing, MI 48909
(517) 373-6920
FAX (517) 373-2751

John Gannon
National Fisheries Center-Great Lakes
1451 Green Road
Ann Arbor, MI 48105
(313) 994-3331
FAX (313) 994-3331 (Voice Contact)

Doug Wilcox
National Fisheries Center-Great Lakes
1451 Green Road
Ann Arbor, MI 48105
(313) 994-3331
FAX (313) 994-3331 (Voice Contact)

John Kangas
U.S. Army Corps of Engineers-N.C.D.
111 North Canal St.
Chicago, IL 60606-7205
(312) 353-6364
FAX (312) 886-1205

Citizens Advisory Committee Members:

Edith Fuller
66 Unity Rd. W.
Caledonia, ON N0A 1A0
(416) 765-2420
FAX (416) 765-2420 Voice Contact

Joe Milauckas
Int. G.L. Coalition
2885 Lakeshore Drive
Saugatuck, MI 49453
(616) 857-4656
FAX (616) 857-2606

Coordinator:

Wendy Leger
Water Planning & Management Branch
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4630
FAX (416) 336-6250

Study Board Liaison:

Maurice Lewis, Director
Engineering Branch
Ontario Ministry of Natural Resources
99 Wellesley St.W.,Whitney Block Rm. 5620
Toronto, ON M7A 1W3
(416) 314-2391
FAX (416) 314-2427

Fred Brown
488 W. Ashby Rd., Rt. 5
Midland, MI 48640
(517) 835-9625

Corresponding Members:

Francis Boudreau
Environnement Quebec
2360 Chemin Ste-Foy
Ste-Foy, QC G1V 4H2
(418) 643-5397
FAX (418) 646-6169

Oscar J. Dittrich
Dittrich Engineering Inc.
1041 E. Circle Drive
Whitefish Bay, WI 53217
(414) 962-9040

Glenda Daniels
Executive Director
Lake Michigan Federation
59 East Van Buren St., Suite 2215
Chicago, IL 60605
(312)939-0838
FAX (312) 939-2708

Martin Jannereth
Michigan DNR
530 West Allegan, Box 30028
Lansing, MI 48909 (48933 for courier)
(517) 373-1950
FAX (517) 373-9965

George Stafford
New York State Dept. of State
162 Washington Ave.
Albany, NY 12231
(518) 474-3643
FAX (518) 473-2464

R. Kerry Kehoe
Coastal States Organization
Suite 312, 444 N. Capitol St.,N.W.
Washington, D.C. 20001
(202) 508-3860
FAX (202) 508-3843

EROSION PROCESSES TASK GROUP

United States Section

Co-Chair

Joan Pope
Coastal Structures and Evaluation
Coastal Engineering Research Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
(601) 634-3034
FAX (601) 634-3080

Members

Joe Milauckas
International Great Lakes Coalition
2885 Lakeshore Drive
Saugatuck, MI 49453
(616) 857-4656
FAX (616) 857-2606

Roger Gauthier
U.S. Army Corps of Engineers
Detroit District
477 Michigan Avenue, 6th. Floor
Detroit, MI 48231-1027
(313) 226-3054
FAX (313) 226-2398

Canadian Section

Co-Chair

Chris Stewart
Water Planning & Management Branch
Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4582
FAX (416) 336-6250

Members

Ralph Moulton
Water Planning & Management Branch
Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4580
FAX (416) 336-6250

Consultants

John Fisher
Geomatics International
3370 South Service Road
Burlington, Ontario L7N 3M6
(416) 632-4259
FAX (416) 333-0798

Dr. Rob Nairn
316 Maple Avenue
Oakville, Ontario L6J 2H7
(416) 845-5385
FAX (416) 845-0698

Dr. Robin Davidson-Arnott
Department of Geography
Unversity of Guelph
Guelph, Ontario N1G 2W1
(519) 824-4120 Ext 3011
FAX (519) 837-2940

Bill Baird
W.F. Baird & Associates Coastal Engineers
38 Antares Drive, Suite 150
Ottawa, Ontario K2E 7V2
(613) 225-6560
FAX (613) 225-59

Technical Support

Andrew Morang
USAE Waterways Experiment Station
Coastal Engineering Research Center
Prototype Measurement & Analysis Branch
P.O. Box 631
Vicksburg, MS 39180-0631
(601) 634-2064
FAX (601) 634-3080

Charles Thompson
U.S. Army Corps of Engineers
Detroit District
477 Michigan Ave., 6th. Floor
Detroit, MI 48231-1027
(313) 226-6792
FAX (313) 226-2398

Heidi Pfeiffer
U.S. Army Corps of Engineers
Chicago District
111 North Canal St.
Chicago, IL 60606
(312) 353-6517

Tom Bender
U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, NY 14207
(716) 879-4238

SOCIAL IMPACTS TASK GROUP

United States Section

Gary Nelson
U.S. Army Corps of Engineers
St. Paul District
1335 USPO & Custom House
St.Paul, MN 55101-1479
(612) 290-2256
FAX (612) 220-0251

Terry Yonker
Michigan State Audubon Society
6011 West St.Joseph Hwy., Suite 403
P.O. Box 80527
Lansing, MI 48908-0527
(517) 886-9144
FAX (517) 886-9466

Joe Milauckas
International Great Lakes Coalition
2885 Lakeshore Drive
Saugatuck, MI 49453
(616) 857-4656
FAX (616) 857-2606

Canadian Section

Wendy Leger
Water Planning & Mgt. Branch
867 Lakeshore Rd.,P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4630
FAX (416) 336-6250

Scott Duff
Ecologistics Limited
490 Dutton Drive, Suite A1
Waterloo, Ontario N2L 6H7
(519) 886-0520
FAX (519) 888-7864

Reid Kreutzwiser
Department of Geography
University of Guelph
Guelph, Ontario N1G 2W1
(519) 824-4120
FAX (519) 837-2940

Daniel Waltz
Minstère de l'Environnement
5199 Sherbrooke Street East
Office 3860
Montréal, QC H1T 3X2
(514) 873-2899
FAX (514) 873-7501

POTENTIAL DAMAGES TASK GROUP

United States Section

Co-Chair

John Kangas
U.S. Army Corps of Engineers - N.C.D.
111 North Canal Street
Chicago, IL 60606-7205
(312) 353-6364
FAX (312) 886-1205

Members

Roger Gauthier
U.S. Army Corps of Engineers-Detr.Dist.
477 Michigan Avenue
Detroit, MI 48231-1027
(313) 226-3054
FAX (313) 226-2398

Joan Pope
Coastal Structures and Evaluation
Coastal Engineering Research Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
(601) 634-3034
FAX (601) 634-3080

Robert Ozanne
P.O. Box 463
Two Rivers, WI 54241-0463
(414) 755-4013

Rao Yalamanchili
U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, NY 14207

Consultants

Carl Argiroff, C.A. Inc.
34143 Coventry
Livonia, MI 48154-2614
(313) 422-8106
FAX (313) 422-8106 Voice Contact First

Canadian Section

Co-Chair

Chris Stewart
Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4582
FAX (416) 336-6250

Members

Ralph Moulton
Water Planning & Mgt.Br.- Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4580
FAX (416) 336-6250

Stan Taylor
Essex Region Conservation Authority
360 Fairview Avenue West
Essex, Ontario N8M 1Y6
(519) 776-5209
FAX (519) 776-8688

Consultants

G.Bryant, Marshall Macklin Monaghan
80 Commerce Valley Drive, East
Thornhill, Ontario L3T 7N4
(416) 882-1100
FAX (416) 882-0055

A. Harrington, Paragon Engineering Limited
871 Victoria St. North, Suite 300
Kitchener, Ontario N2B 3S4
(519) 579-4410
FAX (519) 579-6733

Dr. P.Parker, Department of Geography
University of Waterloo
Waterloo, Ontario N2L 3G1
(519) 885-1211 Ext. 3610
FAX (519) 746-0658

LAND USE AND SHORELINE MANAGEMENT TASK GROUP

United States Section

Co-Chair

Roger Gauthier
U.S. Army Corps of Engineers
Detroit District
477 Michigan Avenue
Detroit, MI 48231-1027
(313) 226-3054
FAX (313) 226-2398

Members

Bill Wiesmueller
Great Lakes Coalition
N2455 Cardinal Lane
P.O. Box 558
Oostburg, WI 53070-0558
(414) 564-3759
FAX (414) 564-2737

George Stafford
New York State Department of State
162 Washington Avenue
New York, NY 12231
(518) 474-3643
FAX (518) 473-2464

Kerry Kehoe
Coastal States Organization
444 N. Capitol Street N.W.
Suite 312
Washington, D.C. 30001
(202) 508-3860
FAX (202) 508-3843

Thomas Crane
Great Lakes Commission
The Argus II Building
400-4th. Street
Ann Arbor, MI 48103-4816
(313) 665-9135
FAX (313) 665-4370

Canadian Section

Co-Chair

Stan Taylor
Essex Region Conservation Authority
360 Fairview Ave., West
Essex, Ontario N8M 1Y6
(519) 776-5209
FAX (519) 776-8688

Members

Chris Stewart
Water Planning & Management Branch
Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4582
FAX (416) 336-6250

Edith Fuller
66 Unity Rd., West
Caledonia, Ontario N0A 1A0
(416) 765-2420
FAX (416) 765-2420 Voice Contact First

Consultants

Ray Tufgar
Triton Engineering Services Ltd.
385 Fairway Rd., South, Suite 200
Kitchener, Ontario N2C 2N9
(519) 748-1285
FAX (519) 894-5082

Scott Duff
Ecologistics Limited
490 Dutton Drive, Suite 1A
Waterloo, Ontario N2L 6H7
(519) 886-0520
FAX (519) 888-7864

Reid Kreutzwiser
Department of Geography
University of Guelph
Guelph, Ontario N1G 2W1
(519) 824-4120

NATURAL RESOURCES TASK GROUP

United States Section

Co-Chair

Bill Wiesmueller
Great Lakes Coalition
N2455 Cardinal Lane
P.O. Box 558
Oostburg, WI 53070-0558
(414) 564-3759

Members

Terry Yonker
Michigan Audubon Society
6011 West St.Joseph Hwy.,Suite 403
P.O. Box 80527
(517) 886-9144
FAX (517) 886-9466

Doug Wilcox
U.S. Fish and Wildlife Service
National Fisheries Center-Great Lakes
1451 Green Road
Ann Arbor, MI 48105
(313) 994-3331
FAX (313) 994-3331 (Voice Contact)

John Gannon
U.S. Fish and Wildlife Service
National Fisheries Center-Great Lakes
1451 Green Road
Ann Arbor, MI 48105
(313) 994-3331
FAX (313) 994-3331 (Voice Contact)

Don Williams
U.S. Army Corps of Engineers
North Central Division-Policy and
Long Range Planning
111 North Canal Street
Chicago, IL 60606-7205
(312) 886-5470
FAX (312) 886-1205

Canadian Section

Co-Chair

Janet Planck
Great Lakes Environment Office
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-6284
FAX (416) 336-6250

Members

Daniel Waltz
Ministère de d'Environnement
5199 Sherbrooke Street East
Office 3860
Montéal, Québec H1T 3X2
(514) 873-2899
FAX (514) 873-7501

Laurie Maynard
Canadian Wildlife Service
70 Fountain Street East
Guelph, Ontario N1H 3N6
(519) 766-1593
FAX (519) 766-1750

Wes MacLeod
Fisheries and Habitat Mgt.,
Bayfield Institute-Dept of Fisheries and Oceans
867 Lakeshore Rd.,P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4522
FAX (416) 336-4819

Scott Painter
Rivers Research Branch - NWRI
Environment Canada
867 Lakeshore Rd.,P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4789
FAX (416) 336-6430

Michelle Nicolson
G.L. Water Level Communications Centre
Water Planning and Management Branch
867 Lakeshore Rd., P.O. Box 5050
Burlington, ON L7R 4A6
(416) 336-4551
FAX (416) 336-6250

CRISES CONDITION TASK GROUP

United States Section

Ronald Wilshaw
U.S. Army Corps of Engineers-Detroit Distr.
477 Michigan Avenue
Detroit, MI 48231-1027
(313) 226-6440
FAX (313) 226-2056

Phil Gersten
U.S. Army Corps of Engineers-Detroit Distr.
477 Michigan Avenue
Detroit, MI 48231-1027
(313) 226-2394
FAX (313) 226-2056

John Kangas
U.S. Army Corps of Engineers-N.C.D.
111 North Canal Street
Chicago, IL 60606-7206
(312) 353-6364
FAX (312) 886-1205

Anthony Eberhardt
U.S. Army Corps of Engineers-Buffalo Distr.
1776 Niagara Street
Buffalo, NY 14207
(716) 879-4257 (FTS 292-4257)
FAX (716) 879-4426

Deborah Lee
G.L.Environmental Research Laboratory-NOAA
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-1593
(313) 668-2148
FAX (313) 668-2055

Dan Injerd
Illinois Dept of Transportation-Div.of Water
310 S. Michigan Ave., Room 1606
Chicago, IL 60604
(312) 793-3123
FAX (312) 793-5968

Canadian Section

David Fay
Great Lakes-St. Lawrence Office
Suite 232, Lionel Chevrier Bldg.
111 Water Street, East
Cornwall, Ontario K6H 6S2
(613) 938-5725
FAX (613) 938-1924

Andre Carpentier
Ministere de l'Environnement de Quebec
2360 Chemin Ste-Foy
Ste-Foy, QC G1V 4H2
(418) 644-3430
FAX (418) 643-6900

Rob Fox, Flood Coordinator
Aviation, Flood and Fire Mgt. Br.
Ontario Ministry of Natural Resources
70 Foster Drive, Suite 400
Sault Ste.Marie, ON P6A 6V5

Working Committee 2 Members

Scott Thieme
U.S. Army Corps of Engineers
Detroit District
477 Michigan Avenue, P.O. Box 1027
Detroit, MI 48231-1027
(313) 226-3054
FAX (313) 226-2398

Chris Stewart
Water Planning & Management Branch
Environment Canada
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 336-4582
FAX (416) 336-6250

APPENDIX II

GLOSSARY

WORKING COMMITTEE 2

GLOSSARY OF KEY TERMS

Accretion -	The volumetric addition of material to the shoreline.
Aeolian - **(or Eolian)**	Created, shaped or transported by wind.
Anthropogenic -	Of, relating to, or influenced by the impact of humans on nature.
Average (or Expected) Annual Damages -	Total dollar value of expected damages that would occur due to flooding, extreme low water or erosion, divided by the number of years included in the period of time studied.
Aquatic Habitat -	The physical, chemical and biological components of a species underwater environment.
Barrier Beach -	Refers to a single elongate sand ridge rising slightly above the waterline and extending generally parallel with the coast, but separated from it by a small bay, or body of water.
Barriers and Facilitators -	Institutional arrangements, including legislation, governmental authorities, etc., which would either preclude or assist in the implementation of a selected shoreline management practice.
Base Maps -	Maps covering a specific site or lake system used to depict information on coastal characteristics and land use information. They typically include shorelines, political boundaries, transportation networks and tributary rivers and creeks.
Bathymetry -	The measurement of depths in the oceans, seas and lakes; also information derived from such measurements.
Breakwater -	An offshore structure protecting a shore area, harbor, anchorage, or basin from waves.
Census -	A complete enumeration of the population - in this case a complete enumeration of all living along the shoreline of the Great Lakes and connecting channels.
Climate Change -	A long-term change in the climate due to a perturbation on the global climate system.

Cohesive -	Unconsolidated material which is held together primarily by electrical charges on the soil particles rather than by intergranular friction.
Competition -	The negative effects that one organism has upon another by consuming or controlling access to a resource that is limited in availability.
Competitive - Dominant	A species that suppresses others by consuming or controlling access to resources.
Conservation - Authorities	A series of watershed based agencies in Ontario responsible for floodplain and shoreline management issues within their defined watershed.
Contour -	A line on a map or chart representing points of equal elevation.
Cross-Shore - Modelling	A coastal engineering technique that utilizes computer modelling to examine and model the natural coastal processes that occur "across" the shore zone, e.g. waves, water level changes, on-offshore currents.
Current -	The flowing of water in the lakes; can be generated by wind, waves, seiches and tides (oceans).
Datum -	Horizontal plane to which surroundings, ground elevations or water surface elevations are referred.
Demographic -	Relating to the statistical study and dynamic balance of human populations.
Detailed Site - Study	The investigation of selected locations to gather information on flooding, low water and erosion impacts of natural and potentially regulated lake levels.
Dewatered -	Water levels lowered to expose soils or sediments previously flooded.
Digitized -	Information on paper maps that has been electronically encoded into a computer based mapping system or Geographic Information System.
Downcutting -	Erosion of that portion of the shore profile (lake bed) that is underwater (i.e.beneath the surf zone or area of breaking waves).
Dunes -	A low hill, ridge, or bank of sand created by wind action.
Dykes -	A wall, or earth mound built around low lying areas to prevent flooding.
Dynamic - Equilibrium	The state whereby a shoreline is actively eroding or accreting, but maintains its overall geometric form.

Ecosystem -	A community of interdependent organisms (living beings) together with the environment in which they inhabit, with which they interact; it is not defined by the size, but rather by its homogeneity.
Electronic - Planimeter	An instrument for measuring the area of a plane figure by tracing its boundary line.
Erosion -	The wearing away of the shoreline and lake or river bed by the action of waves, currents and other natural processes.
Erosion Sensitivity -	The predicted "recession" response of various shoreline types as a result of a change in water level elevation.
Erosion Sensitivity - Index	A ranking given to each of the shore types on the Great Lakes to represent it's erosion sensitivity.
Equilibrium Profile -	A shore profile that has reached it's preferred or natural shape.
Fetch -	The distance of water over which waves are generated by a wind having a generally constant speed and direction.
Final / Climax - Community	The gradual process of development that occurs within an ecosystem.
Fish Spawning - Habitat	A site where eggs are deposited and fry are produced.
Fish Nursery - Habitat	A site where young-of-the-year fish congregate.
Floristics -	A branch of biology / ecology that deals numerically with plants and plant groups.
Fluctuation, - Water Level	A period of rise (or fall) and succeeding period of decline (or rise) of water level; can occur seasonally, over a period of years, or decades, and in the short-term as a result of periodic events such as storms, surges, ice jams, etc.
Forbs -	Herbaceous plants other than grasses.
Gabion -	A cage, or wire enclosure, commonly filled with rock, and used in the construction of shoreline protection, or slope stabilization.
Geographic - Information System	Computer systems for storing, analyzing and presenting basic geographical information.

Geomorphology -	The field of earth science that studies the origin and distribution of landforms, with special emphasis on the nature of erosional processes.
Geo-referencing -	The assigning of specific latitude and longitude coordinates to places, features, buildings, etc., commonly done when entering information into Geographic Information Systems.
Groyne -	A shore protection structure built out at an angle from the shoreline to trap sand and to protect the shore from erosion by currents and waves by making a beach.
Gully, Gullies -	Deep V-Shaped trenches carved by newly formed streams, or groundwater action.
Habitat Mapping -	An activity based on a variety of survey and inventory techniques whereby boundaries are drawn around areas with homogeneous habitat characteristics.
Hazard Areas -	Those areas along the shoreline where past flooding, erosion and wave impact have occurred, or where flooding, erosion and wave impact may occur in the future.
Herbaceous - Vegetation	Submerged and emerged plants, which will include a layer permanently flooded and a layer that may be exposed. The permanently inundated, or hydrophytic layer, is composed of a variety of vegetation, including submerged and floating aquatic plants (e.g. water lilies) and emergent plants (e.g. cattails and pickerelweed).
Hydrodynamics -	A branch of science that deals with the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.
Hypothesis -	A tentative assumption made in order to draw out and test its logical or empirical consequences.
International - Great Lakes Datum	A reference elevation from which water levels are measured and recorded.
Inundation -	Flooding
Inundation Flow - Damage Curves	Graph developed by plotting anticipated flood elevations against amount of damages expected at those elevations.
Isopleth -	A line on a map connecting points at which a given variable has a specified constant value.

Lag Deposit -	Residual accumulations of coarser particles from which the finer material has been blown away.
Land Use -	The past, existing or future human uses and environmental conditions of the shorelines of the Great Lakes - St. Lawrence River system.
Land Use - Patterns	The distribution of land uses within a political unit, generally by township / county in the U.S. and by county or Conservation Authority in Canada.
Land Use Trends -	The change in land use distribution in a political unit, determined by comparing past land use patterns to existing conditions, or by projecting existing or anticipated shoreline development into the future.
Littoral -	Pertaining to or along the shore, particularly to describe currents, deposits and drift.
Littoral Drift - (Longshore Transport)	The movement of sediment along beaches and in the nearshore zone by the prevailing currents and oblique waves.
Littoral Zone -	An indefinite zone extending seaward from the shoreline to just beyond the breaker zone.
Macrophyte Bed -	A site supporting a concentration of rooted aquatic plants.
Marsh -	A portion of a wetland that is permanently flooded; often includes a zone which is periodically flooded. Typified by herbaceous vegetation.
Model, Computer -	A series of equations and mathematical terms based on physical laws and statistical theories that simulate natural processes.
Model, Physical -	A scaled-down version of a shoreline area or feature, commonly assembled and constructed in a laboratory setting, which can be subjected to "real" coastal processes such as waves and water level changes (also appropriately scaled-down).
Natural Resource -	Element of an ecosystem which is of use to humans.
Nutrient -	An element used (consumed) by plants to grow, found in simple or complex forms such as calcium or nitrogen in soil.
Old-Field Plants -	Upland plants typically found in abandoned, formerly cultivated fields.
100 Year Flood - Limit (Elevation)	The elevation or mapped line where flooding occurs on average once in every 100 years.

100 Year Erosion - Limit (Line)	The inland extent of erosion or recession that may be expected 100 years in the future, based upon historic recession rates, shoreline characteristics, land uses and protective structures.
Organism -	A living being (plant, animal or human).
Plant Community -	Grouping of plants forming a structural cluster living in the same environmental (ecological) conditions.
Potential Damage -	The amount (in dollars) or type of flood, erosion or low water damage anticipated or expected to occur in the future under natural or modified water level regimes.
Profile - Beach Profile	The cross-sectional shape of the beach and nearshore zone.
Profile Response - (Beach Profile Response)	Changes in the cross-sectional shape of the beach and nearshore zone as a result of waves, currents, water levels changes and tides.
Reach -	A length of shore with fairly uniform onshore and offshore physiographic features and subject to the same wave dynamics.
Reach Study -	The investigation of existing conditions within a reach to update existing stage-damage curves, to estimate increases in shoreline development, and to collect information on the costs of shore protection measures.
Recession -	A landward retreat of the shoreline due to the removal of shoreline materials by natural processes.
Reef -	An elevated area of firm lake bottom having sharp relief, consisting of submerged bedrock outcrops and / or boulders, cobbles and gravels.
Resource -	What is available for means of growing plants, such as soil, humus, water, nutrients, and sunlight.
Riparian -	Related to, or living, or located on the bank of a natural watercourse. In this study, generally applied to all those individuals owning shoreline property on the Lakes or connecting channels.
Scaled Grid - Square Sheets	A paper, or transparent overlay used for calculating areas of polygons on map sheets.
Seiche -	An oscillation in water level from one end of a lake to another due to wind or atmospheric pressure.

Set-Up, Wave -	Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.
Set-Up, Wind -	The vertical rise in the still water level on the leeward side of a body of water caused by wind stresses on the surface of the water.
Shoal -	Similar to reefs, but with low relief.
Species Richness -	Number of species occurring in a specified area.
Stage-Damage - Curve	See Inundation-Damage Curve.
Stage-Frequency - Curves	Graph developed by plotting a range of flood water elevations against the frequency with which they occur.
Statistically - Significant	A phrase used to indicate that the quantitative relationship between two variables (e.g. location on the lakes and incidences of low water) are positively related and that the relationship discovered in the sample has not arisen by chance. Commonly, relationships between variables that occur more than 95% of the time are said to be statistically significant.
Stratigraphy -	The vertical variation in unconsolidated material or rock at a given location.
Subaerial -	Situated, formed or occurring on or adjacent to the surface of the earth.
Subaqueous -	Existing, formed or taking place in or underwater.
Succession -	The gradual process of ecosystem development occurring when new species become established, when species already present are destroyed, or when both occur simultaneously. In wetlands, this is a cyclic process and does not result in a final or climax community.
Survey -	In this study, a series of questions regarding fluctuating water levels posed to a representative sample of shoreline property owners (riparians).
Swamp -	An area which is saturated with water much of the time, but the soil surface is not deeply submerged; generally seasonally flooded; dominated by woody plants, namely trees and shrubs.
Turbulence -	An irregular movement of a fluid, characterized by randomness.
Uncertainty - Analysis	Analysis of stage-damage curves that involves the definition of upper and lower bounds of potential damages (i.e. the development of a range of potential damages.

Water Level - Regulation Scenarios	A combination of lake levels and connecting channel flows that would result from restricting or increasing water flows at existing or potential control structures.
Wave -	An oscillatory movement in a body of water which results in an alternate rise and fall of the surface (see attached figure).
Wave Climate -	The nature (height, period, length) and type of waves occurring at a particular location along the shoreline.
Wave Hindcasting -	The use of historic wind data to calculate wave conditions that probably occurred in the past.
Wave Run-Up -	The rush of water up a structure or a beach upon the breaking of a wave.
Wetland -	Land having the water table at, near, or above the land surface, or which is saturated for a long enough period to promote wetland or aquatic processes.
Zero Damage - Elevation	The water level elevation at which damage to structures or contents begins to occur.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—747-730


N