Both nonstructural and structural approaches can be considered in isolation or in combination, as adopting more than one measure may lead to a preferred outcome.

If structural measures are being considered that return the conveyance characteristics of the St. Clair River to be similar to that of a previous time period, the question will be one of what level of adjustment to consider. This may require an evaluation of remediation measures that reflect a selection of alternative target conditions. This could be expressed as target conveyance levels associated with earlier time periods, such as circa 1940, 1965, 1980 and 2005 conditions. Note that these dates are given only for example purposes. Should remediation measures of a dynamic nature be considered, a regulation plan and operating rules for such measure would need to be developed in concert with Lake Superior outflow regulation. Any plan would also need to be able to respond to unusual hydrological conditions, including the potential for changes in water supply as a result of climate change and variability affecting the upper Great Lakes system. Modelled future conditions may also be considered within this context to help illustrate impacts within the system on stakeholders should erosion be on-going. Resource evaluations, which are described in Chapter 4, would be required to adequately evaluate the impact of each option. Outcomes would be evaluated based on an analysis of benefits and losses from economic, social and environmental perspectives.

Within the International Lake Ontario-St. Lawrence River Study, a “shared vision” computer model was constructed to facilitate the assessment of potential options (IJC, 2005). For the Upper Lakes Study, a similar model would be helpful in assessing the effects of various remediation options on aspects of importance to stakeholders. The intent of such a model is to combine key information from various “resources evaluations” in such a way that various scenarios or options can be assessed to estimate the potential positive or negative impacts on various interests. These results can lead to the development of additional remediation options that can further limit damages or increase benefits, resulting in the development of potentially “acceptable” remediation plans for consideration by the IJC.

The costs for the St. Clair River evaluation of the study are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$500K	$1,250K	$1,250K	$500K	$0K
or					
Total Cost (Canadian dollars)	$600K	$1,500K	$1,500K	$600K	$0K

The total cost for the St. Clair River evaluation would be about $3,500K (U.S. dollars). This is equivalent to about $4,200K in Canadian dollars.

3.0 Regulation Plan Review

The principal purpose of this Plan of Study is to create a framework for three major items related to the regulation of Lake Superior: (i) review the operation of the structures controlling the outflows from Lake Superior in the light of the impacts of those operations on water levels, flows, and consequently affected interests in the Upper Great Lakes system from Lake Superior downstream through Lake Erie, including the environment; (ii) assess whether changes to the Orders or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner, including climate change scenarios; and (iii) evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation.

To accomplish these goals, the study will begin by reviewing the Orders of Approval (including all Supplementary Orders), the operating rules and criteria currently in use and any past deviations from the regulation plan. Options will be developed as to what items may be adjustable. Additionally, climate change/variability scenarios will be generated to ensure any new regulation plans have the ability to operate over a future range of conditions. Any significant items investigated in the St. Clair river portion of the study will be incorporated in new regulation plans also. Lakes Michigan-Huron outflow changes will impact any alternative regulation plans and subsequent Orders of Approval. These analyses will then be used as input to the design process for alternative regulation scenarios. Extreme high and low ranges of these possible changes can then be analyzed to determine the maximum effect that is achievable on water levels and flows in the system. Based on the magnitude of these potential water level and flow changes, due to alternative regulation scenarios, an estimate of the degree of impact on various resources will be known. This will help guide the creation and evaluation of candidate alternative regulation plans.

The findings from the consultations with the International Lake Ontario – St. Lawrence River Study staff that are directly applicable to this study are highlighted as “Lessons Learned” in the following sections.

3.1 Orders of Approval, Operating Rules and Criteria

3.1.1 Current Orders, Rules and Criteria

The following is a listing of the pertinent conditions and criteria currently in effect as noted in the original Orders of Approval and any Supplementary Orders. The original Orders of Approval were issued in May 1914 in response to applications of the Algoma Steel Corporation, Limited and the Michigan Northern Power Company for approval of the obstruction, diversion and use of the waters of the St. Marys River on the Canadian and United States side of the international boundary at Sault Ste. Marie, Michigan and Ontario. They authorized the construction of the Compensating Works and the regulation of Lake Superior outflows. They also created “The board of control” to oversee the operation of all the said works, canals, headgates and by-passes. The major items listed below refer to the conditions dealing with control and operation. Any items that were deleted by subsequent supplementary orders have not been listed. Any items that have been amended are only listed as the currently amended wording in effect as of the most recent supplementary order. These are the items to be reviewed for possible update and their subsequent effect on alternative regulation plans.

The Supplementary Order of Approval, dated 27 September 1978, includes the following provisions:

- Condition 2:
    - Upon completion of the remedial works to maintain the sport fishery in the St. Marys Rapids , the outflows of water from Lake Superior shall be distributed according to the following order of priority:
    - a) the requirements of navigation will be met;
    - b) a flow sufficient to protect the sport fishery in the St. Marys Rapids shall be maintained;
    - c) the use and diversion of water as approved in the 1914 Orders of Approval shall be maintained, without prejudice to any determination by Governments of the ownership and distribution of waters diverted into Lake Superior from Long Lac and Ogoki.

The Supplementary Order of Approval, dated 3 October 1979, includes the following provisions:

- Condition 1:
    - maintain the monthly level of Lake Superior as nearly as may be within its recorded range of stage below elevation 183.86 metres (602.0 feet)(IGLD 1985);
    - provide no greater probability of exceeding elevation 183.86 metres (602.0 feet) (IGLD 1985) than would have occurred using the 1955 Modification of the Rule of 1949;
    - maintain the levels of Lake Superior and Lakes Michigan-Huron at the same relative position within their recorded ranges of stage and with respect to their mean monthly levels, assuming supplies of the past as adjusted; and in such a manner as not to interfere with navigation. Supplies of the past as adjusted are defined as the monthly water supplies for the period 1900-1976 adjusted to a condition assuming a continuous diversion out of the Great Lakes Basin of 90 m^3/s (3100 ft^3/s) at Chicago and a continuous diversion into the Great Lakes Basin of 140 m^3/s (5000 ft^3/s) from the Albany River Basin.
    - ***Criterion a:*** The level of Lake Superior shall be maintained within its recorded range of stage when tested with supplies of the past as adjusted. The regulated monthly mean level of Lake Superior shall not exceed elevation 183.86 metres (602.0 feet) (IGLD 1985) or fall below elevation 182.76 metres (598.4 feet) (IGLD 1985) under these conditions.
    - ***Criterion b:*** To guard against unduly high stages of water in the lower St. Marys River, the excess discharge at any time over and above that which would have occurred at a like stage of Lake Superior prior to 1887, shall be restricted so that the elevation of the water surface immediately below the locks shall not be greater than 177.94 metres (582.9 feet) (IGLD 1985).
    - ***Criterion c:*** To guard against unduly low levels in Lake Superior, the outflow from Lake Superior shall be reduced whenever, in the opinion of

the Board, such reductions are necessary in order to prevent unduly low stages of water in Lake Superior, and shall fix the amounts of such reductions; provided, that whenever the monthly mean level of the Lake is less than 183.40 metres (600.5 feet) (IGLD 1985), the total discharge permitted shall be no greater than that which it would have been at the prevailing stage and under the discharge conditions which would have been obtained prior to 1887.

- Condition 2:
  - The mean elevation of Lakes Superior, Michigan and Huron shall be ascertained by taking the mean of the readings of automatic gauges on each lake. The gauges shall be so located that the combined readings on each lake provide a representative mean level on that lake. At least four gauges shall be utilized on Lake Superior, two of which are maintained by Canada and two by the United States; at least six gauges shall be utilized on Lakes Michigan-Huron, two of which are maintained by Canada and four by the United States.

- Condition 3:
  - A Board of Control to be known as the International Lake Superior Board of Control, consisting of an equal number of members from Canada and the United States, is hereby established. The members of the Board of Control shall be appointed by the Commission.

- Condition 5:
  - The amount of water available in each country for power purposes, under the 1914 Order, as amended, shall be one-half of the total amount available for power purposes as determined by the approved regulation plan and the requirements regarding flow allocation of the said Order, as amended, without prejudice to any determination by Governments of the ownership and distribution of water diverted into Lake Superior from Long Lac and Ogoki.

The Supplementary Order of Approval, dated 11 December 1985, includes the following provisions:

- Condition 2:
  - The outflows of water from Lake Superior shall be distributed in accordance with Condition 2 of the Supplementary Order dated 27 September 1978.

- Condition 3:
  - a) flows through the section of the Compensating Works which is between the dike and St. Marys Island will achieve a minimum water level between the dike and Whitefish Island equal to that provided by opening four (4) gates in the Compensating Works prior to construction of the dike;

- flows sufficient for fisheries habitat management to a maximum of 0.8 m^3/s (30 ft^3/s) will be maintained in the Whitefish Channel between Whitefish Island and St. Marys Island; and
- the water level in the main St. Marys Rapids to the south of the dike will be at least equal to that which occurred with one half (1/2) gate open in the Compensating Works before the dike was constructed, and will reach the bottom toe of the dike.

There are a number of additional operational rules, guidelines and limitations, not specifically noted in the Orders of Approval that merit review as well. These are:

- The maximum winter outflow is 2,410 m^3/s (85,000 ft^3/s)
- The minimum winter outflow is 1,560 m^3/s (55,000 ft^3/s)
- The maximum change in outflow, from month to month, can not exceed 850 m^3/s (30,000 ft^3/s)
- The minimum gate setting in the Compensating Works shall not be less than ½ gate open
- The balancing routine and its parameters
- The outflow forecasting routines and trigger levels
- Each remaining Plan 1977-A parameter
- U.S. Slip water level relationships
- S.W. Pier water level relationships

3.1.2 Improvement Opportunities for Orders, Criteria and Regulation Plans

There are a variety of work items that have been studied in the past, specifically the recent Levels Reference Study and issues that have recently come to light that need review to make the regulation plan as robust as possible.

- The specified upper and lower water level limits for Lake Superior, while being sufficient for data of the recorded past, may not be appropriate under a climate change scenario or under conditions reflecting normal climate variability. These should be reviewed for their relevance and the necessity of having the elevations specifically noted, rather than optimal ranges noted.
- Review the supply forecast method used in the plan and consider if there are more useful approaches.
- The balancing equation for Lake Superior and Lakes Michigan-Huron should be reviewed and the possibility of incorporating water supply forecasts into the balancing routine considered. In addition, the parameters that define the state of balance between the lakes should be reviewed and updated if necessary.
- Consider other means of systemic regulation as alternatives to the balancing equation approach of Plan 1977-A. An example would be a regulation plan using a multi-objective, multi-lake optimization approach.
- The outflow limits in the plan should be reviewed for their appropriateness. There are limits specified for maximum outflows, minimum outflows, winter outflows, maximum changes from month to month, as well as the pre-project criteria to prevent flooding in Soo Harbor and unduly low Lake Superior levels. Modifying the outflow limits could improve the balancing of the levels and would allow greater flexibility in responding to extremes.

- The outflow forecasting procedures should be evaluated to determine if improvements can be made to smooth the transition of flows from month to month while maintaining the responsiveness of the plan. Issues to be addressed may include incorporation of trigger levels for introducing high or low water supplies, changing the length of the forecast period used, using seasonal trigger levels, and better linkage between outflow forecasting and balancing.
- Update the Niagara River stage-fall-discharge equation and St. Clair – Detroit River stage-fall-discharge equations used in the hydraulic routing as well as varying ice and weed retardation impacts.
- The split of water for power production is currently 50/50. Recent developments show that the generation capacity of the U.S. side is slightly more. This results in either a non-50/50 split or spilled water.
- Peaking and ponding is not specifically mentioned in the Orders of Approval or the Supplementary Orders. The power companies currently engage in this practice, under the auspices of the Board. Should this issue be definitively addressed in updated Orders?
- Some criteria, guidelines and limitations can cause large flow changes from month to month, resulting in excess water discharges which are not available for power generation. These larger releases cause fishery and environmental concerns as well. New plans could be more flexible in spreading the release of water.
- Fishery interests note that the ½ gate open minimum setting is not sufficient to water the entire bed of the Rapids. Investigations into providing a greater permanently watered surface area should be conducted, taking other parameters such as velocity, depth and habitat into consideration as well.
- Sea lamprey trapping personnel have noted that high flows in the rapids during the months of June and July decrease the effectiveness of the trapping program.
- Investigate the need for the International Lake Superior Board of Control (ILSBC) to have discretionary authority to deal with deviations from the regulation plan. This may take on more importance in dealing with climate variability and possible St. Clair River remediation options.
- Review the membership of the ILSBC to determine if additional members are necessary to reflect the diversity of interests in the basin and to meet emerging needs.
- Review any other aspects of the ILSBC to see if changes are warranted based on past deficiencies or future needs, including public communications.

These items should be reviewed as to their compliance with the Boundary Waters Treaty, and how they meet the contemporary and emerging needs and interests and preferences for managing the system in a sustainable manner. The items that are deemed acceptable for change/update should become part of alternative regulation plans. Several of these options may have a range of increments with which they can be implemented. Sensitivity analyses would be beneficial here to see the magnitude of the impacts of each option.

3.2 Response to Climate Change and Variability

The climate of the upper Great Lakes basin has a great impact on the requirements and effectiveness of the Lake Superior outflow regulation plan. Net basin supply is a function of climate. Over the long term, the net basin supply received limits the amount of water that can be stored in or released from a lake. The net basin supply has had historical variations on many timescales. Periods of higher and lower water supplies will undoubtedly occur in the future due to the natural variation in climate, with and without the effects of anthropogenic increases of greenhouse gases in the atmosphere. To design a regulation plan that would be more useful under a wider range of supplies, consideration would be given to generating hydrological sequences based on the statistical properties of existing historical supply using, for example, a stochastic approach as was done in the International Lake Ontario – St. Lawrence River Study.

A qualitative assessment of changes due to demographic and other possible factors, such as consumptive uses, would be made to illustrate how such changes may affect water supplies and related hydrological factors. Alternative basin supplies could then be routed through the hydraulic model to determine the impacts on levels and flows using the modelling environment described in Section 2.5.

Lake Superior Regulation Plan 1977-A was developed and tested using 1900-1986 historical water supplies to Lake Superior and the downstream lakes, adjusted to certain assumptions concerning water diversions and outlet conditions of the downstream lakes. Since 1986, more extreme supplies have been recorded. These include the rapid decline in the water supplies in 1987-1988, the very high supplies of the mid 1990s, and the very low supplies that began in the late 1990s and have continued through current times. Among the first steps in this study would be the review and updating of the historical water supplies through to the most recent available year and defining other basic parameters in the modelling environment such as diversions, outlet conditions, and ice and aquatic growth impacts on flows. Some of this work may have to be revisited if it is found that significant changes in the St. Clair River flow capacity have occurred in recent decades.

Climatic factors contribute to the variability in the levels of the Upper Great Lakes. The utility of observed time series of lake levels has been enhanced by the use of a 50,000-year stochastically generated time series of net basin supply having statistical characteristics similar to those of the observed time series (Fagherazzi et. al. 2005. Lee, et al. 1994). This is a useful method for synthesizing time series of net basin supply to test the robustness and performance of a regulation plan under a wide array of plausible supply conditions. These series can also be applied for calculating the frequency of exceedence of various lake levels under scenarios corresponding to experimental outflow regulation plans. Work done for the International Lake Ontario – St. Lawrence River Study would be directly applicable here. In that study the equivalent of 50,000 years of NBS sequences for each of the upper lakes were generated and routed to create the NTS series for Lake Ontario. These data could be used directly in the Upper Lakes Study.

Additional analyses would also be undertaken making use of, and possibly extending, the application of climate change general circulation models (GCM) to estimate future supplies to the Great Lakes. The future supply scenarios that were generated for the upper lakes as part of the International Lake Ontario – St. Lawrence River Study (Croley 2003) could be directly applied for this study, but consideration should also be given to generating new scenarios based on more current GCM and Regional Circulation Model (RCM) results should they be available. RCMs provide potentially higher resolution output, which may be more physically representative of the Great Lakes geography, leading to more accurate results, however at the time of the Lake Ontario – St. Lawrence River Study, even these models did not account for lake-atmosphere interactions.

Rather than assessing variability as depicted by general circulation models (GCM), it might be more fruitful to attempt to gain greater understanding of the long-term variability of the past, whose modes might be extended into the future. This includes the relationship between climatic variables and lake levels at time scales from a few years to a few decades and an understanding of the manifestations and causes of common variability of climate and lake levels at timescales of a few years to several decades. The long-term modes of variability involve regimes of wet-cold, wet-warm, dry-cold, and dry-warm conditions, which are connected to large-scale, persistent atmospheric circulation patterns. These circulation anomalies have been characterized by teleconnection indices, such as El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and others. Empirical matching of combinations of the magnitudes and phases of these indices with the precipitation-temperature regime of the Great Lakes region could be carried out, leading to enhanced physical understanding of the causes of teleconnections between the climate of the Great Lakes region and foci of oceanic forcing.

Scenarios of net basin supply can be generated by extension of observed net basin supply through stochastic synthesis of a long time series, and also through reconstruction of paleo-levels. Baedke and Thompson (2000) reconstructed high stand levels of Lake Michigan over the past 4700 years, which may be useful in assessing historical net basin supply, and input into a hydraulic routing model. They have demonstrated that a 150- to 160-year cycle in lake levels exists concurrently with a 30- to 33-year cycle, both of which they believe to be related to climatic factors. A similar reconstruction is pending for Lake Superior levels.

These various methods will be investigated to provide the best scenario to model future climate variability and change, and therefore not all of these approaches will be adopted in the study. The selected climate-related studies would be coordinated with hydraulic and hydrological studies, with the outputs from the climate studies being used as input to hydrological models, as well as channel routing and lake regulation models. The water levels and flows resulting from the various regulation plans and climate scenarios will be evaluated using the approach developed in the study to assess impacts on the resource groups.

LESSON LEARNED: When running the coordinated routing model with stochastic scenarios during the International Lake Ontario – St. Lawrence River Study, Plan 1977-A did not do well under extreme high supply conditions, suggesting changes are necessary to make the regulation plan more robust for future climate.

3.3 Maximum Impact Achievable on Levels and Flows

During Phase II of the IJC's Levels Reference Study, Task Group 1 of Working Committee 3 developed several alternative regulation scenarios. They were specifically designed to better balance the levels of Lakes Superior and Michigan-Huron and provide benefits to the middle Great Lakes in the form of decreased frequency of extreme levels. The most promising plan was designated PL2 by the Working Committee and when combined with a Lake Ontario regulation plan, was designated Plan 1.21 by the Study Board. This plan included: changes to the outflow forecasting routines; an increase in the winter maximum outflow limit; and modifications to the balancing equation and its parameters.

This experimental plan was run for the 1900-1989 time period along with the basis of comparison plan. Comparison of lake levels during this 90 year period, including mean, maximum and minimum, is shown in Table 3.

The frequency of occurrence of extreme levels on Lakes Michigan-Huron and Erie were decreased, while they were increased on Lake Superior. As shown in Table 3, the range of levels were reduced by 13.1 centimetres (0.43 feet) and 5.8 centimetres (0.19 feet) on Lakes Michigan-Huron and Erie, respectively, and increased by 12.5 centimetres (0.41 feet) on Lake Superior. It was found that the experimental plan balanced the levels of Lakes Superior and Michigan-Huron better, while decreasing the frequency of large changes in outflow from month to month. The plan decreased the number of months when the Lake Superior outflows were below the capacity of the hydropower plants.

Table 3
Summary Statistics for Levels Reference Study Plan 1.21
(Relative to Plan 1977-A)

• Lake Superior mean water level	-3.4 centimetres (-0.11 feet)
• Lake Superior max water level	+7.6 centimetres (+0.25 feet)
• Lake Superior min water level	-4.9 centimetres (-0.16 feet)
• Lakes Michigan-Huron mean water level	0.0 centimetres (0.00 feet)
• Lakes Michigan-Huron max water level	-5.2 centimetres (-0.17 feet)
• Lakes Michigan-Huron min water level	+7.9 centimetres (+0.26 feet)
• Lake Erie mean water level	+0.3 centimetres (+0.01 feet)
• Lake Erie max water level	- 1.2 centimetres (-0.04 feet)
• Lake Erie min water level	+ 4.6 centimetres (+0.15 feet)

The plans evaluated in Phase II of the Levels Reference Study did not include all the options which may be reviewed in this Plan of Study. This past work shows that there are additional potential benefits to be obtained from the consideration of alternative regulation plans. It is recommended that early in the study, some preliminary work be done to establish the maximum achievable impacts on levels and flows from regulation. This could include all possible changes to the regulation plan at one time, without final determination as to their applicability. These ranges of level and flow changes will then give the resource evaluation groups an estimate of the outer extremes of impacts possible by changing the regulation plan. This information can guide decisions on how detailed any resource evaluations will need to be.

3.4 Formulation and Evaluation of Alternate Regulation Plans

The evaluation of Lake Superior regulation plans, the practicality of proposed criteria, and the hydrological impacts on the resource groups, require computer simulation of water levels and flows. Computer models currently exist, including the CGLRRM, which can be used for these evaluations. This model incorporates the existing Lake Superior regulation plan and hydraulic outlet conditions of the St. Clair, Detroit, and Niagara Rivers and Great Lakes diversions. The model computes water levels and flows of the upper Great Lakes and their connecting channels through Lake Erie and the Niagara River, given historical water supplies or other supply scenarios. In addition to outflow regulation study, the model may be a useful tool in assessing the impacts of dredging, diversions, and climate variability. There are also other hydrological models, such as the hydrological prediction and basin runoff models developed and operated by GLERL or the coupled weather and WATFLOOD hydrological models of Environment Canada that could be used in these analyses. Model environments developed for the St. Clair River investigations would possibly be used here as well.

Due to the size and response time of the upper Great Lakes to water supplies, the Lake Superior outflows are regulated on a monthly basis. Most historical water supply data are also developed on a monthly basis. Studying the implications of a change to more frequent regulation, such as weekly, would be very time intensive and costly. For example, data including net basin supplies and river flows would need to be calculated from 1900 to the present time on a quarter monthly basis. Daily data necessary for these analyses may not be available. Assessing the potential gain or loss from more frequent regulation may not be economically feasible due to the expense of generating the necessary data sets. Thus, for the testing and hydrological evaluation of regulation plans, and for climate change studies, levels and flows would likely be computed on a monthly basis using the regulation plan and supply routing model discussed above. With this time step, it is possible to ignore short-term non-regulation effects such as those caused by winds and transients set-up by flow changes.

To examine short-term water level effects, for example, daily or weekly flow changes at Sault Ste. Marie, detailed hydraulic models would be needed to simulate changing water levels and flows of the St. Marys River. 1- and 2-D hydrodynamic models of the St. Marys River exist. There may be sufficient daily and hourly water level and flow data available for recent years to study short-term effects, however additional detailed data may be required to properly calibrate these models. The study team should investigate the availability of these models and data at study inception to determine if they would be feasible tools. Such models would be required to investigate impacts of dredging and other factors in the St. Marys River.

3.4.1 Basis of comparison supply scenario

In order to compare alternative regulation plans, the Study Team needs to develop a basis of comparison (BOC) scenario of levels and flows to compare against. It is recommended that the BOC be developed from Lake Superior through Lake Erie. This BOC would assume Plan 1977-A as the plan of regulation, along with current hydraulics and hydrology, including diversions and channel hydraulics and outlet conditions. This data set should encompass the period from 1900 to the date of study inception and include statistics such as maximum, minimum and average values as well as frequency of occurrence information.

LESSON LEARNED: There is a need to review the water supplies for Lake Erie for the past 30 years, as there appears to be a shift in their magnitude.

3.4.2 Climate change supply scenarios

As noted in Section 3.2, any alternative regulation plans must be able to manage the system in a sustainable manner, not only for the historical range of levels and flows, but also for future levels and flows that might result due to climate change and variability. Using some of the methods noted in Section 3.2, the Study should develop a series of level and flow scenarios to cover the possibilities of potential climate variability and future climate change including use of scenarios such as wet-cold, wet-warm, dry-cold and dry-warm.

3.4.3 Lake Superior Pre-Project Outlet Conditions

To compare water level and flow conditions under regulation to those that would have occurred without regulation, a model using the pre-project or unregulated Lake Superior outlet hydraulic relationship would be applied. This can be done with the CGLRRM. Levels and flows under pre-project conditions are essential, particularly for assessing impacts on resources throughout the basin. The results obtained would also facilitate the consideration of options consistent with systemic regulation, but which would result in mean levels and variability closer to those in the state of nature. This state of nature regime of water levels and flows is also essential for all the resource committees to assess the impacts of a regulation scenario that simulates pre-regulation or pre-project outflow conditions.

The routing of water supplies would assume existing downstream hydraulic outlet conditions in the St. Clair and Detroit River system. If necessary, the routing of supplies could include assumed St. Clair – Detroit River outlet conditions for previous time periods, such as prior to the major dredging projects of the 1930s and 1960s. A fairly comprehensive hydraulic analysis would be needed to accurately determine the stage-fall-outflow relationships for the St. Clair – Detroit River system for different channel regimes. This will likely be carried out as part of the St. Clair River investigations noted in Chapter 2.

This pre-project scenario will be created in an effort to help estimate the impacts of historical human activities on levels and flows within the system. It is intended to show what water levels and flows would have been like without any past regulation. It will be evaluated as another possible plan, along with alternative regulation plans. It will not be used as an additional basis of comparison to evaluate alternative regulation plans. Alternative plans will only be compared to the Basis of Comparison when evaluating new options.

3.4.4 Diversions, Consumptive Uses, Groundwater and Land Use

The impacts on Great Lakes water levels and outflows due to existing major water diversions would be updated using the CGLRRM. The most recent estimate of consumptive uses would be updated if applicable. The impacts on Great Lakes water levels and flows due to current and projected consumptive uses would be determined. A qualitative assessment of the relationship between Great Lakes water levels and groundwater flows would be made. An assessment would also be made of the impacts on Great Lakes water levels and flows due to changes in land use, such as urban development and de-forestation, should historical data be available that are suitable for analytical purposes. Diversions, consumptive uses, groundwater and land use changes, and their subsequent impacts are not regularly monitored or recorded. Therefore reliable data will be difficult to obtain. Sensitivity analysis will be conducted to bound the uncertainties associated with these data and provide a range of what may be occurring and its system-wide impacts.

3.4.5 Alternative Regulation Plans

A range of alternative regulation plans will be developed to address the Directive's purposes of reviewing the operation of the structures controlling the outflows from Lake Superior and the examination of physical processes and possible ongoing changes in the St. Clair River. These will address the issues noted in Section 3.1.2.

This review will also need to address the response of the alternative regulation plans to possible remediation measures that could be proposed for the St. Clair River. This will likely be dealt with by creating new hydraulic relationships for the St. Clair River to simulate remediation over an incremental range of levels and flows.

Levels and flows will be generated using all alternative regulation plans, as well as with the BOC conditions, climate variability/climate change supply scenarios and various remediation options. It is recommended that any alternative plans developed for evaluation and consideration by the Study Board not be given names. Use of some generic identifier, such as a letter or number, may be better so that study members and the public do not seem to prefer certain plans based on conceptual ideas of what a specific name might imply.

Tasks would include the following:

- Assess the impacts on water levels of the St. Marys River due to peaking and ponding operations by hydropower plants at Sault Ste. Marie, develop guidelines governing peaking, taking into consideration the needs and concerns of other resources; work with the Superior Board to coordinate efforts based on what has already been done.
- Investigate all issues related to improvement opportunities for Orders, criteria, operational rules, guidelines and limitations.
- Update historical water supply sequence through the current year.
- Establish pre-project Lake Superior outlet conditions (utilizing the historical supply sequence), and determine resulting water levels and outflows in all lakes and connecting channels, assess water level impacts of existing outflow regulation.
- Qualitatively assess impacts of future basin water needs and land use changes on water levels and flows.
- Investigate relationship between groundwater and levels and flows.
- Incorporate any relevant findings from the St. Clair River investigations.
- Summarize the impacts of man-made changes in the Niagara River (e.g., installation of hydropower works and fills in the river) on Lake Erie water levels.
- Investigate and incorporate technical changes to Plan 1977-A, as listed in Section 3.1.2.
- Generate levels and flows under the base case, using Plan 1977-A.
- Generate levels and flows under pre-project conditions.
- Develop regulation scenarios to address user needs/preferences of water level/flow ranges and frequencies; generate levels and flows for these scenarios.
- Generate water levels and flows for alternative regulation plan(s) under potential climate change/variability scenarios; recommend regulation plan improvements to enhance their robustness in response to climate variability and their ability to cope under changing climatic conditions.

LESSONS LEARNED: Net basin supplies were computed for all the lakes during the Lake Ontario Study and may be useable for the Upper Lakes Study. The 50,000 years of stochastic supplies may be useful too. The climate change study results may still be applicable for the Upper Lakes Study, as well.

The costs for the hydraulics and hydrological evaluation (including climate variability) of the study are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$350K	$650K	$650K	$530K	$200K
or					
Total Cost (Canadian dollars)	$420K	$780K	$780K	$636K	$240K

The total cost for the hydraulic and hydrological evaluation would be about $2,380K (U.S. dollars). This is equivalent to about $2,856K in Canadian dollars.