The Ecological Evaluation of Lake Superior Regulation Plans for the International Upper Great Lakes Levels Study

A Strategy Document for IPR Review
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Summary

The key goal of the International Upper Great Lakes Study is to formulate and evaluate options to improve the rules for regulating levels on Lake Superior. The constant interplay of highly variable and largely unpredictable lake level fluctuations with the various emerging and growing uses of the Great Lakes system has created a complex decision process that necessarily must consider balancing the equitable distribution of benefits and costs amongst the various users and the needs of the natural system. Creating an evaluation and decision making framework that will enhance and explicate Board decisions in an open and transparent manner, and which readily encompasses public inputs is a challenging endeavor. To achieve that goal, the Study Board has developed a systematic framework for evaluation which was outlined in an earlier document – Shared Vision Planning [Bill get the proper reference]. The evaluation framework, of necessity, focuses on an accounting of the social, economic and ecological benefits and costs of each of the regulation options, and their distribution across the four lakes of the upper Great lakes system.

Ecological evaluation is a very important component of the IUIGLS, yet it may be the most difficult aspect of the IUIGLS Board and TWG analysis, simply because the available data, models and basic theory relating lake level changes to ecosystem productivity and integrity is relatively underdeveloped. Furthermore, the anticipated changes and differences among the various plans that will be formulated and evaluated are likely small enough that the uncertainties in the basic ecological data and performance metrics created to differentiate between various plans and their outcomes will probably overwhelm those distinctions. Finally, protection of the ecosystem of the Great Lakes is not formally part of the Treaty structure, as far as water level management is concerned (restrictions of Article VIII of the Treaty), even though water quality concerns have been elevated over the past three decades. So, any evaluation framework must accommodate the ‘second class’ status of ecosystem needs with respect to all the explicitly specified uses in the 1909 Treaty. This will become especially relevant when tradeoff choices have to be made among the various water-using sectors and geographic areas.

Invasive species, coupled with progressive water quality degradation, have undoubtedly caused more harm to the current ecosystem than any combination of lake level regulation options could ever impose on the system. So, it will be difficult to unravel the relative effects of water level fluctuations versus invasive species and water quality degradation from thousands of sources around the lakes, and attribute specific impacts solely to water level fluctuations – such is the state of the art. Nevertheless, it is important to try to develop a reasonable evaluation framework that captures the specific relationships between water levels and ecosystem productivity, as best we can, in order to determine what those changes might be, especially during the anticipated scenarios of climate change, so that management options,
including adaptive management can be employed to monitor those changes in a targeted manner.

Based on preliminary analyses of prospective regulation plans, it is likely that the physical water level changes under the new regulation plan(s) recommended by the Study Board will not be much different from the current regulation plan, which in itself is not much different from ‘no regulation’, which is nearly equivalent to a natural system state (accounting for connecting channel modifications over the past 100 years). There is always uncertainty in predicting the consequences of one plan or another, over an extended time horizon of 30-50 years. One of the realities that the Board will face, for both economic and environmental evaluation is that, given the relatively small differences in average lake level elevations between plans (measured in centimeters), it may be that the errors in the most sophisticated and exhaustive estimation of ecological impacts are likely to be greater than the differences between the actual ecological consequences of any two plans. An exhaustive assessment would require a data collection and modeling effort that would cost far more and take far longer than the budget and schedule for this study.

The crux of the evaluation framework is to directly relate lake level fluctuations and critical threshold levels to ecological productivity and ecosystem integrity. This is accomplished through the use of ‘performance indicators’ (PI’s), which uses conventional ecological information and metrics routinely used for traditional environmental impact analysis. These PIs are then used to compare and evaluate the relative performance of the various indicator species for each plan, and compared with changes in each economic sector (hydropower, commercial navigation, recreational boating, etc.) under the range of historical and anticipated lake level fluctuations – across all sectors and lakes.

The evaluation framework that the Study Board has designed should be sufficient for a comparative (relative) evaluation and ranking of plans, even if the absolute magnitude of the impacts is in doubt. Furthermore, there are qualitative factors to consider in any evaluation, dealing with the equitable distribution of impacts, benefits and costs, across all sectors and geographic areas. The Study Board has undertaken a ‘representative site analysis’ approach, for all of the sectors, including the environment, which selects key areas around the lakes that most clearly reflect the range of valued ecological activities and can serve as proxies for those ecosystems and biomes. There simply is not enough time or money to collect data at all sites where there could be significant impacts. However, the Environmental Technical Working Group went through a thorough process, with considerable input from a large number of researchers to help select those key representative areas. The Board has chosen to enlist expert opinion to identify sites where different regulation plans are most likely to have different consequences, and then using an incremental process to explore more sophisticated analysis.

The Study Board must also consider how well regulation plans would work and how the plans might have to change if future water supply to the lakes were substantially different from the patterns seen in the last 150 years or so that supplies have been measured and recorded. There is considerable evidence to support that possibility, both because of natural climate variability.
and climate change caused by carbon emissions. The effort to estimate ecologic impacts under
the recent climate also helps the Board conceptualize what issues it would face, and what
research and monitoring would be required if water levels rose higher or fell lower or sustained
levels longer than any period for which impact data has been collected. The Board recognizes
that the large uncertainties engendered by climate variability and change would require an
‘adaptive management’ plan to explicitly deal with those uncertainties. This report presents a
preliminary proposal for peer review to support the Board’s design process.
# Table of Contents

Summary ..................................................................................................................................................  iii


1. Introduction .......................................................................................................................................... 1

  1.1 Overview: The Boundary Waters Treaty and the IJC ................................................................. 1

  1.2 The Larger Planning Context ....................................................................................................... 2

  1.3 Geographic Study Area ................................................................................................................ 3

  1.4 Recent IJC Levels Studies .......................................................................................................... 4

2. Plan Evaluation .................................................................................................................................... 8

  2.1 Factors driving the evaluation process design .............................................................................. 8

    2.1.1 Overall Study Process Guidelines ...................................................................................... 10

    2.1.2 Lake Superior Plan Evaluation Guidelines ......................................................................... 10

    2.1.3 Long-Term Management Guidelines ................................................................................ 11

  2.2 Site Studies ..................................................................................................................................... 11

  2.3 Contextual Narratives ................................................................................................................ 12

  2.4 Risk and Uncertainty .................................................................................................................. 12

    2.4.1 The importance of adaptation to manage risk .................................................................. 12

    2.4.2 Uncertainties and risks ...................................................................................................... 13

3. Impact Assessments ........................................................................................................................ 16

  3.1 Interest Categories ....................................................................................................................... 16

  3.2 Economic Advisors ..................................................................................................................... 17

  3.3 Recent Board Decisions Affecting Impact Assessments ............................................................. 17

4. Ecosystem Impacts .......................................................................................................................... 19


  4.2. Internal assessment of the analysis: probably adequate ......................................................... 20

  4.3 Context ........................................................................................................................................ 21

    4.3.1. Human Health ................................................................................................................... 22

    4.3.2. Wetlands .......................................................................................................................... 22

    4.3.3 Invasive Species ................................................................................................................ 23

    4.3.4. Contamination ................................................................................................................ 23

    4.3.5 Biotic Communities ......................................................................................................... 23

    4.3.6 Coastal Zones and Aquatic Habitat ............................................................................... 24
ESG7.2 Substitution Effects and Adaptive Behaviour ................................................................. 64
ESG7.3 Erosion of Undeveloped Land and Beach Accretion .................................................. 65
ESG7.4. Seasonal Electricity Power Prices .................................................................................. 66
ESG7.5 Value of Peaking .............................................................................................................. 66
ESG7.6 Economic Valuation of Environmental Benefits ............................................................ 66
ESG.7.7 Social Impacts .................................................................................................................. 67
References ...................................................................................................................................... 69

Figures

FIGURE 1 THE GEOGRAPHIC STUDY AREA .................................................................................. 3
FIGURE 2 SIMULATED TIME SERIES OF LAKE SUPERIOR LEVELS, UNREGULATED AND AS THEY ARE REGULATED NOW
(HISTORICAL WATER SUPPLIES) .............................................................................................. 7
FIGURE 3 SIMULATED TIME SERIES OF LAKES MICHIGAN-HURON LEVELS, CURRENT AND NO REGULATION,
HISTORICAL WATER SUPPLIES.................................................................................................. 7
FIGURE 4 RELATIONAL DIAGRAM OF IUGLS EVALUATION FRAMEWORK ............................................. 9
FIGURE 5 LOSL STUDY BOARD SCREENING FACTORS ........................................................................ 9
FIGURE 6 GREAT LAKES US UNEMPLOYMENT, DECEMBER 2008 (NY TIMES BASED ON BUREAU OF LABOR
STATISTICS) ................................................................................................................................ 16
FIGURE 7 COMPARISON OF CHESAPEAKE BAY AND LAKE SUPERIOR AREAS .................................. 25
FIGURE 8 LONG-TERM CLIMATE CYCLES FOR LAKE ST. CLAIR ...................................................... 26
FIGURE 9 LANDSCAPE FEATURES THAT CANNOT ADAPT TO DIFFERENT WATER LEVEL REGIMES .......... 33
FIGURE 10 HYPOTHETICAL RESPONSE OF ECOSYSTEM TO CHANGES IN MAGNITUDE, TIMING (SEASONALITY), AND
DURATION IN RESPONSE TO CHANGES IN WATER LEVEL REGIME .............................................. 35
FIGURE 11 PLANT ZONATION IN OPEN COASTAL (FRINGING) WETLANDS ASSOCIATED WITH LARGE LAKES AND
SUBJECT TO WAVE ENERGY AND NATURAL WATER LEVEL VARIABILITY (FROM UZARSKI IN PRESS) .......... 37

Tables

TABLE 1 DIMENSIONS OF THE GREAT LAKES BASIN ........................................................................ 4
TABLE 2 DESCRIPTION OF BIOLOGICAL CONDITION (DAVIES AND JACKSON 2006; BAIN 2007) ..................... 29
TABLE 3 SUMMARY OF ECOLOGICAL COMPONENTS AND PERFORMANCE INDICATORS ................... 31
TABLE 4 POTENTIAL STUDY SITES IDENTIFIED IN THE ETWG WHITE PAPER .................................. 42
TABLE 5 PERFORMANCE INDICATORS ............................................................................................. 44
TABLE 6 SEQUENCING OF ADAPTIVE MANAGEMENT TASKS ............................................................. 55

The IJC issued a directive to the Upper Great Lakes Study Board under the signatures of its U.S. and Canadian secretaries, approved in principle December 13, 2005 and signed February 7, 2007. It is available at http://www.iugls.org/en/mandate/Mandate_directive.htm. The first two of fifteen sections of that text deals with the substance of what the IJC asks the Board to do and is copied below, with selective emboldening added to the sections most relevant to this paper.

1. “Pursuant to the Boundary Waters Treaty of 1909 (Treaty), the International Joint Commission has an ongoing responsibility for assuring that projects it has approved continue to operate in a manner that is consistent with the provisions of the Treaty as interpreted by the Commission and the governments of Canada and the United States (governments). In carrying out this responsibility, the Commission has prepared and submitted to the governments The Upper Lakes Plan of Study for the Review of the Regulation of Outflows from Lake Superior (Plan of Study), dated October, 2005. The Plan of Study describes the work for the Upper Great Lakes system from Lake Superior downstream through Lake Erie required to: examine physical processes and possible ongoing St. Clair River changes and its impacts on levels of Lake Michigan and Huron; review the operation of structures controlling Lake Superior outflow in relation to impacts of such operations on water levels and flows, and consequently affected interests; assess the need for changes in the Orders or regulation plan to meet the contemporary and emerging needs, interests, and preferences for managing the system in a sustainable manner, including under climate change scenarios; and evaluate any options identified to improve the operating rules and criteria governing Lake Superior Outflow regulation. Additionally, depending on the nature and extent of St. Clair River changes and impacts, recommend and evaluate potential remedial options. In reviewing the Order and Regulation plan, and in assessing their impacts on affected interests, the Commission will be seeking to benefit these interests and the system as a whole, consistent with the requirements of the Treaty.”

2. “This directive establishes the International Upper Great Lakes Study Board (Study Board). The mandate of the Study Board is to undertake the studies required to provide the Commission with the information it needs to evaluate options for regulating levels and flows in the Upper Great Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty, and the Board shall be guided by this mandate in pursuing its studies. These studies include:

   a. examine physical processes and possible ongoing St. Clair River changes and its impacts on levels of Lake Michigan and Huron. Additionally, depending on the nature and extent of St. Clair River changes and impacts, recommend and evaluate potential remedial options;
b. **review the operation of structures controlling Lake Superior outflow in relation to impacts of such operations on water levels and flows, and consequently affected interests;**

c. **assess whether changes to the Order or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner; and**

d. **evaluate any options identified to improve the operating rules and criteria governing the system.**

The Study Board shall provide options and recommendations for the Commission’s consideration. In carrying out this mandate, the Study Board is encouraged to integrate as many relevant considerations and perspectives into its work as possible, including those that have not been incorporated to date in assessments of The Upper Great Lakes System regulation, to assure that all significant issues are adequately addressed.”

So, the fundamental purpose of the Study is to develop and evaluate a set of alternative regulation plans that improves on the current regulation Plan 77-A. The crux of the matter is what does ‘improves’ mean? How does one decide whether a plan is better; what are the criteria by which this evaluation is conducted? Who decides on these evaluation criteria, and how can a new and ‘improved’ Plan be devised that is consistent with a fairly restrictive set of priority (‘order of precedence’) uses enumerated in Article VIII of the 1909 Treaty? The environment is not listed as a protected priority use in the Treaty, nor is the large recreational boating economy of the Great Lakes. Nevertheless, this study will be evaluating the economic and environmental contributions of every major water-using sector of the Great lakes, in order to better understand how lake levels affects the functioning and viability of each sector, and what their optimal conditions might be, and how they overlap.
Ecological Evaluation of Lake Superior Regulation Plans

Summary for Peer Review

1. Introduction

This document and the associated appendices will present the overall strategy and methods that will be used by the International Upper Great Lakes Study (IUGLS) for the International Joint Commission (IJC) to assess and consider the ecological implications of new sets of rules for regulating the release of water from Lake Superior. This is a companion piece to the Plan Formulation and Evaluation Strategy that was submitted for peer review in April, 2009 and a concurrent document on economic impacts. This summary is meant to help peer reviewers begin their task of assessing whether the Study Board will have appropriate metrics to evaluate the ecological response to alternative plans for the regulation of Lake Superior outflows.

The peer review process will be dynamic, and there will likely be additional papers needed as the process goes on. Chapter 4 of this document was written by Scudder Mackey, Project Manager for the Ecosystem Technical Working Group. Other parts of the report apply to the study in general, and were written by Bill Werick and Wendy Leger, the U.S. and Canadian leads for the Plan Evaluation Group (PEG), with review comments from leads of the technical working groups (TWGs) doing economic analysis including; Mike Shantz and Scott Thieme (Coastal), Paul King-Fisher and Steven Rose (Hydropower), Dave Wright and Ralph Moulton (Commercial Navigation), Bill Boik and Glenn Warren (Recreational Boating and Tourism), and Dick Bartz and Carol Salisbury (Municipal and Industrial Water Supply). Steven Renzetti (McMaster University) and John Hoehn (University of Michigan), economic advisors to IUGLS, reviewed the paper. Additional comments and review were provided by David Fay and Tony Eberhardt, the Canadian and U.S. leads for the Lake Superior Regulation Task Force and by Ted Yuzyk and Gene Stakhiv, Study co-Directors.

1.1 Overview: The Boundary Waters Treaty and the IJC

The International Joint Commission (IJC), a Canadian-US organization created by the Boundary Waters Treaty of 1909, approved the construction and regulates the operation of structures that control the flow of water from Lake Superior into the St. Marys River (IJC, 1914) and the waters of Lake Huron-Michigan. There is an analogous structure on the St. Lawrence River used to regulate releases from Lake Ontario and the IJC completed a study to develop alternative rules for its operation, the Lake Ontario St. Lawrence River (LOSL) Study, in 2006 (LOSL Study Board, 2006). The IJC established the IUGLS for two reasons; to update the Lake Superior regulation rules and to investigate whether physical changes in the St Clair River may have caused lower Lake Michigan/Huron levels (IJC, 2007). This strategy paper deals with only the rules for regulating Lake Superior releases. In 2005, the IJC directed the Board to review the operation of structures controlling Lake Superior outflow in relation to impacts of such operations on water levels and flows, and consequently affected interests; assess the need for changes in the regulation plan or Orders to meet the contemporary and emerging needs, interests, and preferences for managing the system in a sustainable manner, including considering climate change scenarios; and evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation.
One of the key aspects of this planning effort, which stands as a significant constraint are the rules and principles within the Boundary Waters Treaty (Article VIII) that specify the ‘order of precedence’ among the various users of the waters of the Great Lakes system.

“The following order of precedence shall be observed among the various uses enumerated hereinafter for these waters, and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence:

1. Uses for domestic and sanitary purposes;
2. Uses for navigation, including the service of canals for the purpose of navigation;
3. Uses for power and irrigation purposes

The foregoing provisions shall not apply to or disturb any existing uses of boundary waters on either side of the boundary.”

Hence, any of the new uses of the Great Lakes system that have emerged since the 1909 Treaty, such as, extensive recreational boating and shoreline recreation, or the growth in shoreline residences must be considered with the principal management objectives of the enumerated ‘order of precedence’ and pre-existing uses. This makes devising a new regulation plan for Lake Superior all the more difficult because any changes made in the plans cannot diminish the priority of uses and benefits currently enjoyed by those principal users – i.e. municipal and industrial water users; commercial navigation; hydropower and irrigation. This also requires interpretation of the extent of the pre-existing riparian uses and ecological needs for sustaining wetlands, fisheries etc. that may not have been fully recognized when previous orders of approval and regulation plans were implemented. However, previous orders of approval have recognized minimum flow requirements for the fish habitat management in the St Marys Rapids (Supplementary Order of Approval for Lake Superior 1985) and extended benefits to shore property owners (e.g. 1956 Supplementary Order of Approval for Lake Ontario).

A Regulation Plan simply codifies and quantifies, through a set of criteria and operating rules the management of lake levels to achieve the priority uses, while accommodating, to the extent possible, all the newly emergent uses and users. The regulation plans were last revised in 1979, and implemented in 1990. The order of precedence for the various purposes kicks in normally during extremely high levels and extreme low levels, as occurred recently, from 1999-2007. A set of specific operating rules are devised to ensure, to the physical extent possible, that the system is managed to deliver the services required for the priority users. For much of the time (90%), however, the management of lake levels adequately serves all the users. It is at the extremes that choices and tradeoffs must be made among the various users.

1.2 The Larger Planning Context

A review of the entire strategy for formulating, evaluating and ranking plans (“The Formulation and Evaluation of Lake Superior Regulation Plans for the International Upper Great Lakes Levels Study; A Strategy Document for Independent Peer Review”, April 2009) has been provided separately, and serves as the synthesis of the overall planning and evaluation strategy. That PFEG Peer Review paper explains the background and context for the economic analyses described in this document, including the IJC’s directives to the Study Board, the shared vision planning approach, the methods being used to formulate plans, public participation, the consideration of climate change by the Board, the ‘informed consent’ approach to refining Board evaluation principles and decision criteria and creating a sound, defensible and transparent decision, and the shared vision model. The Plan Formulation and Evaluation report discussed the difficulties of defining an evaluation paradigm for Lake Superior regulation plans.
First, any new regulation plan is expected to have a relatively small impact on water levels (smaller on Michigan-Huron than Superior, almost nothing on Lake Erie), making it difficult to quantitatively differentiate the impacts of the new plan from the existing one, simply because the information is coarse and the uncertainties surrounding projections of future economic activity are relatively large. Second, the ratio of study money to miles of shoreline is much less than it was for the LOSL study, making it impossible to replicate some of the detailed assessment methods used in the LOSL study to evaluate recreational boating, coastal, and ecological impacts. Other sampling methods and interpolation and extrapolation approaches have to be used to provide a reasonable basis for evaluating and comparing the relative effects and changes in each water-using sector for each alternative regulation plan that is devised to meet a certain set of management objectives.

1.3 Geographic Study Area

Figure 1 The Geographic Study Area
The study area is the Great Lakes drainage basin including lakes Superior, Michigan, Huron and Erie and the connecting channels up to Niagara Falls. The focus of assessment is on those areas and regions impacted by changes to the regulation of outflows from Lake Superior including almost 17,500 kilometres (10,900 miles) of shoreline. Impacts in the upper watersheds of these lakes are not generally studied because the impacts there from changes in the regulation plan are negligible. However, water supplies used to test the new regulation plan under climate change will include changes in runoff from the upper portions of the watersheds due to changes in precipitation.

### 1.4 Recent IJC Levels Studies

The “Great Lakes – St. Lawrence Basin Levels Reference Study” (1993) was one of the major studies that influenced the scope of the current IUGLS Study. The purpose of that study, conducted for the IJC, was...
to identify measures for alleviating adverse consequences of fluctuating water levels. It was the last comprehensive study of the entire Great Lakes related to water levels. It recommended the following actions (among 43 recommendations) specifically related to Lake Superior regulation:

- The Board recommends that the regulation plans of Lakes Superior and Ontario be modified to achieve water levels and flows similar to those described in Measure 1.21.
- The Board recommends that the Orders of Approval for the Regulation of Lake Superior be reviewed to determine if the current criteria are consistent with the current uses and needs of the users and interests of the system.
- The Board recommends that the International Lake Superior Board of Control be authorized to use its discretion in regulating the outflows from Lake Superior subject to conditions similar to those which authorize discretionary action by the International St. Lawrence River Board of Control.

Plan 1.21 is among the early plans formulated by the PFG, based on the recommendations of the “Levels Reference Study”. The second recommendation is also being addressed in the IUGLS Study, since the existing Orders of Approval may not be consistent with the current uses and needs of the interests (The 1914 order states “regulated so as to benefit navigation and reasonably protect the property and interests public and private...”, words which establish general intent but which are open to differing interpretation. The 1979 order explicitly recognizes environmental interests as well. The IUGLS Study mandate asks that other users be included as beneficiaries of any regulation options that would be developed, to include: recreational boating and tourism, environment/ecosystems and riparian landowners. Finally, the third recommendation addresses the option of allowing the Lake Superior Board of Control to deviate from the approved regulation plan when it believes that altered outflows would provide additional benefits to the interests without adverse impacts to others. The IJC granted the Board authority to make emergency deviations by letter of March 15, 2002, but not discretionary deviations like the St Lawrence Board. The IUGLS Board will be developing management options not only for new regulation plans and criteria, but also how to better deal with extreme high and low flow conditions, as well as appropriate institutional arrangements for exercising these discretionary choices.

The Study Board for the Lake Ontario-St. Lawrence River Study (2000-2006) offered three options for regulating Lake Ontario levels. The overall planning method used in that study is being used in the Superior regulation portion of IUGLS, and the hydrologic and climatologic studies conducted in that study produced the upper Great Lakes water supply sequences being used in the initial stages of IUGLS; they will be replaced later with updated supplies based on IUGLS research.

Although the regulation plan for lake Superior has been periodically adjusted and updated to reflect new data, conditions and users, and each time new ‘Orders of Approval’ have been formally approved by the IJC, it seems that soon after each revision, lake levels achieve new record highs and lows (as was the case in the recent decadal drought from 1999-2007). Each incremental adjustment to new data, public needs and new thresholds is a form of ‘autonomous adaptation’, while the demands of each water-using sector becomes increasing more stringent. Each new record high or low exposed the difficulties of managing such a large body of water where nature’s extremes – highs and lows – are virtually impossible to ‘control’ in any physical sense. All that can be done under those circumstances is to alleviate or slightly modify the worse adverse impacts for the water-using sectors. Figure 2 and Figure 3, page 7, show that regulation has a very modest, if not negligible effect on the extremes of the water levels spectrum.
**WATER LEVELS CHANGE VERY LITTLE BECAUSE OF WATER LEVEL REGULATION**

Figure 2 Simulated time series of Lake Superior levels, unregulated and as they are regulated now (historical water supplies)

The figure above shows that the current regulation of Lake Superior produces levels fairly similar to unregulated levels, unlike Lake Ontario, (not shown) where regulation has compressed natural variation significantly. Based on historical 20th century supplies, the average difference in plan levels is 6 cm, (about 2 inches). The maximum difference is 20 cm, or 8 inches.

Figure 3 Simulated time series of Lakes Michigan-Huron levels, current and no regulation, historical water supplies

The effect of the current regulation plan on Lakes Michigan-Huron compared to no regulation is even less because these levels are affected more by local runoff, precipitation and evaporation. Using 20th century supplies, the average difference between plans is 2 cm (an inch); the maximum difference is 10 cm (4 inches). The average difference on Lake Erie is 1 cm, and the maximum difference is 5 cm (2 inches).
2. Plan Evaluation

2.1 Factors driving the evaluation process design

The IUGLS Study Board is designing an evaluation framework based on the Study Directive and their perception of a reasonable (implementable) set of management goals for the upper Great Lakes. There is an active, dynamic effort to give stakeholders a voice in designing the framework and providing their views of preferred management objectives and regulation criteria. In addition, a broad range of expert advice from the participating federal and state agencies and academia and NGOs is employed to make sure the evaluation framework – i.e. the evaluation principles, management objectives and regulation criteria is defensible. Figure 4, next page, illustrates these relationships.

The overall goal is to create a sustainable management plan for Lake Superior releases. The concept of sustainability is difficult to define, but in this context it means that the Study Board wants to design a regulation plan that enhances and balances economic, environmental and social benefits, while minimizing the adverse impacts during extreme lake level events in the near and long term (over at least the next 30 years).

The shared vision planning process (SVP) is a rational analytic process that supports evaluation and decision making by simulating the impacts of alternative decisions using a uniform framework for analysis. There is always a difference between the simulated and real outcomes of a decision, but there are at least five factors that make uncertainty about the future greater than normal for this study. These include (1) economic and (2) environmental uncertainty, (3) available study resources, (4) the minimal impact of regulation on Lakes Michigan-Huron and Erie and (5) climate uncertainty. Because of these uncertainties, the Board is using a limited plan evaluation process and placing a greater emphasis on ‘adaptive management’ as a process designed to update information after the Study ends, and integrate the new information into operating decisions within a new regulation plan that, presumably, can be made to function in a more adaptive and flexible manner to accommodate the known uncertainties. The section on Forecasting, period of analysis, and discount rate (page 26) includes a more thorough discussion of uncertainty and the five factors. As part of the overall SVP, the IUGLS Study Board will define their concepts of sustainability, which in turn will comprise the set of evaluation and decision criteria they will employ in agreeing on preferred regulation plan options.

The SVP method includes a process for determining a collective set of decision criteria derived from the legislated responsibilities of each decision making participant and reflective of the public interest that would inform the execution of those responsibilities. The development of those criteria is linked dynamically to the model and research design so that the research and model will provide the information decision makers need and the decision will be transparent. In the LOSL study, for example, the shared vision model included a matrix (Figure 5) that showed the criteria individual study board members would use, and those criteria were hyperlinked to sections of the model that displayed performance indicators (such as economic benefits) for different alternative regulation plans, and those indicators were linked to study research used to develop the algorithms used in the model (Werick et al, 2008).
Figure 4 Relational diagram of IUGLS Evaluation Framework

Figure 5 LOSL Study Board Screening Factors
The IUGLS recommendation will likely guide the IJC’s choice of a new Lake Superior regulation plan, and the implementation of the new plan will have real economic, environmental and social impacts (presumably mostly benefits to all sectors). The IUGLS Study Board designed its evaluation process to predict, as much as possible, the real world implications of its decisions using management goals and criteria (see the initial set starting on page 10).

Among the functions of the PEG is to help guide the Study Board through the design and application of the decision making process. The first step was to develop a common understanding among the Study Board about the principal decisions and constraints that affect the formulation and evaluation of any new plan. The PEG interviewed each of the Study Board members to help articulate their expectations and to identify the factors each Board member would use in evaluating regulation plans. An initial set of decision guidelines have been developed to lay out a structure for the Study Board’s decision making for the Superior regulation tasks. Clear guidelines help the Board make better decisions and make the decisions more transparent to stakeholders. The initial guidelines, still under review by the Study Board, as they relate to the general study process and to the Lake Superior regulation component of the study are shown below. Clear guidelines also serve as the intellectual blueprint for all the members of the various technical working groups, as an aid to their own analytical endeavors and data collection efforts.

### 2.1.1 Overall Study Process Guidelines

1. Study findings, conclusions and recommendations will be based on the best available data, science, knowledge, scientific interpretation, and state-of-the-art technology recognizing Study budgetary and time constraints.
2. Study decisions will be open and transparent, involving and considering the full range of interests affected by any decisions with broad stakeholder input.
3. Data and modeling uncertainty will be acknowledged and reported on in the Study findings and conclusions and be taken into consideration in the Study decisions and recommendations.
4. The decision process shall be based on a process of iterative “informed consent” whereby the Study Board articulates its decision factors in an open and transparent manner, aligns study conclusions with the research, and refines their findings and decisions as the research conclusions become better understood.
5. The Board will vigorously try to reach consensus on all findings/decisions. If the Board fails to produce consensus, then the results of that process, including the opinions and reasoning of dissenting Board members will be included in the Board’s report.

### 2.1.2 Lake Superior Plan Evaluation Guidelines

These guidelines are a mixture of process rules (number one, for example) and decision criteria (number three). Any change to the Orders of Approval and regulation plan for Lake Superior outflows will:

1. Be based on the best assessment of impacts that can be done given the relatively small effect that Lake Superior regulation has on water levels, and size of the Great Lakes basin relative to the budget available for assessment studies.
2. Accommodate the Treaty’s ‘order of precedence’, while devising regulation plans to improve benefits for new users such as recreational boaters and the ecosystem.
3. Address to the extent possible, all the key ecological, economic, and social impacts associated with the regulation of outflows from Lake Superior, as the basis for making choices among alternative plans, and to understand the relative benefits and costs for each user within each plan.

4. Ensure that plans minimize disproportionate losses to any interest, particularly those enumerated in the ‘order of precedence’ or region, including disproportionate water level changes on one lake at the expense of another.

5. Be designed so that the International Lake Superior Board of Control and the IJC can respond more effectively during emergency conditions and to unusual or unexpected circumstances affecting the Great Lakes system.

2.1.3 Long-Term Management Guidelines

Recognizing that climate and water supplies in the next few decades may be significantly different from those of the 20th century and that regulation of Lake Superior outflows, while potentially having a significant effect on Lake Superior levels, will have little effect on water level changes caused by these climate shifts on Lakes Michigan-Huron and Erie, the Board will consider developing an adaptive management plan that would take into account a number of the following elements:

1. Allow as much adaptation of the Lake Superior Regulation plan to future climates as the Board feels is permissible without a full scale international study
2. Identify and, to the greatest extent possible, promote the long-term monitoring and systems modeling necessary to support that adaptation.
3. Recommend long term partnerships between the IJC and other Great Lakes managers and stakeholders that would facilitate adaptive behaviour of local communities and states and provincial governments based on information developed by the IJC, Environment Canada and the Corps of Engineers about changing water levels.
4. Consider the on-going application and accessibility of the data, tools and models developed for the Study such that they support adaptive management.

The Study Board will develop its final recommendations to the IJC. The Board’s decision process - both for a new set of candidate regulation plans, as well as an adaptive management plan - requires an iterative cycle of “practice decisions” from almost the beginning of the study. Initially, the Board will have very little substantive information to guides its decisions, other than general outlines of each alternative plan, and a preliminary set of generic physical (water levels, frequency), economic, social and environmental impacts. At each step, the Study Board will articulate its evaluation criteria and decision factors. The progressive iteration and refinement of decision factors will correspond with the increased specificity of the available research.

2.2 Site Studies

Given the limited study funds and extent of the study area to cover, the Study team does not consider it possible to undertake a comprehensive and detailed basin-wide evaluation of all the impacts of each alternative regulation plan. It also considers the small affect that the regulation of Lake Superior outflows has on Lake St. Clair and Lake Erie to be negligible. The Study team is proposing a representative study site approach to consider specific locations in detail and then using generalized full data and information to discuss how the site impacts may represent the response of the broader shoreline (potentially only in a qualitative manner). The study sites will not be randomly selected but will
be identified to represent areas where activities of the various interest groups are considered sensitive to differences in water levels as may be seen through alternative regulation plans. Sensitive sites will be identified, among other criteria, based on evidence of past impacts. Sites with existing data will also be a priority as the Study schedule requires completed work on the PIs by September 2010 and there is limited opportunity for new research. TWG specific criteria for the selection of study sites are described in more detail in Section 3, Impact Assessments. Given the reliance on study sites, the ability to undertake a full economic or environmental net benefit analysis within the Study is clearly limited.

2.3 Contextual Narratives

Contextual narratives are being developed by each of the TWGs to provide a general overview of each of the principal water-using interests, including the baseline condition, key trends in an area of interest, how the interest might be expected to adapt to changing water levels, and how they are currently affected by a regulation plan, as compared to other optional regulation plans – i.e. the basis of net effects of any new plan compared to the existing condition. The TWGs have been asked to use their best professional judgment in identifying the most likely trends, outcomes and ways of adapting to changing water levels. The study has also retained the services of two reviewers to assure that the contextual narratives are objective and provide the breadth of context the Board needs for its deliberation. In addition to the six interest-specific contextual narratives, an overview contextual narrative is being developed that includes population projections over the next 30 years for Ontario and the eight Great Lakes states; projections of the number and types of jobs and incomes, and disaggregation of their population and employment projections by coastal counties. The purpose is to provide a general overview of the economic and social state of the Great Lakes Basin. More information regarding the ecosystem context can be found beginning on page 21.

2.4 Risk and Uncertainty

The IUGLS Board will design a new regulation plan based on how the plan performs in computer models. The data and assumptions in the models are meant to replicate conditions and outcomes in the real world, but as with all modeling, there is uncertainty about the degree to how well the models represent reality. Much of the uncertainty comes from our limited ability to correctly specify a set of ‘performance indicators’ (PI’s) that are meant to represent the key changes within a sector under a variety of environmental conditions and lake levels, and then to quantitatively estimate these PIs based on incomplete information and finally, to know when and how future water supplies will cause water levels outside the range of the last 150 years, and whether the PI’s can correctly represent or encompass these projected changes.

2.4.1 The importance of adaptation to manage risk

The more the future is like the 20th century, the smaller the risks posed by a new regulation plan because the impacts will be similar to what has happened in the past. However, there is increasing recognition that past hydrological conditions may not be a good representation of future conditions (Milly et al, 2008). There may be real risks in using the current plan or a slight modification of it should we experience a substantially different water supply regime in the future. Ideally we will design a plan that functions well under a variety of historical hydrological conditions, but there could be future conditions which require a change in regulation philosophy. For example, the current plan makes some effort to balance how far Lakes Superior and Michigan-Huron are from average levels. If water supplies were significantly less, it could be impossible to keep Lakes Michigan-Huron close to the twentieth
century range, while that could be possible for Lake Superior, but only if the existing ‘balancing objective’, encoded in the Orders of Approval, were changed.

Accordingly, an adaptive management plan will be developed as an adjunct to the new regulation plan, as an approach to will manage the most significant risks that may materialize under a different climate regime.

While stakeholders have complained about lake levels in the late 20th and early 21st centuries, the problems were largely caused by nature, not the plan. Plan 1977A does not produce water levels much different from pre-regulation levels (see Figure 3), at most mitigating highs or lows for a short time on Lakes Superior or Michigan-Huron. Nor can any plan do much to reduce the highs or supplement the lows much better than the current plan. Because of that, there is not much concern that regulation on the upper lakes has caused significantly adverse environmental impacts, as it did on Lake Ontario. Though the Georgian Bay area, because of its unique geology and glacial rebound is experiencing a unique set of economic and environmental impacts that may not be easily mitigated. There have been some concerns expressed that the present plan does not make the most efficient use of the water for hydropower or that the month-to-month distribution of flows needs to be improved for better angling opportunities in the St Marys Rapid. It appears likely, at this point, that any new regulation plan will be very similar to the existing regulation plan, in terms of physical effects. However, the small differences in physical effects do not necessarily translate into equivalent social, economic or environmental effects – especially at the extremes. The reasons for this are discussed in more detail in the PFEG report, but in sum, the IUGLS Board has already decided that, in principle, it would not recommend plans that favour one interest over another if there is a disproportionate loss involved, and a plan that mainly preserves existing benefits for all stakeholders will produce similar lake levels. However, conceptually, plans can be devised where one interest can gain substantial benefits, without incurring disproportionate losses by the other interests.

2.4.2 Uncertainties and risks
What we do not know may hurt us, either because it causes us not to act when we should, or because it causes us to act inappropriately. There are three types of uncertainty that the IUGLS Board will have to confront:

1. Traditional data and model uncertainties
2. Changes in the probability distribution of water supply/Hydroclimatic conditions
3. Ignorance about economic and ecological impacts from conditions without precedent (whether because of unprecedented water levels or unprecedented economic or ecological conditions), for which we have no data available.

2.4.2.1 Traditional uncertainties

Traditional data and model uncertainties exist in all studies and are acknowledged in all modelling and impact estimates developed within the IUGLS. There are data uncertainties, model uncertainties, and general uncertainties regarding the ability to understand all contributing components that are required to predict potential outcomes using plausible, but not known, future water supply and economic conditions.
2.4.2.2 Probability distribution shifts

The PFEG report goes into more depth about the difficulty of estimating the frequency, magnitude and duration of low and high water supply periods in the future, but in sum, the normal variability of a stationary climate may be exacerbated by human-induced climate change. Assuming climate is fixed over the long-term, statistical hydrologists can build a model that includes quasi-periodic variability and generates water supply time series data representative of those that could happen in the future so that the probability distribution for the synthetic and historical supplies are similar. By virtue of the much greater number of years in the synthetic dataset, though, it would include wet and dry periods more extreme than any in the historical record, providing a more severe test for regulation plans.

But if climate varies naturally – for example if the mean water supply moves up and down in cycles that vary in length, beyond the 105 year historical record, the probabilities assigned to rare wet and dry periods will be wrong. If the effect of man-made carbon emissions is layered onto climate variability, then probability estimates become even less defensible. In other words, a regulation plan designed for the historical climate may not be the best for the future. While we can determine which plans might perform best under which climates, we cannot predict with any certainty what that future climate and related water supply regime will be.

Other things could affect water levels (such as natural changes in conveyance in the connecting channels) and their associated impacts (such as new invasive species, or changes in shipping and boating activity).

2.4.2.3 Unprecedented conditions for which there is no data

Even if it were possible to know what future water supplies would be under climate change, there is no recent experience in the Great Lakes Basin on how such supplies might change the human and non-human systems affected by the levels. This is a form of model uncertainty; in this case it goes beyond how well the model results fit the data to the issue of whether an impact algorithm (a model) can be defended for conditions outside the range of parameter data.

Consider also uncertainties in both future economic and environmental conditions. The economic future of the Great Lakes is particularly uncertain at this time. The Upper Great Lakes region includes U.S. counties with unemployment rates of over 20% (Figure 6), and the future of the U.S. and Canadian auto industry appears tenuous. The Depression era unemployment rates for some of these counties, coupled with an unprecedented industrial collapse in the region, threaten the economic viability of Great Lakes commercial shipping. The recession has ancillary effects on reducing state and local revenues from tourism and recreational boating, that further has secondary economic effects on coastal zone development and floodplain management, and the Great Lakes environment.

The ecological integrity of the Great Lakes is also uncertain as the region is faced with numerous ongoing threats from invasive species and pollution. Responses to invasive species would require both treatment of the current effects of invasives already lodged in the Great Lakes as well as the reduction in future invasives. Efforts to clean-up the Great Lakes have been on-going for decades, and while improvements have been made, significant issues remain and new issues are continually emerging. The most likely future is that invasives and pollution will continue to be big problems. However, with a recent infusion of expected funding to the Great Lakes region by the U.S. government of up to $475 million per year for 10 years, great progress may be possible.
So there are many areas where we have reason to believe unprecedented change may occur, affecting the performance of any regulation plan. To name some:

- If air temperatures and water temperatures increase, there may be less ice
- The economy of the Great Lakes region may be substantially different and this could affect land and water use and the level of state revenues available for natural resources management;
- The need for Great Lakes wetlands to support threatened species may be greater than it is now
- The ecosystems in the Great Lakes may be ravaged by new invasive species;
- Environmental investments may greatly improve the environmental quality in the Great Lakes basins.
- Persistently lower water levels could expose some timber supports for coastal structures and de-water some wetlands, create a new shoreline (creating a “fresh start” for coastal regulation), change ownership of the coast, reduce flooding and erosion damages, change commercial shipping fleets, and close marinas and recreational harbours

The second and third uncertainty types, water supply frequencies and unprecedented conditions, make it indefensible to use expected values to test the current regulation plan.

Because we have no historical data on which to design impact functions representing these potential futures, with a myriad of unknown positive and negative feedback loops, there can be no useful forecasts used in the evaluations in this study because the decision is flexible and the uncertainty is large. The study Board decisions will likely not involve new structures on the St. Marys River or significant investment costs; the Board will recommend changes in a regulation plan, and devise one that provides greater flexibility to adapt to unforeseen circumstances and which can be adapted to changing conditions. In fact, the Board intends to develop an adaptive element to the plan that will consider decisions beyond revisions to the regulation plan, including possible new structures that deal with the anticipated effects of climate change.
3. Impact Assessments

3.1 Interest Categories

The Plan of Study (2005) identified six interest categories to be considered in evaluating alternative regulation plans. These are the same six interests as were identified in the Lake Ontario – St. Lawrence River Report and they include:

- Commercial Navigation
- Hydropower
- Municipal and Industrial Water Uses
- Coastal interests (shoreline property)
- Recreational Boating and Tourism
- Environment

Impacts in the first five categories are traditionally measured in economic terms. While economic valuation of the environment is possible, it will not be used in this Study. A rationale for that decision is briefly described in ESG4.2 Environmental Benefits, page 62. The methods to be used in assessing environmental impacts are addressed in the separate peer review summary on that subject.
A specific Technical Working Group has been established for each interest category and reports to the Lake Superior Task Team. The Plan Evaluation Group has the lead responsibility for coordinating and integrating all of the work of the Technical Working Group into a Shared Vision Model developed collaboratively by the study team.

### 3.2 Economic Advisors

As the TWGs began to define their performance indicators (measures that quantify the impacts that result from a particular level/flow or series of levels/flows), a number of economic issues began to arise. The need for consistency on approaches between the TWGs became very apparent. It was decided that some expert advice on the most problematic economic issues was needed. To support this effort, two economic experts will provide an arm’s length review of the economic analyses being conducted within the study and will advise on how to deal with specific economic issues. In IUGLS, there are two advisors; Steven Renzetti of Brock University is already engaged and efforts are underway to secure a U.S. economist.

In addition to the support of the Economic Advisors, the PEG has decided to utilize (as appropriate) a set of economic standards and guidelines developed during the LOSL Study for the use in the Study Board’s research and decision making. Many on these standards and guidelines have been adopted either explicitly or implicitly in this IUGLS. They are described in an appendix of this report.

### 3.3 Recent Board Decisions Affecting Impact Assessments

As compared to their unregulated state, Lake Superior regulation has had much less effect on its levels than Lake Ontario regulation has had on its level. Lake Ontario lake levels fluctuate much more widely, and over a shorter period of time than the much larger upper Great lakes. The upper lakes have a regime stability that is a direct consequence of their vast volume and area. The LOSL study concluded that regulation had eliminated much of the natural variability under which the Lake Ontario coastal environment had developed over centuries, while the lake levels produced by the current Lake Superior regulation plan are somewhat similar to the unregulated levels. The Study Board recognizes that, realistically, there is little that can be done to effectively change regulation criteria sufficiently so that plans are substantially different from the natural regime. First, the current plan is based in large part on a desire to balance Lake Superior and Lakes Michigan and Huron (which are hydraulically the same lake) levels, meaning that the intent is to keep Superior and Michigan-Huron about an equal number of standard deviations from their means. While regulation cannot achieve that objective - the main influence on Michigan-Huron levels is the net basin supplies to those lakes, which is typically several times larger than the change in Superior release designed to balance the lakes. Second, the benefits of regulating to produce very different lake levels are, at least at this early stage, not likely to be large or well distributed. Regulation is most effective at maintaining Lake Superior levels within ranges preferred by shippers and coastal landowners; it is much less effective in controlling Michigan-Huron levels and has even less effect on Lake Erie. The vast majority of the Great Lakes population lives around the lakes below Superior, the vast majority of hydropower energy is produced at Niagara Falls, not at Sault Ste Marie, (but regulation of Lake Superior has minimal effect on Niagara power generation) and commercial navigation benefits are largely dependent on multiple lake levels (only about 2% of total Great Lakes tonnage is confined to Lake Superior).

This study does not have adequate funding to undertake a detailed economic and environmental analysis of the entire shoreline – nor is it necessary, for the reasons given above. The Study Board
accepts that the Study will not be able to fully extrapolate across the basin. Given this, the requirement for dollar metrics is less necessary for evaluating plans and may not be gathered for all interest categories. Certainly, dollars will not be used for the ecosystem as will be discussed in that peer review document.

As discussed earlier, economic, environmental and climate change uncertainty negates our ability to develop defensible estimates of expected future impacts. Without economic forecasting, there may be no point to selecting any particular period of analysis or using a discount rate. But while forecasting would introduce variability in exogenous variables, the rate at which one plan or the other erodes the shoreline and shoreline protection structures is an endogenous variable that can be used to rank plans only if the plan evaluation framework discounts impacts that happen farther into the future. If the Coastal Processes TWG does develop a metric for either component of erosion, either in physical terms (movement of the top of bluff) or economic terms, then discounting will be used to distinguish between plans that take five years to erode a meter of bank and plans that take ten years to cause as much erosion.

Considering all these factors together, PEG recommended and the Board approved the evaluation of plans based on the current economic, social and environmental condition. A 100 year planning horizon will be used so that serially dependent physical phenomena related to lake levels and hydroclimatology such as erosion can be analyzed, but the study setting will not evolve; the viability and scale of navigation, the amount of water withdrawn for cooling, the popularity of recreational boating, the investment in hydropower production, etc. will remain as they are today. The discount rate and planning horizon can be varied as part of a sensitivity analysis to determine if plan ranking is sensitive to the choice of these parameters.

A contextual narrative will be developed for each sector; while not forecasts, these are intended to give the Board information about the state of and trends in the contextual settings for all the performance indicators. The evaluation of the new regulation plan will be based on the current climate (including extremes found in the stochastically generated supplies) and quantifiable impacts from the sample sites (not necessarily economic impacts).

To address future uncertainty the Board wants to develop an adaptive management strategy. The strategy has not been approved by the Board, but there is a summary of the current draft in Chapter 5. Adaptive Management Work Plan, starting on page 48.
4. Ecosystem Impacts

4.1 Ecosystem Technical Working Group – Framework, Organization, and General Approach

The Ecosystem Technical Work Group has adopted an approach that is focused on assessing ecosystem vulnerabilities to changing Upper Great Lakes water level regimes. The objective of this approach is first, to identify water-level ranges and thresholds that represent the modern historic condition for ecosystem maintenance; and second to identify those levels that can improve the conditions for biotic communities and ecosystem function compared to the current operating conditions, i.e. a range of water levels and water-level variability that supports diverse biotic communities and ecosystem functions.

For the purpose of this study, water level regimes are defined as the magnitude, frequency, timing (seasonality), duration, and rate of change of water levels through time. The fundamental approach used in this study can be summarized as follows:

- Understand the physical responses and associated responses, positive and negative of various ecosystem components to water level regime changes in the Upper Great Lakes;
- Quantify the relationship between changing water level regimes (magnitude, frequency, timing, duration and rate of change) and key ecosystem functions and components by evaluating ecological performance indicators at multiple representative sites throughout the UGL basin;
- Develop and apply an integrated modeling framework (IERM) tool to identify and establish site-specific and regional water-level criteria or thresholds above which, or below which, harm will be done to various ecosystem components and, by extension, to the Upper Great Lakes ecosystem;
- Use the IERM tool to identify criteria or threshold exceedances that might occur in response to proposed water level regulation plans; and
- Identify vulnerabilities and potential opportunities for ecological improvement as a function of changing water-level regimes (adaptive management).

Individual field sites have been selected based on a set of criteria that include: geographic and ecoregional representation across a broad range of ecosystem types and components; sensitivity and responsiveness to changes in water level regime; available historical data and imagery; ongoing research and field activity; and socio-economic interest. These sites will be evaluated and modeled individually to determine critical water level regime thresholds that may result in significant changes to biological communities and/or ecosystem functions. These thresholds will be determined independently and will be based on the needs and responses of the ecosystem.

A standardized description of biological condition will be used to qualitatively assess the ecological response and vulnerabilities to water level change. Ecological response curves will be developed at each site for each of the hydrologic characteristics used to describe water level variability (magnitude, frequency, timing, duration, and rate of change). These curves will link descriptors of biological condition (based on performance indicators) with descriptors of water level variability to identify possible thresholds.

These curves and thresholds will form the basis of the quantitative analysis to be incorporated in the IERM. In addition to incorporation of each relationship in the IERM, the modelers will work with the
ETWG and other coastal ecosystem scientists to prioritize and weight each Ecological Performance Indicator in terms of relative importance to overall site-specific ecosystem health and integrity. This process will permit the development of an integrated vulnerability analysis for a given site. The IERM will also be used as a tool to group the sites by lake, region, and ecosystem type to permit the ETWG to assess regional and ecosystem type vulnerability that will be incorporated into the Shared Vision Model.

As each of the regulation plans may exhibit different hydrologic characteristics, the individual site response curves and thresholds and the integrated vulnerability assessment produced by the IERM tool will be compared with the synthetic water level curves to identify where, when, and how frequently thresholds are exceeded under each alternative regulation plan devised to meet the needs of each of the water-using sectors, including those of the environment. The results of these analyses will be shared with the Plan Evaluation Group and regulatory planners. This approach can also be adapted to evaluate the impact of more significant changes in water level regime on the UGL ecosystem – e.g. under a variety of climate change scenarios.

To initiate the technical evaluation, the ETWG recently contracted with the University of Minnesota – NRRI (Dr. Val Brady) to do a comprehensive literature review of published and grey literature focused on ecological responses to changing water level regimes. This study was recently completed and a copy of the report is attached as Appendix 1. Concurrently, the ETWG recently contracted with a group of technical experts to produce a “white paper” to provide guidance to the ETWG as to how best to approach this study (Ciborowski et al. 2009). The white paper identifies major ecological systems of the UGL and provides recommendations as to: 1) potential water-level related issues or concerns, 2) types of performance indicators and/or data that would be necessary (or available) to evaluate those indicators, 3) responses of ecological components to changing water-level regimes, and 4) project implementation strategies. Portions of that report have been incorporated into the evaluation summary document (this document), and a full copy of that report will be provided separately.

The ETWG is also working to contract several individuals/entities to assist with project implementation. The positions include: a Project Manager/Data Coordination Manager, a GIS/Database Manager, an IERM Model Development Manager, and several Regional Site Coordinators to assist with field evaluations and data collection efforts. These individuals/entities will work with the ETWG and ETWG co-Chairs to ensure that the project goals and objectives are met.

4.2. Internal assessment of the analysis: probably adequate

The IUGLS Board will evaluate a large number of different regulation plans. The evaluation criteria are yet to be determined, and will be based on defining a set of evaluation principles that will be coupled with the more specific PI’s that are being developed for evaluating the physical, economic, social and ecological effects for each water using sector on the Great lakes. Most new plans will probably not have a significant effect on Great Lakes ecosystems, especially when compared with the existing Plan 77-A, but that will be difficult to quantify, as there are large uncertainties associated with ecological data and models. After nearly three years of preliminary studies and discussions, no evidence has been presented to date of significant negative environmental impact can be directly associated with the current regulation plan (holding separate any initial impacts of the regulation structure itself). There are few studies that investigate the connection between small changes in water levels and environmental impacts. But that we mean long-term changes in mean lake levels of a few centimeters between the various plans, which all mimic the historical decadal fluctuations of highs followed by low lake levels.
Even where the vulnerability of some features to water level regime change is evident (see Figure 9 Landscape features that cannot adapt to different water level regimes, page 33) cataloging and surveying those sites would cost millions. There may also be impacts that are significant but beyond our ability to predict. If it is difficult to name impacts from regulation plan changes, it is nearly impossible to develop functions that relate quantified increments of impact to specific changes in water levels. Yet the Study Board must be duly diligent in considering the environmental consequences of their recommendations for a new regulation plan. More difficult yet are attempts to separate the known dramatic changes in ecosystem function and integrity caused by the combined effects of invasive species and water quality degradation over the past 100 years during which the lake levels have been physically controlled. There is evidence to support the notion that the ecological effects of invasive species and water quality degradation overwhelm and mask the relatively minor effects of physical water level control.

New ecosystem impacts caused by land use changes, a progression of new invasive species, as well as the cumulative effects of water quality degradation are more important than those derived from the relatively small water level changes under consideration by the IUF+GLS Board, though climate variability and change impacts are considered to be likely, and potentially significant, but there is even less research on how lake level regulation could ameliorate those impacts. Consequently, an adaptive management plan will be designed, using research about the current relationship between water levels and ecosystem impacts as a starting point.

4.3 Context

The environmental health of the Great Lakes has improved since the Cuyahoga River caught fire on June 22, 1969; future improvements are needed but are uncertain and may even be beyond our ability to control.

The environmental problems of the Great Lakes were caused by development that peaked before broad national environmental legislation like the National Environmental Policy Act (1969); Clean Water Act (1972) and Endangered Species Act (1973) were enacted. The principal environmental issues for the Great Lakes are invasive species, pollution (air as well as point and non-point water pollution), and loss of wetland services.

Improvements in the control of invasive species would require both treatment of the current effects of invasives already lodged in the Great Lakes as well as the reduction in future invasives. The most likely future is that invasives will continue to be a big problem because not enough will be spent to reduce the current problem, while the measures taken to reduce the risk of new invasions are not expected to be 100% effective. Invasive species have greatly altered the food web and ecosystem function of the Great lakes, and will confound the attempts of the IUGLS TWGs to separate the impacts of small water level changes from the larger changes occurring attributed to pollution and invasive species.

Pollution improvements are also uncertain; the great investments required would seem insurmountable, especially given the state of the Great Lakes economy, except that there may be growing public pressure to make these sorts of investments. The primary air pollutant is heavy metals, especially mercury, that bio-accumulate, increasing the damage at the top of the food chain to fish, birds and humans. Any significant improvement would require a large reduction in airborne pollution from coal fired power plants west of the lakes, an expensive proposition, but one that might occur because of rising energy prices (which would keep coal fired plants competitive even with costs for
cleaner emissions) and concerns about carbon emissions and global warming. Acid rain is also a significant problem, especially over Lake Erie.

Pollution from the land surrounding the Great Lakes has been greatly reduced since the Cuyahoga fire (when three foot diameter pipes jutting out of the sheet pile banks spewed untreated chemical waste directly into the river), but the pollutants have not been cleaned out of the Great Lakes. The principal concerns are from persistent organic compounds such as Dichloro-Diphenyl-Trichloroethane (DDT), dioxin and polychlorinated biphenyls (PCBs) which are no longer entering the lakes but have not been completely removed. The lakes can still be polluted from combined sewer overflows in which heavy rains flood systems handling both street drainage and wastewater, forcing wastewater into the lakes before it can be treated. Overland runoff – rain washing gas and oil off roads into the lakes, or agricultural pesticides and fertilizers into the lakes is also a problem.

SOLEC reports and papers collectively provide the most comprehensive, current and quantitative assessment of Great Lakes ecosystem health because these papers routinely assess trends, and because they were preceded by similar papers dating back to 1994.

Overall, the SOLEC 2008 assessment is that the overall status of the Great Lakes ecosystem is a mixed, with some conditions good and others poor, with no overall trend making things better or worse into the future (some things are improving and some are getting worse).

4.3.1. Human Health.
SOLEC reports that the current status is mixed and the future is hard to assess. Levels of PCBs in the fish anglers catch continue to decline, but there are still advisories for Dioxin, PCBs, toxaphene (an insecticide), mercury in Lakes Superior and Huron, PCBs, mercury, dioxin, chlordane, DDT in Lake Michigan, PCBs, dioxin, mercury, mirex in Lakes Erie and Ontario, as well as toxaphene in Lake Erie. Progress is being made to reduce air pollution, beaches are better assessed and more frequently monitored for pathogens, and treated drinking water quality continues to be assessed as good. The connection between these problems and navigation is mostly past and not as important as the connection with invasive species. In the past, highly contaminated sediments were dredged from navigation channels to provide adequate depth and until the late 1960s, were dumped in the open lake. Since then all are placed in confined disposal areas built for that purpose.

4.3.2. Wetlands.
There is no comprehensive, continually updated inventory of Great Lakes wetlands, although there are partial databases with varying degrees of monitoring, so assessments are based on direct and indirect evidence. SOLEC was able to produce the first map of Great Lakes wetlands (217,000 hectares, or about 535,000 acres or 837 square miles, about two times the size of Los Angeles, and half the size of Rhode Island). The extent and composition of coastal wetlands, including coastal birds and amphibians is mixed, but is progressively deteriorating. Coastal wetland plant health is mixed (the water clarity brought by zebra mussels has expanded the area of submerged wetland plants, but the invasive Asian Carp and agricultural runoff in Saginaw Bay, Green Bay and Lake Ontario has had the opposite effect. The IJC study of the regulation of Lake Ontario showed that more natural regulation would be better for wetlands and good for navigation, greatly reducing delays in the St. Lawrence Seaway.
4.3.3 Invasive Species.

SOLEC 2007 reports that the problems associated with aquatic invasive species on four of the five Great Lakes are deteriorating (Lake Superior is holding constant). There are currently at least 184 species of non-native algae, fish, invertebrates, and plants that have become established in the Great Lakes. While the total numbers of non-native species introduced and established in the Great Lakes have increased steadily since the 1830s, numbers of ship-introduced aquatic species have increased exponentially during the same time period. But stopping ships would not stop the invasion of species. According to SOLEC 2008, “The unauthorized release, transfer, and escape of introduced aquatic non-native species and private sector activities related to aquaria, garden ponds, baitfish, and live food fish markets are of particular concern.”

High population density, high-volume transport of goods, and the degradation of native ecosystems have also made the Great Lakes region vulnerable to invasions from terrestrial non-native species. The terrestrial non-native emerald ash borer, for example, is a tree-killing beetle that has killed more than 15 million trees in the state of Michigan alone as of 2005. This beetle probably arrived in the United States on solid wood packing material carried in cargo ships or airplanes originating from its native Asia. Botulism is killing tens of thousands of birds around the Great Lakes. Studies indicate that two invasive species triggered the outbreak. The quagga mussel, introduced from Ukraine, filters the water for food, making it clearer. The sunlight that penetrates the lakes allows algae to bloom, and dead algae trigger an explosion of oxygen-consuming bacteria. As the oxygen level drops, the botulism-causing bacteria can multiply. The quagga mussels take up the bacteria, and they in turn are eaten by another invasive species: a fish known as the round goby. When birds eat round gobies, they become infected and die.

Measures to control invasives entry on ship started in 1989 and include exchange of ballast water before entering the lakes. Canada and the U.S. both regulate vulnerability to shipborne invasives, but the regulations consider cost and practicality, and have created controversy. According the Select Committee of the National Academy of Sciences reports of new invasives continue despite the regulations.

4.3.4. Contamination.

SOLEC 2008 reports that the status is mixed but the trend is improving. Contaminant uptake has been measured in gull eggs since 1974, and those levels have declined by over 90% over that time period. The exceptions are concentrations of fire-retardant brominated diphenyl ethers (BDEs), although there are problems remaining in the IJC “Areas of Concern” and there are new chemical concentrations of things like pharmaceuticals that are emerging concerns. But the negative effects on colonial waterbirds are disappearing, as most bird species populations have increased over the last 20-30 years. Contamination from atmospheric deposition of toxic chemicals is mixed, with concentrations of PCBs and dioxins improving, but mercury not changing, this despite a reduction in emissions of mercury.

4.3.5 Biotic Communities

SOLEC 2008 has a mixed report card for biologic components of the Great Lakes ecosystems. Native species at the base of the food web (such as zooplankton) are in decline in some of the Great Lakes, and native preyfish have declined in all lakes except Lake Superior. Lake trout are reproducing naturally in Lake Superior and Lake Huron, but not in the other lakes to any degree. Walleye harvests have increased, although they have not reached preferred levels. Habitat loss and degradation are still the
main threat to wetland birds and amphibians. SOLEC 2008 did not have enough information to make a projection about the future in this category.

4.3.6 Coastal Zones and Aquatic Habitat
SOLEC 2008 reports the status is mixed and trends are indeterminate. Coastal habitats are degraded due to development, shoreline hardening and establishment of local populations of non-native invasive species. Wetlands continue to be lost and degraded. In addition to providing habitat and feeding areas for many species of birds, amphibians and fish, wetlands also serve as a refuge for native mussels and fish that are threatened by non-native invasive species.

4.4 Overall Study Approach
Early on in this study, it quickly became apparent to the Plan Evaluation Group (PEG) and the Ecosystem Technical Work Group (ETWG) that the Study area is too large (see Figure 7 Comparison of Chesapeake Bay and Lake Superior) and budget and time too small to permit a comprehensive basin-wide evaluation of potential water level regime impacts. Preliminary hydrologic simulations of potential regulation plans (‘fencepost plans’) indicate that the regulation of Lake Superior outflows has a lesser impact on Lake St. Clair and Lake Erie and in fact, models of the proposed fencepost plans show that water-level regime changes to Lake St. Clair and Lake Erie are minimal (see comments for Figure 2 and Figure 3, page 7). Without funds for extensive data collection and analyses, the Ecosystem Technical Work Group (ETWG) has focused its efforts on the three uppermost Great Lakes (UGL) – Lakes Superior, Huron, and Michigan - recognizing that regional long-term climate change impacts may extend throughout the entire Great Lakes system including the lower connecting channels, Lakes St. Clair, Erie, and Ontario.

The ecosystems of the upper Great Lakes (UGL) provide a broad range of ecosystem services to society and contain numerous valuable natural resources that benefit North America. Absolute water levels and fluctuations have major influences on the nearshore and coastal regions of the Great Lakes and their ability to support aquatic organisms. Figure 7 illustrates long-term natural cyclicity in Great Lakes water levels and the envelope of potential climate induced water-level change for Lake St. Clair. These longer-term cycles represent basin-wide changes in water supply driven by external forcing functions unrelated to water level regulation or anthropogenically induced climate change (Thompson and Baedke 2000). UGL ecosystems have evolved and adapted to these longer-term cycles and natural water level regimes since the Holocene glaciation. It is not anticipated that Lake Superior water level regulation will impact or alter the long-term cyclicity of UGL water levels. However, changes in water level regime over time play an important role in coastal processes and nearshore ecosystems. Hence, a primary objective of this work is to assess the extent to which water-level regulation will affect the natural variability of water levels and coastal ecosystem structure and function over time, as a basis for the decision of the IUGLS Board in selecting an ‘improved’ regulation plan that will be devised to introduce operating flexibility to incorporate new information as it becomes available. This will be the ‘adaptive management component of the new regulation plan. Ecological responses to longer-term changes in water level regime due to climate change (as illustrated in Figure 7) will be evaluated using an adaptive management approach.
The evaluation of potential ecosystem impacts is a complex task made more difficult by the dynamic nature of the Great Lakes ecosystem. Given the range of water level regime changes inferred from the fencepost models, it is clear that for deeper water areas of the Great Lakes (water depths generally greater than 15m) the direct ecological impacts of these water-level changes are likely to be insignificant. However, direct and indirect impacts to biological communities and ecosystem functions in coastal margin and nearshore areas could be potentially significant. These areas include shallow low-slope embayments (generally < 3 m water depth) and coastal margin ecosystems dependent on direct hydrologic connection to the Lakes. Within the UGL, ecological components include: coastal wetlands, beaches, dunes, tributaries, islands, and the nearshore/coastal margin aquatic habitats and biotic communities that use those habitats. The EWTG has identified these areas as being especially vulnerable to changes in water-level regime.

Figure 7 Comparison of Chesapeake Bay and Lake Superior areas
Unlike the LOSL study, which was designed to evaluate and mitigate ecosystem impacts of reduced water-level variability by water-level regulation, the Upper Great Lakes Study (UGLS) is focused on coastal margin areas that have been subject to water-level regimes that approximate natural pre-project water-level regimes.

As Figure 2 and Figure 3, page 7 show, the current plan 1977A closely approximates pre-project (natural) water-level regimes and ecologically represents the standard or baseline to which other proposed regulation plans will be compared.

Figure 8 Long-term climate cycles for Lake St. Clair.

Blue band represents statistically generated (and superimposed) long-term 160-year, 30-year, and 4 to 8-year long-term cycles for Lake St. Clair (Baedke and Thompson 2000). Shaded red area represents the range of possible combined effects of climate change and long-term cycles on Lake Saint Clair water levels. (Source: modified from workshop presentation – Rob Nairn, W.F. Baird & Associates, 2005)

Unlike the LOSL study, which was designed to evaluate and mitigate ecosystem impacts of reduced water-level variability by water-level regulation, the Upper Great Lakes Study (UGLS) is focused on coastal margin areas that have been subject to water-level regimes that approximate natural pre-project water-level regimes. As Figure 2 and Figure 3, page 7 show, the current plan 1977A closely approximates pre-project (natural) water-level regimes and ecologically represents the standard or baseline to which other proposed regulation plans will be compared.

For example, water level variability is responsible for zonation and plant species composition in coastal wetlands. The regular wetting and drying of sediments at different cycles creates an intermediate disturbance pattern that increases biodiversity because of plant succession and varying species copings. Recurring high and low water periods, such as those that have occurred under the current plan (Plan 1977A) due to climatic conditions in combination with water level regulation, result in a continuum of vegetation zones with dynamic expansion or contraction of some zones associated with interannual and longer-term water level variation.
To the degree that the climate that drove the 20th century water supplies were typical of the climate leading up to and including the period of regulation, the pre-project water-level regime would be the appropriate standard to use, as the native biological communities and ecosystems adapted and evolved to those regimes. But given the effects of development, hydromodification, and pollution in the 20th century, we are unable to predict the “natural” ecological response to pre-project water level regimes with any degree of certainty, and therefore must use the existing UGL ecosystem as a benchmark to assess potential ecological change.

Resource and time limitations severely limit the ability of the ETWG to perform a comprehensive traditional scientific investigation of all ecosystem components that could affected by changes in Upper Great Lakes water level regimes. Typically, these types of detailed studies would evaluate discrete changes in biotic communities in response to a single, or perhaps, several stressors over multiyear periods as was done in the LOSL study. However, because UGL ecosystems are relatively unimpaired (with respect to water-level regime), it may not be necessary or practical to document all of the dynamic responses of a complex coastal ecosystem to every water-level change scenario as long as those water-levels approximate a “natural” water level regime.

In fact, coastal wetland communities of the Great Lakes have evolved in a variable flooding regime (Wilcox 1995, 2004, Albert et al. 2005, Keough et al. 1999, Mayer et al. 2004). The dynamic nature of coastal wetland vegetation has been referred to as ‘pulse stability’ or ‘centrifugal organization’ (Wilcox 2004). Daily variation (seiches and storm surges), seasonal variation, and especially interannual variation serve to maintain zonation, foster biodiversity, and control vegetation succession (Wilcox 2004, Keough et al. 1999). As long as the regulated hydrologic regime approximates a “natural” water level regime, the biotic communities and ecological functions will continue to respond as they have for thousands of years.

Where variability in flooding pattern has been restricted (e.g. in Lake Ontario or in many diked wetlands), wetlands have lost diversity and plant community zonation. Wilcox et al. (2007) and Wilcox and Meeker (1991, 1992, 1995) demonstrated how restriction of lake level variation simplified coastal wetland vegetation, encouraging large, competitive species at the expense of sedge/grass communities. On Lake Ontario, Wilcox et al. (2007) reported that reduction of water level variation by regulation, begun in 1960, resulted in sedge/grass meadow replaced by shrub cover on the upland side of the coastal margin and robust emergents, such as cattail monocultures, on the lakeward side of the coastal margin. Narrowing the ‘wetted edge’ reduces available potential nearshore habitat area and concentrates the zone for erosion; in Lake Ontario, this resulted in property owners and managers constructing various hard structures to protect the shore, but such structures reduce sediment supply and the movement of sediment in the coastal zone, further reducing diverse coastal substrates that form the underpinnings of wetland and beach ecosystems.

In order to maintain biotic diversity and ecosystem function, these studies highlight the importance of maintaining variable water level regimes that approximate natural pre-project hydrologic conditions. To meet the goals and objectives of this study, it is therefore necessary to identify those conditions or

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1 The term water level regime as used in the document refers to water level variation using terms that are adapted from the natural flow regime paradigm in rivers (see Poff et al. 1997). Water level variability is typically described by the magnitude (range), frequency, timing (seasonality), duration, and rate of change of water levels through time (see Poff et al. 1997).
water level regimes that diverge from the natural water-level regime and to establish thresholds or transition periods where changes to the water-level regime result in significant long-term alteration of biotic communities and/or ecosystem function. These thresholds may vary by lake, ecoregion, ecological component (and associated performance indicators), and may be influenced by local anthropogenic alterations. More importantly these thresholds are solely a function of the underlying biotic community responses and fundamental structure of the ecosystem; knowledge of proposed water-level regulation plans and/or potential climate change induced water-level regime scenarios is not necessary to identify these thresholds.

A similar bottom-up strategy was presented by Dr. Casey Brown at a recent IUGLS Adaptive Management workshop held in Windsor, Ontario in May 2009. In his presentation, Dr. Brown suggested that it would be more efficient to perform vulnerability assessments in response to changing water-level regimes. These vulnerability assessments would establish water-level regime conditions necessary to maintain a desired state (e.g. biotic diversity and ecosystem function). These thresholds would be determined solely by the requirements of the ecosystem. Once those conditions or thresholds have been established, it would then be appropriate to ask the plan formulators and climate-change modelers which hydrologic scenarios yield water level regimes that exceed those threshold conditions.

It is then possible to use the IERM tool to identify and integrate the magnitude, location, and timing of potential ecosystem impacts by lake and by ecological component when those conditions (or thresholds) are exceeded. By adopting this focused approach, the ETWG is not required to evaluate ecological impacts for a list of climate change scenarios generated by climate models; the ETWG will work with the Hydroclimate TWG to identify those climate change scenarios that exceed site-specific thresholds that will potentially cause significant long-term impacts to the UGL ecosystem.

In order to do this, a descriptive framework of biological condition is helpful to identify progressive changes that result from ecological degradation (Table 2, page 29). These types of descriptive frameworks are typically applied to riverine systems as part of an aquatic-life use designation process (e.g. U.S. EPA 2005). The example framework in Table 2 is derived from an aquatic classification scheme developed and used by Davies and Jackson (2006) and applied by Bain (2007) to the St. Marys River. This classification scheme provides a useful way to describe and rank the types of ecological changes that may occur as regulated water level regimes diverge from Plan 1977A and/or pre-project “natural” water level regimes.
In Table 2, page 29, the first three conditions represent the “natural state” of the ecosystem that has historically been maintained by natural water level regimes. Water level regime changes within natural ranges and variability have minimal impact to the ecosystem, even though there will be some minor

<table>
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<tr>
<th>Impact Score</th>
<th>Biological Condition</th>
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</table>
| 1            | Natural or native condition  
Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within range of natural variability |
| 2            | Minimal changes in structure of biotic community; minimal changes in ecosystem function  
Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within range of natural variability |
| 3            | Evident changes in structure of biotic community; minimal changes in ecosystem function  
Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive–ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system |
| 4            | Moderate changes in structure of biotic community; minimal changes ecosystem function  
Moderate changes in structure due to replacement of some sensitive–ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes |
| 5            | Major changes in structure of biotic community; moderate changes in ecosystem function  
Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased buildup or export of unused materials |
| 6            | Severe changes in structure of biotic community; major loss of ecosystem function  
Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism conditioning is often poor; ecosystem functions are severely altered |
changes in biotic communities and ecosystem functions (green shaded area). The third condition represented by the yellow shaded area just below the horizontal dashed line in Table 2 represents more substantive changes to the structure of the biotic community, which will generally be the result of more extreme periods (but still within the envelope of historic natural variability). For this study, detailed investigation of these types of ecological changes is generally not necessary as they would fall within the natural variability of the system. However, the lessons from the LOSL study must be considered to guard against changes in water-level variability that may affect ecologically important long-term variability.

The fourth condition represented by the orange shaded area below the single solid line in Table 2 represents moderate changes in the biotic community including measurable changes in ecosystem function. At this stage, the ecosystem is starting to respond to water-level regimes that are approaching critical thresholds that when exceeded, will result in significant changes to the ecosystem. In most cases, these types of ecological changes would be considered to be undesirable and should be avoided. However, there may be compelling (ecological) reasons to justify a regulatory plan that diverges significantly from 1977A or pre-project (“natural”) water-level regimes. An example might be to prevent the loss of widespread habitat that is essential to support fundamental ecological functions and/or to maintain an ecologically important biological community or species on a lakewide basis. However, this case is unlikely under the current proposed regulation plans, but may have to be considered as part of a broader-scale evaluation of climate change scenarios.

**Biological conditions represented by the red shaded area below the double solid lines in Table 2 are ecologically unacceptable.** These conditions represent substantive long-term impacts to biotic communities and disrupted ecological functions that may severely impair the UGL ecosystem.

The Plan Evaluation Group (PEG) has introduced the idea of “coping zones”, i.e. a range of conditions that allow specific attributes to function at a desired state. This desired state may represent an “acceptable” condition, but not necessarily an ideal condition. For the ecosystem, “natural coping zones” are represented by the green and yellow condition indicators Table 2 where the natural range of water levels is maintained such that biotic communities and natural ecosystem functions are not significantly impaired. The boundaries of these coping zones are defined by site-specific water level regime thresholds derived from analyses of ecosystem responses to changing water level regimes and/or by the historic natural range of water level regimes at that site. Regulation plans with water level regimes that are anticipated to fall within the boundaries of these “natural coping zones” are likely to have minimal impacts on the UGL ecosystem. Conversely, regulation plans with water level regimes that are anticipated to fall outside the boundaries of these “natural coping zones” are likely to have significant impacts on the UGL ecosystem.

### 4.5 Ecological Components and Performance Indicators

The recognition that suitable performance indicators of Great Lakes coastal margin condition were lacking (e.g. SOLEC 1998) stimulated several agencies to provide research funding to support their development. The central basis for the IUGLS is contained in the so-called “White Paper” (Ecosystem Responses to Regulation-based Water Level Changes in the Upper Great Lakes, Ciborowski, Niemi, et al), provided separately. Chow-Fraser, funded from various sources including NSERC and the Great Lakes Fishery Commission, derived quantitative and effective indices of water quality (Chow-Fraser 2007), phytoplankton (McNair and Chow-Fraser 2003), zooplankton (Lougheed and Chow-Fraser 2002),
macrophytes (Croft and Chow-Fraser 2007), and fishes (Seilheimer and Chow-Fraser 2006, 2007). The US EPA GLNPO-funded Great Lakes Coastal Wetland Consortium independently derived multimetric-based indices of zoobenthos (Burton et al. 1999, Uzarski et al. 2004), fish (Uzarski et al. 2005), macrophyte (Albert et al. 2005, 2008), amphibian (Timmermans et al. 2008a, and bird (Timmermans et al. 2008b) community condition. The US EPA STAR program supported the Great Lakes Environmental Indicators (GLEI program; Niemi et al. 2006), which derived indicators of various taxa including diatoms (Reavie 2007), fish (Bhagat 2005, Bhagat et al. 2007, Bhagat et al. in review), bird assemblages (Howe et al. 2007, Miller et al. 2007), emergent plant species (Johnston et al. 2007), and anurans (Price et al. 2007). The GLEI approach also identified stress gradients across the US Great Lakes coastal region that can serve as a framework for monitoring and analysis of the coastal zone (Danz et al. 2005, 2007).

Different sampling design approaches, geographic and habitat coverage, and analytical techniques were used by each group, reflecting the groups’ unique research questions and priorities. Pat Chow-Fraser’s research emphasized quantifying biological responses to wetland water quality and habitat degradation. The mandate of the GLCWC was to develop a binational monitoring program to assess and inventory the condition of Great Lakes coastal wetlands that could be reported to SOLEC (2007). In contrast, GLEI proposed to develop and test indicators of ecological condition of all Great Lakes coastal margins, not just wetlands. This also entailed special interest in defining and quantifying the bounds of reference condition. The emphasis of Chow-Fraser was on prediction, that of GLCWC was on monitoring status and trends of ecosystem health, and that of GLEI was on diagnosis and understanding cause/effect relationships.

<table>
<thead>
<tr>
<th>Component</th>
<th>PI Description</th>
<th>Scale</th>
</tr>
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<tbody>
<tr>
<td>Landscape Features</td>
<td>Shoreline Type, Hardening, Nearshore Slope, Location</td>
<td>Regional</td>
</tr>
<tr>
<td>Hydrology</td>
<td><strong>Magnitude, Frequency, Timing, Duration, Rate of Change</strong></td>
<td>Regional</td>
</tr>
<tr>
<td>Wetland Vegetation</td>
<td>Change in Type, Area, Diversity, Invasives</td>
<td>Site Based</td>
</tr>
<tr>
<td>Fish</td>
<td>Change in Potential Spawning/Nursery Habitat (Nearshore/Riparian Connectivity), Sentinel species (Northern Pike, Yellow Perch, Brook Trout)</td>
<td>Site Based</td>
</tr>
<tr>
<td>Invertebrates</td>
<td>Change in Type, Diversity, Abundance</td>
<td>Site Based</td>
</tr>
<tr>
<td>Birds and Waterfowl</td>
<td>Change in Potential Nesting Habitat</td>
<td>Site Based</td>
</tr>
<tr>
<td>Species at Risk</td>
<td>Change in Type, Diversity, Abundance, Habitat</td>
<td>Site Based</td>
</tr>
</tbody>
</table>
Although each of these approaches to indicator development has focused more on water quality and habitat alteration stresses than on fluctuations in water level regime, many of the effects are still mediated through degradation of the structure and extent of aquatic plant communities. Thus, some are amenable to modification for the assessment of effects of water level fluctuations and may be used to identify and establish threshold criteria for significant water level regime impacts. Based in part on these studies, the fundamental ecological components, landscape and hydrologic attributes, and performance indicators that we deem to have the most value for diagnosing likely effects of water level alteration are summarized in Table 3 and described in more detail in Table 5, Section 4.8 and in the attached ETWG white paper (see Ciborowski et al. 2009).

4.5.1 Landscape Features and Hydrology

In Table 3, page 31, Landscape Features and Hydrology are fundamental attributes (identified by the blue shading in Table 3) that can be used to assess site vulnerabilities. These attributes are technically not ecological performance indicators, but at specific sites may severely constrain the ability of biotic communities to respond to changes in water level regime. They therefore can be used as a surrogate performance indicator for a broad range of ecosystems responses. For example, landscape features such as shoreline type, presence or absence of shore protection structures (upland hardening), and nearshore slope directly affect the vulnerability of coastal margin communities to change in water level regime. These factors affect the mobility, connectivity, and zonation of coastal margin communities.

Inability of biotic communities to migrate up or down-slope and the loss of hydraulic connectivity due to shallow channel sill depths can threaten the continued existence of specific types of coastal wetlands (Figure 9). This loss of connectivity may also impact multiple species of fish that rely on these shallow connected embayments and nearshore wetlands for spawning and nursery habitat. In recent correspondence with Dr. Pat Chow-Fraser, there are multiple examples of isolated wetlands in eastern and northern Georgian Bay that are connected to Lake Huron via narrow channels floored by a bedrock sill. As Lake levels decline, the hydrologic connection becomes more tenuous and the wetlands are eventually lost. Along the western coast of Michigan, Dr. Don Uzarski has documented dune-swale wetland complexes that are hydrologically connected to Lake Michigan that are extremely sensitive to falling water level regimes. As Lake levels decline, the adjacent coastal margin groundwater table drops eliminating the hydrologic connection to the Lake resulting in the loss of the dune-swale wetland complex.

These are examples where hydrologic thresholds can be clearly identified and ecological impacts assessed. Note that “natural coping zones” would exist between these thresholds and/or within the historic natural range of water level regimes at these sites. These losses may have occurred periodically during droughts in the past, and they may be more common in the future both because of increased conveyance in the St. Clair River, which may have permanently lowered Lakes Michigan-Huron, and because the land on the northern shore of these lakes is rising in isostatic rebound from the glacial period.
The hydrologic attributes of water level regimes are defined by water-level and flow characteristics such as the magnitude, frequency, timing (seasonality), duration, and rate of change of water levels at a site. The multidimensional and complex temporal nature of UGL water level regimes has led the ETWG to work cooperatively with the Plan Evaluation TWG (David Fay) to explore different ways to express and visualize statistical and timing differences between the proposed water level regulation plans. Using simulated Pre-Project and Plan 1977A based on historical 20th century water supplies, the ETWG and the Plan Evaluation TWG are evaluating different types of statistical metrics that may provide some insight as to the causative factors behind the response of different ecological components. For example, parameters that are currently being explored include, but are not limited to:

- Mean level of Annual Peak compared to Pre-Project
- Standard Deviation of Annual Peak compared to Pre-Project
- Mean level of Annual Min compared to Pre-Project

Figure 9 Landscape features that cannot adapt to different water level regimes

Assessment of water level regime vulnerability for these types of landscape features is relatively straightforward, either because biotic communities will not be able to migrate up- or down-slope or because hydrologic connections are controlled by the minimum elevation of the connecting channel and/or the minimum elevation of dune swales. Not shown, and likely unique to Lake Superior are the small to medium size tributaries that have large cobble or bedrock interfaces with the lake. These types of tributaries, along the north shore of Superior, have the potential to strand species as water levels drop (high water is not an issue). Tributaries with sand or gravel interfaces can restructure themselves; not so with bolder or bedrock interfaces.
• Standard Deviation of Annual Min compared to Pre-Project
• Mean Difference between Annual Peak and Annual Min compared to Pre-Project
• Standard Deviation of Difference between Annual Peak and Annual Min compared to Pre-Project
• Average rate of Monthly Change compared to Pre-Project
• Standard Deviation of rate of Monthly Change compared to Pre-Project
• Timing of Annual Peak compared to Pre-Project
• Range of the annual growing season peak over 20 years compared to pre-project

These analyses will help to establish conceptual interest satisfaction curves for various ecological components and may provide guidance to site coordinators as to which water level regime characteristics are changing in response to a proposed regulation plan.

Even though the statistical analyses described above compares Plan 1977A to Pre-Project water level regimes, the ETWG is using Plan 1977A as the ecological base line to which other proposed regulation plans will be compared. One way of evaluating these performance indicators is to normalize the indicators to Plan 1977A (described as the PI Ratio in Table 5, Section 4.8 and in Ciborowski et al. 2009) and establish “natural coping zones” and thresholds for different ecosystem components. As the deviation from the Plan 1977A water level regime increases, it is anticipated that disruptions to biotic communities and ecological function will increase, but not necessarily in a linear fashion. Moreover, it is not anticipated that these impacts (or thresholds) will be uniform across Lakes, ecoregions, sites, or ecological components. Note that deviation from Plan 1977A toward Pre-Project water level regimes would likely result in minimal disruption to biotic communities and ecosystem functions and may result in ecological improvement.

A hypothetical example water level regime response curves is presented in Figure 10, page 35. Note that each of the water level regime characteristics are evaluated separately using the criteria developed by Dean and Jackson (2006) and implemented by Bain (2007) in the St. Marys River. The fundamental concept presented here is that all of the water level regime characteristics (i.e. magnitude, frequency, timing (seasonality), duration, and rate of change) must yield an appropriate ecosystem response; otherwise the proposed regulation plan may impact the ecosystem in an undesirable way. Bain (2007) assigned impact scores to each of his biological descriptions. These scores provide a convenient and simple way to plot changes in ecosystem condition in response to changing water level regimes, but other descriptive systems and scoring mechanisms could be used as well.

However, the time scales over which each of the water level regime characteristics occur may be different. Currently, the synthetic water level curves are generated for monthly mean water levels. This is based on the fact that flow adjustments are made once a month at the St. Marys River. However, certain parameters such as frequency, duration, and rate of change may be ecologically significant at somewhat shorter time scales. The ETWG is currently working with the Plan Evaluation TWG (David Fay) to explore ways to generate synthetic water level curves based on shorter-term historic water level variability to assess potential differences in water level regime (variability) between proposed regulation plans. These curves could also be compared with potential thresholds to assess potential impacts to the ecosystem.
Figure 10 Hypothetical response of ecosystem to changes in magnitude, timing (seasonality), and duration in response to changes in water level regime.

Thresholds and biological condition are draped over the distribution curve to indicate where exceedance causes significant ecological disturbance. Colors match Table 2 Description of biological condition (Davies and Jackson 2006; Bain 2007) page 29. Horizontal arrow and heavy vertical lines denotes range of historic natural values.
4.5.2 Wetland Vegetation

Again, the White Paper analysis (Ciborowski and Niemi, et al, 2009) provides the basis for the wetlands analysis here. Great Lakes coastal wetlands often contain predictable gradients of chemical and physical conditions that extend from open water toward shorelines. These gradients, which are central to the biodiversity of these systems, are driven largely by hydrology. The dynamics of water level fluctuations create and maintain plant zonation, which in turn creates its own chemical and physical gradient. Water regulation impacts will primarily influence vegetation structure and interrelated features that are affected by the presence and type of vegetation at a site. Vegetation provides the physical three-dimensional template of habitat for organisms living at or near coastal margins. Coastal habitats are commonly characterized by the hydrogeomorphic attributes of aquatic habitats (e.g., ‘riverine’, ‘protected’, fringing) and/or the names of the dominant and subdominant plant community types (e.g. emergent, floating leaf, submergent, and unvegetated zones). As performance indicators, the ETWG considers the type, area, diversity, and susceptibility of wetlands to colonization by invasive species to be critically important to an evaluation of the UGL ecosystem. Site coordinators will use detailed bathymetry, aerial photography, coupled with existing (and perhaps new) field data sets to document historical and current wetland distributions for both high and low water periods to evaluate wetland responses to changes in water level regime.

Albert et al. (2008) summarized common species of the Great Lakes coast that are sensitive to lake-level variation and could be used as potential indicators. These include: bulrush (Schoenoplectus acutus and S. pungens), purple loosestrife (Lythrum salicaria), wild rice (Zizania aquatica/Z. palustris), narrow-leaved and hybrid cattail (Typha angustifolia and T. X glauca), common reed (Phragmites australis), upright sedge (Carex stricta) and bluejoint reedgrass (Calamagrostis canadensis). Albert et al. (2008) suggested a few rare plant species that are sensitive to water level; these included Pitcher’s thistle (Cirsium pitcheri), eastern prairie fringed orchid (Platanthera leucophaea), Smith’s bulrush (Schoenoplectus smithii), and a species of arrowhead (Sagittaria montevidensis). These species may reflect variable lake level, either because they are early colonizers (bulrush, loosestrife, cattail, and common reed); because they are specialists of variable water levels (upright sedge, bluejoint reedgrass); or because they are rare species that require recently exposed substrate.

Where appropriate data are available, it may be possible to use individual plant species as indicators of water-level change on a site-specific basis. These data can be used to develop vegetative change models that predict site-specific responses to changes in water level regime. However, due to climatic differences among ecoregions, site-specific aspects such as size, topography/bathymetry, geomorphology, and disturbance and stressors unrelated to water level; the ETWG has expressed considerable concern about using individual plant species as regional indicators of changing water level regimes.

With respect to hydrology, water level fluctuations occur on three major time-scales: short-term, seasonal, and interannual (long-term). Each adds to the dynamic nature of these coastal systems. Seiches are quasi-daily (< 24 hours) water level fluctuations caused when persistent wind forcing and/or differences in atmospheric pressure cause water level on one side of a large lake to be higher than the other. The result in the Great Lakes is a persistent and cyclic inundation and dewatering of shoreline and wetland ecosystems for the duration of the seiche event. In some areas seiches can change water levels by nearly a meter in a matter of hours. Seiches as high as 1.5 m have been recorded on Lake Michigan and as high as 3 m on Lake Huron following high wind events. However, 10 to 20-cm changes in water
levels are more typical in the UGL. Seiches circulate water throughout the wetland complex and influence short-term wetting and dewatering of wetland surfaces. Biota found in these environments are adapted to abrupt changes in water depth or even complete dewatering (Uzarski in press). Changes in water level regulation are not likely to affect seiche frequency or amplitude, but may alter the location and elevation of the coastal wetted area affected by the seiche events.

![Figure 11](image-url)  
**Figure 11** Plant zonation in open coastal (fringing) wetlands associated with large lakes and subject to wave energy and natural water level variability (from Uzarski in press).

Water saturated soils or standing water for significant periods during the growing season (two weeks or more) are a dominant factor in determining the presence and species composition of wetland plant communities (National Research Council 1995). Wetland plants are variously able to cope with hypoxic environments; thus vegetation zones develop, composed of suites of species having similar coping to flooding. A successional series of zones extends from the upland (very seldom flooded) downslope to continuously flooded habitats (shallow open water) (Figure 11). Most tree species and other woody plants are intolerant of prolonged standing water. Obligate wetland plant species have structural and physiological adaptations that permit their survival and growth in flooded conditions. Some species, such as upright sedge (Carex stricta), form tussocks whose living roots extend above the flooded soils, and form an environment suitable for other wetland plant species on the tussocks.

Overlain on short-term variation in water levels are seasonal changes in water level. For example, water levels in the UGL reach seasonal maxima in June (Ontario and Erie), July-August (Michigan and Huron), and August-September (Superior). Seasonal lows generally occur during the winter months as evaporation coincides with a reduction of inflows from precipitation and runoff. The timing effects of
annual water level fluctuations on biota have not been well studied in these systems, but ongoing research suggests that timing is important for the germination and survival of many types of emergent vegetation, especially in the spring and early summer months (Uzarski in press).

Longer–term Interannual water level fluctuations are the result of variability in regional weather patterns from year to year and are generally not predictable. The most pronounced result of interannual water level fluctuations is a regional shift in plant zonation, either lakeward or toward the upland. Vegetation zones (Figure 11, page 37) adjust to hydrologic conditions that are the optimum for each community type at the time of propagule germination from seed banks and/or buried roots and rhizomes (Hebb et al. 2006; Uzarski in press).

To evaluate these wetland complexes, existing data will be used to construct water level regime response curves to identify water level regime thresholds where changes in water–level regime significantly alter the type, area, diversity, and susceptibility of wetland complexes to invasive species. Once established, these curves can be fine-tuned using site-specific vegetative change models to document changes in areal extent and zonation pattern with changing water level regimes. Where available, existing vegetative change models will be used that have been developed for specific sites or regions.

4.5.3 Fish and Invertebrates

Nearshore macroinvertebrate and fish distribution and their community composition reflect plant zonation and associated chemical and physical gradients established by long-term water level regimes. Wetzel (1990) suggested that the highest density and diversity of fishes is associated with high primary productivity in the form of macrophytes and algae. Intact coastal wetlands with several plant zones (sustained by water level fluctuations) provide cover, prey, spawning and nursery habitats (Goodyear et al. 1982; Lane et al. 1996a,b,c). Great Lakes coastal wetlands provide essential habitat for more than 80 species of fish (Jude and Pappas 1992). More than 50 of these species are strictly dependent on wetlands, while another 30+ migrate into and out of them during different periods in their life history (Jude and Pappas 1992, Wilcox 1995). An additional 30+ species of fish may be occasional visitors to coastal wetlands based on occurrence in adjacent habitats (Jude and Pappas 1992). Thus, biotic communities associated with UGL coastal wetlands are critical to the UGL fisheries either directly or as prey base.

Changing water level regimes affect wetland macroinvertebrate habitats by altering the extent and type of wetlands; wetland plant composition, zonation, and diversity; sediment composition; and access to backwater sheltered areas. Because benthic invertebrate communities depend so strongly on aquatic plant habitat zones and types, invertebrate-based indicators are often stratified by plant zone (Burton et al. 1999, Uzarski et al. 2004). Hydrologic variability and anthropogenic disturbances are superimposed on plant zonation (Burton et al. 2004) in shaping invertebrate community composition. While these attributes make macroinvertebrates prime candidates for indicating significant impacts of water level change and fluctuation, we recommend only using them in a restricted sense. For example, long-lived, wetland-obligate invertebrates such as dragonflies and damselflies are relatively easy to collect and their presence indicates that water levels and habitat conditions have been relatively stable over the course of their development, which can be a year or more. Moreover, the value of wetland macroinvertebrates as forage for fish can be determined by estimating macroinvertebrate and microcrustacean biomass per hectare of marsh. Recent ongoing work by Don Uzarski suggests that
water level regime may be an important controlling factor affecting invertebrate biomass in northern Lake Michigan - Huron wetlands. Additional work is needed at other sites to validate the technical approach, but initial results appear to be promising. An evaluation of water level regime impacts on invertebrates is important as invertebrates serve as a food source for many fish species, especially forage fish and larger predators of significant economic interest. Changes to coastal margin invertebrate communities could cascade through the food web and cause ripple effects in coastal fish communities.

Where data are available, nearshore species of interest (e.g. Northern Pike, Coaster Brook Trout) may also be used as potential indicators of water level regime impacts. Each of these species may have specific habitat requirements that may change in response to changes in water level regime. Resident wetland coastal fish species and migratory fishes that use tributaries will most likely be influenced by absolute water levels and variation at different time scales. The complex interaction between water depth, vegetation and other physical, chemical, and biotic variables will determine the location, extent, and accessibility of fish habitats for basic life processes. The vulnerability of migratory fishes water level regime changes will be further assessed based on expected changes (and thresholds) affecting the accessibility of coastal margin and upstream riparian habitats. These physical aspects of these types of analyses were described previously in Section 4.5.1 Landscape Features and Hydrology, starting on page 32 and illustrated in Figure 9, page 33.

Given the study’s short time frame and limited resources, extensive modelling of coastal fish communities across such a large area is not possible. Instead, the ETWG is focused primarily on evaluating potential impacts to changes in nearshore and coastal margin fish habitats and accessibility to those habitats. Existing coastal fish community models will be used on a site-specific basis if the models already exist and can be easily adapted to assess potential water level regime impacts. Other nearshore and coastal margin habitats (such as bedrock / cobble beaches) may also be affected by low water levels, but the extent of these impacts is largely unknown due to a lack of a comprehensive inventory of nearshore habitat types. Even though desirable, time and resource constraints limit the amount of data that can be collected to evaluate these types of habitats, except on a limited site specific basis.

In addition to water level regimes, the regulatory effect of temperature on the life cycle of fishes and the seasonal interaction between thermal and water level cycles is an important factor that triggers migratory, and spawning, and hatching behavior in many UGL fish species. The ETWG is pursuing collaborative discussions with the Hydrology TWG to assess what modelling or predictive capabilities are available to assess potential thermal impacts resulting from altered water level regimes.

4.5.4 Birds, Waterfowl, and Rare, Threatened, and Endangered Species
Few studies have specifically examined the effects of water level changes on semi-aquatic or terrestrial vertebrates in the UGL region. Examination of the effects of water level change on these species is best linked with their associations with habitat conditions. For instance, the approach of Howe et al. (2007a, 2007b) and Price et al. (2007) that links breeding birds and amphibians, respectively, with stress gradients provides a framework to examine variations in water level change in the coastal region of the UGL. Other studies (e.g. Robertson 1972, Picman et al. 1993) outside of the Great Lakes have found
water depth to play a significant role in nest success of wetland breeding birds because lower water depths are associated with increased predation of nests. The ETWG does not include breeding success as a performance indicator for the UGL because there is insufficient information on the breeding biology for most species in the region.

Birds and mammals are highly associated with specific wetland habitat types found in the coastal region of the UGL, and many of the wetland habitats are greatly influenced by water levels and variation in water levels. For instance, three of the endangered bird species (least bittern, king rail, and black tern) identified as susceptible to water level fluctuations can all be found nesting in emergent wetlands (Albert et al. 2008). Least bittern and black tern are found in the deeper water areas with scattered openings within these wetlands (Evers 1997). In contrast, king rail are generally found in drier portions or at the interface of emergent wetlands with sedge meadows or shrub wetlands (Evers 1997, Albert et al. 2008).

The piping plover is endangered in the US, Canada, and many states and is highly associated with open, exposed beaches with a mix of sand, cobble, and sparse vegetation (Haig 1992). There are many factors that have affected the distribution and abundance of the piping plover in the UGL. Fluctuations in lake levels and the availability of protected open sand/cobble beach habitat are an important aspect of their continued survival in the region (US FWS 2003). Lower lake levels would be beneficial to this species because more beach habitat would be exposed, while higher lake levels would be detrimental for the opposite reason.

With the exception of the piping plover, all of the vertebrate species identified by Albert et al. (2008) are linked to wetland habitats found in the UGL. Emergent wetlands are also important to many waterfowl species such as mallard, blue-winged teal (Anas discors), and the rare American black duck (Anas rubripes). The degree to which water levels change within specific areas, and the degree to which wetlands change, will determine the effects on these species that are important to many societal groups such as conservationists, bird watchers, and hunters.

Instead of focusing on wetland bird and waterfowl species, the ETWG will incorporate performance indicators of potential changes to coastal wetland habitat area for both wetland bird and waterfowl species in the UGL. These performance indicators and associated thresholds will be incorporated into the wetlands vulnerability assessment. In contrast, the piping plover is a key performance indicator of open, sandy beach habitat. A separate vulnerability assessment for piping plover will be performed and linked to the Coastal TWG beach assessment performance indicators.

### 4.6 Site Studies

Within the UGL Study area, sites with landscape features and ecological components that are most likely to be affected by water level regime may be affected by changes in water level regulation. Examples of such areas include: coastal wetlands, beaches, dunes, tributaries and river mouths, islands, and the nearshore/coastal margin. The ETWG has identified these types of environments as priority areas as they are especially vulnerable to changes in water-level regime. Many of these low-slope shallow water areas are ecologically significant due to the presence of coastal wetland complexes that support valuable biotic communities. Certainly other coastal habitats will be affected by changes in water level regime, but it is anticipated that the most significant ecological impacts will occur first at these sites.
Using the NOAA 1-meter bathymetry, a preliminary GIS analysis was performed at the University of Minnesota Natural Resources Research Institute (NRRI) to identify low slope and shallow-water areas within the UGL adjacent to identify coastal areas that might be affected by a 1-meter change in water level. Using this map as an initial template, eighteen (18) potential study sites were identified within the UGL as having landscape features and ecological components vulnerable to changes in water level regime (Table 4, page 42). The primary selection criteria included:

- appropriate geographic representation by Lake and ecoregion;
- ecological representation and potential suite of ecological components/performance indicators;
- potential ecological sensitivity and significance;
- potential timeliness and availability of data; and
- ongoing research and/or investigators familiar with the site.

The ETWG is currently performing a more detailed evaluation of these sites based, in part, on the following criteria:

1) ecological and economic significance of the proposed site;
2) appropriate ecological components and measurable performance indicators;
3) high-resolution bathymetric and topographic data, especially in areas potentially affected by water level change;
4) historical data on potential performance indicators, including the length and continuity of the historical data record, especially through periods of low and high water;
5) aerial photography or other imagery, especially over time through periods of low and high water;
6) historical or current field surveys/data to validate air photo interpretation;
7) high-resolution bathymetric and topographic data, especially in areas potentially affected by water level change;
8) anthropogenic disturbance – pristine or degraded;
9) willingness and availability of personnel to acquire additional data (if necessary) and perform water level regime vulnerability assessments; and
10) potential for future long-term monitoring.

Using the more detailed 10-point criteria list, each of these sites is undergoing a more thorough evaluation by the ETWG Project Manager in collaboration with the ETWG co-chairs and potential site coordinators. This evaluation includes a review of available bathymetric, topographic, and biological data (both historic and current) available at the proposed site, and may include an on-site visit with the site coordinator to assess the site(s) in the field. This more comprehensive evaluation includes an assessment of data gaps, data needs, and whether or not appropriate ecological components and potential performance indicators are indeed present and measurable at the site.

Moreover, each site has different landscape features that are unique to that site. The ecological components and associated performance indicators are likely different at each site as well. Specific guidance is required to ensure that performance indicators are evaluated using methodologies that allow for multi-site comparisons and assessments.
Table 4 lists the eighteen (18) potential study sites identified in the initial screening process based on the primary selection criteria. These sites are generally associated with low-slope shallow water areas that were deemed to be vulnerable to somewhat lower UGL water levels and or lower flows, provided geographic representation across Lakes and ecoregions, had ongoing research and/or investigators familiar with the site, and were considered to be potentially ecologically significant. Light green shading indicates areas where site coordinators have been selected and sites identified. Yellow areas indicate pending sites.

Site Coordinators are responsible for an area or region that may contain multiple individual sites. Each of these sites may have different ecological components and associated performance indicators, and will likely have different vulnerabilities and water level regime thresholds as well. The ETWG will be relying on the professional judgment and expertise of the Site Coordinators to ensure that the uncertainties associated with the site vulnerability assessments are adequately captured in the water level regime response curves and thresholds provided to the IERM modelling team. Site Coordinators are also instructed to “think outside the box” and consider not only site vulnerabilities, but opportunities for ecological improvement as well. In addition to assessing site vulnerabilities, Site Coordinators are encouraged to formulate hypotheses about how individual ecological components and performance
indicators may respond to water level changes and to test those hypotheses in the field as part of the vulnerability assessment process.

During the data collection and vulnerability assessment process, there will be a continual dialogue between Site Coordinators, the ETWG Project Manager, the IERM Modeling Contractor, and the ETWG Co-Chairs; with periodic updates provided to the entire ETWG Group. The ETWG Project Manager will coordinate data collection activities with the ETWG GIS Manager to ensure that all site data and analyses are readily accessible to ETWG and PEG members. The ETWG GIS Manager will ensure that all site data are properly formatted, georeferenced, and that appropriate metadata has been collected and recorded for each of the individual datasets.

4.7 Upper Great Lakes IERM

Work will begin shortly to create an Integrated Ecological Response Model (IERM) that quantifies and integrates the key water-level versus ecological response relationships that have been identified by the ETWG. This integration would be performed on a site-specific basis, on an ecosystem type basis, on a region basis, and to the extent possible on a lake basis. It would then represent an integration of vulnerabilities and “coping zones” as a function of water level thresholds. For each Ecological Performance Indicator at each level of integration, the IERM tool would be used to incorporate weighting factors (established by the ETWG) that will be used in making site-wide, lake-wide, and region-wide ecosystem vulnerability assessments. The tool could also identify locations where water levels are within a “natural coping zone” for a specific water level regulation plan.

As described in section 4.5.1 Landscape Features and Hydrology and illustrated in Figure 9, page 33, significant ecological harm may occur if thresholds are exceeded for any of the water level regime characteristics (i.e. magnitude, frequency, timing, duration, and rate of change of water levels). It is envisioned that each of the ecological components (or performance indicators) will be weighted differently as a function of the relative importance of that threshold. For example, the timing of the maximum peak may be critical to provide connectivity to spawning habitat; or the duration of high water levels in the early spring must exceed a specified time in order for wetland seeds to germinate. This approach is similar to that developed for the LOSL study where certain water level conditions had to be met to for long-term maintenance of meadow marsh habitat.

The IERM tool will quantify, integrate, and visually summarize the sensitivities of key ecological performance indicators to water levels by lake, by ecological component (wetlands, fish, and invertebrates), and by region (Saginaw Bay, Georgian Bay). Discussions with the Modelling contractor reveal that the IERM model can be easily modified to perform these calculations and could be applied at multiple scales. There was also discussion of possible scenario testing using the thresholds to identify potential regional ecosystem impacts in response to proposed water level regulation plans. The IERM can also be used in the overall Adaptive Management process (discussed below) by forecasting system response to alternative adaptive management approaches, and by post-auditing the system’s response to management implementation by comparison of model forecast with observed responses.
### 4.8 Ecosystem Performance Indicators

Key performance indicators identified for the UGL region. Not all PI's will be evaluated at all sites. PI metrics are examples but may be modified on a site-specific basis by site coordinators. Water-level response curves and thresholds will be developed where data and site conditions are appropriate.

<table>
<thead>
<tr>
<th>Component</th>
<th>PI Description</th>
<th>PI Metrics</th>
<th>PI Ratio Approach</th>
</tr>
</thead>
</table>
| Landscape Feature Attributes| Describes the ability of a habitat to adapt to changing lake levels; Ability of significant habitats to migrate in response to changing water levels | Local topography and bathymetry (m)  
Shoreline geology and land use/cover (classes)  
Distance from water’s edge to nearest disturbed land use (m)  
Extent and type of shoreline modification (hardening) (e.g., absolute (km; km²) or relative (%) length or area of shoreline converted from natural features to artificial structures (breakwall, sheet piling, paving, dam; levy, causeway, dock, etc.; summarized by class of structure)  
Distance to river mouth (m)  
Hydrologic modification (change in water exchange capacity; unit volume/unit time)  
Alteration of fluvial processes (change in annual sediment transport load; alteration of channel structure; area of rivermouth delta (ha)) | Normalize to Plan 1977A where appropriate                                                                                                           |
<p>| Hydrologic Attributes      | Inundation magnitude, timing and seasonality, duration | Compare seasonal inundation timing (date of start/end; duration (days); magnitude shifts (change in water depth (cm); and area inundated (ha)); and relative variability (SD of above measures) | Normalize to both 1977A and preproject scenarios                                                                                          |
|                            | Change in hydraulic connectivity between lake/river and wetland (same as Fish Habitat Supply and Abundance) | Connection between lake and tributary or wetland; also connection between tributary and wetland Water Exchange Index - product of time connected (days/year) and the opening size (cross-section area/max cross-section area, or wetted perimeter/maximum wetted perimeter of the connection opening). | Normalize to Plan 1977A                                                                                                                 |</p>
<table>
<thead>
<tr>
<th>Component</th>
<th>PI Description</th>
<th>PI Metrics</th>
<th>PI Ratio Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetland vegetation</td>
<td>Wetland vegetation integrity based on presence and maintenance of expected zones of vegetation communities. Habitat structure availability for fish and wildlife and their supporting food webs and ecosystems.</td>
<td>Area of each vegetation zone and non-vegetation zones (such as such as sand beaches, strands and exposed bedrock, forested wetland; ha) vs. expected zone (ha), based on elevation range and condition under Plan 77A; nonvegetated zones include</td>
<td>Normalize to Plan 1977A</td>
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<td></td>
<td></td>
<td>Number and interspersion (e.g., perimeter/area ratio) of vegetation zones relative to condition expected in appropriate elevation ranges under Plan 77A.</td>
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<td></td>
<td>Extent (% wetland area) of invasive plant species-dominated habitat. Interpretation should have regard for the intensity and local extent of agriculture and urbanization and distance between study areas and source populations of invasive species (i.e. propagule pressure)</td>
<td></td>
</tr>
<tr>
<td>Invertebrates</td>
<td>Density of wetland macroinvertebrates and microcrustaceans (if data from vulnerable areas exist)</td>
<td>Density or Biomass per hectare</td>
<td>Normalize to Plan 1977a</td>
</tr>
<tr>
<td></td>
<td>Taxa richness of long-lived, wetland obligate species</td>
<td>Taxa richness (species/area)</td>
<td></td>
</tr>
<tr>
<td>Fishes</td>
<td>Habitat-weighted suitable area (hectares) for fish guilds (incl. forage fish, others TBD) and vegetation (low/high) preference, by lake or site as necessary.</td>
<td>Habitat supply (hectares)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Habitat-weighted suitable area (hectares) for species: particular species TBD, including special submetrics for a. Habitat in the St. Marys River, especially the Rapids (consider depth of water, flow, length of time for flows &amp; seasonality) b. Habitat for beach-oriented species</td>
<td>Habitat supply (hectares)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Species population density indices for multiple life stages (spawn, fry, young-of-year, juvenile, adult) for species: walleye, yellow perch, others TBD</td>
<td>Population density (index)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td>Component</td>
<td>PI Description</td>
<td>PI Metrics</td>
<td>PI Ratio Approach</td>
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</tr>
<tr>
<td>Fishes, cont’d.</td>
<td>Accessibility of spawning and nursery areas (Lake Superior target species = coaster brook trout, lake sturgeon, lake trout, others TBD); consider water depth, connectivity &amp; temperature</td>
<td>Connection between tributary or wetland and lake</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Obligate marsh fish species richness; Northern pike as a sentinel species</td>
<td>Availability of habitat</td>
<td>Normalize to Plan 1977A and season</td>
</tr>
<tr>
<td>Birds</td>
<td>Wetland birds: Change in richness and relative abundance of obligate breeding marsh bird species</td>
<td>Relative area of habitat change (%) in wetlands or change in water-level derived condition index for obligate wetland species (ha)</td>
<td>Normalize to Plan 1977A and season</td>
</tr>
<tr>
<td></td>
<td>Water birds: Change in breeding bird and migratory richness and relative abundance of obligate water-associated species</td>
<td>Relative area of habitat change in wetlands and near-shore habitats or change in water-level derived condition index for obligate water-associated species (ha)</td>
<td>Normalize to Plan 1977A and season</td>
</tr>
<tr>
<td></td>
<td>invasive species (e.g., mute swan) as an indicator</td>
<td>Density (#/ha)</td>
<td>Normalize to Plan 1977A and season</td>
</tr>
<tr>
<td>Herptiles</td>
<td>Change in richness and relative abundance of frog and toad wetland habitat</td>
<td>Or change in water-level and habitat quality derived condition indices for frogs and toads</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Relative area of habitat change in frog and toad habitat (ha),</td>
<td></td>
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<tr>
<td></td>
<td>Change in richness and relative abundance of turtles &amp; snakes of regional interest (e.g., Georgian Bay)</td>
<td>change in water-level and habitat quality derived condition indices for turtles and snakes</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Relative area of habitat change in turtle and snake habitat (ha),</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mammals</td>
<td>Density of muskrat houses in early spring (a surrogate measure of wetland condition)</td>
<td>Density (of limited value) (#/ha); Relative area of habitat suitable for muskrats (percent; requires development)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Density of beavers (a surrogate measure of wetland condition)</td>
<td>Density (of limited value) (#/ha); Relative area of habitat suitable for muskrats (percent; requires development)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td></td>
<td>Habitat area for meadow and heather voles</td>
<td>Relative area of sedge-fen wetland habitat (ha)</td>
<td>Normalize to Plan 1977A</td>
</tr>
<tr>
<td>Component</td>
<td>PI Description</td>
<td>PI Metrics</td>
<td>PI Ratio Approach</td>
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<tr>
<td>Extent of wild rice (cultural value; not a species at risk)</td>
<td>Area of wild rice (ha)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Fish: Habitat area for 2 species: coaster brook trout, lake sturgeon and others as appropriate to habitat type (e.g. pugnose minnow, pugnose shiner, blacknose shiner) (spawning, young-of-year, and adult life stages)</td>
<td>Relative area of suitable area (ha)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Wetland birds: Change in habitat area for 4 species: least bittern, black tern, king rail, yellow rail</td>
<td>Relative area of suitable wetland habitat (ha)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Piping plover: Change in availability of sand and cobble beach-habitat in areas designated as critical to the Piping Plover</td>
<td>Relative area of habitat change in sand and cobble beach habitat (ha)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Nitrogen cycling</td>
<td>Concentration of nitrogen in sediment; Organic sediment depth by area (cm)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Algal productivity</td>
<td>Water column chlorophyll a</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
<tr>
<td>Benthic metabolism</td>
<td>Sediment oxygen demand (mg O₂/m²/d)</td>
<td>Normalize to Plan 1977A</td>
<td></td>
</tr>
</tbody>
</table>
5. Adaptive Management Work Plan

This chapter describes a work in progress, an adaptive management plan for Great Lakes levels. The description here has not been reviewed or approved by the Board or even the study directors, but it represents the most current thinking based on input from a June 2-3, 2009 workshop designed to provide advice to the Board on this subject.

5.1 Background

The Study Board has identified the Plan Evaluation Group as the lead for the development of an IUGLS adaptive management strategy. The PEG presented an initial adaptive management discussion document for Board consideration at its December 2008 meeting and followed-up with an initial draft scope of work at the Feb 2009 Board meeting. PEG will be responsible for the staff work necessary to support the adaptive management effort and for working with study team members in developing a strategy; formal discussions with people outside the study will be led by the two study directors.

This is a revised approach for adaptive management. The changes from the first draft are largely because:

- The Board added a new requirement. In its draft St. Clair report, the Board recommended that “The need for mitigative measures in the St. Clair River be examined as part of the comprehensive assessment of the future effects of climate change on water supplies in the upper Great Lakes basin in Report 2 of the Study, on Lake Superior regulation.”
- The Board decided to sponsor a June 2009 workshop to secure advice on how to conduct the adaptive management efforts.

5.2 Impact of the mitigative structures decision

The Board will be able to draw on assessments of multiple lake regulation done during the Levels Reference Study, but will also need to update and expand that work to meet its second recommendation. Additional work includes:

- Specifying the capacity of previously defined alternative regulation structures to affect Great Lakes levels.
- Modifying the Great Lakes routing model to include release rules for each of these structures.
- Development of a quasi-optimization of multiple structures to affect the best overall results.
- Developing trigger conditions to begin different tasks of the development of these new structures, and assessing the risks of delaying or advancing those phased decisions.
- The development of water supply sequences that represent the range of conditions that might occur in the future.

This work is woven into the tasks described below.
5.3 Impact of the June 2-3, 2009 Adaptive Management Workshop

At the Study Board’s request, the PEG hosted an adaptive management workshop on June 2-3, 2009 in Windsor, ON, bringing together climate as it considers whether and how to craft an adaptive management strategy. A distillation of that advice follows.

Linda Mortsch from Environment Canada outlined the difficulties in determining what climate change scenarios are most relevant for various applications; she said that there is no one “best guess scenario”, so it will be necessary to come up with multiple futures to explore a range of possible future conditions. This was reemphasized by Mike Lewis, a visiting scientist with the University of Rhode Island, who demonstrated that paleo-records show that water levels had been twenty meters lower than today even in the post glacial era, pointing to the variability in climate even without the impact of CO2 forcing (he does not envision levels that low, though, noting that these levels were in part a by-product of arctic ice that does not exist today).

Sue Doka from Fisheries and Oceans Canada provided a comprehensive overview of how adaptive management is defined in the literature. Al Douglas from the Ontario Centre for Climate Impacts and Adaptation Resources enumerated the climate change research projects he oversees in the province of Ontario, and Patrick Doran from the Nature Conservancy described TNC’s climate change adaptation for the Great Lakes which had its first meeting this year.

Casey Brown from the University of Massachusetts argued that we should reverse the accepted climate change evaluation procedures. Rather than generate thousands of GCM based hydrologic scenarios and then crunching through them to find problematic scenarios, he suggested that resources experts work with hydrologists and climatologists to develop problematic scenarios that are plausible.

The argument for reversing the traditional approach begins with the fact that because of climate variability (not man-made) and change (man-made), climatologists cannot estimate the probability of future water supplies. Long term natural variations are not precisely periodic, so it is practically impossible to use the past to forecast when a dry regime will shift to wet or vice verse. And there is irreducible uncertainty in every task of the development of climate change water supplies:

- GCM’s predictions are driven by carbon emission forecasts that are very uncertain because they depend on future economic conditions, policy changes and innovation, all things that are all hard to predict;
- GCMs are global, and the gross scale means that the GCMs do not see significant Great Lakes phenomena such as lake effect precipitation.
- The skill of a particular GCM to re-produce current climate conditions varies based on the parameter used to measure similarity; no model does well across all parameters used in developing water supplies;
- The skill of a GCM in reproducing current climate conditions has never been shown to forecast its ability to model future climate conditions;
- At best, GCM’s produce large scale and generalized estimates of how climate parameters like precipitation and temperature will change; analysts have to create monthly sequences of
precipitation, evaporation and runoff into the lakes, and that translation is a series of educated
guesses and assumptions.

- If the sequences are created by adjusting historical water supplies to reflect forecasts of
  precipitation and evaporation from the GCMs, the sequences will not reflect expected changes
  in frequency distribution or inter-annual variability;
- Regional climate models address the gross scale issues of the global models, but are subject to
  many of the other uncertainties.

Dr. Brown suggested a bottom-up approach that begins with the system or decision and follows three
steps:
1. Identify system/decision vulnerabilities to climate (problematic water supplies)
2. Characterize the plausibility of those climate hazards
3. Use systematic decision approach to address climate risks

The workshop included an opportunity for all participants to provide input to a proposed strategy that
originally included four tasks including:
1. Climate change warning system
2. Methods for improving Impact assessment
3. Rules for modifying levels and flows
4. Mechanism for initiating actions to adapt to levels and flows.

Based on the advice provided by the experts and from the input received by workshop participants, the
adaptive management strategy has been restructured to consider a more bottom-up approach as
suggested by Dr. Casey Brown. A ten task proposal with about the same overall effort (except for the
additional costs for the assessment of multiple regulation structures) is now being proposed:
1. Develop coping zone definitions
2. Develop water supply sequences that cross from preferred to coping regimes
3. Investigate our ability to forecast hydrologic shifts
4. Develop adaptive regulation strategies
5. Evaluate and rank adaptive regulation strategies
6. Evaluate the ability to influence levels and flows through new structures
7. Identify levels related problems regulation cannot address
8. Identify long-term monitoring and modelling requirements
9. Conduct an institutional analysis
10. Develop adaptive management plans for regulation and non-regulation response

5.4 Descriptions of Ten Adaptive Management Tasks

1. Develop coping zone definitions. PEG will work with the TWGs to differentiate between water level
   regimes which, if not ideal, then are acceptable, and water levels which are undesirable but might be
coped with. We know that boaters prefer water levels closer to recent means, for example, and prefer
slightly higher levels to slightly lower levels. But the lower water levels drop and the longer they stay
low, the greater the impact would be on boaters. They could cope by dredging slips, channels and
harbors or buying boats that draft less; or society might decide to change the regulation plan to keep water levels higher on some lakes, or to add a control structure on the Niagara to keep water levels above Niagara Falls higher. Hydropower, Coastal and Commercial Navigation TWGs would identify the limits of the domain of the economic evaluation functions used for evaluation with historical supplies, and all TWGs would generate hydrologic thresholds that would differentiate water level regimes according to known and unknown negative impacts. For example, commercial navigation might say that their economic evaluations are no longer valid when levels persist at 70 cm, below average levels for more than three years, but might also say that if water levels persist 1 m. below average for two or more years that shippers might begin to abandon the Great Lakes. While these thresholds cannot be more than educated guesses, they can be used in later tasks to evaluate adaptation strategies and as triggers for new monitoring or external adaptation.

2. Develop water supply sequences that cross from preferred to coping regimes. This work would be led by the Hydroclimate Group; PEG would act as liaison with plan formulators and the evaluation TWGs. The Hydroclimate Group would generate transition water supply sequences that begin with supplies within historical range and transition to supplies characteristic of extreme high or low supplies. The high or low portions of the sequences could be generated in ways still to be determined, including:
   a. Extremes from a supply set stochastically generated using the mean and standard deviation of the 20th century supplies to capture the range of variability under a stationary climate scenario;
   b. Extreme high or low supplies stochastically generated using an estimated mean and standard deviation from either a portion of the 20th century or suggested from another period, representing quasi-periodic climate variability;
   c. Low supplies generated using a GCM or a stochastically generated variation of one of the climate change sequences used on the LOSL study.

3. Investigate our ability to forecast hydrologic shifts. The effectiveness of adaptation may depend on the accuracy and forewarning time of forecasts. At this time, the Board and the IJC have no defensible method for determining whether recent lake levels are explained by the normal supply variation within a stationary climate, the variation caused by multi-decadal non-periodic climate cycles, or by climate change induced by carbon emissions. Scientists have begun to question whether or not we will be able to sense these shifts early in the transition (cite the GEO article). There is no evidence that we have any skill at knowing when we are entering or leaving a climate regime. The objective of the scope of work in this task will be to attempt to develop one or more mathematical approaches that would produce useful assessments of whether the Great Lakes were at the beginning of a new climate and water level regime. This work will be led by the climatologists, hydrologist and statisticians and will have to take into account risk and uncertainty. The Hydroclimate Group would be asked to survey the literature and conduct mathematical experiments to make an educated guess at the answer.

4. Develop adaptive regulation strategies. PEG will work with plan formulators to develop adaptive regulation rules that change based on climate related triggers. Experimental and perfect forecasts will be used to determine the value of better forecasts and the limits of regulation to reduce impacts.

5. Evaluate and rank adaptive regulation strategies. To the degree possible, PEG will use hydropower and commercial navigation economic benefits. as well as the frequency, vulnerability and resilience of avoiding selected hydrologic thresholds developed by the ecosystem, coastal and water supply TWGs to evaluate adaptive strategies to modify levels and flows to minimize impacts.
6. Assess the ability to influence levels and flows through new structures. This task has three subtasks:

a) A literature review to summarize the past research on this issue, including specific structures and the domain of control – for example, whether or not there was excavation required that would allow greater than natural flows, whether there were structural elements that allowed variable control. This work would define the range of operating rules for those structures.

b) The Great Lakes routing model would then have to be modified to allow that control and a new formulation effort would be required to develop operating rules that, in combination with the St Marys structure, provided a variety of ways to manage levels throughout the Great Lakes. The effect on Lake Ontario and the St Lawrence River levels would also be considered. These new alternatives would be run with stochastic and climate change series with an eye to at least determining how much they could mitigate extreme levels, and perhaps for other objectives, such as moderating levels so they were more like historical levels.

c) A risk management and decision support approach for extreme and uncertain water supplies would be developed that would address several challenges. To what extent will the next generation regulation plan (for 1, 2 or 3 structures) reduce extreme levels? How do we estimate risks from extreme levels when the probability of those levels changes in some unknown way because of climate variability and change? How would we establish triggers for changing the regulation plan (for example, switching from one estimate of the mean lake level in a rule set like Plan 1977A to another estimate)?

The Hydroclimatic Group had always been expected to work with the adaptive managers, but in this new approach, they would work with a risk manager and other TWGs to develop water supply sequences. The questions they would have to address include:

- What range of climate variability would be captured in the water supply sequences (choice of GCMs, RCMs, carbon emission scenarios, etc.)?
- How would the complete range of variability under any climate assumption be represented? (Would we have a series of stochastic climate change supplies?)
- How would new policies be triggered? The team will have to investigate whether and how the risks of adopting too soon or too late to climate change can be managed by changing management (Superior regulation, new structures, stakeholder adaptation) based on an uncertain reading of shifting means or other statistical measures of recent water supplies.

PEG will modify the SVM to represent the multiple structure outcomes, and develop an approach with the risk manager for the Board to use in developing its recommendations on when, if ever, to trigger the next phase of development of the new structures. The multiple structure issue would have to be factored into circles of influence work and there would be some interaction with the sectoral TWGs about impacts, even though a full performance indicator evaluation cannot be done because there is no history of impacts to the extraordinary levels anticipated.

7. Identify levels related problems regulation cannot address. There are two parts to this; problems that cannot be addressed through regulation of Lake Superior, and problems that cannot be addressed with an additional regulation structure in the St. Clair or Niagara River. This effort will focus on comparing the coping zones developed by the TWGs in Task 1 with the water supply sequences that cross from preferred to coping regimes identified in Task 2 and then assess through plan formulation, the ability of existing regulations structures, or new structures to minimize the frequency and duration of the interests being pushed outside of their coping zones. This task will identify the situations or problems that could not possibly be addressed through mitigative measures to modify of levels and flows.
8. Identify long-term monitoring and modelling requirements. One of the first conclusions from the IUGLS is that more observations of the components of water supplies, levels and flows are needed to assess and manage the risks of extreme water levels. The St. Clair portion of IUGLS showed we have not collected enough data to know when conveyance of the St. Clair changed. Evaporation measurement on Lake Superior began only because of IUGLS. Evaporation rate change is expected to an important part of the oncoming climate change, but unless measurement continues on all the lakes, we will only be able to guess whether it is changing in the future. If future levels are much different, studies may be needed to identify what happens to lake ecosystems or marinas or water supply systems when water levels move outside interests coping zones. This task would be led by PEG but conducted primarily by the TWGs, who would imagine what research and monitoring efforts would be most important for identifying when hydrologic thresholds were crossed and the subsequent impacts once they have been crossed. This would be required both for understanding when action might be possible to modify levels and flows to reduce impacts and maintain coping zones, and for understanding when alternative actions will be necessary.

9. Conduct a two part institutional analysis. Identification of the agencies responsible for taking resilient action and their decision framework and begin to design a process of developing a coordinated adaptive management strategy for addressing risks.

The focus for this Study would be on an adaptive management strategy for adapting the rules for changing the regulation, or otherwise modifying the levels and flows of the Upper Lakes to minimize the impacts of climate risks (see Tasks 4, 5, and 6). This effort will include the exploration of what is necessary in terms of data, information, resources and institutional arrangements to provide for the rules for modifying a regulation plan or building new structures in the face of climate change. However, given the limitations of regulation in mitigating impacts, especially on Lake Michigan-Huron, St. Clair and Erie, there is a recognized need for considering alternative resiliency strategies for adapting to changing levels and flows. This Study provides an opportunity to identify the agencies that would make those decisions, and to begin working with them to identify a mechanism for the development of a coordinated adaptive management strategy for addressing climate change/variability by changing behavior, investments and policies to build greater resiliency into the system. The IJC and its Study Board would help facilitate this process but the responses would typically be undertaken outside the IJC by various levels of governments and the private sector.

10. Develop adaptive management plans for regulation and non-regulation response. Based on the previous tasks, PEG would develop two draft documents for the Board and would shepherd an active review process leading to two recommendations from the Board to the IJC.

The subject of the first document would be an adaptive regulation strategy. It would be an adjunct to the Board’s recommendations for a new regulation plan. This document would include:

- An explanation of why adaptive regulation rules are needed
- Rules for changing the regulation plan, including language that could be included in a new order
- A trigger strategy for study and development of an additional Great Lakes regulating structure, to the degree the Board supports that position.
- A budget for ongoing and conditional monitoring and research
The subject of the second document would be adaptation beyond regulation to new level regimes. This document would identify a trigger and response plan, with the triggers generated by the IJC and its hydrologic and hydraulic support agencies, and the responses generated by others including private enterprise, NGOs, and federal, state, provincial, local governments. It would identify the responsible agencies and their institutional framework and provide recommendations for a mechanism for the development of a coordinated adaptive management strategy. It would be written as a recommendation from the Study Board to the IJC with letters of support from the potentially responding agencies.
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<td>2. Develop water supplies that cross from preferred to coping regimes</td>
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<td>3. Investigate our ability to forecast hydrologic shifts</td>
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<td>4. Develop adaptive regulation strategies</td>
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<td>5. Evaluate and rank regulation adaptive strategies</td>
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<td>6. Identify residual problems</td>
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Appendix 1 Environmental and Economic Standards and Guidelines

On the LOSL Study, the Study Board agreed to standards and guidelines for the use of economics in their research and decision making. The IUGLS Board has implicitly made some of the same choices in their decisions about the scopes pursued by the technical working groups. This section uses the structure of the LOSL Economic Standards and Guidelines to establish the positions the IUGLS Board has yet to define or has already taken, implicitly or explicitly.

The guidelines:
- Identify the role for and the contribution of economics to the process of plan formulation and evaluation
- Establish a framework for estimating the economic impacts of current and alternative hydrologic criteria and regulation plans
- Prescribe standards and guidelines for the conduct of economic analyses setting guidelines for the presentation of findings.

ESG1 Baseline Specifications

ESG.1.1 Baseline Plan

Standard: Plan 1977A is the baseline against which all alternative criteria and regulation plans shall be compared.

If no recommendations from this study were put in place, future releases from Lake Superior would be made according to this rule set. All impacts from alternative plans are compared to the impacts of the baseline plan. This comparison defines the sign and magnitude of economic benefits. An alternative that reduces shipping costs by $1 compared to Plan 1977A is said to produce a benefit of $1. Similarly, an alternative that increases the value of hydropower by $1 over the value produced by Plan 1977A produces a benefit of $1.

The use of 77A as the baseline also makes it clear to the Study Board and the IJC what benefits would be lost if there is no agreement to a new plan.

ESG1.2 Baseline of Current Conditions

Standard: Evaluations of current and alternative criteria and regulation plans shall be prepared using data collected as part of the study or immediate past time-periods.

Each of the six TWGs is carrying out studies to inventory current conditions. TWGs were directed to use data on prices, costs, benefits, commodity flows, and levels of economic activity that were being collected during the study period (e.g., recreational boating, coastal zone) or in the immediate past (e.g., commercial navigation). Efforts to specify the baseline focused on those components that are most important to the analysis.
The Board has not yet established the currency (US or Canadian dollars) or price level year that will be used to compare benefits and costs.

**ESG1.3 Baseline Economics**

The LOSL Board preferred alternatives that produce net benefits without causing disproportionate loss to any sector, believing that plans with a disproportionate loss would be seen as unfair and would not be implemented. In order to establish an objective basis for defining disproportionate loss, the LOSL Board established a **guideline** that the TWGs should evaluate the change to major sectors as percentage of the current scale of the activity. Baseline were selected that were appropriate to the performance indicator for a particular interest. Percentage changes provided insight into the socioeconomic scale and significance of a performance indicator. (Thomas, et al, 2002)

The IUGLS Study Board had said that it would not recommend plans that would provide disproportionate benefits, but has yet to specify a guideline for the basis of that determination.

On the LOSL Study, these were the bases:

- **Recreational boating:** The activity was pleasure boating. The baseline value was willingness-to-pay for boating multiplied by the number of trips taken by boaters under the baseline plan.
- **Coastal erosion:** The activity was living along the shoreline. The baseline value was the value of shoreline buildings in annualized terms using a 3.6% depreciation of the shoreline building and shore protection, representing an annual loss of investment irrespective of regulation plan.
- **Hydroelectric power:** The activity was hydropower production. The baseline value was the economic value to society of the electricity produced in an average year, taking into account representative market values and operating costs at the Moses-Saunders and Beauharnois-Cedars hydroelectric plants on the St. Lawrence River and the Moses-Beck hydroelectric plant on the Niagara River, which are affected by Lake Ontario flows and levels.
- **Commercial navigation:** The activity was shipping on those waters. The baseline value was estimated net revenues under the baseline plan.
- **Municipal, industrial and domestic water uses:** No quotient was necessary because the plans all had the same impact (zero net benefits).
- **Environment:** There was no estimate of the economic impact of environmental changes.

A more detailed description of the LOSL baseline determination is available if needed.

**ESG2. Geographic Units**

The IUGLS Board has approved studies that in some cases only partially cover the entire geography of the lakes. The focus varies by technical working group, but in general, impacts will be measured at sites, and aggregated by lake and connecting channel.

The commercial navigation TWG will consider ten distinct route categories spanning the Upper Great Lakes, with each route defined based on the lakes the ships have to traverse. The depth of water available for those routes is then the minimum depth in any of the lakes making up the routes, or at the individual at the individual dock used for loading or unloading. The ten route categories are: 1-Superior,
ESG3 Period of Analysis - Time and Discounting

Standard: A period of about 105 years of historical water supply data will be available during the study, and although the analysis will use much more than just the historical data, the 105 (or so) year period will probably be used in all cases to simulate, evaluate and appraise the economic effects of the baseline, and alternative criteria and regulation plans. A record this long accommodates most biological cycles that we know about, and it is convenient to match the length of the historical record.

ESG3.1 Time (Testing of Future Possibilities)

Guideline: Hydrological sequences should be constructed so that they are representative of future possibilities. The number of hydrological sequences used in the final analysis should be large enough so that the group of sequences is representative of future possibilities in the sense of statistical sampling. (Thomas et al., 2005)

This was the LOSL guideline and the IUGLS Study Board and the IUGLS Plan of Study require a similar guideline. The PEG and Hydroclimate group are still debating how to develop water supply datasets that defensibly represent the array of possible future supplies.

ESG3.2 Serial Dependence

Guideline: The calculation of annual average net benefits depends on whether the annual impacts on a given interest are dependent on time or not.

- The impacts on a given interest do not depend on time if its benefits in a given year depend only on water flows in that year and not on water flows in other years. For these interests, annual average benefits are derived by calculating mean benefits across the sample of years and sequences used in the analysis.
- The impacts on a given interest are time dependent if its benefits in a given year depend on water flows in previous years. For these interests, annual average benefits should be calculated in sequence by year for each year in the sample of hydrological sequences used in the analysis. (Thomas et al., 2005)

Performance indicators for interests such as recreational boating and shipping have the same expected impact in each future year because the impact is essentially independent from year to year. With the PIs for recreational boating and shipping a series of identical annual impacts result in the same economic benefits and damages since gains and losses do not carry over from year to year. Each year of impacts is independent of other years, so there is no need to consider impacts with durations longer than a year. PIs that do not depend on time will be considered as single-year experiments. In other
In words, flooding occurring in a given year did not change the possibility of flooding nor flooding damages in following years.

There are two economic PIs that are serially dependent; coastal erosion and shore protection structure damage. At this point, we are not certain that we will be able to estimate dollar damages for these impacts, but we would like to. **If we are not able to estimate these dollar damages, the issue of serial dependence will be moot.** Coastal erosion and damage to shore protection structures are inevitable (i.e., this damage happens under all regulation plans), so the only difference between plans is how fast the damage happens, and that is a function of both the plan and the future sequencing of wet and dry supplies.

To estimate serially dependent damages, the expected timing of damages has to be calculated and discounted to account for time preferences. Discounting in this manner is referred to as the present worth of damage. The technical difficulty in measuring the timing of erosion damages is that the timing of erosion depends on the timing of water conditions. Very high and very low water levels accelerate erosion damages, but when will high and low levels occur? Our ability to forecast water levels beyond a few months into the future quickly declines to no better than a statistical gamble, meaning we can “forecast” that there is a better chance of normal water levels than extremely high or low water levels. The challenge was to find a way to estimate the chances of different sequences of water levels. On the LOSL study, we did this by recording the FEPS outputs from the 50,000 year hydrological sequences. Erosion damage caused by each candidate plan was measured for each quarter-month in a 101-year sequence. The evaluation was repeated with successive centuries until there were quarter-monthly damage estimates for each of the 495 centuries representing 495 possible futures. With the hydrological cycle varying across each of the 495 possible futures, erosion damages occurred faster in some of these centuries than in others. “Expected” future damages for each quarter-month of the century after plan implementation were the averages of the damages for that quarter month from the 495 centuries (from quarter month 1 to 4,848). These averages created an expected future erosion loss pattern for each plan that could then be discounted. Plans that delayed erosion had higher benefits.

**ESG3.3 Discounting**

Standard: The present value and amortization calculations shall use a discount rate that reflects a real borrowing rate suitable for government investments over a time horizon consistent with the period of analysis. A baseline discount rate of 3.5 percent appears appropriate for a 20 to 30-year time horizon. Sensitivity analysis should be conducted with lower and higher discount rates to determine how the performance indicators change with changes in the discount rate. (Thomas et al., 2005)

If we are able to estimate average impacts for erosion and shore protection maintenance for each quarter-month, then they will be discounted to represent the present worth of those damages. The present worth of the damages was then expressed as an average annual impact, using the same mathematical approach that would define an indefinite annuity funded by a deposit (present worth) today.
ESG4. Measuring Benefits

Standard: Performance indicators should be constructed so that a positive number means that an interest gains net benefits from a plan and a negative number means that an interest loses net benefits from a plan relative to Plan 1977A.

Performance indicators are based on the net benefits of an alternative lake level management minus the net benefits of Plan 1977A. A positive measure means that an interest gains benefits relative to 1977A. A negative measure means that an interest loses benefits relative to 1977A. It is not necessary to measure benefits and costs that are constant across plans since these constants cancel out in the difference between the alternative plan and Plan 1977A.

ESG.4.1 Economic Benefits

Standard: TWGs shall develop performance indicators that use either U.S. or Canadian dollars as their metric of measurement. All of the economic performance indicators are to be represented as net benefits. All performance indicators except hydropower shall be measures of cost or loss of value. Net hydropower benefits are calculated as alternative plan benefits minus Plan 1977A benefits, where the benefit is the product of energy produced times the estimated market price of the energy (modified from Thomas et al., 2005).

The LOSL EAC advised that the economic TWGs develop performance indicators based, as closely as possible, on the economic concept of net economic benefits, and this is the direction the IUGLS Board is taking. With the exception of hydropower, the benefits will be calculated using very traditional economic evaluation procedures that were designed to emulate market based values. Such procedures have been vetted by experts over the course of many studies and applications. Similar procedures have been used and evaluated in hundreds of other water resources studies. Recreational boating measures will reflect net economic value lost at sites known to be problematic by recreational boaters and charter boat patrons as water level varies from ideal levels for boating based on willingness to pay estimates. The intent for coastal performance indicators is that they will be measures of flooding, erosion and shore protection maintenance costs to shoreline property owners. Commercial navigation will measure the total transportation costs associated with commercial navigation on the Upper Great Lakes. So far, it is not clear whether there will be economic performance indicators for M&I.

The method used to evaluate hydropower benefits was suggested by the LOSL EAC and supported by outside consultants. Hydropower seeks to maximize the value of the power production where the price of power is determined by the demand for power and the resources available to meet that demand. The performance indicator for hydropower measures the economy-wide gains and losses of benefits to producers and consumers and is measured as the change in revenues from the sale of hydropower when the costs of the hydropower installations are unaffected by differences between water management plans.

To the degree that a new method can be considered accepted, the hydropower benefit fungibility is supported by the use of accepted benefit estimation methods.
**ESG4.2 Environmental Benefits**

Guidance: The environmental TWG shall develop non-monetary performance indicators based on metrics and measures that accurately portray the environmental consequences of alternative water management plans.

Early on in the LOSL Study process, the EAC suggested that the Study Board consider an economic valuation of the environmental performance indicators to allow for a more straight-forward comparison of impacts. A study was conducted by Dr. Frank Lupi of Michigan State University and presented to the Study Board but the Study Board rejected the idea of conducting an economic valuation of the environmental performance indicators because they were not convinced of its usefulness in the decision-making process. The IUGLS Ecosystem TWG is struggling to develop even non-economic indicators sensitive enough to make alternative plan outcomes distinguishable with some certainty from one another, and the translation of these impacts into the value of these impacts would inject unacceptable uncertainty into what might be an already frail conclusion.

The IUGLS Study is on course to use something like the environmental ratio approach developed collaboratively by Limno-Tech Inc. and the LOSL Environmental Technical Work Group to provide a clear indication of whether an alternative plan was better for the environment than Plan 1958DD. The ratios were defined so that a ratio greater than 1.00 represented an improvement, and anything below 1.00 a deterioration relative to 1958-DD. This allowed for a simple determination of which plan was “better” for each performance indicator. For example, a score of 1.44 indicated that a performance indicator performed 44% better under the evaluated plan than under 1958-DD.

The LOSL Study Board used a variety of perspectives to judge whether a difference in environmental ratios would make them select a plan. First was the use of a 10% range suggested by environmental scientists; they suggested that ratios of 0.90 and lower could be considered clearly worse than 1958DD and ratios of 1.10 and greater clearly better. Next, decision makers asked whether the direction of the result clearly agreed with a simple qualitative assessment of how water levels would affect the score.

**ESG5. Contextual Narratives**

Standard: The TWGs shall develop brief Contextual Narratives for their areas of study. The Contextual Narratives shall explain baseline conditions, key trends in an area of interest, how an interest adapts to changing water levels, and how an interest is affected by a management plan. TWGs should use their best professional judgment in identifying the most likely trends, outcomes, and ways of adapting to changing water levels. (Thomas et al., 2005)

Most water resources studies include a significant effort to forecast how the world affected by the decision will change over the next fifty years. The reason this is done for water project feasibility studies is that once large water resources projects such as dams, locks and levees are built, their effects will last for decades or centuries, and the present day construction must address needs that will arise over that period of time. Planners traditionally forecast what will happen in the future to the things that drove construction (population that needs water, demand for transportation, flood frequencies) and things that will be affected by the structure (number and value of homes in the floodplain, sedimentation
below dams, reduction in truck and rail congestion). These forecasts are especially important when the time required to build a structure is long. For example, a growing city will often forecast population thirty years or more into the future, knowing that it may take nearly that much time to develop additional supplies if they are needed.

These forecasts are always wrong to some degree (even expert expectations for next month’s unemployment or inflation rates are often wrong by enough to warrant a headline) but when used as part of an overall evaluation that uses sensitivity analyses, forecasts still help decision makers balance what is certain (the new project will cost lots of money and will not be torn down for decades at least) and what might happen (the future need may not be as great, other developments might address the need, the impacts could be worse than imagined).

The LOSL Study Board, with the support of PFEG and the EAC, determined that the expense of forecasting studies would not be worthwhile in this study, for three primary reasons, and these apply to the IUGLS Board decision as well:

1. First and foremost, this is not a decision to build a project; it was a decision to make modest and reversible changes to a regulation plan that had been used for forty years.
2. Second, there were no elements of the study for which quantified demand forecasts would be useful in plan formulation. In the decision to build a water supply reservoir, the size of the reservoir is based in part on the number of people it will have to supply decades from now. There is no capacity driven issue in this study.
3. Forecasting studies cost money and are often speculative and controversial. Even when they are needed, stakeholders often allege that the range of error in the forecast is enough that any decision could be supported.

ESG6. Sensitivity Analysis

Guideline: Sensitivity analysis should be used to assess how key analytical assumptions affect the degree of fungibility across the performance indicators. TWGs should conduct sensitivity analysis with respect to key assumptions in the technical analyses. Key assumptions include adaptive behaviour and growth rates, but are not limited to these. Key assumptions important for sensitivity analysis include those parameters and coefficients for which a reasonable change in their size or description would have a substantial impact on the performance indicators. Any complex quantitative analysis is likely to have at least a few of these key assumptions, and the sensitivity analyses should focus on these few. The analyses should draw on the expert knowledge within each TWG to identify the key assumptions and suggest how the performance indicators may change under reasonably likely alternatives. The sensitivity results should be reported in the final Contextual Narrative. (Thomas et al.2005)

Possible areas for sensitivity analyses include:

- Changes in the amount and timing of projected hydropower pricing
- Increases in recreational boating activity
- Changes in the value assigned to a day of boating
- The effect of adaptive behaviour and importance of the poor marina locations.
- The potential for increased coastal development and adaptive behaviour such as flood proofing.
• Assumptions about coastal damage functions
• Changes in the scores of key environmental PIs
• Impact of significant increase/decrease in a particular commercial navigation commodities

**ESG7 Key Economic Decisions**

During the study, several economic issues were raised and answered. The resolution of those issues is summarized below.

**ESG7.1 Secondary Benefits and Regional Expenditures**

Standard: The contextual narratives should explain potentially significant secondary and regional benefit categories not addressed by the current performance indicators. (Thomas et al., 2005)

The Study Board and Technical Work Groups agreed early on to focus on primary benefit categories that could specifically be linked to changing water levels and flows. While the Study Board did not prevent the TWGs from proposing secondary impacts as performance indicators, it was recognized that these impacts would be more difficult to quantify.

**ESG7.2 Substitution Effects and Adaptive Behaviour**

Guideline: Negative impacts might be reduced without water level changes if people changed behaviour. The LOSL Board agreed that no adaptive behaviour should be considered for any sector unless it could be done within a short time period, such as one year. The IUGLS Board has not considered this in depth, but is likely to take similar positions.

The LOSL Board asked that adaptive behaviours underlying a performance indicator should be described in the Contextual Narrative. The description of adaptive behaviours should provide insight as to why a particular adaptive behaviour was chosen from among alternative possible behaviours and should detail the rationale and historical evidence for the adaptive behaviours underlying the performance indicators (adapted from Thomas et al., 2005)

The general rule of thumb was that adaptive behaviours were to be considered only if a) they were good approximations to the behaviours that actually occur, and b) the action would likely occur within one year of the damage, unless the PI was serially dependent. For example, shoreline erosion damages were capped at the cost of building shore protection, and commercial navigation costs were assessed using the cost of revenue forgone with the light loading of freighters due to the shallower draughts necessary with lower lake levels because these behavioural adaptations—building shore protection and light loading—are good approximations to the behaviours that actually occur. Homeowners spend $50,000 for a protective structure so they do not have to pay $150,000 to build a new home. The serial dependence of the erosion indicator means that this action should be considered. Shippers quickly adjust loads to the depths available rather than not ship, and this is done regularly and in a short period of time (days to weeks). With recreational boating impacts, there is little evidence that boaters or marina operators dredge rather than forego boating opportunities in the same year. Likewise shoreline property owners experiencing a flood event are not likely to invest in flood proofing action within that same year. Additionally, if an action like flood proofing were to be implemented early on in the time...
series analysis, then all later flooding within the sequence would be either reduced or eliminated as a result of the adaptive behaviour. This would have greatly underestimated potential damages. The EAC agreed that this was a reasonable approach and that no adaptive behaviour should be considered for any sector unless it could be done within a short time period, such as one year.

The TWGs were asked to identify the types of adaptive behaviour that could be expected from their sector and develop assumptions to govern how households/firms receipt of benefits or costs would likely bring about one or more shifts or “switch points” in behaviour, i.e. stepwise thresholds. For example, what type of adaptive behaviour have the recreational boating community taken in the past? How likely would a community adjust and what are the critical driving forces that would create a significant change in behaviour? The TWGs were asked to report on adaptive behaviours in their contextual narratives.

**ESG7.3 Erosion of Undeveloped Land and Beach Accretion**

Standard: The LOSL Board developed this standard and the IUGLS Board will almost certainly adopt an identical position. Beach accretion should not enter into the calculation of the economic performance indicators. As an alternative, it may be useful to describe sediment transport and beach accretion processes in the Contextual Narrative. (Thomas et al., 2005)

The bluff shorelines of the Great Lakes have been eroding for thousands of years. This process provides new sand and gravel for the nearshore zone and thus is the source of new material for beach and dune environments around the lakes. Without a “background” erosion rate, there would be no new sand and gravel to nourish the beaches and dunes along the shore. There is also some economic damage from erosion to undeveloped land that provides some of this new material. PFEG considered measuring the value of both, but each had problems.

To measure the value of land lost on parcels without development, an estimate of the value of the lost land would have to be developed. This might be estimated by multiplying the value of the entire parcel by the percent of the parcel lost, but there is no evidence that large parcels become worthless because the shoreline erodes a few inches per year. PFEG and the EAC believed that the damages would be relatively small compared to damages to developed parcels. One indication of this is the fact that the parcels are left unprotected and erosion is allowed to continue until shoreline buildings are threatened.

In addition, to measure the benefit that eroded land would provide to beach accretion, credible mapping of larger particle size soils from bank to beach through the littoral system would have had to have been developed and validated. Modelling the deposition process would require the ability to model the composition of soil being eroded along the entire coast, its transport along the coast and into deep water, and the time and place of its deposition – a task not deemed possible within this Study. The LOSL Coastal TWG did estimate the costs of trucking material to beaches, based on several broad assumptions, and a “back of the envelope” calculation, and found the costs of artificial sand replacement would be very high.

In the end the LOSL EAC supported the notion that we should assume that the value of eroded land from undeveloped parcels was equal to the value provided by the eroded material in nourishing beaches. This conclusion was based on the following findings:
• A credible mapping of bank erosion to beach nourishment over time for the whole of Lake Ontario would be needed, but very costly, with no assurance that the work would be successful.
• There was no obvious and credible way to estimate damages to undeveloped parcels, but the expectation was that they would be small.
• Although the costs of hauling sand to nourish beaches was high, there was not much evidence that communities actually did this, suggesting that the benefit of bigger beaches was smaller than the costs of hauling sand to create them.
• To the degree that the emphasis on minimizing losses was making all plans more alike, the chances that plan rankings would be affected because of enormous changes in the value of either of these impact categories was small.

**ESG7.4. Seasonal Electricity Power Prices**

Guidance: The Hydropower TWG should obtain an expert assessment of seasonal electricity power prices. Electricity prices are at the core of the performance indicator analysis. It is essential that the analysis use representative seasonal electricity prices. (Thomas et al., 2005)

In the LOSL study, Synapse Energy Economics was hired to secure data and determine how these data would be used for pricing. Synapse provided representative prices for each quarter-month of the year for the next two years. The LOSL shared vision model calculated the energy benefit using the Synapse estimates.

**ESG7.5 Value of Peaking**

Standard: Open so far.

Peaking is the additional benefit that comes from within week variations in releases to produce more energy during the middle of work days when demand and prices are highest. Ponding refers to storage on the weekend for use during the week. The IUGLS Board, unlike the LOSL Board, will consider peaking and ponding rules as part of its charge to develop monthly regulation rules.

The issue is granularity. Do we need to consider hourly or daily sub-modelling to capture the nuances of peaking and ponding rules or can we produce a robust analysis of those rules using aggregated values, such the percentage of the month versus percentage of average flows.

**ESG7.6 Economic Valuation of Environmental Benefits**

As the LOSL performance indicators began to be developed in the second year of the Study, the study team considered the possibility of an economic valuation of environmental PIs. Dr. Frank Lupi did an assessment of whether or not it would be feasible to use environmental valuation methods to estimate, in monetary terms, the effects of alternative regulation plans on non market values associated with biodiversity (e.g., direct use, indirect use and non use values) in the LOSLRS area; the merits of alternative environmental valuation techniques; and, the extent to which the findings of valuation studies can assist in distinguishing between alternative regulation plans.
Dr. Lupi concluded an economic valuation would be feasible, noting that economic valuation translates preference for changes in environmental quality, as inferred through market or non-market choices of individuals into dollar values. Dr. Lupi noted that environmental valuation is not just about dollars and that it provides quantitative preference information about the public’s willingness to make tradeoffs and the importance they assign to the environment. He noted that there are thousands of valuation studies in the literature and that environmental valuation is indeed feasible. He presented his findings to the Study Board in May of 2003. His report highlights change in environmental quality as key, not the total value of the environment. Plans affect environmental service flows and it is these changes that Dr. Lupi suggest be assessed. Dr. Lupi presents a number of methods in his report (Lupi, 2003) including factor income/market methods, Hedonic valuation/property values, recreation/travel cost method, stated preference, and contingent valuation. Based on his review of the LOSL Study needs, Dr. Lupi recommended two stated preference methods. The first was a stated preference study of environmental processes enhanced by criteria with high opportunity costs. The second was a scientific sample of the environmental trade-offs made by the public in a mail survey.

The first study recommended was a stated preference study of environmental processes enhanced by criteria with high opportunity costs, for example a high lake level every 25 years. The concept was for the survey to present experimentally designed trade-offs to individuals and their choices would reveal values and preferences.

The second study recommended was a stated preference study of trade-offs at the study level. This was to involve public rankings of possible plans and associated outcomes to reveal the public’s willingness to make trade-offs among all study areas (e.g., environment, navigation, hydro, etc.). The concept was to have centralized group interviews of the general public with a description of what plans do to each of the areas and their rankings would reveal their values and preferences.

The LOSL PFEG presented the results of Frank Lupi’s Environmental Valuation Feasibility Study at a Study Board Meeting in May 2003 and again in September 2003. The Study Board was not convinced that these studies would help in the decision process and were concerned by the amount of money and the length of time they would take. The Board rejected Dr. Lupi’s concept of assessing value of changes in environmental quality through conducting stated preference studies. Instead they agreed to present the environmental results in non-monetary terms and rank plans using both economic and non-economic metrics, a widely accepted practice that reflects the idea that sustainable natural resource decisions must balance economic and environmental consequences and must be equitable.

Given the much smaller ecosystem impacts expected from the new Superior regulation plan and the fact that the IUGLS study is funded less and covers more area, it is likely the IUGLS Board will continue with their de facto agreement not to estimate the economic value of environmental impacts.

**ESG.7.7 Social Impacts**

Standard: None yet.

With the exception of the ETWG, the LOSL EAC did not recommend the use of non-monetary performance indicators for any of the sectors. This was primarily due to the fact that these indicators could not be properly compared with the other PIs. Nevertheless, there were some non-monetary PIs
that were developed and reported in the contextual narratives so the Study Board could take them into consideration, and similar measures will likely be developed by the IUGLS TWGs. The following is a summary of the social PIs developed:

- Beach access: While an economic function was developed to determine the impacts of high and low lake level, the EAC did not believe that this performance indicator had the proper rigor to be compared with the other economic performance indicators and advised that it not be included in the analysis, but rather reported in the contextual narrative.
- Barrier beaches and dunes: The purpose of this PI was to highlight the important relationship between water levels and erosion/sedimentation cycles. There was no economic PI developed for this, however water level criteria was developed.
- Lower River Societal Flooding PIs: The Coastal TWG established societal PIs to better capture the full implication of downstream flooded. The non-economic PIs included:
  - Number of flooded residential buildings;
  - Number of expropriated properties;
  - Total area (in hectares) of flooded lands quantified by land-use type; and
  - Total length (in kilometers) of flooded roads quantified by road type
  - The TWG did not collect similar data for Lake Ontario and the Upper River, although the number of houses flooded could be determined from the FEPS program.
- Shoreline wells, groundwater contamination and sewage overload were evaluated by the Municipal and Industrial Water Uses TWG but not represented as performance indicators because the impacts were found to be marginal. A discussion of all issues and problems was included in Annex 2 of the final report.
- A Task Force study was conducted of impacts to the Native community at Akwesasne/St Regis and reported in a contextual narrative for Aboriginal Peoples in Annex 2 of the final report.

The intense involvement of the public not only in the study analysis but also the practice decisions allows many issues like fairness to be decided by process rather than metrics.
References


Ecosystems section:


Brady et al. 2009 ETWG Draft Literature Review


Hebb et al. 2006 Climate change and water-level impacts


