Chapter 8

Addressing Future Water Levels: The Role of Adaptive Management

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Lake Superior Regulation:
Addressing Future Water Levels in the Upper Great Lakes

Final Report to the International Joint Commission

by the
International Upper Great Lakes Study

Chapter 8 considers the role that adaptive management can play in helping interests in the upper Great Lakes basin better anticipate and respond to future water levels. It outlines the approach of the International Upper Great Lakes Study (the Study) to adaptive management and proposes a long-term adaptive management strategy for Great Lakes water management.

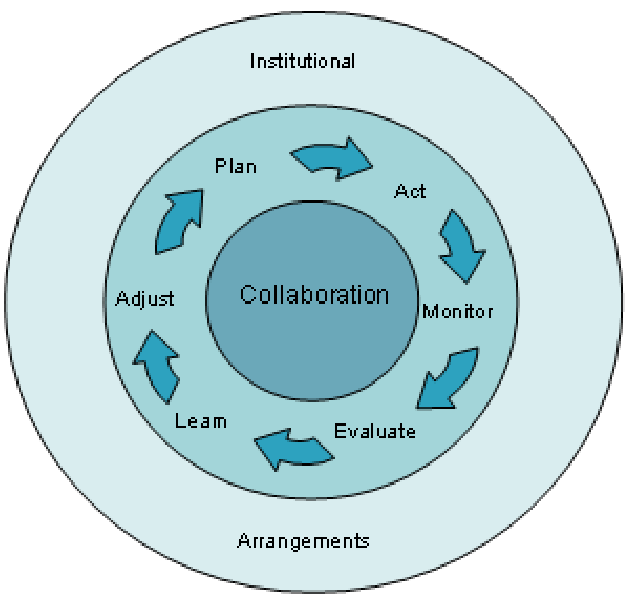
8.1. The Study's Approach to Adaptive Management

8.1.1. The Purpose of Adaptive Management

Adaptive management is a planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modelling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change. It is not a 'trial and error' process, but one that is built on "learning while doing." (Williams *et al.*, 2007).

Figure 8-1 illustrates the conceptual framework for adaptive management (Colosimo *et al.*, 2006; International Joint Commission [IJC], 2008). Core components are the overarching institutional arrangements (governance) and the need for strong, effective collaboration. The process involves an ongoing effort to reduce specific uncertainties and test management options and policies (Crawford *et al*., 2005; Gunderson and Light, 2006). Monitoring of implemented management options is needed to evaluate the expected performance of those policy choices with the results used to learn and adjust decisions. Adaptive management is designed to complete the feedback loop whereby the uncertainties associated with future choices are reduced through the application of new knowledge (Nudds *et al.*, 2003; Williams *et al.*, 2007).

Figure 8-1
Adaptive Management Conceptual Framework



(Source: IJC, 2008)

It is important to note the distinction between *adaptive management*, which is the iterative process for "learning while doing' and adjusting actions as necessary to address changing conditions, and *adaptation* itself, which is the broader context of responses taken and actions implemented to address risk. This chapter discusses both aspects, as they are inherently linked. However, the adaptive management strategy itself is focused on what is necessary in terms of ongoing monitoring and modelling to gain greater understanding of the appropriate adaptive actions and of when and how they should be implemented or adjusted to minimize future risks.

8.1.2 Decision-scaling Process

As discussed in **Chapter 4**, recent research indicates that the climate is changing in the basin, but that there remains great uncertainty in how climate change will affect lake levels in the upper Great Lakes region. The Study was faced with the challenge of how to assess a regulation plan under a changing climate, together with a wide range of associated uncertainties.

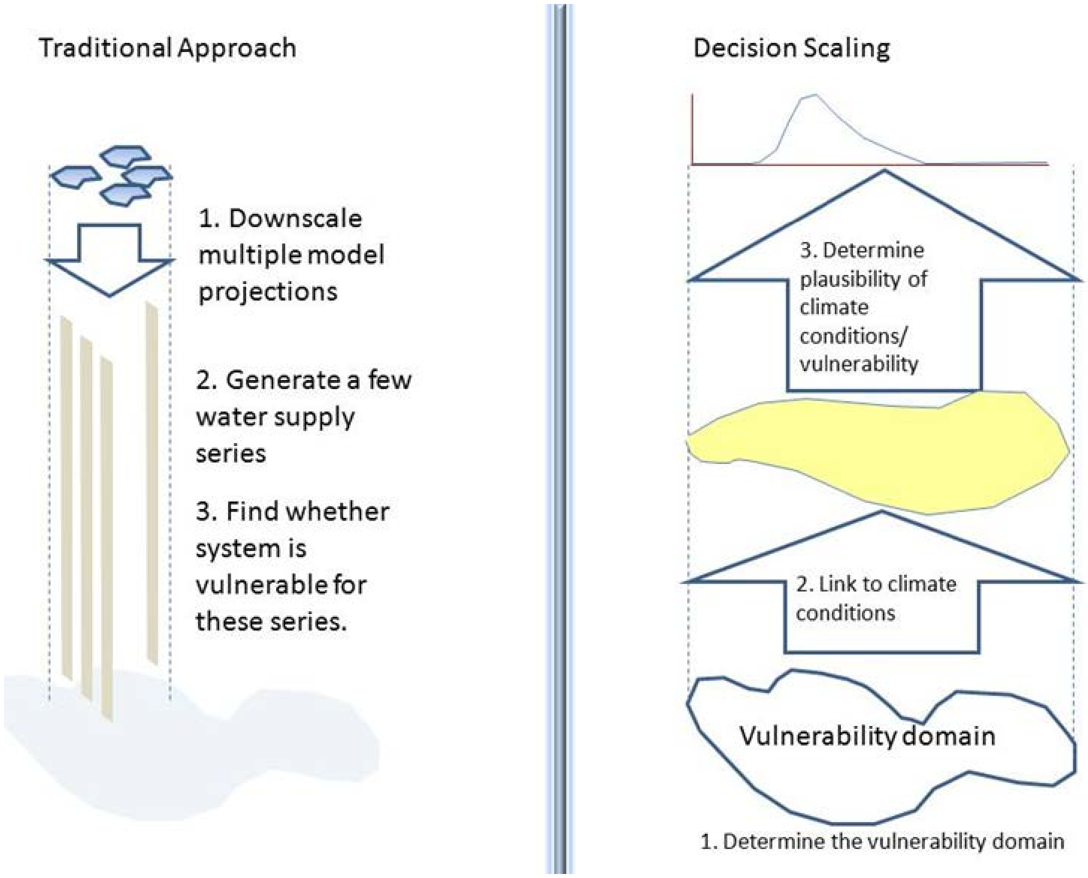
As outlined in **Chapter 2**, the Study early on considered adaptive management as a viable mechanism for addressing future uncertainty. A separate technical work group (TWG) was established to assess the need for adaptive management and develop a strategy.

Following consultation with climate experts and resource managers in the upper Great Lakes basin, the Study adopted a *decision-scaling* approach to adaptive management (Brown *et al.*, 2011). Decision-scaling differs from the more traditional down-scaling approach in that rather than relying on a small suite of General Circulation Models (GCM)-based scenarios to define system vulnerabilities, the approach begins with stakeholders and then determines the domain of vulnerabilities and assesses whether those conditions are possible or plausible based on the available climate science (Figure 8-2). This approach allows for incorporating data and models from a broader array of information sources than just GCM outputs.

An eight-step process, based on the decision-scaling perspective, was developed to form the basis for an adaptive management work plan (Figure 8-3):

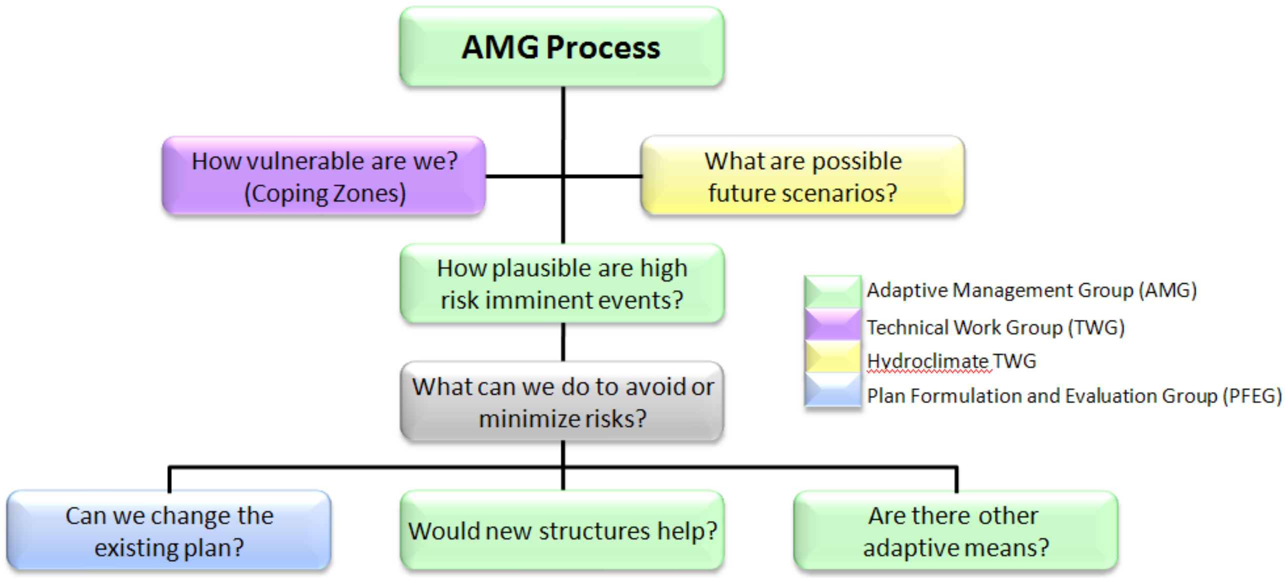
1. Define system vulnerabilities.
2. Develop risk scenarios.
3. Define plausibility of risks.
4. Develop Lake Superior regulation strategies to address future risks.
5. Evaluate new water level control structures.
6. Identify long-term monitoring and modelling needs.
7. Conduct an institutional analysis.
8. Develop and rank adaptive management plans.

Figure 8-2
Comparison of the Traditional *Down-scaling* the *Decision-scaling* Approaches



(Source: Brown *et al.*, 2011)
(Note: graphic text to be slightly modified: ***Down-scale*** *in left column;* ***Decision-scaling*** *in right side column)*

Figure 8-3
Key Steps in Addressing Adaptive Management



(Note: graphic to be modified by deleting colour code referencing specific groups.)

1. Defining System Vulnerabilities

As described in **Chapter 2**, the Study established TWGs based upon the various interests that might be affected by the regulation of Lake Superior levels. The TWGs were tasked with the job of identifying key areas where those individuals, businesses, communities and organizations within their specific area of interest were vulnerable to lake level fluctuations.

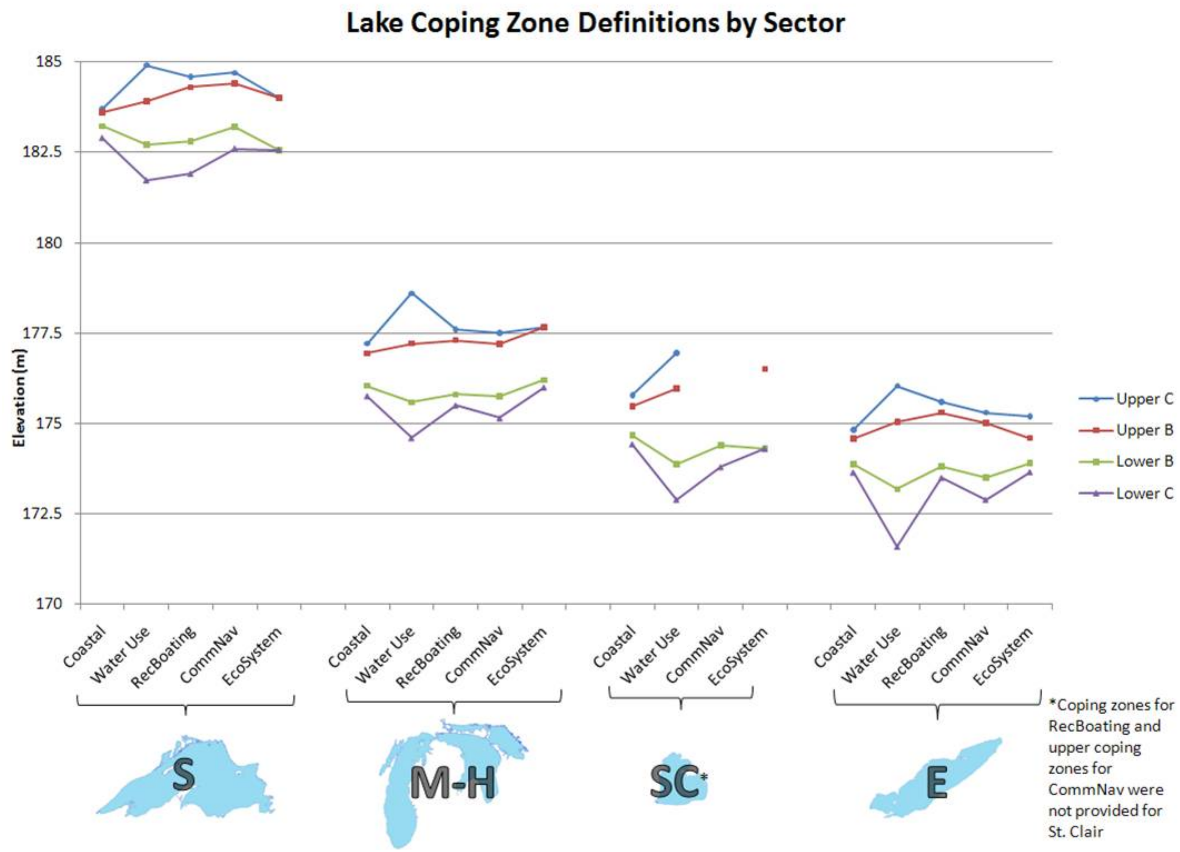
Chapter 3 provides background information on the key interests considered in the Study. Table 3-1 summarizes the vulnerabilities of each interest group to water level fluctuations. The Study found that vulnerabilities to water level fluctuations varied from interest to interest, by geographic location within a lake and among the lakes, and by local conditions. In addition to the range in water levels, other important factors include the frequency, duration and rate of change. Rapid changes in lake levels generally result in more damages than gradual changes because the key interest has less time to adjust to the change.

Each TWG developed a range of “coping zones” for its specific interest that assessed vulnerability to water level fluctuations as well as confounding factors such as glacial isostatic adjustment (GIA), wind/waves/storm surges and precipitation patterns. Each TWG identified three levels of progressively more challenging water level conditions for the interest:

- *Zone A*: a range of water level conditions that the interest would find tolerable;
- *Zone B*: a range of water level conditions that would have unfavourable though not irreversible impacts on the interest; and,
- *Zone C*: a range of water level conditions that would have severe, long-lasting or permanent adverse impacts on the interest.

Figure 8-4 illustrates the coping zone results. It shows a single point based on the most conservative minimum and maximum water level provided by the TWGs for each interest and for each lake (the mean annual threshold was used in the case of Coastal Zone interests).

Figure 8-4



Coping zone by interest and by lake, for lakes Superior, Michigan-Huron, St. Clair and Erie.

Note: ecosystem zones are only surpassed if combined with a consecutive sequence (*e.g.,* above or below a mean level during the growing season for five or more consecutive years) (DePinto, Redder and Mackey, 2011).

A critical aspect in defining the coping zones is determining the thresholds that mark the transitions between zones. The TWGs determined the factors that can push their interest from one zone to another and assessed the ability to recover should the levels return to more acceptable conditions. These thresholds are not only defined by water level, but also duration, frequency and rate of change and recognizing that persistent conditions at or near the zone thresholds could lead to long term damage within any one interest.

Chapter 6 discusses how the coping zone concept was used in evaluating regulation plan options.

2. Developing Risk Scenarios and Defining Plausibility of Risks

While the Study's TWGs established coping zones and thresholds for vulnerabilities, the Hydroclimate TWG developed a series of possible future water supply scenarios, using a variety of techniques (**Chapter 4**). The objective was to assess the range of possible future water supply scenarios that a regulation plan might be exposed to and assess whether a candidate plan could perform adequately under those conditions.

Study researchers developed a model to estimate the frequency of negative impact occurrences as a function of changes in climate, using the coping zones to define *negative impacts* (Brown, C., 2011a). Given that it was not possible to estimate probabilities of future climate conditions, the researchers instead developed subjective probabilities of future climate states, based on a compilation of climate information. These subjective probabilities were termed *plausibilities* and were used for sensitivity analysis in place of formally evaluating risk.

The analysis began with a "hazard discovery", an exploration of the stochastic simulation to identify problematic climate conditions *(i.e.*, the climate conditions that caused unacceptable impacts as defined by the coping zones). The model estimated the number of coping zone occurrences for a given climate condition, where climate was defined as a 30-year estimate of mean net basin supply (NBS), standard deviation of NBS, and serial correlation of NBS (representing both the mean climate and variability). Thus for any climate change, the impacts could be directly estimated based on the changes in those three statistics. Finally, the impacts of any NBS future scenario could be estimated using this model by calculating the three statistics from that particular source.

With the future positive or negative impacts estimated for each alternative regulation plan from each separate source of future NBS, the plausibility of those impacts could be estimated. In this application, the plausibility serves as a risk prioritization or weighting scheme for risks. The plausibility concept is based on the premise that the more sources of climate information (*e.g.*, paleo-, GCM's, stochastic, trends) that indicate impacts are probable, the greater the consideration that impact should be given in the overall determination of which plan is the 'best' or most robust for the given range of conditions. This process also helps identify the limitations of the regulation plans in addressing plausible risk. At the same time, events that are highly unlikely, but that could result in relatively large adverse impacts in any future scenario, should not be ignored, given that plausible risks only outline a range of irreducible uncertainty but not necessarily the entire range of uncertainty.

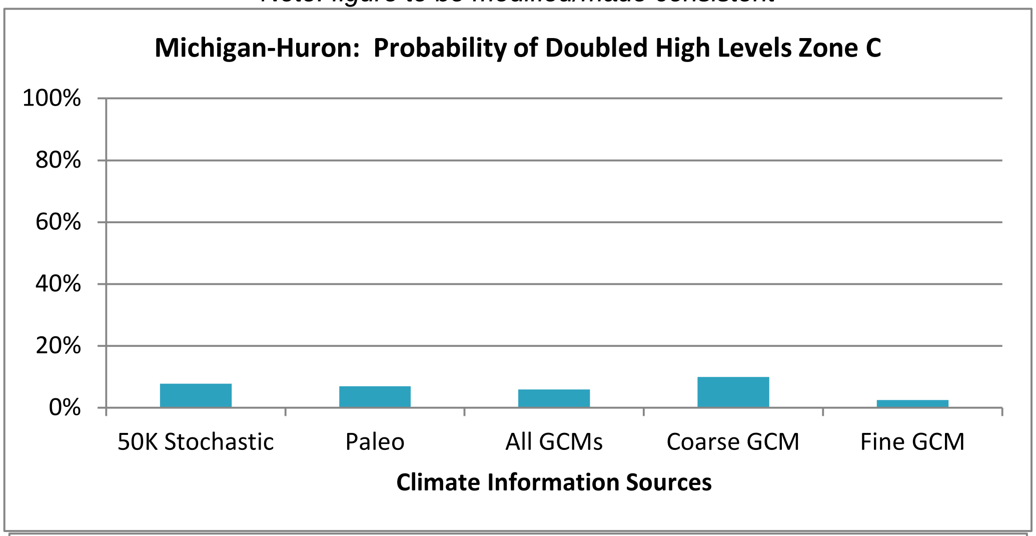
General guidelines used for estimating plausible risk were that if the impact:

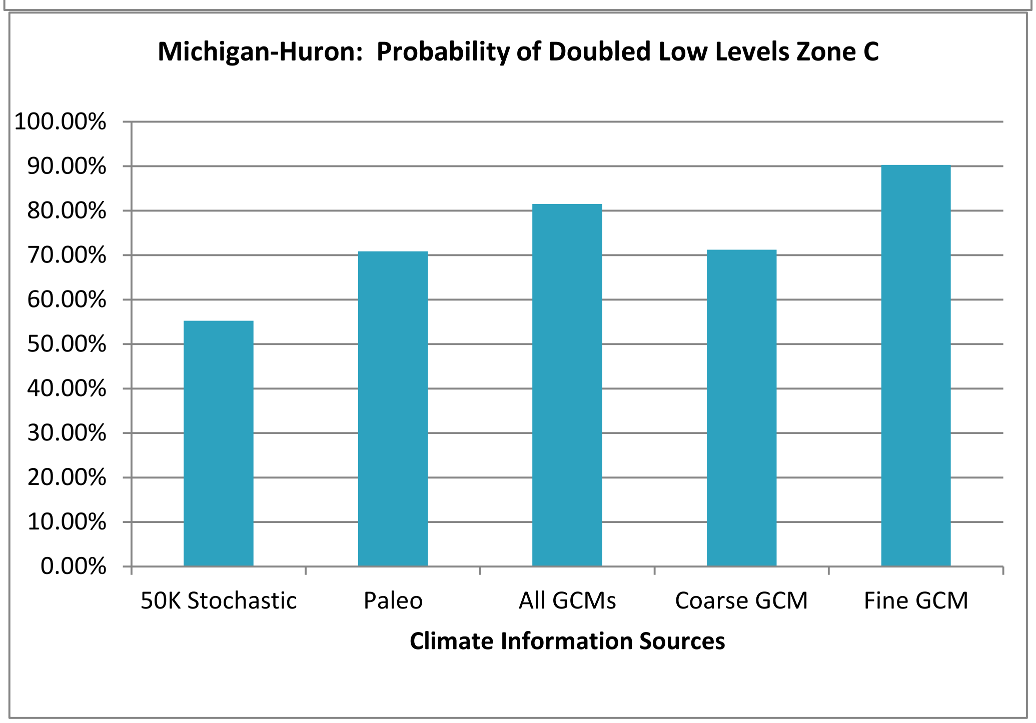
- is likely in multiple futures, then it is considered a high risk;
- is likely in a single future, then consider the source; and,
- is unlikely in any future, but the impacts would be severe if it happened, then consider addressing it.

In the historical 100-year record for the Coastal Zone interest, there were six occurrences of low water level Zone Cs and five occurrences of high water level Zone Cs. Figure 8-5 shows an example of the plausibility estimates for Lake Michigan-Huron of the climate conditions that would cause coastal riparian Zone C occurrences to *double relative to the historical number of occurrences* (1900-2008) (*i.e.*, the probability of twice as many Zone Cs as in the historical record, as estimated from each of the climate information sources).

Figure 8-5
Example of Plausibility Estimates for High and Low Water Level Zone C Occurrences for Lake Michigan-Huron
(based on the Coastal Zone Interest threshold)

Note: figure to be modified/made consistent





(Note: see **Chapter 4** for a detailed discussion of the different climate information sources.)

Overall, the Study's analysis of risk plausibility indicated that extremes (both high and low) outside of the historical record are plausible, with far greater frequency of Zone C incursions arising from extreme low level conditions. The Study's analysis suggests that the magnitude and timing of these risks are highly uncertain and that plausibility estimates for the individual lakes vary widely. While the increased risk of Zone C incursions associated with low levels on Lake Michigan-Huron stand out as more plausible, as shown in Figure 8-5, impacts due to high lake levels should not be ignored, given that the occurrence of such levels cannot be ruled out and that the magnitude of socio-economic impacts may be greater for high lake levels.

For a more complete discussion of the modelling of risk plausibilities and the results for each interest in each of the upper Great Lakes, see the Adaptive Management TWG Final Report (2011).

3. Developing Lake Superior Regulation Strategies to Address the Risks

The regulation of water flowing out through the existing control structures on the St. Marys River has limited ability to reduce extremes, particularly downstream of Lake Superior. As described in **Chapter 6,** the evaluation of alternative regulation plans under a series of extreme water supply conditions revealed that all of the different formulations of regulation plans that were considered could only influence the water levels of Lake Michigan-Huron by a few centimetres without exacerbating the historical extreme lake level conditions on Lake Superior. Thus, any regulation plan will have limited ability to moderate lake levels, most notably extremes.

While water level regulation plans can do little to minimize risk downstream of Lake Superior, the analysis does indicate that some work is warranted on testing the regulation plans under extreme conditions (outside the historical range) to see if adjustments under these conditions could be made in time to improve plan performance for Lake Superior. In addition, it is important to verify whether any future changes in conveyance in the St. Clair River system would warrant a change in the regulation plan.

4. Evaluating New Water Level Control Structures

As described in **Chapter 7**, the Study investigated the potential for addressing future water level conditions in the upper Great Lakes basin through additional structures, by means of restoration-type structures in the St. Clair River and multi-lake regulation in the Great Lakes-St. Lawrence River system.

The analysis found that new control structures would generate a mix of benefits and adverse impacts for various sectors and locations. For example, higher water levels from these structures likely would benefit commercial navigation in the lakes, as well as shoreline property and wetlands in Georgian Bay, but adversely impact hydroelectric generation and shoreline property and wetlands along Lake St. Clair and Lake Erie. The analysis also concluded that multi-lake regulation can help mitigate but cannot fully eliminate risk of water level extremes outside the historical range. In addition, restoration structures and multi-lake regulation would be costly and would require many years to review, approve and construct.

5. Reviewing the Potential for other Adaptive Measures

Successful implementation of adaptive management is dependent upon the ability of institutions and agencies to undertake their own forms of adaptation. These could range from modest efforts (*e.g.*, new collaborative arrangements, establishing new priorities, exercising unused authorities, redirecting or seeking additional funding) to more ambitious efforts (*e.g.*, securing new legislative or regulatory authority, establishing a new international agreement and/or institution, establishing/ funding major new monitoring and modelling programs).

An institutional analysis undertaken by the Study on implementing non-regulation adaptive response to water levels found that the legal, regulatory and programmatic "institutional infrastructure" varies considerably from one jurisdiction to the next (Donahue, 2011). Federal, state and provincial governments generally provide the policy/regulatory framework, while site-specific selection/ application of adaptive risk management measures is generally a local government responsibility. Efforts to coordinate approaches and promote consistency have been limited. The primary focus of this "infrastructure" is on accommodating seasonal lake level fluctuations and the occasional extreme high and low water events. Little focus has been placed on long-term implications of climate change-induced impacts, and the prospective need for new adaptive risk management measures.

Integrated coastal management strategies at the local and regional level are an effective means for identifying important vulnerabilities and possible solutions. Better coordinated data and information related to hydroclimate and climate change is required by coastal zone managers and decision makers to research and advance means to induce and promote adaptive actions, which implies a commitment to monitoring, modelling, observing changes and regularly evaluating strategies to manage resources in light of uncertainty and new conditions.

Finally, information and education are powerful components of adaptive management. They contribute to both anticipating and preventing lake level-induced damage, particularly when focused on understanding risk, the limits of regulation, inherent uncertainties and system vulnerability.

8.2 Elements of an Adaptive Management Strategy for Great Lakes Water Management

Long-term policies that ignore uncertainty tend to, over time, lead to unsatisfactory outcomes (Morgan *et al.*, 1990). As noted above, the Study Board concluded that it may not be possible to design a regulation plan for Lake Superior outflows that is optimal for all future conditions, particularly given the dynamic nature of the Great Lakes system and the uncertainties created by climate change. In addition, regulation of Lake Superior outflows alone can do little to reduce risks downstream of Lake Superior. Managing potential risks under an uncertain future is a challenge both for managers of water levels and flows and for those adapting to water levels and flows. The more they can anticipate what to expect, the better prepared they can be.

Regardless of the Lake Superior regulation plan adopted by the IJC, ongoing efforts for monitoring, modelling and research will be required to continue to assess risk and address uncertainties and changing conditions and to identify appropriate adaptive actions. The Study identified the following six core elements of an adaptive management strategy to address future water levels in the upper Great Lakes basin:

- bi-national Great Lakes hydroclimatic monitoring and modelling;
- tracking and understanding of changes in the physical system;
- information management and distribution;
- tools and processes for decision makers; and,
- a regional Great Lakes-St. Lawrence River system adaptive management study for dealing with climate extremes; and,
- governance for implementing adaptive management.

These six elements are common to other Great Lakes initiatives (*e.g.*, the Great Lakes Water Quality Agreement) that are also considering adaptive management in light of climate change. The following sections offer a more detailed explanation of these six areas as they pertain to adaptive management of the upper Great Lakes.

8.2.1 Bi-national Great Lakes Hydroclimatic Monitoring and Modelling

1. Monitoring and Modelling Priorities

The Study identified specific needs and priorities for hydroclimatic monitoring and modelling to improve decision making by reducing uncertainties in the various components of the Great Lakes water budget. These uncertainties exist due to inadequate spatial coverage of monitoring networks, inconsistent data gathering methodologies, temporal data gaps or insufficiently long records, failure to seamlessly present data from different networks and incomplete use of new or emerging technology.

The following were identified as priority needs over the near-term (five years).

1. Improved Measurement of Component NBS

Precipitation: The first priority should be the introduction of a metadata management system for Great Lakes precipitation gauges, which would improve the usability of currently monitored data and any additional data collected in the future. An improved monitoring network is also needed, including an expanded gauge network in northern Ontario and an improved network of snow accumulation gauges.

Over-lake evaporation: Under the Study, the first eddy covariance gauges were installed to measure over-lake evaporation on the Great Lakes, with stations on Lake Superior and Lake Michigan-Huron. The station located at Stannard Rock on Lake Superior has proven to be of particular value in reducing uncertainty in modelled evaporation estimates. The Study has provided funding to establish these gauges and operate them for a several years. The Study is in the process of funding an additional two gauges, one on Lake Michigan and another on Lake Erie. These gauges will aid in future event-based monitoring of winter storm events on this lake, which was also identified as a key task for reducing uncertainty in the measurement and modelling of over-lake evaporation and precipitation.

Runoff: Multiple methods and estimates of Great Lakes runoff are now available through various agencies, partly as a result of the work of the Study. A comprehensive evaluation and coordination of Great Lakes runoff estimates is a priority. Estimates of runoff would benefit from an improved and possibly expanded streamflow network. The first step for achieving this should be a comprehensive streamflow gauge network evaluation.

2. Improved Measurement of Residual NBS

Change in lake storage/volume: Thermal expansion and contraction of lake volume is not accounted for in estimates of residual NBS, resulting in a seasonal, systematic error in these estimates. Therefore, a priority must be the investigation of the use of hydrodynamic/thermodynamic lake models and other means of estimating thermal expansion and contraction.

Connecting channel flows: The Study implemented new index velocity flow gauges on the St. Marys, St. Clair and Detroit Rivers. These gauges provide a more accurate means of measuring flow in the connecting channels. This approach is expected to be more effective than current methods, particularly during less than ideal monitoring conditions, such as when flows are affected by ice. Therefore, ongoing maintenance of these gauges is a high priority. Furthermore, the first part of the Study, on the St. Clair River, demonstrated the importance of ongoing monitoring of channel conveyance through data collection and analysis (IUGLS, 2009). Given the uncertainty in the causes of conveyance changes in the St. Clair River, ongoing monitoring of connecting channel conveyance capacity is considered a top priority. The first step will be developing a sustainable framework for continuous conveyance monitoring, which should include a combination of frequent analysis of hydrometric data and hydrodynamic modelling, and periodic bathymetric surveys that follow established protocols to ensure the collection of accurate data. Additionally, further investigations into the cause of conveyance changes observed are necessary, and it is proposed that a study of ship-induced hydrodynamics be pursued to investigate the possible impact of commercial ships on bed morphology.

3. Integration of Great Lakes Water Balance Estimates

Ongoing maintenance of and improvements to Great Lakes basin hydroclimatic models will lead to improved water balance estimates and insight into closure of the water budget. Closure of the water budget requires that all the inflows and outflows across defined spatial and temporal boundaries, as well as the change in storage within those boundaries, to equate to zero. However, there are inherent uncertainties and biases in Great Lakes water balance estimates as a result of imperfect information on the different components being estimated. Uncertainty results from a number of factors, including: data accuracy limitations and limited spatial/temporal coverage of monitored data; incomplete knowledge of the true physical processes being observed; the need to represent complex physical systems with simplified models; and, natural variability and randomness. A study focused on reconciling water balance estimates over all lakes simultaneously through application of an integrated state-space model will allow for assessing uncertainty and tracking changes and systematic differences in water balance components on an ongoing basis, and is a priority for reducing uncertainty across the entire basin.

Improvements in these areas will help lead to the elimination of ‘bias’ in NBS estimates, and considerably reduce uncertainty in each of the components of the Great Lakes water balance.

2. Improved NBS Forecasting

With greater certainty in the Great Lakes components of NBS, improvements can be made to NBS forecasting both in the short-term (two-four weeks) and mid-term (six-eight months). Study findings indicated that improvements in forecasting could significantly help improve regulation plan performance if accurate forecasts are developed and can be utilized as part of the regulation plan (Brown C., 2011b). Efforts through the Lake Ontario-St. Lawrence River Study (LOSLR, 2006a) indicate that the greatest potential benefit appears to be for determining Lake Ontario outflows and this should be identified as a priority for NBS forecasting research. Reductions in the uncertainty of the components of NBS from the first task will help improve forecasting capabilities, making further research in this area more productive.

It is proposed to improve both Environment Canada's Modélisation Environnementale Couplé: Surface et Hydrologie (MESH) modelling system currently under development and the Great Lakes Advanced Hydrologic Prediction System (AHPS) system of the National Oceanic and Atmospheric Administration (NOAA). The latter model has been in use for nearly 20 years. The AHPS system was recently evaluated (Gronewold *et al.*, 2011) and is targeted for a series of critical improvements. This system is currently used by the United States Army Corps of Engineers (USACE) in an operational forecasting framework.

It is proposed that the MESH system be coordinated with AHPS and other tools to improve daily ensemble forecasts.

3. Improved Climate Change Prediction for the Great Lakes Basin

The analysis in **Chapter 4** indicated that while some impacts of climate change are evident in the Great Lakes Basin (increased temperature, and wind speeds), there is uncertainty associated with regional projections of climate into the future, particularly with respect to precipitation patterns. The Study's analysis of future climate change scenarios found that while low water extremes are more likely, high water level extremes over the coming century are also plausible and should not be dismissed. Decision making for addressing these potential risks into the future needs to be informed by improved science and outputs from GCMs and regional climate models, better attribution of observed trends in climate, as well as improved understanding of the extent of current and future climate related risks.

8.2.2 Tracking and Understanding of Changes in the Physical System

Changes to the physical characteristics of the Great Lakes system, from both natural processes and human activities are expected to continue in the future. These changes can be large scale such as the impact of GIA or small scale, such as the building of a shore protection structure in front of a single property. However, these changes cumulatively can influence levels and flows and the vulnerability of interests to fluctuating water levels and flows. The following were identified as priority needs over the near-term:

1. GIA Monitoring

Ongoing monitoring of GIA effects, through the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (CCGLHHD) is needed to gauge the extent to which the land is adjusting and to inform future changes in vulnerabilities that may result. There is a need to ensure that data and information on GIA are incorporated into hydrologic and shoreline models. From a regional perspective, GIA can exacerbate the adverse anticipated impacts of global warming-related lake level changes for specific areas, such as Georgian Bay (rising) or Duluth, MN (subsiding).

2. Monitoring and Modelling of Shoreline Processes

Tracking of natural erosion and depositional processes is important at more regional and local scales to help inform local decisions and better understand vulnerabilities. Improved understanding and modelling of shoreline processes will need accurate nearshore bathymetric data and shoreline profile data over a number of years to investigate how systems respond to changes in water level conditions.

A related priority is the monitoring of changes in ice conditions as well as storm patterns and wind direction to track trends and assess implications to shoreline vulnerabilities.

3. Tracking of Shoreline Modifications and Wetland/Ecosystem Changes

There is a need to undertake a comprehensive and coordinated approach to tracking shoreline protection measures and changes in the upper Great Lakes basin. A top priority is to develop an updated geospatial database on the type and extent of shoreline protection measures, along with ongoing assessment of shoreline wetland/ecosystem changes including potential ecosystem implication of shoreline protection.

Related monitoring measures include:

- recording permit applications for shoreline modification (*e.g.*, dredging, dock extensions);
- documenting land use changes around particular sites to assess whether encroachment is likely to impact vulnerabilities to shoreline property and ecosystems;
- monitoring reported shoreline damages, to provide a context for the overall assessment of water-related damages in the basin; and,
- tracking changes in wetland and ecosystems to monitor changes in the type and extent of various ecosystems.

8.2.3 Information Management and Distribution

Information collected and generated by the Study, as well as ongoing hydroclimatic monitoring and modelling afterward will support coastal zone management efforts. This information is also highly relevant to other Great Lakes initiatives such as the Great Lakes Water Quality Agreement and the Great Lakes-St. Lawrence River Basin Sustainable Water Resource Agreement.[1] As well, the ongoing hydroclimatic monitoring, modelling and data management systems of different agencies can be utilized to inform the learning culture that is needed to support coastal zone management and other Great Lakes resource management programs.

At present, there are numerous agencies involved in generating hydroclimatic information, with different though occasionally overlapping roles. These agencies include: NOAA, the United States Army Corps of Engineers (USACE), the United States Geological Survey (USGS), Environment Canada, Fisheries and Oceans Canada, Natural Resources Canada, state and provincial resource management agencies, local and regional non-government agencies, conservation authorities, the private sector and academia. In the absence of a formal bi-national study, there is no formal mechanism or driver for collecting and coordinating the hydroclimatic information on a continuing basis. Such coordination and oversight however, is required to develop an effective and efficient means of both compiling, vetting, coordinating and distributing hydroclimatic data and information to those who need it.

The distribution of hydroclimatic information will require information management infrastructure. Distribution also may need data sharing agreements and staff support from partner agencies. The organization responsible for distributing the information should have formal status under the IJC or be supported by the two federal governments to give it the necessary authority and a reporting structure. Funding of this group would also be required. Coastal zone managers and regulatory agencies would need to take steps to incorporate the information into their decision-making processes.

The proposed effort could build on existing initiatives such as the efforts that are underway by NOAA and the Great Lakes Observing System to develop gateways to Great Lakes hydroclimatic information.

[1] For information on the Great Lakes Water Quality Agreement, see the IJC's website: www.ijc.org/en/activities/consultations/glwqa/agreement.php
For information on the Sustainable Water Resource Agreement, see the website of the Council of Great Lakes Governors: www.cglg.org/projects/water/CompactImplementation.asp

8.2.4 Tools and Processes for Decision Makers

As outlined in **Chapter 6**, the Study sought to develop as robust a regulation plan as possible by testing options under a wide variety of possible water supply scenarios. However, the future remains unknown. The recommended plan, however robust, may not be resilient under all possible future conditions. As a result, ensuring the continued maintenance of the tools and processes for monitoring plan performance and making necessary changes into the future is important to an adaptive management process.

1. Maintenance and Updating of Evaluation and Modelling Tools

A number of evaluation tools were developed in the Study to support plan evaluation and ranking that are critical to assessing the effectiveness of any given regulation plan. These tools should be maintained and updated as new information and knowledge is acquired and to accommodate software and hardware improvements. The tools include the:

- Shared Vision Model (SVM);
- Structures Analysis Tool (for shore protection);
- Integrated Ecological Response Model 2 (IERM2) for the upper Great Lakes; and,
- Multi-lake optimization modelling tool.

All of these models were developed by outside experts under contract to the Study. To support the ongoing use and updating of these tools, full documentation (*e.g.*, a user's manuals, process flow diagrams, data specifications, sample data bases) is required, particularly for the SVM and IERM2. Training for United States and Canadian agency staff is necessary so that they could apply, update, revise and continue to expand on and improve these tools. Integration of these tools with similar tools developed for the management of the Lake Ontario-St. Lawrence River system, would allow for system-wide analyses, which may be of particular importance in future climate change analyses and any future work in the area of multi-lake regulation.

2. Ongoing Plan Evaluation

How and when these evaluation tools are used in decision making are important to adaptive management. As outlined in section 8.1.1, the two major purposes for adaptive management are to:

1. verify, through ongoing evaluation, that the decision is achieving its intended results and adjust if necessary; and,
2. determine if the decision needs to be modified in the future to address changing conditions.

In terms of the first purpose, based on plan formulation and evaluation efforts undertaken in the Study, there have been few performance indicators identified that would be greatly improved or degraded as a result of a new regulation plan. This suggests that minimal followup of performance indicators will be required in the near term, though ongoing assessment of emerging issues may identify additional performance indicators over the longer term. As an initial priority, follow-up analysis will be needed to assess the implications of the new regulation plan on just a few performance indicators isolated to the St. Marys River area.

The St. Marys River provides critically important wetland, fish spawning, and nursery habitat for many species in the upper Great Lakes. The Study developed ecological criteria to identify flows and water level regimes that will adversely affect or enhance the St. Marys River ecosystem. During the development of these criteria, considerable effort was made to protect or enhance vulnerable habitat areas and species, including vulnerable Lake Sturgeon spawning habitat.

Opportunities have been identified to improve the St. Marys River ecosystem by manipulating flows and implementing operational changes at the compensating works or the St. Marys River hydropower plants. In addition, concerns have been raised regarding the stability of the St. Marys compensating works under rare, though possible, high water levels. These issues require follow-up monitoring and analyses on behalf of the International Lake Superior Board of Control, as follows:

- Approximately 90 percent of the sea lamprey in the upper Great Lakes spawn in the St. Marys River. Based on data collected by the Great Lakes Fishery Commission (GLFC), sea lamprey are attracted to high flow. Operational changes at the hydropower plants may increase trapping efficiencies (thus eliminating more sea lamprey) and allow GLFC control agents to better assess the number and distribution of sea lamprey in the rapids and St. Marys River. If changes to the flow are successful in improving trapping efficiencies, then ongoing assessment and monitoring would be required to develop changes in the flow operation.

- Significant environmental benefits may result from operational changes at the compensating works. By slowing the rate of water level change to less than 10 cm (about 4 in) per hour, flushing and dewatering effects in the St. Marys River rapids are minimized, thereby enhancing fish production within the rapids. These changes, however, would have planning and timing implications for the hydropower companies. Therefore, follow-up monitoring would be required to ensure that the operational changes were having the intended results.

- The St. Marys River is a critical spawning area for a genetically distinct population of Lake Sturgeon. Lake Sturgeon mature at about 20 years and the females reproduce every four to nine years. Lake Sturgeon spawning is very sensitive to habitat conditions. Studies indicate that periodically flows need to exceed 1,700 m^3/s (about 60,000 ft^3/s) in June to flush the substrate. This flow will be accommodated through operational adjustments to the outflows under the new regulation plan. Follow-up monitoring and verification of the flow requirements would be needed over time to verify results, with the information fed back into regulation decision process as part of an adaptive management effort.

- A 1987 IJC task force study on high water levels in the Great Lakes basin concluded that Lake Superior water levels should not be raised above 184.1 m (603.8 ft) above sea level without a detailed study to identify any necessary modifications to the compensating works on the St. Marys River (Great Lakes Water Levels Task Force, 1987). Through the Study's analyses of multiple future scenarios, it has been determined that, while rare, there is the potential risk for water levels to exceed this level under all the regulation plan options evaluated. Therefore, it is suggested that a stability analysis of the compensating works be conducted as part of an adaptive management process.

3. Incorporating Adaptive Management into a New Regulation Plan

There are questions as to how an adaptive management plan can be incorporated into a new regulation plan. Any new objective for Lake Superior regulation to achieve a different purpose from that approved by the IJC in the 1914 Orders would require new authorities from the two national governments. This was the procedure followed with respect to the adoption of the principle of systematic regulation and a change to the Lake Superior regulation plan to implement Plan 1977A. This change in regulation had been recommended by the International Great Lakes Levels Board in its report to the IJC in 1973 (International Great Lakes Levels Board, 1973). This recommendation was reviewed by the IJC, including the receipt of public comment at public hearings. The IJC subsequently forwarded this recommendation in their report to the governments in 1976 and in 1979 issued a Supplementary Order that adopted the objective of systematic regulation and changed the way Lake Superior's outflows are regulated (Brown, D., 2011).

The Orders of Approval should include a periodic review of the operating plan to adjust for changed conditions. The IJC has issued such a procedure in its 2001 letters approving peaking and ponding guidelines which were subject to periodic review and approval by the IJC. Alternate contingent regulation objectives to address different future conditions such as climate change would be difficult to address through Supplementary Orders. However, it may be possible to provide greater flexibility in the Orders to allow for changing conditions. For example, decision protocols could be included to identify when and how to change the regulation plan (Brown, D., 2011). A decision protocol would have to be established for how information is reviewed, assessed and brought forward to the International Lake Superior Board of Control for its attention and decisions made as to who can decide to change a regulation plan and the levels of approval required.

Proposed improvements to the monitoring and modelling of hydroclimatic factors would address the second purpose of an adaptive management plan -- determining if the decision should be adjusted to address future conditions. Efforts will be required to understand when and if a change is necessary and what change should be made. Given that Lake Superior regulation is more effective in regulating Lake Superior levels and has a much smaller effect on levels below the St. Marys River, the most likely decisions relative to very high or very low levels will be whether to hold more or less water on Lake Superior. Past experience has shown that despite the inability to affect levels to any great degree on the lower lakes, public pressure will be to try to minimize adverse impacts to downstream interests because the great majority of Great Lakes residents live below Lake Superior. For example, during the record high1985-1986 water levels, the IJC directed the International Lake Superior Board of Control to hold back water on Lake Superior to reduce Lake Michigan-Huron levels, even though Lake Superior was also very high and the hold back affected water levels on Lake Michigan-Huron by only a few centimetres.

It will be important to revisit the plan's objectives during extreme conditions to ensure the objectives for the plan are still appropriate under these conditions and to test the hypotheses that "it will be possible to improve future outcomes under extreme conditions." To that end, three scenario objectives should be tested as part of an adaptive management strategy; to compress Lake Superior levels, to compress Lake Michigan-Huron levels and to address an additional (*e.g.*,10 cm [about 4 in] drop) in Lake Michigan-Huron levels as a result of unforeseen increases in St. Clair River conveyance.

Critical impact thresholds could be established to isolate the problem water level regimes (including range, frequency, duration and rate of change). Next steps would then be to:

- relate these water level regimes to potential hydroclimatic indicators/triggers and/or socio-economic and environmental triggers;
- test plan adjustments under extreme conditions;
- link plan adjustments to hydroclimatic and/or impact triggers; and,
- clarify the limitations of regulation for addressing risks.

8.2.5 A Regional Great Lakes- St. Lawrence River Adaptive Management Study

Integrated coastal zone management initiatives have been identified as a potential means of researching and advancing methods to induce and promote adaptive actions on a regional scale. This implies a commitment to monitoring, modelling, observing changes, and regularly evaluating strategies to manage resources in light of uncertainty and new conditions.

A regional study of the feasibility and effectiveness of such coastal zone management initiative to address specific local and regional vulnerabilities is a priority for identifying possible solutions and mechanisms for ongoing adaptive management to address changing conditions. The Study's work on climate change impacts under a wide variety of possible scenarios indicated that neither future high lake level scenarios, nor very low water level scenarios can be readily dismissed. The Study also showed that the current two-lake water regulation system is inadequate to deal with extreme climate scenarios. Hence, the Study Board recognizes the need for an adaptive management study that builds on the work that the Study initiated at four specific areas (Duluth, Chicago, Lake St. Clair and Georgian Bay), and expand that analysis to additional sites for each of the lakes, downstream through the St. Lawrence River to Montreal. This research should:

- critically assess vulnerabilities of the key interests and potential costs and benefits of lake level extremes;
- assess potential regional adaptive actions that could address specific issues and minimize risk;
- identify costs and specific institutional requirements for implementing such actions; and,
- establish the long-term adaptive management processes for ongoing assessment of any implemented actions including costs avoided by actions taken.

As part of this adaptive management study, additional feasibility-level analysis would be conducted on various options for a multi-lake regulation scheme, building on the preliminary analysis conducted by the Study (see **Chapter 7**) and expanding it to include a full benefit-cost analysis taking into account potential environmental implications. In conjunction with the regional adaptive management study, this analysis of multi-late regulation would allow for a better understanding of the most effective and cost efficient means of addressing risks related to climate extremes. Conducting such a preparatory study is consistent with the *precautionary principle*[2] and adaptive management principles advocated for dealing with climate change uncertainty. The analysis could be conducted either by an independent IJC Study Board, or under the auspices of a new IJC Water Management Advisory Board.

8.2.6 Governance for Implementing Adaptive Management

1. A Great Lakes-St. Lawrence River Water Management Advisory Board

A successful adaptive management program requires a proper governance structure and funding mechanism to ensure its implementation and operation. This is particularly important for ensuring the data and information is being properly utilized in the decision process. The Study reviewed several options with respect to governance, including:

[2] "*In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."* – Principle 15, Rio Declaration, United Nations Conference on Environment and Development (Earth Summit).

- an adaptive management committee reporting directly to the International Lake Superior Board of Control;
- the expansion and formalizing of the existing CCGLHHD; and,
- a new advisory board under the IJC responsible for implementing a Great Lakes-St. Lawrence River system perspective and responsible for implementing the adaptive management strategy.

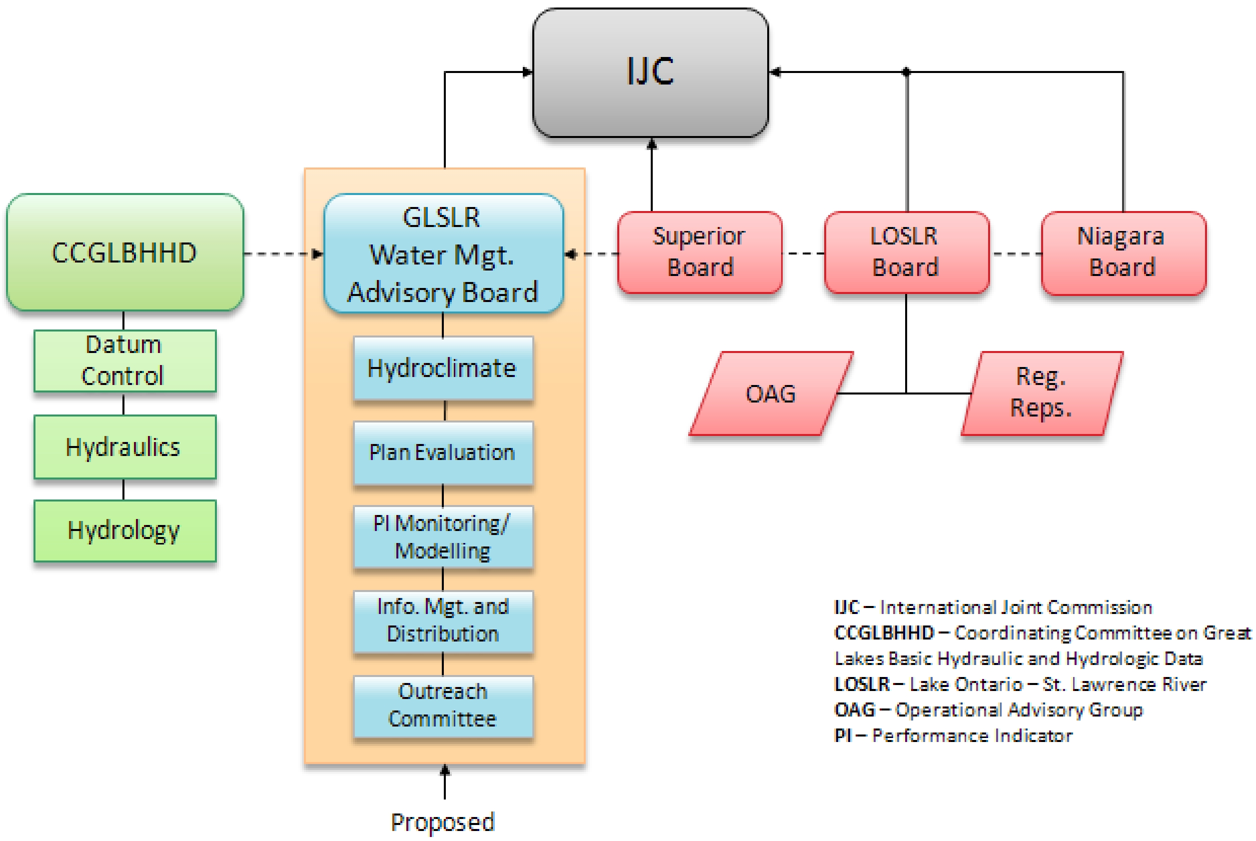
The third option, a new advisory board, was identified by the Study Board as the preferred approach, given the restricted mandates and composition of the first two options. A new advisory board could better coordinate activities and implement a basin-wide adaptive management strategy for the Great Lakes-St. Lawrence River system. The advisory board, tentatively named the *Great Lakes- St. Lawrence River Water Management Advisory Board*, would report directly to the IJC and coordinate with all the Boards of Control and the CCGLHHD. It would be responsible for:

- coordinating, vetting and managing Great Lakes-St. Lawrence River hydroclimatic data and science;
- advising on required hydroclimatic monitoring and modelling needs to:
    - improve Great Lakes-St. Lawrence River water budget estimation,
    - recommend on observation network requirements,
    - support improved forecasting, and
    - improve climate change prediction and track hydroclimatic triggers;
- ensuring distribution of water level and hydroclimatic information to users;
- maintaining and updating plan evaluation tools and monitoring critical performance indicators;
- supporting the periodic review of regulation plans;
- addressing special water level management related issues;
- undertaking outreach and education;
- considering further analysis of multi-lake regulations and other alternative adaptive actions; and,
- reporting regularly to the IJC.

Membership could be drawn from federal, state and provincial governments, academia, non-government organizations, and the public.

The Advisory Board would be mandated to identify and work with the appropriate agencies in the United States and Canada to ensure that required monitoring and modelling needs are met to support improved short-term and long-term forecasting and climate change prediction to support all the IJC Boards. It would coordinate forecasting and climate change research for the Great Lakes-St. Lawrence River and be the primary authority for Great Lakes-St. Lawrence hydroclimatic data. Technical sub-groups could be established to coordinate necessary performance indicator monitoring and modelling in support of the adaptive management program. These sub-groups would maintain the tools necessary for ongoing assessment by the Boards of Control of their regulation plans and address other water management and science related questions that arise through governments or the IJC. They would also support information management and distribution for Great Lakes-St. Lawrence River hydroclimatic data and information, and consult with the users of the data and information distribution system to ensure a direct link to the Advisory Board's activities (see figure 8-6).

Figure 8-6
Governance Option for the Proposed
Great Lakes-St Lawrence River Water Management Advisory Board



2. The Role of the IJC

The IJC has undertaken numerous water level studies over the past 50 years. These studies have generated considerable data and knowledge, and have helped inform governments on courses of action. However, there has been limited continuity between these studies. The data and information gathered for one study are not necessarily maintained for the next. Rather, the monitoring, data gathering, information management and data to decision protocols generally have been issue-specific and not designed for long-term continuity and decision making.

The IJC is working with governments to establish a new approach to managing the outflows of Lake Ontario while continuing to provide benefits to other interests in the Lake Ontario-St. Lawrence River system. An adaptive management program is being developed as an essential component of this new approach. Coordination between this effort on the Lake Ontario-St. Lawrence River and the Study's efforts would be a more effective use of resources and provide an overall coordinated program for the whole system.

While the IJC has a Water Quality Advisory Board and a Science Advisory Board, it does not have a board to advise on Great Lakes-St. Lawrence River system-wide water quantity management issues. Such a board could provide the oversight for implementing an adaptive management program for the entire system and coordinate with and provide guidance for all cross-over issues among the existing Boards of Control and the CCGLHHD.

3. Funding Considerations

A structured long-term adaptive management program aimed at minimizing the risks of adverse water level related impacts through ongoing hydroclimatic monitoring and modelling and through protocols for informing the appropriate decision makers would be an effective mechanism of addressing future risks. In addition, the monitoring and modelling proposed by the Study would support other initiatives that must consider the implications of fluctuating water levels and uncertain future conditions in the Great Lakes, such as the Great Lakes Water Quality Agreement and the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement. The success of an adaptive management program will depend on the commitments of the IJC, federal and state/provincial governments in securing the necessary resources required to support the program. In the long run, this could have considerable cost savings, and provide immeasurable benefits.

Initial cost estimates for the adaptive management program outlined here suggest an initial investment of five years at \$1.5M-\$2.5M a year, with ongoing requirements at a more reduced level. (For a detailed discussion of funding issues, see Adaptive Management Technical Work Group, 2011).

8.3 Key Points

With respect to the role of adaptive management in addressing future water levels in the upper Great Lakes basin, the following points can be made:

- Adaptive management is a process of "learning while doing." It provides a structured, iterative approach for improving actions through long-term monitoring, modelling and assessment, so that decisions can be reviewed, adjusted and revised as new information and knowledge become available and/or as conditions change.

- The Study's approach to considering adaptive management was based on *decision-scaling*. The approach begins with stakeholders rather than climate models, and determines the domain of vulnerabilities and then assesses whether those conditions are plausible based on the available climate science.

- Adaptive management has an important role to play in addressing the risks of future changes in water levels in the upper Great Lakes. Lake Superior regulation on its own can do little to address risks of extreme lake levels downstream of Lake Superior. Multi-lake regulation cannot fully eliminate risk of extreme lake levels outside the historical range. New structures in various parts of the Great Lakes Basin could take decades to implement and cost billions of dollars. Therefore, regardless of the Lake Superior regulation plan adopted by the IJC, ongoing monitoring and modelling efforts will be required to continue to assess risk and address uncertainties and changing conditions.

- Information and education are powerful components of adaptive management. They contribute to both anticipating and preventing lake level-induced damage, particularly when focused on understanding risk, the limits of regulation, inherent uncertainties and system vulnerability.

- The Study identified the following six core elements of an effective adaptive management strategy:

    - bi-national Great Lakes hydroclimatic monitoring and modelling;
    - tracking and understanding of changes in the physical system;
    - information management and distribution;
    - tools and processes for decision makers;
    - a regional Great Lakes-St. Lawrence River system adaptive management study for dealing with climate extremes (including further study of multi-lake regulation) and,
    - governance for implementing an adaptive management program.

- Governance of adaptive management is a particularly important challenge. Existing legal, regulatory and programmatic efforts related to adaptive management vary considerably from one jurisdiction to the next. Federal, state and provincial governments generally provide the policy and regulatory framework, while site-specific selection and application of adaptive risk management measures is largely a local government responsibility. To date, efforts to coordinate approaches and promote consistency have been limited and generally have focused on accommodating seasonal lake level fluctuations and the occasional extreme high and low water events. Little focus has been placed on long-term implications of climate change-induced impacts, and the prospective need for new adaptive risk management measures.

- Adaptive management to address future levels in the upper Great Lakes basin has direct relevance to several important initiatives in the Great Lakes-St. Lawrence River system, including:

    - adaptive management efforts in the Lake Ontario-St. Lawrence River part of the system;
    - the Great Lakes Water Quality Agreement; and,
    - the Great Lakes-St. Lawrence River Basin Sustainable Water Resource Agreement.

- No bi-national organization exists to oversee an ongoing coordinated adaptive management effort in the Great Lakes basin. Nineteen years ago, the IJC's Levels Reference Study recommended that a Great Lakes-St. Lawrence River Advisory Board be created to coordinate, review, and provide assistance to the IJC on issues relating to water levels and flows of the Great Lakes and St. Lawrence River (Levels Reference Study Board, 1993). This recommendation remains relevant and, given the uncertainties associated with climate change, even more applicable today.

8.4 Recommendations

Based on the findings presented in this chapter, the Study recommends that:

1. ***The IJC should seek to establish a Great Lakes-St. Lawrence River Water Management Advisory Board to help implement an adaptive management strategy for the entire Great Lakes-St. Lawrence River System.***

2. ***The adaptive management strategy should address future water levels in the upper Great Lakes basin through six core initiatives:***

   - ***strengthening hydroclimate monitoring and modelling;***
   - ***improving tracking and understanding of changes in the physical system;***
   - ***ensuring more comprehensive information management and distribution;***
   - ***improving tools and processes for decision makers;***
   - ***establishing a regional Great Lakes-St. Lawrence River system adaptive management study for dealing with climate extremes (including further study of multi-lake regulation) and,***
   - ***strengthening governance for implementing an adaptive management program.***

3. ***The IJC should work with governments to pursue funding options and coordinate this effort with the Lake Ontario-St. Lawrence River Working Group and the renewal of the Great Lakes Water Quality Agreement.***