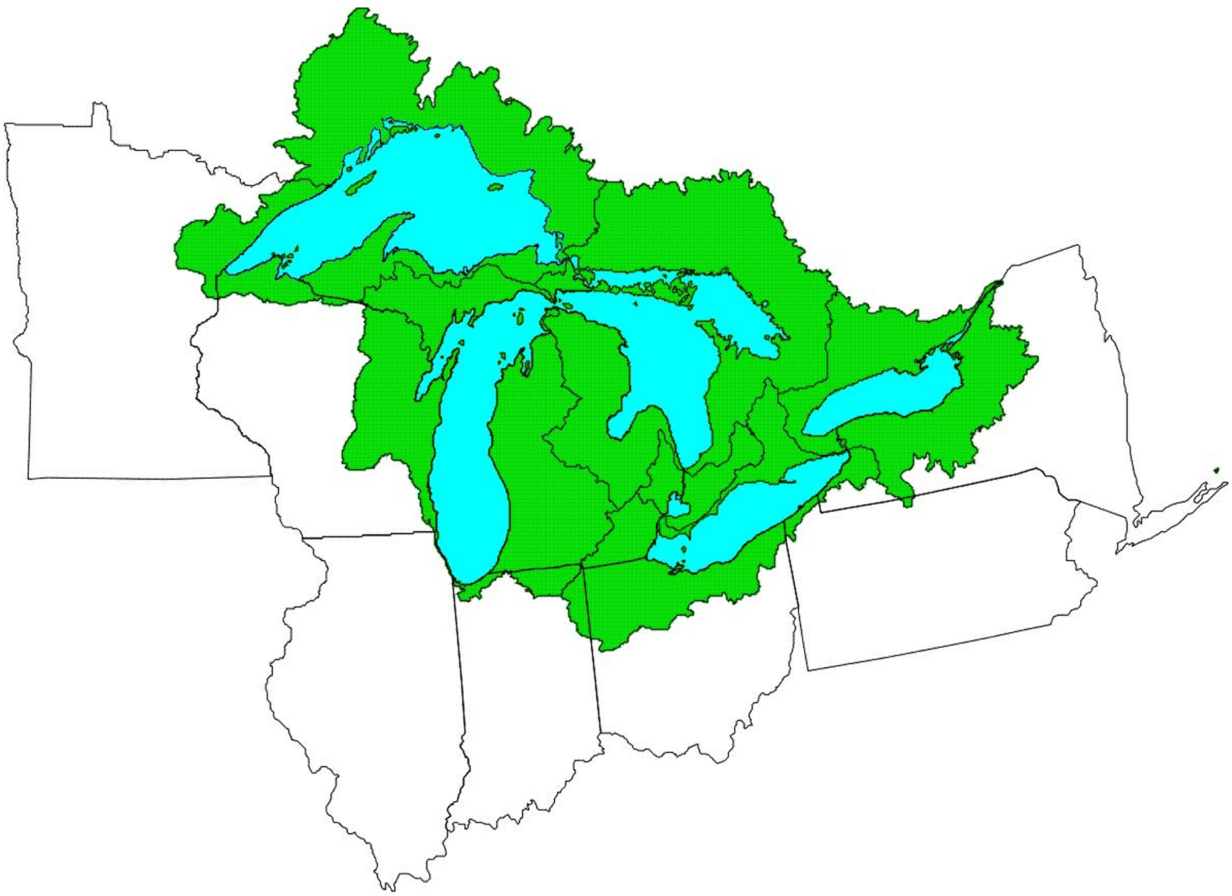
John Glenn Great Lakes Basin Program
Biohydrological Information Base

In response to Public Law 106-53, Water Resources Development Act of 1999,

Main Report



April 2005

US Army Corps
of Engineers®

Executive Summary

Introduction

The Great Lakes, their connecting channels and the St. Lawrence River collectively comprise the world's largest body of fresh surface water. The 6.5 quadrillion gallons contained in the Great Lakes system represent more than 85 percent of the freshwater resources of the North American continent. This system provides the region's eight U.S. states and two Canadian provinces with an abundance of high quality fresh surface water. The Great Lakes – St. Lawrence River system influences and is inseparably linked to the region's environmental health, economic well-being and quality of life. While the water resources of the system seem inexhaustible, the ecosystem is fragile. Even minor physical, chemical or biological changes can have individual and cumulative effects on the conservation, protection and use of the resource.

While the water-rich Great Lakes - St. Lawrence region has historically been immune from serious water shortages and supply problems experienced in other parts of North America, some of its tributary watersheds have come under increasing stress. Demand for water for municipal water supply, agricultural irrigation, manufacturing processes and human consumption have generated concerns about the sustainable use of these resources.

Anthropogenic water management of the Great Lakes system is a complex and vital issue in regard to how it is being managed now and is expected to be managed in the future. Well-orchestrated agreements and policies must be developed and implemented on a basinwide scale to be truly effective. Current water management of the system on the Federal level involves the water diversions of the New York State Barge Canal, the Chicago Ship and Sanitary Canal and the Long Lac-Ogoki (Lake Superior) diversion.

Water quantity is also managed (regulated) via the International Joint Commission (IJC). It's Lakes Superior, Niagara and Ontario Boards of Control (BoC) allow coordination between the U.S. and Canada. The IJC regulates the outflows from Lake Superior (at Sault Ste. Marie) and Lake Ontario (mainly through the Moses-Saunders Powerhouses), which influences the water levels of Lakes Superior and Ontario. U.S. Federal agencies, such as the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) have missions and lead roles in various water resource issue areas. State agencies within the Great Lakes basin, such as the Departments of Natural Resources, have water management authority over their inland lakes, wetlands and impoundments.

The USACE provides the U.S. member to the IJC Boards. An additional assigned mission is to monitor and forecast Great Lakes water levels and flows. Observed and forecasted data is coordinated with Canadian counterparts before dissemination and acts as input information for regulating outflows through the control structures on Lakes Superior and Ontario. Great Lakes water supply data is paramount to making sound water management decisions in this regard. Data to support this decision-making process is collected from various U.S. and Canadian agencies; the reliability and usability of these data needs to be very good to support decisions of such regional impact.

Many other influences man exerts on Great Lakes water levels and flows are not regulated, measured, reported or even known. Consumptive uses (any amount of water taken and not returned to the system) may be a minor subtraction in relation to the relative volume of the Great Lakes, however, over time, could add up to a significant volume of water removed from the system. Consumptive uses involve agricultural (irrigation) use, public water supply (drinking,) irrigation, industry and power production.

Various large-scale proposals to remove water from the Great Lakes - St. Lawrence River system (or bring water into the system) have been proposed over the last century. Many of the early proposals did not generate significant attention because they were considered economically and/or environmentally unviable. Since the late 1970s, due to concerns about interest from regions outside the basin to divert and use Great Lakes water, the Great Lakes governors and premiers began to consider the importance of a regional approach to managing the system's water resources. Since that time, numerous regional initiatives, studies and agreements have demonstrated this heightened awareness and increased interest in developing ~~the~~ water resources data, information and tools necessary to support sound water resources decisionmaking.

Such decisions involve permitting groundwater and surface water withdrawal requests, diversion or relocation of water, adding water to the system, discharges of non-consumptive use water back to the system and filling or encroachment of a wetland or water body. To make proper regulatory decisions, reliable data is needed about historic and current water quantities, river and connecting channel flows and stages, existing water table elevations and groundwater flows, climate and meteorological data, and other water resource data pertinent to the request. Information specific to the immediate locale of the request and the expected area of impact from the applicant's action should be the responsibility of the applicant; data specific to the region of the request should be supported by the decisionmakers.

All information has inherent uncertainties, however. Failure to deal with these uncertainties can materially detract from wise decisionmaking and sustainable water resource management. Uniform and consistent data and information are fundamental to the decision support systems needed for water resources science, planning and management. A decision support system is a broad concept that typically involves both descriptive information and standard, prescriptive management approaches. The value of information to support and enhance water resources decisionmaking has been understood in the Great Lakes - St. Lawrence River basin since the mid-1800s when programs were established to monitor and measure lake levels, precipitation and stream flow. A substantial amount of the hydrologic, hydraulic and meteorologic monitoring over the system has been historically operated and maintained by the U.S. federal government.

This information, however, generally exist to support each specific agency, with varying degrees of ability to collect the needed information, with little design towards integrating information and data in a master database under one approved format. *Since the federal government already has national monitoring authority and responsibility over the inland waters of the U.S., these information systems should be maintained and expanded by the federal government for use by local and state decisionmakers.*

However, it should also be noted that different agencies have varying amounts of quality control and ability to verify the accuracy of these data. As resources for such quality control decline, datasets will become more suspect. Inconsistencies in datasets, difficulty in locating needed information due to the lack of a centralized database and non-existent data for portions of the basin all lend to water resource decisions being made with various degrees of uncertainty. The purpose of this report is to outline the existing water management data information that is available, collecting and improving upon the quality and quantity of these data, streamlining its storage, and improving the accessibility of this information to the various agencies for a multitude of uses.

In 2001, the eight governors of the U.S. states and the two premiers of the Canadian provinces that lie within the Great Lakes – St. Lawrence River system signed an Annex ("Annex 2001") to the Great Lakes Charter of 1985. The Great Lakes Charter is a non-binding agreement between the governors/premiers to manage the water quantity of the system, with particular focus on water withdrawals, diversions and consumptive uses.

Under the key "Directives" of the Annex 2001 is Directive 5 – Develop a decision support system that ensures the best available information. "This design will include the assessment of available information and existing systems, a complete update of data on existing water uses, an identification of needs, provisions for a better understanding of the role of groundwater, and a plan to implement the ongoing support system".

This Directive ties in under Principal V of the original Great Lakes Charter, which states "…commit to pursue the development and maintenance of a common base of data and information regarding the use and management of the Basin water resources."

In anticipation of the results of the Great Lakes Charter Annex process, the Congress of the U.S. directed the U.S. Army Corps of Engineers (USACE) in 1999 to inventory available information on the hydrology, hydraulics, meteorology and biology of the system and assess the adequacy of this information for water resource management within the region. This report addresses this directive.

Study Authority and Approach

The authority for this study is provided in Section 455 (b) of the John Glenn Great Lakes Basin Program of WRDA 1999, which instructs the USACE to request, from each relevant federal agency, data and information relevant to the Great Lakes biohydrological system and to provide an inventory of such information in the possession of each agency. Information to be collected includes:

- groundwater and surface water hydrology;
- natural and altered tributary dynamics;
- biological aspects of the Great Lakes system influenced by and influencing water quantity and water movement;
- meteorological projections and the impacts of weather conditions on Great Lakes water levels; and
- other Great Lakes biohydrological system data relevant to sustainable water use and management.

The USACE is instructed to consult with the Great Lakes states and provinces, Indian tribes and U.S. and Canadian federal agencies in the conduct of this study. Following consultation, the USACE is to submit a report to the Congress, the International Joint Commission (IJC) and the Great Lakes states, outlining ways for improving biohydrological information to support environmentally sound decisions regarding water management of the system.

In 2001, the USACE prepared a reconnaissance report to determine the federal interest in the biohydrological information area and developed an approach for conducting the inventory, evaluating federal interest and preparing this feasibility report. A process was developed to accommodate ~~for~~ stakeholder input to ensure that the biohydrological data inventories contained in the report appendices were comprehensive, that unmet information/modeling needs were identified, and that appropriate solutions were defined.

Discrete tasks to develop an integrated information system for water resource management of the Great Lakes – St. Lawrence River system are identified in the report's appendices and summarized in the main report. Each task is defined within the context of five implementation scenarios using the USACE's plan formulation approach. This approach provides a systematic evaluation of the essential components of a comprehensive decision support system. Expected benefits that would be derived from implementation of the component tasks, at differing funding levels are provided. This evaluation should be the basis for consideration of the federal role in supporting the states' Great Lakes Charter Annex decisionmaking process.

Information Inventories and Appendices

Appendix A provides an overview of the physical system of the Great Lakes – St. Lawrence River system and hydrologic factors affecting water supply and water use across the basin.

Appendix B explains the nature and significance of the region's groundwater system and the knowledge base that currently exists on geology, soil characteristics and aquifer characterization.

Appendix C explains the importance of streamflow data for watershed modeling, including an assessment of the adequacy of the current U.S. stream gauging program.

Appendix D evaluates the adequacy of information used to calculate the basin's water balance, including methods for estimating inflows and outflows through the interconnecting waterways, diversion canals and St. Lawrence River and overlake hydrologic processes.

Appendix E describes the importance of meteorological observations over the land masses of the Great Lakes – St. Lawrence River basin. Overland meteorological observations provide information crucial for input to hydrologic watershed response models.

Appendix F describes the important role of water use data in the decision support system and the need for an enlarged federal role in water use data reporting for the region.

Appendix G summarizes the role that a sustainable water supply plays in the health and diversity of the ecosystems throughout the Great Lakes – St. Lawrence River system. This appendix describes the various habitat types found in the basin, describes the data and information currently available for monitoring habitats, and identifies data and information gaps.

Appendix H describes the various classes of organisms found in Great Lakes – St. Lawrence River basin habitats. This appendix assesses the current state of data and information for each particular group of organisms. Data and information related to organisms is inventoried and presented in the last section. Additionally, gaps in data and information for each organism group are assessed.

Appendix I provides a summary of current land cover and land use information covering the region and the role of this information in determining anthropogenic impacts on streamflow characteristics and forecasting future water demands.

Appendix J provides an assessment of current information system resources available across the basin, including listing of binational programs, U.S. federal and state agency clearinghouses and Canadian federal and provincial collaborators.

Appendix K outlines the procedures employed to determine the range of prospective costs for implementing the various solutions provided throughout the report. It also includes the results of the risk assessment analysis conducted under the project.

Appendix L provides all background materials to support the overall report, including listings of project participants, summaries of related initiatives and acknowledgements.

Tasks Involved in Improving the Biohydrological Information Base

A total of 59 tasks have been identified in the development of an integrated biohydrological information system for the U.S. portion of the Great Lakes – St. Lawrence River system. These tasks are a logical subdivision of information collection, analyses, physical and ecological process modeling, information integration and decision support requirements. These tasks can be improved individually with substantial benefits gained, but comprehensive implementation would provide more aggregate benefits than "the sum of the parts." Implementation of each of these 59 tasks, at the higher investment levels, would reduce uncertainties associated with decisionmaking about permitting water withdrawals.

Strategies Considered

- *Future Conditions without Additional Investment (Without Project Strategy)* - Without additional investment, current funding is expected to either remain the same or diminish. Groundwater monitoring and modeling will be insufficient to meet anticipated decisionmaking needs. Existing uncertainties involving Great Lakes water supplies and flows in the interconnecting waterways, St. Lawrence River, and diversions will continue to impede evaluations of cumulative withdrawal impacts on the system at large. Inconsistent information on water withdrawals and uses from groundwater, in-stream and from the open lake will continue to exist. Without additional funding, periodic updates of regional water use database will not occur. Biohydrological data will remain fragmented across federal agencies compromising science-based water resources management decisions across the basin. Inconsistent, incomplete, non-uniform and unreliable information will continue to be the norm. Limited model integration will proceed out of necessity, but not in a systemic approach. Holistic analysis will continue to be too generalized and not cost effective.

- *Biohydrological Information System – Minimum Investment Strategy* – This strategy is the least costly collection of measures to address the most essential questions about water withdrawals. Not all system components of an integrated information system are included in this option. It simply addresses the most critical information shortcomings at the least cost. Modest improvements would be made to maintain the existing groundwater observation network over the basin. Additional funding would be made available to maintain the integrity of the U.S. stream gauging network on an increased federal cost-sharing basis. New efforts would be made to produce operation streamflow forecast models for a few high priority tributary watersheds. Water use inventories would be updated albeit with inconsistent estimates over the region. Pilot studies would be conducted to develop habitat assessment tools for key tributary watersheds to anticipate impacts of potential water withdrawal proposals, individually and cumulatively. Funds would be used to implement regional data exchange agreements. The total cost for the "Minimum Investment" strategy is approximately $36 million, with the majority of work conducted over five years.

- *Biohydrological Information System – Selective Implementation Strategy* – This strategy is the least costly option for an integrated information system that includes all major hydrologic, hydraulic, geological, ecological, and social data components. It is comprised of prioritized investments, which focuses on increased scientific rigor and defensibility in support of water resources decisionmaking. Few components are fully funded, but no essential components are excluded. This strategy represents a substantial monetary commitment to collect basic data, conduct detailed research and integrate information systems. The expected cost for the Selective Implementation strategy is approximately $370 million over a 10-year project plan. A comprehensive summary of this plan is included in the Main Report with more detailed descriptions of plan components in each report appendix.

- *Biohydrological Information System – Enhanced Implementation Strategy-* This strategy is the medium-cost~~ly~~ option for an integrated information system that includes all essential hydrologic, hydraulic, geological, ecological, and social data components. It is comprised of extensive data collection, analyses and modeling, with significantly improved information accuracies and decision support functionalities. This integrated information system option comes at a substantial capital cost. The expected cost for the Enhanced Implementation strategy is approximately $800 million over a 10-year project plan, which may be unattainable. A comprehensive summary of this plan is included in the Main Report with more detailed descriptions of plan components in each report appendix.

- *Biohydrological Information System – Full Implementation Strategy* – This strategy is the most costly option for an integrated information system that includes all hydrologic, hydraulic, geological, ecological, and social data components, fully funded. This option includes comprehensive and detailed data collection and analyses, state-of-the-science modeling and fully operational and integrated information systems at all levels of government involved in Great Lakes – St. Lawrence River water resources decisionmaking. It provides for the highest level of information integration attainable and highest level of predictive modeling capability. The expected cost of the Full Implementation strategy is approximately $1.640 billion over a 10-year project period.

Risk Assessments and Cost Evaluations

In accordance with established USACE planning guidance, the Biohydrological Information System report includes a Risk Assessment and Cost Evaluation to analyze the various investments versus the return on each investment. The report also includes a comparison of the benefits/disbenefits of each strategy and a qualitative risk assessment. Quantitative risk analyses is frequently not possible in this project since no real property or human losses can be identified in the past or expected in the future as a consequence of information collection, analyses and integration. Risk is considered in terms of accepted environmental and natural resources economic practices, however.

The costs for each task for the four strategies that require an additional investment are estimated within the report and appendices. The "Minimum Investment Strategy" does not reflect a comprehensive solution since it only includes selected tasks. The "Minimum Investment Strategy" also differs from the three comprehensive strategies (Selective, Enhanced and Full) in that implementation is projected over a 5-year project horizon while the three comprehensive strategies will require at least 10-years to fully implement.

The cost for implementation is based on the best available information through research and review by project collaborators. Implementation costs are not duplicated under other tasks, but some economies of scale would be realized as higher investment is made due to program synergies.

Cost uncertainties are provided for each strategy as a likely range of costs. These uncertainties are evaluated via standard risk assessment procedures involving statistical distributions and Monte Carlo simulations to derive expected costs for all tasks that are summed by strategy and reported herein. This assessment includes a subjective assessment of the value (or relative merit) of each task in the overall integrated solution for each strategy.

The three comprehensive implementation strategies (Selective, Enhanced and Full) are designed as integrated solutions. They should not be interpreted as being "all or nothing" approaches, however. Individual elements from one particular strategy could be funded separately at a differing level, which would provide an important contribution to the Great Lakes - St. Lawrence River basin information base. Even modest increases in funding over the "Without Plan Strategy" can enhance decisionmaking. Water resource managers should examine both the full complement of task elements as well as individual tasks to discern where progress can be made if new allocations are limited.

Table of Contents

APPENDICES

Main Report

Improvements to the Great Lakes – St. Lawrence River Biohydrological Information Base

1. Study Authority

a. The authority to conduct this study is included in Public Law 106-53, Water Resources Development Act of 1999 (WRDA, 1999), Section 455(b), John Glenn Great Lakes Basin Program, entitled Great Lakes Biohydrological Information. The text of the authorization language is included here.

WRDA 1999 SEC. 455 JOHN GLENN GREAT LAKES BASIN PROGRAM

(b) GREAT LAKES BIOHYDROLOGICAL INFORMATION
(1)INVENTORY –
(A) IN GENERAL – Not later than 90 days after the date of enactment of this Act, the Secretary shall request each Federal agency that may possess information relevant to the Great Lakes Biohydrological system to provide an inventory of all such information in the possession of the agency.
(B) RELEVANT INFORMATION – For the purpose of subparagraph (A), relevant information includes information on –
(i) ground and surface water hydrology;
(ii) natural and altered tributary dynamics;
(iii) biological aspects of the system influenced by and influencing water quantity and water movement;
(iv) meteorological projections and the impacts of weather conditions on Great Lakes water levels; and
(v) other Great Lakes Biohydrological system data relevant to sustainable water use management.
(2) REPORT
(A) IN GENERAL – Not later than 18 months after the date of enactment of this Act, the Secretary, in consultation with the States, Indian tribes, and Federal Agencies, and after requesting information from the provinces and the federal government of Canada, shall –
(i) compile the inventories of information;
(ii) analyze the information for consistency and gaps; and
(iii) submit to Congress, the International Joint Commission, and the Great Lakes States a report that includes recommendations on ways to improve the information base on the biohydrological dynamics of the Great Lakes ecosystem as a whole, so as to support environmentally sound decisions regarding diversions and consumptive uses of Great Lakes water.
(B) RECOMMENDATIONS – The recommendations in the report under subparagraph (A) shall include recommendations relating to the resources and funds necessary for implementing improvements of the information base.
(C) CONSIDERATIONS – In developing the report under subparagraph (A), the Secretary, in cooperation with the Secretary of State, the Secretary of Transportation, and the heads of other agencies as appropriate, shall consider and report on the status of the issues described and recommendations made in –

(i) the Report of the International Joint Commission to the Governments of the United States and Canada under the 1977 reference issued in 1985; and

(ii) the 1993 Report of the International Joint Commission to the Governments of Canada and the United States on Methods of Alleviating Adverse Consequence of Fluctuating Water Levels in the Great Lakes St. Lawrence Basin.

b. Funds in the amount of $136,000 were appropriated in FY 2002 and $30,000 in FY 2004 to conduct the study.

2. Purpose and Scope

This is a report of the U.S. Army Corps of Engineers (USACE) to Congress, the International Joint Commission (IJC), and the Great Lakes States concerning an inventory of available information on the Great Lakes biohydrological system, the adequacy of this information for decisionmaking and strategies to reduce data gaps. It is submitted in response to Section 455(b) of WRDA (1999) – the John Glenn Great Lakes Basin Program. This authority was established in anticipation of implementation of Annex 2001 to the Great Lakes Charter of 1985. The Great Lakes Charter is an agreement between the Governors of the Great Lakes states, including Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York and the Premiers of Ontario and Quebec to develop a decisionmaking process for managing water resources for the region.

The purpose of the Great Lakes Biohydrological Information Study is to assess the adequacy of federal information resources to support federal, state, provincial agencies when decisions are made on proposed water withdrawals from the system. The study entails a systematic assessment of the federal role in information collection, analysis, and distribution across the Great Lakes – St. Lawrence River basin.

The IJC, Federal (U.S. and Canadian), Provincial and State governments all play various roles and have differing responsibilities regarding the management of water resources within the Great Lakes basin. The binational IJC and its Boards of Control have outflow and water level regulatory authority over Lakes Superior and Ontario and is responsible to meet the terms set forth in the 1909 Boundary Waters Treaty and the Niagara Treaty of 1950, between the U.S. and Canada.

State and local governments in the eight Great Lakes basin states and the Provinces and local governments of Ontario and Quebec have varying laws and regulations governing the impoundments, water levels and outflows of certain inland lakes whose watersheds drain to the Great Lakes. Also, with the recent attention that has been given to large-scale commercial groundwater and stream withdrawals, and the recognition of the impact this has on the total water supply to the Great Lakes, regulation of such activities is a major issue.

All Great Lakes states have state and/or local regulatory limits as to the amount of water that may be withdrawn from the ground or rivers and streams for daily commercial consumptive uses. However, there is no basin-wide blanket regulation that contains mutually agreed daily withdrawal limits for commercial use and the region does not have a sufficient conservation plan and regulatory structure to protect Great Lakes surface freshwater and groundwater. There is also no current mechanism in place for states to regulate new diversions (other by consensus or litigation) and there is no mechanism in place for state, provincial or tribal governments to regulate consumptive uses.

Furthermore, groundwater demand for municipal and agricultural consumption continues to rise, and, with the regional droughts that occurred across much of the Great Lakes basin in the late 1990's and early 2000's, groundwater supplies fell short of demand. The drawdown is becoming so severe in parts of the basin that water withdrawals have to be staggered from peak use times to avoid interruptions.

Present groundwater and surface water databases are maintained by federal government agencies such as the USACE, the U.S. Geologic Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA). The problem with these databases is that they were designed, created and implemented to serve the individual needs of that agency or a targeted stakeholder group, without consideration toward integration or accessibility by external users.

Government decisionmakers continue to rely on incomplete, inaccurate and/or outdated hydrologic data to base permit and withdrawal capability decisions on. If capability is overestimated, negative impacts will continue to be exacerbated throughout the basin.

The adoption of the Great Lakes Charter and the supplemental Annex 2001 would address the development of a common, resource-based conservation standard to address any new or increased diversion or consumptive use of the water resources of the Great Lakes basin. The Council of Great Lakes Governors (which includes the Premiers of Ontario and Quebec) have made some progress on a management plan, but the existing " charter" on water withdrawal, signed in 1985, is non-binding. Conversely, Directive 1 of Annex 2001 calls for the development of a new set of binding agreements that would strengthen the initiative to create collective, basin-wide management standards.

The ongoing Lake Ontario Reference Study outlines a decision support process that helps guide those making water management decisions. On December 12, 2000, the IJC created the International Lake Ontario-St. Lawrence River Study Board to evaluate the procedures and criteria used to regulate the outflows of Lake Ontario and the management of the levels of the Lake and St. Lawrence River. Prior to the Board's establishment, an international team developed a report entitled "Plan of Study for Criteria Review" in September 1999. The report identified interests that should be considered including wetland/environment, recreational boating, coastal zone (including riparian/shore property erosion and flooding), commercial navigation, hydroelectric and domestic, industrial and municipal water uses. A common data needs group was suggested that would collect information that could be used by several interests.

Various large-scale proposals to remove water from the Great Lakes - St. Lawrence River system (or bring water into the system) have been proposed for nearly a century. Many of the early proposals did not generate significant attention because they were considered economically and/or environmentally unviable. Since the late 1970s, due to concerns about interest from regions outside the basin to divert and use Great Lakes water, the Great Lakes governors and premiers began to consider the importance of a regional approach to managing the system's water resources. Since that time, numerous regional initiatives, studies and agreements have demonstrated this heightened awareness and increased interest in developing the data, information and tools necessary to support sound water resources decisionmaking.

In August 2000, a study was initiated to assess data and information availability and requirements to assist water resources decisionmaking across the region. A report entitled *Toward a Water Resources Management Decision Support System,* over forty recommendations were presented that address needs to improve understanding of the basin's physical and biological components; improve understanding of current resource uses; adapt monitoring and modeling to the needs of the Great Lakes Charter Annex; use modeling and data collection to improve understanding of ecosystem responses to water withdrawals; and conduct research on water conservation and resource improvement standards. The report acts as a model and provides a basic structure for this Biohydrological Information Database work.

3. Location of Study, Congressional Districts

a. The study area is located within the Great Lakes – St. Lawrence River basin, including the watersheds of lakes Superior, Michigan, Huron, St. Clair, Erie and Ontario and the interconnecting waterways between them (St. Marys, St. Clair, Detroit and Niagara rivers) and the watershed of the St. Lawrence River downstream to the international border at Massena, New York / Cornwall, Ontario. The Great Lakes - St Lawrence River basin includes territories in the U.S. states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin and the Canadian provinces of Ontario and Quebec. Groundwater resources can extend well outside the mapped surface divide; hence, the study area includes a 100-mile buffer outside of the surface water boundary. It is difficult to discern exactly where groundwater basins begin and end, or which basin a particular groundwater flow feeds. The referenced geographical extent of the study area (both do not necessarily reflect the legal or regulatory boundaries of the basin) is delineated by the recognized surface watershed of the Great Lakes basin, as defined by the USGS.

b. The study area lies within the jurisdiction of the following Congressional Districts:

Illinois Congressional Districts:
Senator Richard J. Durbin (D)
Senator Barack Obama (D)
1st Bobby L. Rush (D)
2nd Jesse Jackson, Jr. (D)
3rd William O. Lipinski (D)
4th Luis Gutierrez (D)
5th Rahm Emanuel (D)
6th Henry J. Hyde (R)
7th Danny K. Davis (D)
8th Philip M. Crane (R)
9th Janice D. Schakowsky (D)
10th Mark Steven Kirk (R)
11th Jerry Weller (R)
13th Judy Biggert (R)
14th J. Dennis Hastert (R)
16th Donald Manzullo (R)

Indiana Congressional Districts:
Senator Paul Evan Bayh (D)
Senator Richard G. Lugar (R)
1st Peter J. Visclosky (D)
2nd Chris Chocola (R)
3rd Mark E. Souder (R)
6th Mike Pence (R)

Michigan Congressional Districts:
Senator Carl Levin (D)
Senator Debbie Stabenow (D)
1st Bart Stupak (D)
9th Joe Knollenberg (R)

2nd Peter Hoekstra (R)
3rd Vernon J. Ehlers (R)
4th Dave Camp (R)
5th Dale Kildee (D)
6th Fred S. Upton (R)
7th Joe Schwarz (R)
8th Mike Rogers (R)
10th Candice S. Miller (R)
11th Thaddeus McCotter (R)
12th Sander M. Levin (D)
13th Carolyn Cheeks-Kilpatrick (D)
14th John Conyers, Jr. (D)
15th John D. Dingell (D)

Minnesota Congressional Districts:
Senator Norm Coleman (R)
Senator Mark Dayton (D)
8th James L. Oberstar (D)

New York Congressional Districts:
Senator Charles E. Schumer (D)
Senator Hillary Rodham Clinton (D)
20th John E. Sweeney (R)
22nd Maurice Hinchey (D)
23rd John M. McHugh (R)
24th Sherwood L. Boehlert (R)
25th James T. Walsh (R)
26th Thomas M. Reynolds (R)
27th Jack Quinn (R)
28th Louise M. Slaughter (D)
29th Armory (Amo) Houghton, Jr. (R)

Ohio Congressional Districts:
Senator Mike Dewine (R)
Senator George V. Voinovich (R)
5th Paul E. Gillmor (R)
9th Marcy Kaptur (D)
10th Dennis J. Kucinich (D)
11th Stephanie Tubbs Jones (D)
13th Sherrod Brown (D)
14th Steven C. LaTourette (R)

Pennsylvania Congressional Districts:
Senator Arlen Specter (R)
Senator Rick Santorum (R)
3rd Phil R. English (R)
5th John E. Peterson (R)

Wisconsin Congressional Districts:
Senator Russel Feingold (D)
Senator Herbert Kohl (D)
1st Paul Ryan (R)
2nd Tammy Baldwin (R)
4th Gwen Moore (D)
5th F. James Sensenbrenner, Jr. (R)
6th Thomas E. Petri (R)
7th David R. Obey (D)
8th Mark Green (R)

4. Prior Studies, Reports and Existing Water Projects

a. 1985 IJC Diversions and Consumptive Uses Study

The *Report of the International Joint Commission to the Governments of the United States and Canada under the 1977 reference issued in 1985* established the International Great Lakes Diversions and Consumptive Use Study Board to conduct the required technical investigations.

Part One of the report examines the effects of existing diversions, the potential to improve extremes in Great Lakes levels by changing existing diversion flow rates, and existing and projected consumptive uses in the Great Lakes basin. Part Two provides a broader context within which to address the longer-term prospects for the use of Great Lakes waters.

The IJC report presented several recommendations to assess Governments in effectively addressing future considerations regarding the use of Great Lakes water. It recommended:

(1). Establish a bilateral data committee to monitor all existing diversions and consumptive use in the Great Lakes basin and publish data as appropriate, no less frequently than biennially.

(2). Establish a bilateral task force on diversions and consumptive uses to update previous consumptive use projections, review potential new or changed diversions and make recommendations.

(3). Institute a co-operative review of current public policies at the federal and state/provincial levels to examine consumptive uses.

(4). Identify and quantify existing and proposed small diversions and establish a mechanism.

(5). Develop an engagement process for Governments of nice and consultation before additional new and changed diversions are approved.

b. 1993 IJC Levels Reference Study Report

In response to public concern in 1985-1986, the governments of Canada and the United States provided a reference to the IJC to develop a comprehensive study which led to the 1993 Report *of the International Joint Commission to the Governments of Canada and the United States on Methods of Alleviating Adverse Consequences of Fluctuating Water Levels in the Great Lakes Basin*. The IJC final report responded to issues raised in the Reference from governments and the subsequent Directive from the IJC. The report recommended 42 acts that governments can take in six key areas:

(1). Guiding principles for future management of water levels issues;

(2). Measures to alleviate the adverse consequences of fluctuating Great Lakes - St. Lawrence River water levels;

(3). Emergency preparedness planning for high or low water level crises;

(4). Institutional arrangements to assist in implementing changes;

(5). Improvements in communications with the general public on water level issues; and

(6). Management and operational improvement to facilitate future Great Lakes - St. Lawrence River water level management.

Through this report, the IJC Study Board recommended that comprehensive emergency preparedness planning by all levels of government begin immediately. The Board recommended comprehensive and coordinated land use and shoreline management measures, as well as improvements to operational capabilities that should be undertaken over the long-term. Further recommendations for changes to institutional structures and public communications practices are presented as means to achieve long-term improvements in the way governments, together with citizens and interest groups, address water level issues in the Great Lakes – St. Lawrence basin.

c. 1999 Statement of the Council of Great Lakes Governors

The Council of Great Lakes Governors issued a statement in 1999 outlining a set of principles to guide the development and maintenance of a strengthened water resources management framework for the Great Lakes - St. Lawrence River system. This statement refocused regional discussion on these issues and led to the development of the Great Lakes Charter Annex, signed by the governors and premiers on June 18, 2001. The statement reaffirmed the governors' and premiers' commitment to the 1985 Charter, and outlined the following set of principles for a water management regime:

- It must protect the resource. Resource protection, restoration and conservation must be the foundation for the legal standard upon which decisions concerning water withdrawals are based.

- It must be durable. The framework for decisions must be able to endure legal challenges based upon, but not limited to, interstate commerce and international trade. It must be constitutionally sound on a bi-national basis, and the citizens of the basin must support this framework.

- It must be simple. The process for making decisions and resolving disputes should be straightforward, transparent and based on common sense.

- It must be efficient. Implementation of the decisionmaking process should engage existing authorities and institutions without necessitating the establishment of new and large bureaucracies. The decisionmaking process should be flexible and responsive to the demands it will confront.

- It must retain authority in the basin. Decisionmaking must remain vested in those authorities, the Great Lakes governors and premiers, who manage the resource on a day-to-day basis.

In signing the Great Lakes Charter Annex, the governors and premiers reaffirmed their commitment to the broad principles set forth in the Great Lakes Charter, but also acknowledged the need to re-examine the strength and adequacy of Charter provisions, particularly regarding the legal foundations upon which current regional water management authorities rest.

The Great Lakes Charter Annex is a non-binding agreement that serves as a blueprint for water management programs to be developed over a period of several years. The Annex objectives were developed on the basis of state and provincial experience with water management, and were influenced by the Great Lakes Charter and by WRDA 1986.

The Annex also reflects the governors' 1999 statement on water management, findings from the February 2000 IJC reference study report on water export, and a study commissioned by the governors on Great Lakes and international water law. That study was supported by the Great Lakes Protection Fund and completed in May 1999.

d. 2000 IJC Protection of the Waters Report

In the light of recent proposals to export water from the Great Lakes and other areas of the United States and Canada, the governments decided to refer the issue of water use along the border to the IJC. In a letter in 1999, the governments noted that the number of proposals to use, divert, and remove greater amounts of water that flow along or across the boundary is increasing. They further stated their concern that current management principles and conservation measures may be inadequate to ensure the future sustainable use of shared waters. Within this context, the governments requested the IJC to examine, report upon, and provide recommendations on the following maters that may affect the levels and flows of water within the boundary or transboundary basins and shared aquifers:

- existing and potential consumptive uses of water,
- existing and potential diversions of water in and out of the transboundary basins, including withdrawals of water for export,
- the cumulative effects of existing and potential diversions and removals of water, including removals in bulk for export, and
- the current laws and policies as may affect the sustainability of the water resources in boundary and transboundary basins.

The Reference instructed the IJC, in preparing its recommendations, to consider in general terms potential effects on the environment and other interests of diversions and consumptive uses and, where appropriate, the implications of climatological trends and conditions. The IJC's final report was entitled *Protection of the Waters of the Great Lakes Final Report to the Governments of Canada and the United States*.

e. 2003 Report on Water Resources Management Decision Support Systems

In August 2000, the Great Lakes Commission (GLC) initiated a study to assess data and information availability and requirements to assist water resources decisionmaking across the region. This work was funded by the Great Lakes Protection Fund and it included substantive participation of the Great Lakes – St. Lawrence River stakeholder community. The report of this study entitled *Toward a Water Resources Management Decision Support System* presented findings and over forty recommendations that call for an improved understanding of the basin's physical and biological components; better awareness of current resource uses; adapting current monitoring and modeling to the needs of the Great Lakes Charter Annex; using modeling and data collection to gain a better understanding of ecosystem responses to water withdrawals; and conducting research on water conservation and resource improvement standards. The water Management Decision Support Study is viewed as public domain and is still in the review process.

One major facet of this project was the identification of "essential questions" that would need to be answered through an interjurisdictional decision process, which would fundamentally rely on an integrated information system, which is addressed within this report. These fundamental questions are repeated hereafter, since they are of significant relevance to the Biohydrological Information Study design, and task determinations.

Essential Questions

From: *Toward a Water Resources Management Decision Support System for the Great Lakes-St. Lawrence River Basin*

Category 1: Basic Information on Water Withdrawal

The first category of questions covers basic information on the proposed water withdrawal, the proposed use of the water, and information related to the structure and operation. These questions also address to the proposed withdrawal, and the associated impacts.

1. *Where is the proposed water withdrawal?*
   - If water withdrawal is from a Great Lake, St. Lawrence River, or Connecting Channel:
     - What is the specific location and depth of withdrawal?
     - What are the relevant hydrology, geometry, hydrodynamics, and water quality in the vicinity of the withdrawal?
   - If water withdrawal is from a river:
     - Where is it located on the river?
     - What are the statistics on flow regime (average flow, 7Q10, 100 year flow)?
     - What are the key characteristics of the river and watershed?
     - Characterize subwatersheds by land use types.
   - If water withdrawal is from an inland lake:
     - What are the inflows and outflows?
     - What is the lake geometry?
     - What is the range of water levels?
     - What is hydraulic retention time?
   - If water withdrawal is from a groundwater source:
     - What is the elevation of the water table?
     - What is the size of the aquifer?
     - What is the general characterization of the aquifer?
     - What is the estimated sustained yield of the aquifer?
     - How does this aquifer relate to the surface waters of the Great Lakes basin?

2. *What is the existing quality of the source water and sediments?*
   - Temperature
   - Nitrates
   - Dissolved oxygen
   - Buffering capacity
   - BOD
   - Salinity

- Total dissolved solids
- Sulfur
- Pathogens
- Water conductivity
- Dissolved organic carbon
- Persistent toxic substances

3. Describe the current assimilative capacity of the source and return water.

4. Describe the key habitat characteristics for habitats associated with the source or receiving water (i.e., quality, access, resilience)

• Are there endangered or threatened species or fragile habitats associated with the source water? If so, list and describe.

• Does the area of influence contain a significant amount of seasonal/semipermanent wetlands, bogs or fens that are directly linked to the water table? If so, describe.

5. What components of the system are most sensitive to withdrawals? Which of these will most likely improve?

6. What are the existing uses (e.g., drinking water) of the source water body?

7. Is there a watershed management plan or objective for the area where the withdrawal is proposed to be made? For the source water? If so, is the proposal consistent with the plan?

• What are the existing water quality standards for the source water? For the return water?

8. What is the proposed use of the withdrawn water?

• Will its water quality be altered by this use? What are the water use processes? If so, explain.

• Will the use be consumptive? If yes, what fraction of withdrawn water is consumed?

• What is the potential for future changes in the proposed use?

9. What is the proposed rate of withdrawal?

• Will there be seasonal or diurnal variations in withdrawal rate? If so, describe.

• What is the anticipated duration of this withdrawal?
Will the diversion be essentially irreversible?

• Is an increase in water withdrawal anticipated in the future?

10. Where is the unconsumed water proposed to be returned?

• Will the water be impounded before being returned? If so, describe.

• Will it be treated before it is returned? If so, describe treatment.

• If in same water body, where is return located with respect to withdrawal?

• If different water body, what is the location of the water return?

• What is the quality of the receiving water for the return?

- Are there endangered or threatened species or fragile habitats associated with the receiving water? If so, describe.
- What are the existing uses of the receiving water for the return?

11. What will be the physical structure and operation of the proposed water withdrawal and return? Describe the intake structure and operational plan in detail. Will there be any physical, chemical, or biological impacts due to the withdrawal operation? Describe in detail and include entrainment or impingement effects.

12. Are other options to this proposed withdrawal available? Can the location of the proposed withdrawal be changed to minimize the impact? If so, describe the impacts that are associated with these .

Category 2: Water Quantity

Questions in this category relate to flows, water levels, groundwater yields, and other information about water quantity in the source and the receiving water.

1. For the source water, receiving water for returns, and any other impacted waterbodies (including bypassed reaches, downstream waterbodies and impacted wetlands), does the withdrawal affect: If yes to any of the questions, describe the impacts.

- Baseflow?
- Range and timing of water levels or water table elevation fluctuations (including seasonal ranges or fluctuations)?
- Flows and flow variability?
- High water mark? Stream status (permanent or intermittent)?
- Index?
- Recession (rate of recharge)?

2. How large is the proposed water withdrawal in the context of total system flows in the source water and the receiving water?

3. If there are impoundments, will there be a reduction in peak flows?

- Will there be a loss in variation of water levels? If yes, describe the impacts.

4. For groundwater withdrawals:

- How important is groundwater seepage in the overall water budget and water characteristics of hydrologically-connected surface waterbodies (e.g., baseflows, water temperature)?
- Will there be a reduction in the amount of groundwater exchange with the river?
Or timing of? Explain.
- Will there be an effect on any drinking water wells? If yes, explain.

Category 3: Sediment Dynamics and Characteristics

Questions in this category relate to potential changes in sediment suspension and distribution, or sediment characteristics as a result of the water withdrawal.

1. Will there be a change in sediment suspension and distribution (i.e., erosion, accretion/ deposition, turbidity) in the source water or the return water?

- What is the anticipated magnitude and extent of this impact?
- Will this alter the shoreline geomorphic features or the location and area of shallow water zones? In what way?
- Will this change result in the need for increased dredging? Explain.
- If there are impoundments, will there be a reduction in total sediment delivery? Explain.
- Will there be significant effects on dynamic beach/coastal processes? Explain.

2. Will the water withdrawal affect wave energy dynamics? If yes, describe the effects.

3. Will there be a change in sediment characteristics in the source water or the return water?

- Will there be an increased sediment contamination by persistent toxic substances?
- Will there be a change in the properties of suspended or bedded sediments?
- Will there be an alteration of the organic carbon content of sediments?
- Will there be an increased sediment oxygen demand?

<u>Category 4: Water Quality</u>

The following questions relate to the quality of the source and receiving water, including any potential impacts related to invasive species.

1. How will the withdrawal alter the water quality of the source water and the return water? Address changes in:

- Temperature
- Nitrates
- Dissolved oxygen
- Buffering capacity
- BOD
- Salinity
- Total dissolved solids
- Sulfur
- Pathogens
- Water conductivity
- Dissolved organic carbon
- Persistent toxic substances
- Nutrients

2. Are there invasive species in the source water or return water? Please list.

- How are invasive species in the source water affected (negative and positive impacts)?
- What pathways, if any, will be created by the withdrawal/diversion that would allow invasive species to spread?

3. Will the water use (e.g., irrigation) lead to degradation of unrelated water supplies (e.g., ground-water)? Explain.

4. Will there be alteration of the thermal profile in the source or receiving water? Explain.

5. If there are impoundments, will there be an increase in water temperature? Explain.

Category 5: Ecological Impacts

Questions in this category relate to potential impacts on habitats, structure and function of the ecosystem, and any ecological benefits that may occur as a result of the proposed activity.

1. For the source and return systems, will the changes in water quantity, sediment dynamics, and/or water quality:

- affect aquatic or terrestrial habitats?
- affect habitat loss or gain?
- impact habitats reliant by biota (fish, benthos, birds, amphibians, reptiles, mammals, invertebrates)? Will any sensitive species such as piping plover be impacted?
- impact habitat attributes? For example, for migratory species, will access or connectivity be affected? Will resiliency of the habitat be affected?
- affect production or diversity of flora (including phytoplankton, periphyton, and macrophytes)?
- cause acute or chronic toxicity to any species?
- affect population levels or growth rates of any species in impacted system?
- affect hyporheic zone and subsequently affect surface aquatic systems?
- have an ecological impact on assemblages of endangered/threatened species?

Describe any changes in detail. Include consideration of any seasonal pattern of withdrawals,
and the related effects on impacted species (e.g., access to fish spawning areas in the spring).

2. For the source and return systems, will the changes in water quantity, sediment dynamics, and/or water quality:

- affect predator-prey relationships or food web structure and/or function in the impacted system?
  - If yes, which species are impacted?
  - If yes, how will the whole community structure and function be impacted?
- cause a change in the energy flow or nutrient cycling through the ecosystem?
- cause an increased bioaccumulation of contaminants in the food web?
- lead to human health impacts through increased contaminant levels in fish or other pathways?

The Information Inventories and Appendices listed below (and attached to this main report) are designed to address the current state of, and recognized needs and shortcomings of, various water resource data and information identified as significant.

Appendix A provides an overview of the physical system of the Great Lakes – St. Lawrence River system and detailed descriptions of the hydrologic cycle affecting water supply and water use across the basin. Emphasis is on natural and human-induced forces that affect water quantity in the system. Additional information is provided on major water uses who are direct clients of the decision support system provided under the Great Lakes Charter Annex.

Appendix B explains the nature and significance of the region's groundwater system. It describes the programmatic efforts of various agencies and organizations to gather and synthesize information that contributes to the understanding of groundwater resources. Types of data and information relevant to the groundwater system include digitization of soil survey data, groundwater well monitoring, three-dimensional geologic mapping and groundwater modeling. The appendix presents an assessment of current data collection activities in these areas and the needs of regional decisionmaking on groundwater withdrawals.

Appendix C explains the importance of streamflow data in determining water balance within the Great Lakes - St. Lawrence basin. The water balance is a mathematical model used to account for the inflow to, outflow from and storage in, a hydrologic unit. Also, an assessment of the adequacy of current stream gauging in meeting present and future regional water resources management needs is presented.

Appendix D evaluates the adequacy of information and data used to calculate the basin's water balance. Water withdrawal impacts are first realized in the change in the system's hydrology. Water balances are calculated to assess changes in the system's hydrology. Based on analysis of data gaps discussion is provided regarding observations of overlake precipitation and evaporation, outflow measurements in the interconnecting waterways and St. Lawrence River and accounting of diversion flows.

Appendix E describes the importance of meteorological observations over the land masses of the Great Lakes – St. Lawrence River basin. Overland meteorological observations provide information crucial for input to hydrologic watershed response models. Data are collected at hundreds of weather station locations around the Great Lakes basin and by satellite and radar imagery. Several federal, regional and state agencies are involved in meteorological data collection, storage, analysis and dissemination.

Appendix F describes the important role of water use data in the decision support system. Many agencies, organizations, users and consumers, such as federal, state local and regional water management agencies, policymakers, scientists, educators, business and industry employ data on water use. Water supply planning is important to the understanding and the management of uncertainty related to water withdrawal, conveyance, distribution, application, discharge and reuse. This appendix identifies the need for a federal role in data reporting for the region.

Appendix G summarizes the significant role that a sustainable water supply plays in the health and diversity of the various habitats throughout the system and the organisms that depend upon them. Emphasis is placed on Great Lakes shorelines and nearshore waters, tributary stream lowlands and terrestrial uplands, all of which will manifest different ecological responses to cumulative water withdrawals and other anthropogenic and/or climatic effects. This appendix also describes currently available data and information resources, identifies gaps and provides for improving predictive modeling of hydrologic impacts on various habitat types.

Appendix H describes the various classes of organisms found in Great Lakes – St. Lawrence River basin habitats. This appendix assesses the current state of data and information for each particular group of organisms. Data and information related to organisms is inventoried and presented. Additionally, gaps in data and information for each organism group are assessed.

Appendix I provides a summary of current land cover/use information compiled over the Great Lakes – St. Lawrence River basin. This information is vital to answering essential questions that the biohydrological information system is designed to address. Recommended tasks for periodic updates of these information themes are included.

Appendix J provides an extensive assessment of current information system resources available across the basin, including listing of binational programs, federal and state agency clearinghouses and Canadian federal and provincial collaborators. An extensive inventory of modeling tools available for application in the water resources decision support system is also provided. Emphasis is also placed on the need for institutionalizing data exchange in a more formal approach to facilitate standardized regional decisionmaking.

Appendix K presents the cost evaluation and risk assessment for the project. Implementation costs for each component task of the integrated information system are evaluated against each of the five implementation strategies considered. Information on structural improvements to the system such as new stream gauge stations, additional instrumentation and system operations are based upon current competitive costs for these activities. Programmatic activities such as research and development of new modeling procedures and ecological assessments are based upon time estimates of qualified staff, organizational overhead and existing contracting procedures. Operations and maintenance costs of an integrated biohydrological information system are estimated by similar means.

Appendix L provides all background materials to support the overall report. It includes listing of project participants, brief summaries of related Great Lakes initiatives and acknowledgement of report contributors.

6. Strategy Development

a. General

The Great Lakes Biohydrological Information Study is focused on summarizing biohydrological data information collected or funded by U.S. federal agencies that can be used to inform science-based water resources decisionmaking in the Great Lakes - St. Lawrence River basin. The Study is comprised of four key parts, all of which are detailed in the respective topical appendices: 1) an inventory of existing information needed to assess essential questions dealing with prospective water withdrawals; 2) an assessment of the adequacy of existing biohydrological information and data collection programs that would provide necessary input to water resources decisionmaking; 3) a listing of individual tasks to address information shortfalls; and, 4) development of strategies for addressing these tasks.

b. National and Regional Objectives

The national objective of the Biohydrological Information Study is to evaluate the adequacy of existing information resources to maintain the biological integrity and sustainability of the continent's greatest freshwater reserve. The Great Lakes – St. Lawrence River system is home to a vast array of birds, fish, mammal, amphibians, reptiles, insects, plants and others flora and fauna which migrate across the watershed divide and affect the biological diversity of the nation.

Increased demand on Great Lakes water resources can adversely affect the economics of the nation directly and indirectly. Water levels of the Great Lakes and flows in their interconnecting waterways can be deleteriously affected by cumulative reduced water supplies caused by increased demand of the resource base. This can easily parlay into economic losses to intrastate commerce of goods and materials shipped via lake freighters and ocean vessels and could impact the global competitiveness of industries across the region and elsewhere in the nation.

The regional objectives of the Biohydrological Information Study is to comprehensively assess the adequacy of information resources and data collection systems needed to meet the water management decisionmaking needs of the governors and premiers of the region. This objective is focused on evaluating the U.S. federal information collection and data management programs as key components of a regional decision support system. One of the primary goals of the study is to present existing water resource information inventories currently available to decisionmakers and estimate the expanded information needs of regional decisionmakers in the future.

Reduced uncertainty in water resource decisionmaking is another important regional objective. All data collected on the hydrology, hydraulics, meteorology, climatology, sediment dynamics, etc. needed to support legally defensible water permitting programs conducted by state, provincial and local units of government have uncertainties attached. Frequently, these uncertainties are too large, precluding the governments from being able to scientifically predict, with a reasonable level of confidence, likely outcome of their permitting actions.

The decision to commit new or additional resources to the improvement of current water management information systems will have to be weighed against the expected benefits (monetary and non-monetary) of investing in such an endeavor. A tool (model) to properly make this analysis does not exist at this time; such a tool would have to define the "poor", "adequate" and "desired" levels of information required to make water resource decisions (from basic to complex) through the removal of various levels of uncertainty. The level of investment in such an information system needed to avoid making poor decisions has to be established, then the amount of additional data and information needed to remove enough uncertainty to accommodate sound water resource and regulatory decisions has to be identified.

c. Public Concerns

The public within the Great Lakes – St. Lawrence River basin are very concerned about the sustainability of water supplies to the system. A recent request to transport Great Lakes waters via ocean vessels to the Orient drew considerable news coverage and adverse public reaction, leading to cancellation of a permit issued by the province of Ontario. Introduction of new commercial water bottling operations in Michigan has caused public rancor about the marketing of precious freshwater resources. Diversions of water across the surface water divide by municipal water systems in Wisconsin, Indiana, Ohio and New York have increased public debate about the value of the resource and the decision process employed for its management.

Losses of life and onset of severe illnesses in Ontario caused by biological contamination of groundwater has increased public concerns about the health risks associated with inadequate groundwater monitoring and municipal water treatment across the region. Biological contamination of beaches across the Great Lakes has increased regularly over the last decade causing decreased use of these recreational assets with incumbent economic and social loss. Inability of fish to spawn in areas of decreased water supply, particularly in colder headwaters streams has increased public interest in water quantity management by anglers and sportsmen.

Further the public has continuously manifested concern that new uses of water resources within the region will increase and that there is an inadequate accounting system in place to manage resources appropriately. The public has presented a clear consensus opinion that Great Lakes water resources are threatened by growth of other regions across the continent. Protectionism of regional water resources is a frequent spoken public desire.

d. Description of Existing Conditions

(1). Physical Settings

The Great Lakes - St. Lawrence River basin in its entirety covers about 302,000 square miles and includes part or all of the eight U.S. states of Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York and the Canadian provinces of Ontario and Quebec. The Great Lakes - St. Lawrence River basin spans over 900 miles from east to west and about 700 miles from north to south.

Fifty-nine percent of the surface area of the Great Lakes - St. Lawrence River basin is in the United States; 41 percent is in Canada (GLC, 2003). This includes all land, rivers and streams from which waters drain into the Great Lakes. The Great Lakes - St. Lawrence River system is comprised of Lakes Superior, Michigan, Huron, Erie and Ontario; their connecting waterways, St. Mary's River, St. Clair River, Lake St. Clair, Detroit River and Niagara River; and the St. Lawrence River, which carries the waters of the Great Lakes to the Atlantic Ocean (Figure 1).

The system includes several man-made waterways and control structures that either interconnect Great Lakes or connect the Great Lakes to other river systems. The Great Lakes - St. Lawrence River basin consists of 109 watersheds in the U.S. and 67 watersheds in Canada. Because of the vast size of the system, it responds slowly to climatic and environmental changes in respect to months or years, rather than days.

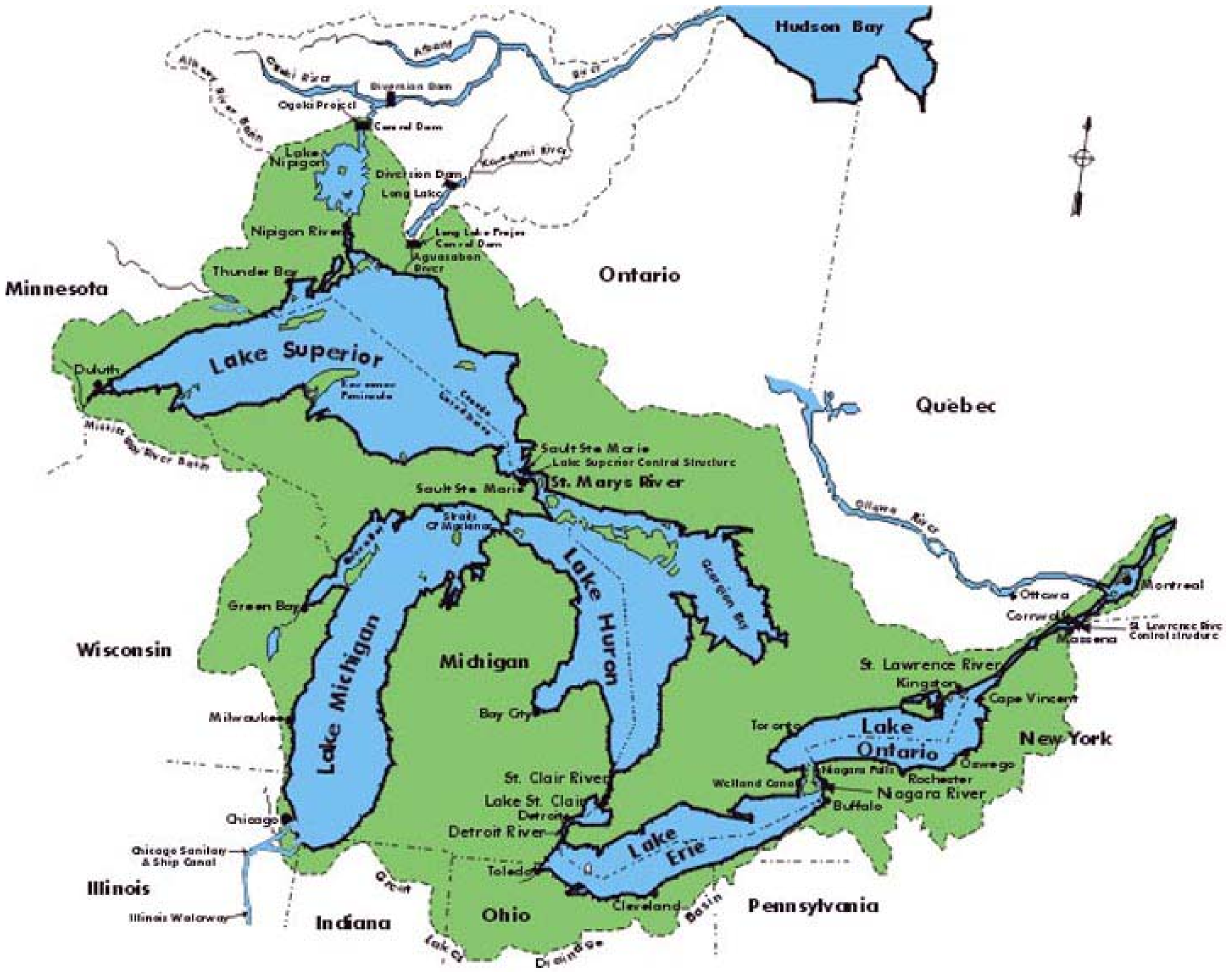


Figure 1: Great Lakes – St. Lawrence River Basin

The system includes several man-made waterways and control structures that either interconnect two of the Great Lakes or connect the Great Lakes to other river systems. The IJC regulates the outflows from Lakes Superior (at Sault Ste. Marie) and Ontario (mainly through the Moses-Saunders Powerhouses), which influences the water levels of Lakes Superior and Ontario. Coordinated decisions between the U.S. and Canada governing outflows are derived from regulated plans that utilize coordinated water level forecasts, observed monthly mean lake levels and basin precipitation from the previous months, Net Basin Supplies (NBS) for the months leading up to the forecast date, meteorological outlooks for the coming six months and current snow-water equivalent estimates from the basin.

Currently, the data to support this work is gathered from different and sometimes unrelated sources, and in varying formats. The gathering, compilation and preparation for use of these data are often time-consuming and cumbersome. Gathered data has not always been subjected to quality control by the originating agency, and the availability of the individual data sources is not always reliable. NBS calculations are derived from monthly mean average lake levels; estimated outflows are then calculated based on those averages and other macroscale considerations. The systems are not refined or sensitive enough, and the input data not specific enough to make adjustments for other factors that may impact water supplies in individual lake basins.

Because of these uncertainties, human intervention is required by experienced hydrologists to adjust the final modeled water supply outputs to match what is observed or intuitively expected. Because of these shortcomings, decisions by these water management experts have intrinsic uncertainty with each decision made. And, until more reliable and robust datasets are made available, along with better predictive models, this uncertainty will continue.

It is anticipated that the federal government would be responsible for the data to support water management activities such as consumptive uses and water withdrawals in the Great Lakes basin for several reasons. First, the federal government (USACE, USGS and NOAA) already maintains basinwide and national databases of water levels, stream and river flows, hydrologic basin supplies, groundwater data, water temperature, geology and other pertinent physical data. Also, the federal government, with its jurisdiction that covers all states, is better situated to develop a uniform base of data and information than would likely occur if left to state or local governments.

On the other hand, state and local governments can be more familiar with the unique characteristics of the area of the proposed withdrawal or regulatory action. It would be the responsibility of the local and state governments, along with the applicant, to supply all pertinent ancillary data (including environmental data) to support the application.

e. Description of Future Conditions

With the ongoing update of the Lake Ontario Regulation Plan and anticipated review of outflow strategies for Lake Superior, it is expected that future Great Lakes basin water management plans will have to be adaptive to potential changes to these plans. Natural factors that also have to be considered in future years include the anticipation of climate change due to rising greenhouse gas concentrations in the atmosphere. If the predicted global warming does occur, Global Circulation Models executed under four different combinations of scenarios (warm/wet, warm/dry, not-as-warm/wet and not-as-warm/dry) all point to declining water supplies and lower lake levels into 2050.

This would indicate that, with a warmer climate, lake water evaporation would be consistently greater than during the 100-year period of record for the lakes. Whether there would be an adverse effect on water supplies (rain and snowfall) is a point of debate.

However, this translates into the need for continuing improvements in meteorological prediction models and the density and capabilities of observation stations (especially lake buoy stations) that can collect more data than is currently available. Especially lacking is lake-based data stations; since measurements of over-lake wind speeds, surface water temperature and evaporation measurements are key to anticipating negative water balances from lake surface evaporation.

Hydrologic prediction models would likely become more accurate from having near real time lake data, and would be a useful tool in anticipating water balance trends. With timely and reliable hydrologic trend indicators, water resource decisionmakers could adaptively manage regulated systems and potential water-withdrawal issues with greater certainty than today.

f. Problems and Opportunities

(1). Identified Problems

(a). Use of water within the Great Lakes – St. Lawrence River basin will increase over time as population increases internally. Few conservation measures are in place to preclude this increased demand. Current categories of water uses include public supply, domestic supply, irrigation, livestock, industrial, fossil fuel power, nuclear power and hydroelectric power. Some of these categories have consumptive uses, meaning water is not returned in total to the system.

(b). Demand for transboundary water transfer will likely increase. Initial demand is already occurring, principally by suburbs outside the surface water divide seeking expansion of services from major municipal water systems within the basin. Groundwater extraction from outside the basin can affect sustainable base flows to tributary streams within the basin.

(c). Increased marketing of bottled water, beer, fruit juices, etc and other manufactured goods outside the region using water resources from within the basin.

(d). Cumulative demand on water resources will increase for all tributary watersheds to the Great Lakes and their interconnecting waterways. The quantity, timing and duration of this cumulative demand have very large uncertainties associated with it. These uncertainties reduce scientific and legal defensibility of regional decisions.

(e). Predictive modeling of ecological consequences from cumulative water withdrawals are largely unavailable or inconsistent across the region.

(2). Opportunities

(a). Increased demand for water resources from within and outside the region can justify additional expenditures for improving accounting of water use within the region.

(b). Demands for transboundary water transfers can justify improvements in the scientific knowledge base about the interaction of surface water systems, groundwater aquifer systems and ecological communities reliant upon them.

(c). The increased market value for water-dependant commodities can provide a prospective funding source for improved accounting of water demands and use.

(d). Increased demand and market value can increase the importance for research and development needed to improve overall system accountability with inherent reduction in decision uncertainties.

(e). Ecological forecast models can be developed to scientifically predict outcomes of water withdrawal permit actions and increase their legal defensibility.

(3). Biohydrological Information System Tasks

It is important to recognize that water withdrawal permitting conducted by the states, provinces and local units of government across the Great Lakes – St. Lawrence River basin will increasingly need to be conducted in a holistic fashion. A comprehensive decision support system is needed, based upon the best scientific information, computer modeling and information integration tools. The appendices to this report identify the component parts of a comprehensive biohydrological information system needed to support regional decisionmaking. Each of these component tasks are needed to satisfactorily address the essential questions outlined in the 2003 WRMDSS project report and repeated herein. In summary these tasks as identified within the appendices to this report are as follows:

Task 1: The Natural Resources Conservation Service (NRCS) needs to complete all soil survey maps within and immediately adjacent to the Great Lakes - St. Lawrence River basin in a consistent manner and to encode them in digital form.

Task 2: High resolution, digital, three-dimensional geologic maps need to be produced by the U.S. Geological Survey (USGS) and collaborating state agencies to define the aquifer systems in the Great Lakes - St. Lawrence River region.

Tasks 3-7 (Groundwater Modeling): The USGS, in association with collaborating state agencies, needs to define groundwater flow characteristics and monitor changes over time that impact the Great Lakes - St. Lawrence River region.

Task 3: The USGS needs to develop, maintain, and expand the network of groundwater observation wells within and immediately adjacent to the Great Lake-St. Lawrence River basin.

Task 4: The USGS needs to define the infiltration, recharge and drainage characteristics of the Great Lakes - St. Lawrence River basin that affect water supplies within the region.

Task 5: The USGS, in cooperation with regional and state agencies, needs to conduct focused research to improve accounting of groundwater extraction rates from the Great Lakes - St. Lawrence River basin.

Task 6: The USGS, in cooperation with regional and state agencies, needs to conduct focused research on improving consumptive use estimates of Great Lakes - St. Lawrence River groundwater resources.

Task 7: The USGS, in conjunction with other federal agencies, regional, state and academic institutions, needs to develop comprehensive modeling procedures that can be used to assess impacts of groundwater withdrawals within and adjacent to the Great Lakes - St. Lawrence River basin.

Task 8: The USGS, in conjunction with other federal agencies, regional, state and academic institutions programs, needs to conduct research to define the natural stream dynamics of all U.S. tributary watersheds within the Great Lakes – St. Lawrence River system and identify the salient flow characteristics affected by anthropogenic changes.

Tasks 9-13 (Watershed Modeling): The U.S. Army Corps of Engineers (USACE) needs to coordinate the development of consistent and comprehensive watershed models for all gauged watersheds in the U.S. portion of the Great Lakes – St. Lawrence River basin in cooperation with other U.S. federal agencies, regional and state governmental units, and academic institutions.

Task 9: The USGS needs to maintain, expand and upgrade the stream gauging network in the U.S. portion of the Great Lakes - St. Lawrence River basin. Under this task the USGS needs to conduct appropriate network analysis to identify headwater areas where additional stream gauging is warranted to meet water resource management needs. In addition, the USGS needs to identify and expand streamflow gauges at the tributary river mouths employing state-of-the-art instrumentation.

Task 10: The USGS needs to upgrade and maintain adequate instrumentation to monitor abiotic streamflow characteristics at key stream gauging locations.

Task 11: The USGS, in cooperation with Great Lakes Commission and state authorities, needs to develop procedures to improve accounting of instream withdrawals.
Task 12: The USGS, in cooperation with the Great Lakes Commission and state authorities, needs to develop and improve consumptive use estimates from instream withdrawals for application in watershed modeling.

Task 13: The USACE, in conjunction with other federal agencies, regional, state and academic institutions, needs to develop, test and operationally implement simulation and predictive flow models for gauged watersheds within the U.S. Great Lakes – St. Lawrence River basin.

Task 14: The USACE, in conjunction with other U.S. federal agencies and regional, state and academic institutions needs to develop watershed estimation tools to assess water withdrawal impacts on ungauged watersheds.

Task 15: The USACE, in conjunction with other U.S. federal agencies, Canadian authorities and academic institutions, needs to improve the accuracy and detail in Great Lakes water balance models and needs to monitor changes in net basin supply for each of the Great Lakes on a monthly basis.

Task 16: The National Oceanic and Atmospheric Administration (NOAA), in conjunction with the USACE and other U.S. federal agencies, Canadian authorities and regional academic institutions, needs to develop an operational program to measure over-lake precipitation using land-based weather radar and ancillary satellite observations to reduce the level of uncertainty in water balance models.

Task 17: The NOAA, in conjunction with the USACE and other U.S. federal agencies, Canadian authorities and academic institutions, needs to generate improved daily estimates of lake evaporation conditions by applying satellite, airborne and in-situ observations.

Task 18: The NOAA needs to improve monitoring of over-lake hydrologic and meteorological parameters (barometric pressure, wind direction and speed, wave energy, relative humidity, dew point, solar radiation, air and lake surface temperatures and precipitation) by upgrading and expanding the Great Lakes buoy and fixed station network to meet the data and information needs of the Great Lakes Charter Annex.

Task 19: The NOAA, in conjunction with other U.S. federal agencies, needs to improve the spatial resolution of ice cover mapping over the Great Lakes. The USACE needs to lead U.S. federal research efforts into short- and long-term ice cover effects on nearshore habitats.

Task 20: The USACE, in cooperation with other U.S. federal agencies, needs to improve monitoring of wave conditions in the nearshore environment and update wave hindcast models for each of the Great Lakes and Lake St. Clair.

Task 21: The USACE, in conjunction with the NOAA and regional academic institutions, needs to implement high-resolution hydrodynamic modeling for each of the Great lakes and their embayments on a daily operational basis.

Task 22: The NOAA, in cooperation with regional academic institutions, needs to improve monitoring of abiotic parameters in the nearshore environment and off-shore by upgrading and expanding instrumentation on buoys and fixed stations and applying satellite remote sensing to provide input to nearshore habitat modeling. These parameters include surface water temperature, pH, salinity, dissolved oxygen and conductivity.

Task 23: The USACE, in conjunction with the NOAA, the USGS and Canadian authorities and in cooperation with regional academic institutions, needs to implement continuous modeling of water levels, outflows, and hydrodynamics in the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Task 24: The NOAA, in conjunction with other U.S. federal agencies and hydropower authorities, needs to upgrade instrumentation at water level gauging stations to better monitor abiotic conditions in the habitats of the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Task 25: The USACE needs to be provided authorities to work with other U.S. federal agencies, Canadian authorities and state, provincial and municipal entities to improve monitoring, modeling and accounting of all ~~in~~flows ~~and outflows~~ into, between, and out of the Great Lakes drainage basins by employing state-of-the-science measuring techniques, numerical modeling approaches and automated observing systems.

Task 26: The USGS needs to strengthen the National Water Use Information Program (NWUIP) and integrate this program with other related federal programs to support implementation of the Great Lakes Charter Annex.

Task 27: The USGS, in cooperation with regional interests, needs to implement periodic reporting of water withdrawals and use for the Great Lakes - St. Lawrence River basin.

Task 28: The USGS, in cooperation with regional, state and provincial authorities, needs to define and implement metadata standards to improve knowledge of inherent uncertainties in water use and withdrawal data for the Great Lakes – St. Lawrence River basin.

Task 29: The USGS, in cooperation with regional, state and provincial authorities needs to improve estimation techniques of water withdrawal and use for surface and groundwater whenever direct measurements are unavailable to support Great Lakes Annex decisionmaking.

Task 30: The USGS needs to work collaboratively with regional, state and provincial authorities to implement direct measurements of water withdrawal and use, wherever technically feasible and implementable, to support decisionmaking under the Great Lakes Charter Annex.

Task 31: The USGS, in cooperation with regional, state and provincial authorities needs to develop a systematic method for estimating consumptive use for those water use categories where direct measurements are not possible.

Task 32: The USGS needs to coordinate development of consistent demand forecasts of water withdrawals and uses for all USGS major watersheds in the Great Lakes - St. Lawrence River basin at the state and local levels, including integration current and projected land use information.

Tasks 33-37 (Interconnecting Waterways Ecological Modeling): U.S. federal agencies need to work collaboratively with regional, state and Canadian federal and provincial agencies, to improve modeling of potential hydrologic impacts of cumulative water withdrawals on habitats in the interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Task 33: The USGS, in conjunction with the USACE, and in cooperation with other U.S. federal agencies, Canadian federal and provincial interests, and other governmental and non-governmental institutions, needs to develop detailed models of habitat impacts in the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River as a consequence of cumulative water withdrawals.

Task 34: The USGS, in conjunction with the USACE, and in cooperation with other federal agencies, state and provincial authorities and regional academic institutions, needs to develop standard modeling procedures to evaluate the impacts of land use modifications on adjacent habitats of the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Task 35: The USGS, in conjunction with the USACE, and in cooperation with state and provincial authorities and regional academic institutions, needs to develop standard modeling procedures to determine effects of sedimentation on habitats of the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Task 36**:** The USGS, in cooperation with other federal agencies, state and provincial authorities and regional academic institutions, needs to classify habitats of the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River by their hydrologic and geomorphologic characteristics.

Task 37: The USGS, in conjunction with the USACE, and in cooperation with other federal agencies, state and provincial authorities and regional academic institutions, needs to develop standard modeling procedures for evaluating abiotic changes in habitats of the Great Lakes interconnecting waterways, Lake St. Clair and the St. Lawrence River.

Tasks 38-42 (Nearshore Ecological Modeling): The USGS, in conjunction with the USACE, and in cooperation with other federal agencies, state and provincial authorities and regional academic institutions, needs to develop standard procedures for modeling hydrologic impacts on nearshore habitats of Great Lakes and shorelines.

Task 38: The USGS, in conjunction with the USACE and NOAA , and in cooperation with state agencies and regional academic institutions, needs to develop and implement standard modeling tools for evaluating the hydrologic impacts of cumulative water withdrawals on nearshore habitats in the Great Lakes and their embayments.

Task 39: The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for repetitive evaluations of the impacts of land use modifications on nearshore habitats.

Task 40: The USGS, in conjunction with the USACE, and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for determining effects of sedimentation changes on nearshore habitat.

Task 41: The USGS, in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to classify nearshore habitats by their hydrologic and geomorphic characteristics.

Task 42: The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for periodically evaluating abiotic changes in nearshore habitats.

Tasks 43-47 (Lowland Ecological Modeling): The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to improve modeling of hydrologic impacts on lowland habitats including wetlands, inland lakes, streams, rivers and river mouths.

Task 43: The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for periodically evaluating water levels and flow impacts on lowland habitats including wetlands, inland lakes, streams, rivers and river mouths.

Task 44**:** The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for periodically evaluating the effects of land use modifications on lowland habitats including wetlands, inland lakes, streams, rivers and river mouths.

Task 45: The USACE, in conjunction with other U.S. federal agencies and in cooperation with state agencies and regional academic institutions, needs to develop and implement standard modeling procedures for determining the effects of cumulative withdrawals on sedimentation from lowland habitats including wetlands, inland lakes, streams, rivers and river mouths.

Task 46: The USGS, in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop standard procedures for classifying lowland habitats including wetlands, inland lakes, streams, rivers and river mouths by their hydrologic and geomorphologic characteristics.

Task 47: The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop standard monitoring and modeling procedures for periodically evaluating changes in abiotic conditions in lowland areas, including wetlands, inland lakes, streams, rivers and river mouths.

Tasks 48-51 (Upland Ecological Modeling): The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to improve modeling of cumulative water withdrawal impacts on upland habitats.

Task 48**:** The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop standard modeling procedures for periodically evaluating the hydrologic implications of ground water withdrawal on upland habitats.

Task 49: The USGS, in conjunction with the USACE and in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to develop standard modeling procedures for periodically evaluating the effects of land use modifications on upland habitats.

Task 50: The USGS, in cooperation with other U.S. federal agencies, state agencies and regional academic institutions, needs to comprehensively classify upland habitats by their geomorphic characteristics.

Task 51: The USGS, in collaboration with NOAA, USACE and other U.S. federal agencies, and in cooperation with state, regional and academic institutions, needs to develop standard modeling procedures for monitoring upland habitat responses to climatic changes.

Task 52: The USGS, in conjunction with the NOAA and the USACE and in cooperation with state agencies, needs to produce comprehensive and consistent land cover datasets for the entire Great Lakes - St. Lawrence River basin on a five-year repeat cycle.

Task 53**:** The USGS, in conjunction with the USACE and in cooperation with state agencies, needs to produce high-resolution land cover data within the Great Lakes - St. Lawrence River basin to support detailed assessments of specific water withdrawal proposals.

Task 54: The USGS, in conjunction with the USACE and in cooperation with state agencies, needs to produce land cover change evaluations from available data and 30-year land use projections for the entire the Great Lakes – St. Lawrence River basin to refine ecological impact assessments and anticipated future demands on water resources.

Task 55: The USACE, in conjunction with the USGS and in cooperation with other U.S. federal agencies, state entities and Canadian interests, needs to ensure that all federal biohydrological data for the Great Lakes – St. Lawrence River is served on registered NSDI clearinghouse nodes.

Task 56: The USACE, in conjunction with the USGS, and in cooperation with other U.S. federal agencies, state entities and Canadian interests, needs to develop metadata standards to handle all hydrologic, meteorologic, ecological and water quality data needed for Great Lakes – St. Lawrence River water resource decision support.

Task 57: The USACE, in conjunction with the USGS, needs to ensure that all U.S. federal biohydrological data that is collected and stored for the Great Lakes –St. Lawrence River to have metadata created and posted on a NSDI registered clearinghouse node.

Task 58**:** The USACE needs to lead U.S. federal interagency coordination for promoting regional data exchange agreements covering all required Great Lakes – St. Lawrence River biohydrological data.

Task 59: The USACE, in cooperation with other U.S. federal agencies, state entities, Canadian interests, and regional academic institutions needs to develop procedures for maintaining and promoting linkages between computer models needed to support implementation of the Great Lakes Charter Annex.

(4). Expected Future without Project Conditions

With the "No Change" or "Without Project Strategy", current funding levels and federal manpower commitments may or may not be stable over the next 10 years to address the increased needs for biohydrological data to support water resources decision processes. Without some additional investment, or implementation of a more cohesive and comprehensive implementation option the current status may actually decline. The costs of not implementing any task in the integrated implementation strategies are presented in the respective appendixes wherever possible.

With this strategy, geologic investigations on the quantity and quality of aquifer resources within and adjacent to the Great Lakes – St. Lawrence River system will be substantially less than needed to meet anticipated decisionmaking needs. Under existing funding limitations, geologic mapping projects will be limited to very few pilot projects funded under the Central Great Lakes Geologic Mapping Coalition and limited STATEMAP cost sharing projects. Soils mapping, needed for hydrologic response models will not be completely digitized until 2007 for the entire region.

Groundwater monitoring networks are currently compromised by poor spatial detail and will likely decrease due to maintenance funding constraints. Estimates of impervious surfaces needed to model groundwater recharge rates are coarse and lack consistency. Infiltration, recharge, and drainage characteristics may exist in some key areas, but are not comprehensive and are likely not to be improved without additional financial resources. Some groundwater modeling will be developed for individual watersheds or subwatersheds based upon critical need, but these efforts will be inconsistent between states, reducing utility for regional decisionmaking.

Streamflow information, vital to address the essential questions associated with withdrawal proposals across the U.S. watersheds, will continue to be problematic. Methods for estimated streamflow in ungauged watersheds will likely remain inconsistent from state-to-state. The current U.S. gauging station network of 372 stations will be diminished within three to five years, when short-term gauges are discontinued. The network of long-term gauges will likely continue to deteriorate due to reductions in federal and non-federal funding support, as operation and maintenance costs rise. This reality has occurred over the last two decades.

Modeling of tributary stream dynamics is gaining some momentum, with work being conducted by several federal and state agencies and at academic institutions, albeit not comprehensive and consistent. Use of these models in a shared regional decisionmaking process will be problematic at best.

The current knowledge of Great Lakes hydrology and water supply is likely the most developed information component of the water resources decision support system. Because of the vast size of the Great Lakes, uncertainties in water supply estimates outweigh the magnitude of multiple prospective withdrawals from groundwater and in-stream sources. Reductions in uncertainties associated with overlake meteorological processes (e.g., precipitation, evaporation) are likely to be modest at best with current funding levels.

Operations and maintenance of buoy systems that provide important observations of subtle changes in the lake's physical, chemical and biologic resources will likely be under continued stress. Ice-cover monitoring, a key indicator of climatic variability, will not be improved with limited manpower and funding resources. Wave energy estimates will continue to be coarse. Knowledge of wave energies is important for modeling coastal responses and determining impacts of decreased water supply due to cumulative water withdrawals from other unrelated physical forces.

Improvements in monitoring lake and interconnecting waterways circulation patterns using advanced hydrodynamic models will be modest. Due to limited funds, however, they will not be put into operation to simulate, predict and monitor changes.

Abiotic parameters, surface water temperatures, pH, salinity, dissolved oxygen and conductivity in the nearshore, within the interconnecting waterways and St. Lawrence River, will largely continue to be absent, compromising the ability to model the response of sensitive habitats to cumulative water withdrawals.

The accuracies of accounting for water flow between lakes, out from the St. Lawrence River and in diversion canals will likely remain to be suspect. While some facilities and river courses are extremely well monitored and outflows are calculated with high accuracy, other key hydraulic features are poorly assessed. With existing financial resources, this complex situation will likely become more complex as infrastructure continues to deteriorate and monitoring programs are decreased. Without significant improvement, most conclusions about the impacts of cumulative water withdrawals from the Great Lakes – St. Lawrence River system will be challenged for scientific validity.

Inconsistent information on water withdrawals and uses from groundwater, in-stream and from the open lake will continue due to differing levels of cooperation by states, inside and outside of the Great Lakes region. Incomplete, non-uniform and unreliable information will continue to be the norm, compromising science-based water resources management decisions. Groundwater and in-stream withdrawals are estimated or calculated based upon pumping capacity and/or estimation techniques for selected water use sectors. Accounting is inconsistent from state to state. Future approaches are not likely to change without significant additional collaboration. Consumptive use of groundwater and in-stream water resources will continue to be estimated by developing coefficients that are frequently inconsistent and unreliable.

Currently water withdrawal and use data are at least partially measured for the public water supply, thermal-electric, thermal-nuclear, hydroelectric power, and industrial categories. Without additional authority and funding, improvements in direct measurements of these categories will not occur. Without additional funding, periodic updates of regional water uses will not occur. Demand forecasting will occur sporadically with no coordination among or between jurisdictions. This will negatively impact implementation of the Great Lakes Charter Annex due to the paucity of data. With little or no financial and programmatic support at the state level, demand-forecasting tools will not be developed.

Significant work is underway to model water levels and flow impacts on habitats along Great Lakes shorelines, particularly over the Lake Ontario and St. Lawrence River shorelines. This work, however, is limited in scope to site specific project areas. Future work will likely not be comprehensive or spatially and temporally consistent. Hydrologic impact models along most tributary streams in the Great Lakes – St. Lawrence River basin do not exist. This situation will not change with existing funding levels.

Land use and cover maps are complete for the U.S. Great Lakes – St. Lawrence River shoreline. However, they are inconsistent, outdated and do not provide information on temporal changes. This situation will remain without additional funding.

Biohydrological data will remain fragmented across the different federal agencies, compromising science-based water resources management decisions across the basin. Continued decreases in funding to most U.S. federal resource management agencies within the region will result in further degradation of information resources. Inconsistent, incomplete, non-uniform and unreliable information will continue to be the norm. Current federal standards do not cover all of the datasets required to make informed management decisions in the Great Lakes - St. Lawrence River system. Inconsistent investment in creation of metadata for important biohydrological data resources will continue, compromising easy access to basic data for decisionmaking.

The ability to assess likely impacts of potential water withdrawals will continue to be compromised due to inconsistencies between model inputs and outputs. Limited model integration will proceed out of necessity, but not in a systemic approach. Holistic analysis will continue to be difficult and lack cost effectiveness.

In further evaluations described in detail in Appendix K: *Cost Evaluations and Risk Assessments*, a subjective assessment is made about the relative value of all 59 tasks in accomplishing a truly integrated information system. In this analysis, the No Change strategy is expected to lead to a significant disbenefit in total for the region. This is attributed to continuing losses in basic information collecting and analysis directly proportional to anticipated decreased funding.

f. Planning Objectives

(1). The primary planning objective outlined in this effort is to objectively assess the benefits, disbenefits and likely consequences involved in each implementation strategy. These strategies are constructed with increasing levels of costs, complexity, and comprehensiveness and provide increasing confidence when used in predictive modeling.

(2). A secondary planning objective has been to anticipate the integrated nature of the decision support system needed to meet the varied requirements of the decision makers across the region. The integration inherent in the decision process requires careful assessment of the roles, responsibilities and commitments of each level of governance in addressing the design, implementation and operation of the decision support system.

g. Planning Constraints

A significant planning constraint is insuring that all component parts of the decision support system are thoroughly addressed. In many cases, insufficient information is available to adequately assess the resource requirements for advancing ecological and physical process modeling required for decisionmaking. In addition, water uses from many sectors can only be estimated currently due to incomplete or inconsistent sampling methods.

h. List of Strategies

Four implementation strategies have been identified which vary significantly by the degree of investment, the breadth of information collection and analysis and, most importantly, by the degree to which they provide greater confidence (or reduced uncertainty) in managing cumulative water withdrawals from the Great Lakes – St. Lawrence River system. The four implementation strategies are described in detailed in the appendices to the report, task by task. Following are brief descriptions of the scope of each strategy, total expected costs for each and primary benefits that would be achieved.

(1). Biohydrological Information System – Minimum Investment Strategy

The "Minimum Investment Strategy" includes the least costly measures needed to ensure minimum functionality of a decision support system. Not all system components of an implementation plan are included in this option, so it is not considered to be a "true plan" on its own accord. It simply addresses the most important information shortcomings at the least cost.

Under this strategy, modest improvements would be made to maintain existing groundwater observation network over the basin, thereby incrementally improving knowledge of infiltration and extraction rates. Substantial new aquifer mapping, however, would not occur. Prototype groundwater modeling would be accomplished over a few watersheds.

Additional funding would be made available to maintain the integrity of the U.S. stream gauging network on an increased federal cost-sharing basis. Data from the stream-gauging network is one of the most significant hydrologic information needs for water resources management, and is under substantial stress. Modest funding would be sought to improve and consolidate methods for estimating streamflow in ungauged areas. A substantial effort would be made to produce operation models for 20% of the highest priority tributary watersheds in the U.S. Great Lakes – St. Lawrence River basin by exploiting available data.

Increased funding would be directed towards expanding the focus of the National Water Use Information Program (NWUIP) to include groundwater and surface water measurements and estimation and coordination over the Great Lakes – St. Lawrence River basin. An important caveat of this approach would be to seek new authority under the NWUIP for pass-through funding to each Great Lakes state and regional coordinators to generate consistent and uniform water withdrawal and use information. With this strategy, a systematic comparison of water use estimation methods in the Great Lakes states would be conducted and reported for all categories of use where estimation is currently utilized. Funds would be available to initiate modest improvements in consumptive use estimates from groundwater and surface water resources. Pilot studies would be conducted to directly measure consumptive use for both surface and groundwater for a few key water use categories or facility types.

A consistent and uniform methodology for demand forecasting of water withdrawals and uses for all USGS major watersheds would be developed, along with a uniform schedule for conducting additional forecasts elsewhere. A prototype demand forecast would be conducted for one of the 109 USGS major watershed of the Great Lakes – St. Lawrence River basin.

Modest funding would be directed to define potential improvements in flow accounting at major and minor diversions in the U.S. portion of the Great Lakes – St. Lawrence River system.

Efforts would be expended to develop habitat assessment tools to anticipate impacts of potential water withdrawal proposals, individually and cumulatively. A pilot study using continuous circulation models and involving land use analysis would be conducted for one specific shoreline habitat on one of the Great Lakes. Data from existing offshore buoys, nearshore ecological impact modeling, and continuous circulation models would be interfaced in this pilot study to evaluate the broader applicability of these tools. Land use encroachment analysis would also be assessed to help delineate the role of withdrawals as a forcing function.

Current hydrodynamic models developed for research application for the Detroit and St. Clair Rivers and Lake St. Clair would be expanded to assess implications of water withdrawals on levels, flows and circulation patterns on nearshore habitats in this interconnecting waterway. The necessary steps to implement use of these models in operational decisionmaking would be documented.

Additional funding would be directed towards acquisition and processing of satellite imagery for the entire Great Lakes – St. Lawrence River basin as part of a change analysis cycle and other detailed area impact studies. Modest funding would be used to develop and implement data standards and consistent analysis methods for determining land cover change and future projections specific to the needs of water resource decisionmaking for the system.

A prototype integrated and holistic model would be created to illustrate all the cause-effect relationships that exist between water withdrawals and biological impacts for differing habitats across the U.S. Great Lakes – St. Lawrence River basin. This prototype model would be applied to only 1 of the 109 U.S. tributary watersheds.

Funding would be directed toward posting information on all existing biohydrological data across the Great Lakes – St. Lawrence River system on registered clearinghouse nodes. Funding would be used to support expanding metadata standards that emphasize hydrologic and meteorologic data models and definition of their accuracies and consistencies for model input. Emphasis would be place on ensuring compliance of U.S. federal agencies with provisions of Executive Order 12906 to promote wide information exchange among users in the region. Funds would be used to develop a data exchange agreement and initiate procedures for sharing and accessing data.

Under this strategy, however, no additional investment would be spent on advancing geologic mapping to monitor the use of groundwater resources from Great Lakes – St. Lawrence River aquifers. Watershed response modeling would be compromised by incomplete digitizing of soils survey maps. Further, no new studies are included to evaluate natural stream dynamics, an important area for determining ecological sustainability goals. No improvements in knowledge of overlake precipitation and evaporation processes would occur. No substantial new collection and analysis of information on ice cover, sediment supply, nearshore wave energies and other abiotic parameters would occur. All such collection and analysis is needed to determine cumulative withdrawal impacts on coastal habitats. Limited funding would also delay full integration of modeling and would limit application of models to few problem watersheds.

Nevertheless, the Minimum Investment Strategy is expected to provide about 20% of the problem solutions needed to create an integrated and comprehensive biohydrological information system for the region. This cursory estimate is derived from further evaluations described in detail in Appendix K: *Cost Evaluations and Risk Assessments*. Under these evaluations, a subjective assessment is needed about the relative value of all 59 tasks for accomplishing a truly integrated information system.

(2). Biohydrological Information System – Selective Implementation Strategy

The "Selective Implementation Strategy" is the least costly strategy for an integrated system that includes all major hydrologic, hydraulic, geological, ecological and social data components. It is comprised of prioritized investments, which focuses on increased scientific rigor and defensibility in support of water resources decisionmaking. Few components are fully funded, but no essential components are excluded. This strategy represents a substantial monetary commitment to collect data, conduct research and integrate information systems.

Under the Selective Implementation Strategy, substantial improvements would be made to address the most-critical data gaps that currently exist. Detailed descriptions of the components of this plan are included in each of the report appendices.

With this strategy, knowledge of groundwater processes would be significantly improved. Increased priorities would be placed on digitizing soil survey information, conducting mapping of the stratigraphy in key watershed areas, and groundwater observation stations would be restored and maintained. Detailed aquifer mapping would be limited to a few high priority watersheds. Comprehensive detailed aquifer mapping would not occur, as is currently desired. Groundwater modeling would be developed for individual watersheds or subwatersheds based upon ~~critical~~ need. These models however could remain to be inconsistent between states, due to the detail of available data, adversely affecting regional decisionmaking.

Additional funding would be provided to maintain and improve the integrity of the U.S. stream gauging network at an increased federal cost-share. At least 50 new gauging stations would be installed in priority watersheds that are under increased demand for withdrawals, representing a 15% increase in the existing network. Additional instrumentation would be added to high priority gauging stations to collect information on abiotic parameters (water temperature, dissolved oxygen, conductivity, etc.). Installation and operation of all new gauging stations and instrumentation would be fully federally funded.

Detailed streamflow simulation modeling would be completed for at least 30 high priority gauged watersheds of the nearly 60 gauged watersheds within the U.S. Great Lakes – St. Lawrence River basin. The remaining gauged watersheds could not be modeled in detail within the costs outlined for this strategy. Meanwhile, a robust method would be developed for estimating streamflow in the approximate 50 ungauged watersheds within the U.S. Great Lakes – St. Lawrence River basin. A limited amount of funding would be provided under the Selective Implementation Strategy to support work by state natural heritage and historic programs to digitize archival maps of biological and cultural resources in riverine areas.

Under the Selective Implementation Strategy, advances would be made in monitoring and modeling the Great Lakes water balance. This is very important since the uncertainties in water supply estimates outweigh the magnitude of multiple prospective withdrawals from groundwater and in-stream sources. Reductions in uncertainties associated with overlake meteorological processes (e.g., precipitation, evaporation) will be addressed, albeit through strategic prototype projects and limited additional open-lake observations.

The accuracies of accounting for water flow between lakes, out of the St. Lawrence River and in diversions canals would be improved, primarily by advancement in water balance modeling techniques. Strategic investigations would be advanced to identify prospective improvements to the Lake Michigan Diversion accounting procedures to provide greater accuracy and timeliness in reporting.

Under this strategy, additional instrumentation would be added to existing water level gauging stations and on buoys and fixed stations offshore to monitor abiotic conditions such as temperature, salinity, conductivity and dissolved oxygen. In addition strategic advancements would be made in modeling ice and wave processes in the nearshore environments.

Existing hydrodynamic models would be implemented for continuous operations for all interconnecting waterways, Lake St. Clair and the St. Lawrence and calibrated to in-situ flow meters in each channelway. This monitoring and modeling would provide invaluable data for assessing the implications of water withdrawals on levels, flows and circulation patterns on nearshore habitats.

Under this strategy, funding for the National Water Use Information Program (NWUIP) would be increased with a reduced cost-share from the Great Lakes states. The focus of the program would be expanded with greater emphasis on groundwater and in-stream withdrawals, increased accuracies in metering, measuring or calculating withdrawals, and consistency between Great Lakes states. In particular, authority would be provided to require that all facilities in the public water supply and power generating facilities to directly measure and report withdrawals from surface and groundwater above the state registration level of 100,000 gal/day.

A systematic comparison of water use estimation methods in the Great Lakes states would be conducted and reported for all categories of water use and facilities where estimation is currently utilized. Pilot studies would be conducted to directly measure consumptive use for surface and groundwater withdrawals for selective water use categories or facility types. This strategy includes authority for periodic estimations of withdrawal for the livestock, irrigation, self-supplied domestic and other use categories, and withdrawals not directly measured for electric power facilities, public water supplies, and industrial uses below the state registration level of 100,000 gal/day. These investments would enhance consistency and reduce uncertainties in water uses. Scientific defensibility, however, still could not be guaranteed in all prospective cases.

A consistent and uniform methodology for demand forecasting of water withdrawals and uses for all USGS major watersheds would be developed as well. This would include establishment of a uniform schedule for conducting demand forecasts. A demand forecast would be conducted for at least one USGS major watershed draining in each of the Great Lakes. This would still be only about 5-10% of the total drainage basin within the U.S.

An important caveat of each of these water use monitoring endeavors would be new authority under the NWUIP for pass-through funding to regional and state coordinators to maintain uniform water withdrawal and use information across the region and report this information annually. Metadata standards for water use and withdrawal data would also be developed and implemented for all water use categories.

Significant efforts would be expended to develop habitat impact assessment tools to anticipate impacts of potential water withdrawal proposals, individually and cumulatively. Pilot ecological impact studies on lowland habitats would be completed on priority U.S. tributaries. Improvements would be made to the National Wetlands Inventory (NWI) database. Water withdrawal impact on terrestrial upland environments would be conducted as well to assess the utility of existing groundwater withdrawal models for operational decisionmaking.

Under the Selective Implementation Strategy, all nearshore environments in the Great Lakes, their interconnecting waterways, Lake St. Clair and the St. Lawrence River would be classified by geomorphic and hydrologic characteristics. This information would be used in conjunction with hydrodynamic models to initiate monitoring of cumulative water withdrawals impacts on levels, flows and circulation patterns in these environments, with initial emphasis on the St. Clair River – Lake St. Clair – Detroit River system.

Land use encroachment analyses would be conducted for all nearshore environments on the Great Lakes, excluding embayments and sediment transport studies would be conducted for the nearshore areas of lakes Erie and Ontario and in the St. Clair-Detroit rivers system.

Pilot studies would be conducted on historic and futures predictions of hydrologic impacts to high priority tributaries, emphasizing areas adjacent to rivers, streams and headwaters. These modeling initiatives would also focus on sediment transport impacts and abiotic changes.

Under the Selective Implementation Strategy, upland habitats would be classified by hydrology and geomorphology, using digital soils and stratigraphy information. With detailed land use and cover data proposed under this strategy, pilot studies could be conducted on the impacts of land use encroachment, climate change and cumulative water withdrawals for representative upland habitats within the U.S. Great Lakes basin.

Additional funding would be directed towards acquisition and processing of medium-resolution satellite imagery for the Great Lakes region as part of a change analysis cycle under the Coastal Change Analysis Program (C-CAP) and high-resolution imagery would be used to derived detailed land use/cover classification mapping for rapidly changing areas within the Great Lakes basin. Modest funding would be directed towards development of data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system. This strategy does not substantially address the need for rigorous assessments of historic demographic trends, nor does it include necessary periodic updates.

Increased funding would be used to upgrade the National Hydrologic Database (NHD) for the region with higher resolution digital data. Funding would be also directed towards the development of consistent data standards and analysis procedures, currently lacking across jurisdictional boundaries.

Funding would be directed towards integration of existing biohydrological data across the Great Lakes – St. Lawrence River system and posting of associated metadata to registered National Spatial Data Infrastructure (NSDI) clearinghouse nodes. Funding would also be used to support expanding metadata standards which would emphasize hydrologic and meteorologic data models and definition of their accuracies and consistencies for model input. Emphasis would be place on ensuring wide information exchange involving federal agencies in the region.

Finally, a prototype integrated and holistic model would be created to illustrate all the cause-effect relationships that exist between potential water withdrawals and biological impacts for differing habitats across the U.S. Great Lakes – St. Lawrence River basin. This prototype model would be applied to one high priority watershed.

In Appendix K: *Cost Evaluations and Risk Assessments*, a subjective assessment is made about the relative value of all 59 tasks in accomplishing a truly integrated information system. In this analysis, the Selective Implementation Strategy is expected to provide about 40% of the problem solutions needed to create an integrated and comprehensive biohydrological information system for the region.

(3). Biohydrological Information System – Enhanced Implementation Strategy

The "Enhanced Implementation Strategy" is the medium-costly strategy for an integrated information system that includes all essential hydrologic, hydraulic, geological, ecological, and social data components. It is comprised of extensive data collection, analyses and modeling, with enhanced information accuracies and decision support functionalities. This integrated information system option comes at a substantial capital cost though. Detailed descriptions of the components of this plan are included in each of the report appendices.

Under this strategy, knowledge of groundwater processes would be substantially improved. Soil survey information would be completely digitized for use in modeling applications for the entire region and a limited number of counties would be updated to promote consistency. Highly detailed three-dimensional geologic mapping would occur over 60% of the surface watershed of the Great Lakes – St. Lawrence River basin to provide extensive coverage of groundwater resources.

Funding would be dedicated to restoring and maintaining 300 underutilized groundwater observation wells throughout the U.S. Great Lakes groundwater basin. Pilot studies would be conducted in several watersheds to identify infiltration rates for various land cover types. Programmatic initiatives would be pushed to require direct measurements of groundwater withdrawals for all categories of use. Improved estimates of consumptive groundwater use by categories specific to the Great Lakes would be generated by conducting pilot studies that directly measure this attribute. As a consequence of these activities, the state-of-the-science in groundwater modeling would be radically improved. Within this strategy, comprehensive groundwater modeling would be developed for more than half of the U.S. Great Lakes watersheds.

Additional funding would be provided to maintain and improve the integrity of the U.S. stream gauging network at an increased federal cost-share. At least 90 new gauging stations would be installed to provide coverage over at least 75% of the U.S. tributary watersheds. Additional instrumentation would be added to existing and new gauging stations to collect information on abiotic parameters (water temperature, dissolved oxygen, conductivity, etc.). Installation and operation of all new gauging stations and instrumentation would be fully federally funded.

Detailed streamflow simulation modeling would be completed for all gauged watersheds within the U.S. Great Lakes – St. Lawrence River basin. Meanwhile, a robust method would be developed for estimating streamflow in the approximate 50 ungauged watersheds within the U.S. Great Lakes – St. Lawrence River basin.

Funding would be provided under this strategy to support work by state natural heritage and historic programs to digitize archival maps of biological and cultural resources in riverine areas and conduct thorough investigations on natural stream dynamics as a reference for implementing the Charter Annex improvement standard.

Under the Enhanced Implementation Strategy, advances would be made in monitoring and modeling the Great Lakes water balance. This is very important since the uncertainties in water supply estimates outweigh the magnitude of multiple prospective withdrawals from groundwater and in-stream sources. Reductions in uncertainties associated with overlake meteorological processes would be addressed. Additional hydrometeorological observations would be made from additional buoys and off-shore fixed stations. Over-lake precipitation and evaporation estimates would be made on a daily basis, relying on improved satellite and in-situ observations. These data would be used as direct inputs to continuous water balance modeling.

Additional instrumentation would also be added to existing water level gauging stations and off-shore buoys and structures to monitor abiotic conditions such as temperature, salinity, conductivity and dissolved oxygen. Substantial advancements would be made in monitoring nearshore ice and wave conditions and modeling their effects on nearshore ecological processes.

The accuracies of accounting for water flow between lakes, out of the St. Lawrence River and in diversions canals would be improved, primarily by advancement in water balance modeling techniques and in-situ flow metering in the interconnecting waterways and St. Lawrence River. Improvements would be implemented to increase accuracies and timeliness of outflow estimated through the Lake Michigan Diversion and New York State Barge Canal systems. Detailed investigations on the adequacy of diversion accounting would also focus on newer "minor" diversions within and outside the basin, such as municipal water system expansion to adjacent service areas.

Hydrodynamic models would be implemented for continuous operations for all interconnecting waterways, Lake St. Clair and the St. Lawrence and calibrated to in-situ flow meters in each channelway. Similar models for the open lakes would be expanded to include all embayments and enhanced to provide greater spatial detail in the nearshore environments. This monitoring and modeling would provide invaluable data for assessing the implications of water withdrawals on levels, flows and circulation patterns on nearshore habitats.

Under this strategy, funding for the National Water Use Information Program (NWUIP) would be increased substantially with a substantial reduced cost-share from the Great Lakes states. The focus of the program would be expanded with greater emphasis on groundwater and in-stream withdrawals, increased accuracies in metering, mandating direct measurements of groundwater and surface water withdrawals for selected user categories, conducting pilot studies on improving surface water consumptive use estimates and developing consistency in reporting between Great Lakes states. In particular, funding would be used to support of annual reporting of water withdrawal and use within the Great Lakes basin, with pass through funding to the Great Lakes states to build requisite infrastructure. These investments would enhance consistency and reduce uncertainties in water uses. Scientific defensibility for water withdrawal permitting would be substantially improved, if all these initiatives became realities.

An important caveat of each of these water use monitoring endeavors would be new authority under the NWUIP for pass-through funding to regional and state coordinators to maintain uniform water withdrawal and use information across the region and report this information annually. Metadata standards for water use and withdrawal data would also be developed and implemented for all water use categories.

A consistent and uniform methodology for demand forecasting of water withdrawals and uses for all USGS major watersheds would be developed as well. This would include establishment of a uniform schedule for conducting demand forecasts. A demand forecast would be conducted for one major watershed in each Great Lakes state. This could equate to 15-25% of the total drainage basin within the U.S.

Substantial efforts would be expended to develop habitat impact assessment tools to anticipate impacts of potential water withdrawal proposals, individually and cumulatively.

Under the Enhanced Implementation Strategy, all nearshore environments in the Great Lakes, their interconnecting waterways, Lake St. Clair and the St. Lawrence River would be classified by geomorphic and hydrologic characteristics. This information would be used in conjunction with hydrodynamic models to initiate monitoring of cumulative water withdrawals impacts on levels, flows and circulation patterns in nearshore and riverine environments. These models would be used to monitor abiotic changes of all nearshore environments.

Land use encroachment analyses would be conducted for all nearshore environments on the Great Lakes, including embayments. Detailed sediment impact studies would be conducted for the nearshore areas in the St. Marys, St. Clair and Detroit rivers and on all Great Lakes, including Lake St. Clair, but excluding embayments.

Pilot studies would be conducted on historic and futures predictions of hydrologic impacts to high priority tributaries, emphasizing areas adjacent to rivers, streams and headwaters. These modeling initiatives would also focus on sediment transport impacts and abiotic changes.

Under the Enhanced Implementation Strategy, upland habitats would be classified by hydrology and geomorphology, using digital soils and stratigraphy information. With detailed land use and cover data proposed under this strategy, pilot studies could be conducted on the impacts of land use encroachment, climate change and cumulative water withdrawals for representative upland habitats within the U.S. Great Lakes basin.

Additional funding would be directed towards acquisition and processing of medium-resolution satellite imagery for the Great Lakes region to conduct consistent and uniform historic change detection analysis. In addition, funding would be used to acquire and process high-resolution satellite imagery to create a high-resolution land cover dataset for all urban areas and major transportation arteries across the Great Lakes region with updates every 5-years. These tasks would include development of data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system.

Increased funding would be used to upgrade the National Hydrologic Database (NHD) for the region with higher resolution digital data wherever available. Additional, funding would be used to update and improve National Wetlands Inventory products to reflect high resolution and consistent wetlands mapping requirements. Funding would be also directed towards the development of consistent data standards and analysis procedures, currently lacking across jurisdictional boundaries.

Funding would be directed towards integration of existing biohydrological data across the Great Lakes – St. Lawrence River system and posting of associated metadata to registered National Spatial Data Infrastructure (NSDI) clearinghouse nodes. Funding would also be used to support expanding metadata standards which would emphasize hydrologic and meteorologic data models and definition of their accuracies and consistencies for model input. This strategy calls for development and implementation of a regional data exchange agreement to promote wide information exchange involving federal agencies in the region.

Finally, a prototype integrated and holistic model would be created to illustrate all the cause-effect relationships that exist between potential water withdrawals and biological impacts for differing habitats across the U.S. Great Lakes – St. Lawrence River basin. This prototype model would be applied to individual watersheds or subwatersheds based upon priority need.

In Appendix K: *Cost Evaluations and Risk Assessments*, a subjective assessment is made about the relative value of all 59 tasks in accomplishing a truly integrated information system. In this analysis, the Enhanced Implementation Strategy is expected to provide about 60% of the problem solutions needed to create an integrated and comprehensive biohydrological information system for the region.

(4). Biohydrological Information System – Full Implementation Strategy

The "Full Implementation Strategy" is the most costly strategy for an integrated information system that includes all hydrologic, hydraulic, geological, ecological, and social data components, fully funded. This option includes comprehensive and detailed data collection and analyses, state-of-the-science modeling and fully integrated information systems at all levels of government affected by Great Lakes – St. Lawrence River water resources decisionmaking. It represents the highest level of information integration that is potentially attainable.

Under this strategy, knowledge of groundwater processes would be substantially improved. Soil survey information would be completely digitized for use in modeling applications for the entire region and a limited number of counties would be updated to promote consistency. Highly detailed three-dimensional geologic mapping would occur over all of the surface watershed of the Great Lakes – St. Lawrence River basin and one county beyond this boundary to provide extensive coverage of groundwater resources.

Funding would be dedicated to restoring and maintaining 400 underutilized groundwater observation wells and installation of 100 new wells throughout the U.S. Great Lakes groundwater basin. Pilot studies would be conducted in several watersheds to identify infiltration rates for all land cover types. Comprehensive and detailed models of infiltration, recharge and drainage characteristics would be created for all tributary watersheds in the basin.

New programs would be initiated to measure and report groundwater withdrawals and consumptive uses for all water use categories. These requirements would likely require legislation at the federal and state levels and, hence, further consultations with the Great Lakes states. As a consequence of these activities, the state-of-the-science in groundwater modeling would be radically improved. As a consequence of these actions, comprehensive groundwater modeling could be developed for all of the U.S. Great Lakes watersheds.

Additional funding would be provided to maintain and improve the integrity of the U.S. stream gauging network at an increased federal cost-share. At least 250 new gauging stations would be installed to provide complete coverage for the 109 major U.S. tributary watersheds. Additional instrumentation would be added to existing and new gauging stations to collect information on abiotic parameters (water temperature, dissolved oxygen, conductivity, etc.). Installation and operation of all new gauging stations and instrumentation would be fully federally funded.

Detailed streamflow simulation modeling would be completed for all watersheds within the U.S. Great Lakes – St. Lawrence River basin. Within this strategy, no watershed would be ungauged. Additional research would be conducted to adjust historic hydrologic records for previously ungauged watersheds to reflect the enhanced knowledge on watershed response characteristics attained through gauging.

Funding would be provided under this strategy to support work by state natural heritage and historic programs to digitize archival maps of biological and cultural resources in riverine areas. This effort would include conducting thorough investigations on natural stream dynamics as a reference for implementing the Charter Annex improvement standard.

Under the Full Implementation Strategy, substantial advances would be made in monitoring and modeling the Great Lakes water balance. Reductions in uncertainties associated with overlake meteorological processes would be minimized by the production of daily over-lake and evaporation estimates derived from improved satellite and in-situ observations. These data would be used as direct inputs to continuous water balance modeling.

Additional instrumentation would also be added to all water level gauging stations and off-shore buoys and structures to monitor abiotic conditions such as temperature, salinity, conductivity and dissolved oxygen. Substantial advancements would be made in monitoring nearshore ice and wave conditions and modeling their effects on nearshore ecological processes.

The accuracies of accounting for inflows and outflows within the Great Lakes – St. Lawrence River system would be substantially improved, primarily by advancement in water balance modeling techniques and in-situ flow metering in the interconnecting waterways, St. Lawrence River and all major diversion canals. Improvements would be implemented to increase accuracies and timeliness of outflow estimated through the Lake Michigan Diversion and New York State Barge Canal systems and all "minor" diversions within and outside the basin, such as municipal water system expansion to adjacent service areas.

Hydrodynamic models would be implemented for continuous operations for all interconnecting waterways, Lake St. Clair and the St. Lawrence and calibrated to in-situ flow meters in each channelway. Similar models for the open lakes would be expanded to include all embayments and enhanced to provide greater spatial detail in the nearshore environments. This monitoring and modeling would provide invaluable data for assessing the implications of water withdrawals on levels, flows and circulation patterns on nearshore habitats.

Under this strategy, funding for water use accounting and reporting would be increased substantially with a greater U.S. federal role in cost sharing with the Great Lakes states. The focus of the initiative would be mandatory direct measurements of groundwater and surface water withdrawals for most user categories, determinations of groundwater and surface water consumptive uses and development of consistent reporting requirements between Great Lakes states on an annual basis. Scientific defensibility for water withdrawal permitting would be substantially improved, if these initiatives can be implemented.

An important caveat of each of these water use reporting endeavors would be new authority for pass-through funding to regional and state coordinators to maintain uniform water withdrawal and use information across the region and report this information annually. Metadata standards for water use and withdrawal data would also be developed and implemented for all water use categories.

A consistent and uniform methodology for demand forecasting of water withdrawals and uses for all USGS major watersheds would be developed as well. This would include establishment of a uniform schedule for conducting demand forecasts. A demand forecast would be conducted for all 109 USGS major watersheds in the U.S. Great Lakes – St. Lawrence River basin, with updates occurring every decade thereafter.

Substantial efforts would be expended to develop habitat impact assessment tools to anticipate impacts of potential water withdrawal proposals, individually and cumulatively.

Under the Full Implementation Strategy, all nearshore environments in the Great Lakes, their interconnecting waterways, Lake St. Clair and the St. Lawrence River would be classified by geomorphic and hydrologic characteristics. This information would be used in conjunction with hydrodynamic models to initiate monitoring of cumulative water withdrawals impacts on levels, flows and circulation patterns in nearshore and riverine environments. These models would also be used to monitor changes in the abiotic conditions of all nearshore environments.

Land use encroachment analyses and sediment transport modeling would be conducted for all nearshore environments on the Great Lakes, their embayments, interconnecting waterways, Lake St. Clair, and the St. Lawrence River, including embayments.

Comprehensive watershed modeling would be conducted on all lowland habitats throughout the 109 U.S. tributary watersheds to the system to assess historic streamflow changes and predict cumulative impacts from water demand into the future. Additional analyses would be conducted on land use impacts and sedimentation processes to discriminate their hydrologic impacts from cumulative water withdrawals.

Under the Full Implementation Strategy, upland habitats would be classified by hydrology and geomorphology, using digital soils and stratigraphy information. With detailed land use and cover data proposed under this strategy, comprehensive modeling would be conducted for all upland habitats on historic and predictive cumulative impacts from water withdrawals, land use changes and climate change.

Funding would be directed towards acquisition and processing of medium- and high-resolution satellite imagery for the Great Lakes region to conduct consistent and uniform historic change detection analysis. These data would be updated every three years within a prompt distribution schedule. The medium-resolution satellite imagery would be used to generate comprehensive coverages of land use and cover types for input to hydrologic response models of all watersheds. The high-resolution land cover dataset would be used to maintain current mapping for all urban areas and major transportation arteries.

Funding would be used to upgrade the National Hydrologic Database (NHD) for the region with higher resolution digital data wherever available. Additional, funding would be used to update and improve National Wetlands Inventory products to reflect high resolution and consistent wetlands mapping requirements. Funding would be also used for developing consistent data standards and analyses, currently lacking across jurisdictional boundaries.

Funding would be directed towards integration of existing biohydrological data across the Great Lakes – St. Lawrence River system and posting of associated metadata to registered clearinghouse nodes. Funding would also be used to support expanding metadata standards, which would emphasize hydrologic and meteorologic data models and definition of their accuracies and consistencies for model input.

The Full Implementation Strategy includes funding to facilitate coordination between federal, state and provincial agencies in the U.S. and Canada on the adoption of a formal data exchange agreement and implementation of protocols for sharing and accessing data electronically. This would require pass-through funding to the Great Lakes states to build requisite infrastructure.

Finally, an integrated and holistic model framework would be developed and implemented for all 99 watersheds across the U.S. Great Lakes – St. Lawrence River basin to resolve questions related to historic and predicted cumulative impacts of water withdrawals from the system. This integrated approach would include physical process models (groundwater, watershed hydrology, hydraulics, hydrodynamics, coastal and surface water quality) and ecological simulation and prediction models, their interconnections, and user interfaces.

In Appendix K: *Cost Evaluations and Risk Assessments*, a subjective assessment is made about the relative value of all 59 tasks in accomplishing a truly integrated information system. In this analysis, the Full Implementation Strategy is expected to provide a complete set of solutions needed for a comprehensive biohydrological information system for the region.

i. Analysis of Strategies

(1). Biohydrological System – Minimum Investment Strategy

In general, the Minimum Investment Strategy is designed to include the least costly measures needed to insure minimum functionality of a biohydrological information system for the region. Not all system components of an implementation plan are included in this option, so it is not considered to be a complete implementation strategy on its own accord. It simply addresses the most serious information shortcomings at the least cost.

The degree to which specific tasks are to be implemented under this strategy is described in detail within the appendices to this report. In addition, review of the relative values assigned for the tasks to be funded under this strategy showcases their interrelationships. These subjective assessments are contained in Appendix K: *Cost Evaluations and Risk Assessments*.

The Minimum Investment Strategy includes only modest expenditures for geologic and groundwater investigations, with costs expected to be about $4.5 M over five years. Upgrading and maintenance of existing stream gauging stations and development of watershed modeling is limited to about $7 M over the same period. Limited improvements in monitoring and modeling the receiving water of the Great Lakes to detect and predict cumulative water withdrawal impacts is expected to be $10 M over the same period under this strategy. Improvements in vital water use data collection and reporting programs are expected to be about $5.5 M for the same period.

The most important subsection of the integrated information system may well be the habitat impact predictive capabilities, which is expected to cost about $4.5 M over the five year implementation period for limited investment. Finally, limited improvements in monitoring demographic trends through land use/cover mapping projects and development of an integrated information system to provide ready-access for decisionmakers are expected to be about $1 M and $4.5 M, respectively over the five-year implementation period.

The total cost expected for implementing the Minimum Investment strategy is $36 M, with the majority of work to be completed within five years.

(2). Biohydrological System – Selective Implementation Strategy

In general, the Selective Implementation Strategy is designed to include the least costly measures needed to insure minimum functionality of a biohydrological information system for the region. Not all system components of an implementation plan are included in this option, so it is not considered to be a complete implementation strategy on its own accord. It simply addresses the most serious information shortcomings at the least cost.

The degree to which specific tasks are to be implemented under this strategy is described in detail within the appendices to this report. In addition, review of the relative values assigned for the tasks to be funded under this strategy showcases their interrelationships. These subjective assessments are contained in Appendix K: *Cost Evaluations and Risk Assessments*.

The Selective Implementation Strategy includes substantial new investment in geologic and groundwater investigations, with costs expected to be about $169 M over ten years. Upgrading and maintenance of existing stream gauging stations and development of watershed modeling would be significant, costing about $37 M over the same period. Significant improvements in monitoring and modeling the receiving water of the Great Lakes to detect and predict cumulative water withdrawal impacts in the nearshore and in the interconnecting waterways is expected to be $34 M over the same period under this strategy.

Improvements in water use data collection and reporting programs are expected to be about $42 M for the same period. Habitat impact monitoring and predictive forecasting tools are expected to cost about $72 M over the ten year implementation period for this strategy. Improvements in monitoring and predicting demographic trends are expected to cost about $4 M under this strategy, while information integration and modeling are expected to cost about $10 M over the 10-year implementation period.

The total cost expected for implementing the Selective Implementation Strategy is $370 M with work being conducted over a 10-year period.

(3). Biohydrological System – Enhanced Implementation Strategy

The Enhanced Implementation Strategy is the medium-costly strategy for an integrated information system that includes all essential hydrologic, hydraulic, geological, ecological, and social data components. It is comprised of extensive data collection, analyses and modeling, with enhanced information accuracies and decision support functionalities. This integrated information system option comes at a substantial capital cost though.

The degree to which specific tasks are to be implemented under this strategy is described in detail within the appendices to this report. In addition, review of the relative values assigned for the tasks to be funded under this strategy showcases their interrelationships. These subjective assessments are contained in Appendix K: *Cost Evaluations and Risk Assessments*.

The Enhanced Implementation Strategy includes substantial new investment in geologic and groundwater investigations with broad coverage areas, with costs expected to be about $352 M over ten years. Upgrading and maintenance of existing stream gauging stations and development of watershed modeling for broader geographic extent would be significant, costing about $80 M over the same period.

Significant improvements in monitoring and modeling the receiving water of the Great Lakes to detect and predict cumulative water withdrawal impacts in the nearshore and in the interconnecting waterways is expected to be $60 M over the same period under this strategy. Improvements in ~~critical~~ water use data collection and reporting programs are expected to be about $114 M for the same period. Habitat impact monitoring and predictive forecasting tools, deployed over half of the U.S. watersheds are expected to cost about $138 M over the ten year implementation period for this strategy. Improvements in monitoring and predicting demographic trends are expected to cost about $5 M under this strategy, while information integration and modeling are expected to cost about $14 M over the 10-year implementation period.

The cost expected for implementing the Enhanced Implementation Strategy is $800 M with work being conducted over a 10-year period.

(4). Biohydrological Information System – <u>Full Implementation Strategy</u>

The Full Implementation Strategy is the most costly strategy for an integrated information system that includes all hydrologic, hydraulic, geological, ecological, and social data components, fully funded. This option includes comprehensive and detailed data collection and analyses, state-of-the-science modeling and fully integrated information systems at all levels of government affected by Great Lakes – St. Lawrence River water resources decisionmaking. It represents the highest level of information integration that is potentially attainable.

The degree to which specific tasks are to be implemented under this strategy is described in detail within the appendices to this report. In addition, review of the relative values assigned for the tasks to be funded under this strategy showcases their interrelationships. These subjective assessments are contained in Appendix K: *Cost Evaluations and Risk Assessments*.

The Full Implementation Strategy includes substantial new investment in geologic and groundwater investigations with comprehensive coverage of the Great Lakes surface water basin and adjacent areas, with costs expected to be about $648 M over ten years. Substantial upgrading of the existing stream gauging network and development of watershed modeling for all surface water drainage areas would be completed, costing about $195 M over the same period.

Significant improvements in monitoring and modeling the receiving water of the Great Lakes to detect and predict cumulative water withdrawal impacts in the nearshore and in the interconnecting waterways is expected to be about $96 M over the same period under this strategy. Extensive expansion of water use data collection and reporting programs would occur with expected costs of about $365 M for the same period.

Habitat impact monitoring and predictive forecasting tools, deployed over all of the U.S. watersheds are expected to cost about $310 M over the ten year implementation period for this strategy. Improvements in monitoring and predicting land use and cover changes into the future are expected to cost about $10 M under this strategy, while information integration and modeling are expected to cost about $18 M over the 10-year implementation period.

The total cost expected for implementing the Enhanced Implementation Strategy is $1.6 B with work being conducted over a 10-year period.

Although the Full Implementation Strategy requires substantial costs to be implemented, it represents the highest confidence that is likely achievable in supporting water withdrawal decisions. Societal reluctance to extensive monitoring of water uses and other prescriptive measures, however, may severely detract from its implementability.

(5). Risk Assessments

Risk and uncertainty are inherent aspects of all facets of an integrated information system for water management of the Great Lakes – St. Lawrence River system. Risk can be viewed relative to human and aquatic health, to real property, to the ability to attain profit from a commercial venture, or to relative benefits that can be attained at given investment levels.

The integrated information system described within this report, once improved above current conditions, has a very low likelihood of adverse risk to human health, life or personal property. It is simply a monitoring, modeling and predictive system that does not include significant physical structures or construction. The converse does apply however; continued financial stressors on the monitoring system can cause atrophy of monitoring abilities which could, in turn, mask physical, chemical and biologic change to natural streamflow throughout the system. Risk is also factored in throughout this report related to the prospective reward or benefit attained at increasing levels of investment. Each task in the integrated information system is evaluated in terms of cost effectiveness, whenever practical.

Uncertainty is pervasive throughout the design, implementation and operation of any integrated water management system. At the current level of investment in groundwater, surface water and open lake monitoring and modeling, cumulative withdrawals from headwater systems cannot be detected, measured or adequately estimated. Hence, the uncertainty of cumulative hydrologic effects is extremely large under the Without Plan and Minimum Investment Strategies.

Even with Full Implementation Strategy, uncertainty will continue to exist, albeit at a much lower level. This uncertainty would be accompanied, however, with an error budget including almost all hydrologic and biologic factors, which currently does not exist.

The analytical functions of the integrated information system will generally have reduced uncertainties as funding increases from one implementation strategy to the next. In addition, these uncertainties can be computed with greater confidence as more investment is made in the monitoring frame and computer modeling. The legal defensibility of permitting water withdrawal improves as uncertainty is reduced, in part or in total.

The uncertainty associated with the amount of resources needed to solve the information integration problem, however, can be addressed using conventional USACE risk assessment procedures adapted to the area of study addressed in this report. Following is a brief description of how these risk assessment procedures have been employed in this project. Costs have been estimated for the four potential strategies that require additional investment over a 10-year implementation schedule.

Costs are based on the best available information through extensive research and review by project collaborators. These estimations are a means of comparing the costs between the proposed levels of implementation, as well as visualizing the amount of effort needed to support decisionmaking related to groundwater and other physical systems within the Great Lakes basin. The proposed costs for each task consider other costs outlined in other appendices to avoid double accounting. The cost estimates for each implementation option reflect anticipated economies of scale, whenever applicable.

Costs that are proposed under each task for each strategy are evaluated based upon the inherent uncertainties that currently exist. The proposed costs are provided as a range of costs, between lowest possible and highest possible, with a proposed estimate that does not in all cases represent the median of the highest/lowest estimates (normally distributed). A measure of statistical distribution is chosen to reflect the nature of the confidence available for these estimates. The lowest, proposed and highest cost estimates are used, along with an appropriate statistical distribution, in a Monte Carlo simulation of 10,000 possible occurrences to determine an expected cost for each task for each strategy.

The expected costs are then used along with a subjective measure of the relative value of each task in the integrated information system to determine whether one strategy is more cost effective than another. This test is completed for all 59 tasks defined as significant components in the integrated biohydrological information system. The results of the Cost Effectiveness Analysis are provided in the following section of the main report.

An Incremental Analysis is completed after the Cost Effectiveness Analysis in order to compare the per-unit cost of each prospective level of each task. Units of output were represented by an ordinal ranking of the expected outcomes based on knowledge of the respective topics. The incremental cost is then determined based on the expected cost obtained in the Monte Carlo analysis. The results of the Incremental Analysis are presented in the following Trade-Off Analysis section.

The expected costs for each task is detailed in Table 1. Details of the derivation of the expected costs, cost effective test, and incremental cost test are discussed in Appendix K: *Cost Evaluations and Risk Assessments*.

Table 1: Expected Implementation Costs

Task #	App #	Abbreviated Task Description	Without Plan	Minimum (in $M)	Selective (in $M)	Enhanced (in $M)	Full (in $M)
1	B	Digital Soil Surveys	$ 0	$ 0	$ 39.000	$ 50.000	$ 78.000
2		3-D Geological Maps	$ 0	$ 0	$ 120.000	$ 270.000	$ 440.000
-		GW Assessments (Tasks 3-7)					
3		GW Observation Wells	$ 0	$ 0.750	$ 3.200	$ 10.000	$ 20.000
4		Infiltration Rates	$ 0	$ 1.100	$ 1.100	$ 2.000	$ 5.000
5		GW Extraction Rates	$ 0	$ 2.000	$ 5.000	$ 10.000	$ 50.000
6		GW Consumptive Uses	$ 0	$ 0.100	$ 0.100	$ 0.500	$ 20.000
7		GW Modeling	$ 0	$ 0.500	$ 0.500	$ 10.000	$ 35.000
8	C	Anthropogenic Changes	$ 0	$ 0	$ 1.000	$ 3.000	$ 5.000
-		Watershed Modeling (Tasks 9-13)					
9		Streamgauging Network	$ 0	$ 5.250	$ 20.000	$ 35.000	$ 60.000
10		Abiotic Sampling in Streams	$ 0	$ 0	$ 6.000	$ 24.000	$ 60.000
11		Instream Withdrawals	$ 0	$ 1.000	$ 5.000	$ 10.000	$ 50.000
12		Instream Consumptive Uses	$ 0	$ 0.100	$ 0.100	$ 0.500	$ 10.000
13		Gauged Watershed Modeling	$ 0	$ 0.200	$ 4.500	$ 7.500	$ 9.000
14		Ungauged Estimation	$ 0	$ 0.400	$ 0.400	$ 0.400	$ 0.500
15	D	Net Basin Supply Estimation (Incorporates Tasks 16-18)	$ 0	$ 4.000	$ -	$ -	$ -
16		Overlake Precipitation	$ 0	$ -	$ 2.500	$ 6.000	$ 6.000
17		Overlake Evaporation	$ 0	$ -	$ 1.500	$ 1.500	$ 1.500
18		Overlake Hydrometeorology	$ 0	$ -	$ 0.500	$ 2.500	$ 11.000
19		Ice Cover Monitoring	$ 0	$ -	$ 1.500	$ 3.500	$ 5.500
20		Wave Estimation	$ 0	$ -	$ 1.500	$ 2.500	$ 3.500
21		Circulation Modeling	$ 0	$ 1.500	$ 1.500	$ 3.500	$ 3.500
22		Nearshore Abiotic Conditions	$ 0	$ 0	$ 2.000	$ 8.000	$ 18.000
23		Inter Waterways Monitoring	$ 0	$ 3.000	$ 16.000	$ 20.000	$ 23.500
24		Inter Waterways Abiotics	$ 0	$ 0	$ 3.500	$ 6.000	$ 12.000
25		Diversion Accounting	$ 0	$ 1.500	$ 3.000	$ 6.000	$ 12.000
26	E	NWUIP Improvements	$ 0	$ 1.500	$ 16.000	$ 32.000	$ 60.000
27		Water Withdrawal Reporting	$ 0	$ 2.000	$ 6.000	$ 11.000	$ 11.000
28		Water Use Uncertainties	$ 0	$ 0	$ 0.500	$ 2.000	$ 4.000
29		Water Use Estimations	$ 0	$ 1.000	$ 5.000	$ 10.000	$ 20.000
30		Water Use Direct Measurements	$ 0	$ 0	$ 12.000	$ 24.000	$ 62.000
31		Consumptive Use Estimation	$ 0	$ 0.500	$ 0.500	$ 23.000	$ 58.000
32		Demand Forecasting	$ 0	$ 0.300	$ 1.500	$ 12.000	$ 150.000

Table 1 – Expected Implementation Costs (continued)

Task #	App #	Abbreviated Task Description	Without Plan	Minimum (in $M)	Selective (in $M)	Enhanced (in $M)	Full (in $M)
-		IW Habitat Modeling (Tasks 33-37)					
33		Inter Waterways Hydraulics	$ 0	$ 0.500	$ 10.000	$ 10.000	$ 10.000
34		Inter Waterways Land Use	$ 0	$ 0	$ 2.000	$ 2.000	$ 2.000
35		Inter Waterways Sedimentation	$ 0	$ 0	$ 1.000	$ 10.000	$ 15.000
36		Inter Waterways Geomorphology	$ 0	$ 0.250	$ 0.250	$ 0.250	$ 0.250
37		Inter Waterways Abiotic Changes	$ 0	$ 0	$ 1.500	$ 4.000	$ 4.000
-		Nearshore Habit Modeling (Tasks 38-42)					
38		Nearshore Hydrology Impacts	$ 0	$ 0.500	$ 2.200	$ 3.200	$ 3.200
39		Nearshore Land Use Impacts	$ 0	$ 0.200	$ 2.000	$ 6.000	$ 6.000
40		Nearshore Sediment Impacts	$ 0	$ 0	$ 2.000	$ 10.000	$ 20.000
41		Nearshore Classification	$ 0	$ 0.250	$ 0.250	$ 0.600	$ 0.600
42	G	Nearshore Abiotic Changes	$ 0	$ 0	$ 1.500	$ 1.500	$ 3.000
-		Lowland Habitat Modeling (Tasks 43-47)					
43		Lowland Hydrology Impacts	$ 0	$ 1.000	$ 1.000	$ 3.000	$ 5.000
44		Lowland Land Use Impacts	$ 0	$ 0	$ 2.000	$ 10.000	$ 50.000
45		Lowland Sediment Impacts	$ 0	$ 0	$ 25.000	$ 50.000	$ 150.000
46		Lowland Geomorphology	$ 0	$ 1.000	$ 12.000	$ 12.000	$ 12.000
47		Lowland Abiotic Changes	$ 0	$ 0	$ 6.000	$ 13.000	$ 20.000
-		Upland Habitat Modeling (Tasks 48-51)					
48		Withdrawals on Upland Habitat	$ 0	$ 0.500	$ 0.500	$ 0.500	$ 2.500
49		Upland Land Use Impacts	$ 0	$ 0	$ 1.000	$ 1.000	$ 3.000
50		Upland Geomorphology	$ 0	$ 0	$ 0.250	$ 0.500	$ 0.500
51		Upland Climate Change	$ 0	$ 0	$ 1.000	$ 1.000	$ 3.000
52		Medium Land Cover Mapping	$ 0	$ 0.300	$ 0.300	$ 0.500	$ 1.500
53	I	High Land Cover Mapping	$ 0	$ 0.600	$ 3.000	$ 4.500	$ 7.000
54		Land Cover Change	$ 0	$ 0.200	$ 0.200	$ 0.300	$ 1.600
55		Clearinghouse Node	$ 0	$ 0.700	$ 0.700	$ 0.700	$ 0.700
56		Metadata Standards	$ 0	$ 0.500	$ 2.000	$ 4.000	$ 6.000
57	J	Metadata Postings	$ 0	$ 0.700	$ 0.700	$ 0.700	$ 0.700
58		Regional Data Exchange	$ 0	$ 1.000	$ 5.000	$ 5.000	$ 5.000
59		Decision Support Model Integration	$ 0	$ 1.500	$ 1.500	$ 3.000	$ 5.000
Total Expected Costs (rounded to nearest $10M)			**$ 0**	**$ 36,000**	**$ 370,000**	**$ 800,000**	**$ 1,640,000**

j. Trade-off Analysis

(1). Biohydrological Information System – Minimum Investment Strategy

The results of the Cost Effectiveness and Incremental Analyses, as presented in Appendix K: *Cost Evaluations and Risk Assessments,* does show that the Minimum Investment Strategy is less cost effective for only 1 of the 59 requisite tasks of the integrated biohydrological information system.

The Incremental Analysis provides additional information as some tasks have a lower incremental cost under the Minimum Investment Strategy than the other strategies, while others have somewhat higher incremental costs. This should be expected since the degree of investment for an individual task within a strategy was designed to provide an integrated solution, with cost being the primary discriminator. As such, trade-offs between implementation strategies need to be based upon the willingness to fund implementation of each component task as a function of the anticipated benefits attained (greater accuracy in decisionmaking).

The Minimum Investment Strategy is the basic essential level of investment in improving the knowledge base dealing with cumulative water withdrawal impacts on the sustainability of the water resources within the Great Lakes – St. Lawrence River watershed. Substantial detail and significant improvements in reducing uncertainties will not be achieved, however, under this strategy. This strategy simply arrests the deterioration of the streamflow and groundwater monitoring networks over the region and puts monetary resources behind key tasks needed to support the water withdrawal permit decisionmaking process.

(2). Biohydrological Information System – Selective Implementation Strategy

The results of the Cost Effectiveness and Incremental Analyses, as described in Appendix K: *Cost Evaluations and Risk Assessments,* does not show that the Selective Implementation Strategy is less cost effective than any other strategy for any of the 59 requisite tasks of the integrated biohydrological information system. The Incremental Analysis provides additional information, but this information may not be extremely relevant for the Trade-Off Analysis. Again, some tasks have a lower incremental cost while others have higher incremental costs than the other strategies. This should be expected since the degree of investment for an individual task within a strategy was designed to provide an integrated solution, with cost being the primary discriminator. As such, trade-offs between implementation strategies can only be based upon the willingness to fund implementation of each component task as a function of the anticipated benefits attained (greater accuracy in decisionmaking).

The Selective Implementation Strategy represents a substantial shift in investment towards monitoring, mapping, modeling and analysis of cumulative anthropogenic impacts on Great Lakes – St. Lawrence River water resources. Over the last two decades substantial encroachment or atrophy has affected the viability of the stream gauging and groundwater observation networks. Meanwhile water resource problems have become more complex involving a host of economic, environmental and social factors and cumulative impacts of water uses over space and time. As such, it is prudent to consider this strategy over the Minimum Investment Strategy. Although this represents a 10-fold increase in cost over the Minimum Investment Strategy, it is shown through the relative value assessment process contained in Appendix K to provide an invaluable two-fold increase in information and attendant reductions in uncertainty.

This strategy, like the more expensive strategies discussed below, is designed to be conducted over a 10-year implementation schedule. Implementation of this strategy would allow for a reevaluation of the applicability and importance of the biohydrological information system components presented within this report a decade from the present. As such, adoption of this strategy may in fact be an interim measure that would clarify the needs for more intensive monitoring, analyses and modeling and would likely refine the cost estimates and scheduling for further investments.

(3). Biohydrological Information System – Enhanced Implementation Strategy

The results of the Cost Effectiveness and Incremental Analyses tests, as described in Appendix K: *Cost Evaluations and Risk Assessments,* show that the Enhanced Implementation Strategy is less cost effective than the other three strategies for only 3 tasks (Task 10: Abiotic Stream Sampling, Tasks 23: Interconnecting Waterways Hydrodynamics and Task 30: Water Use Direct Measurements) of the total 59 tasks involved in the integrated biohydrological information system. In these cases, the cost effectiveness tests are missed slightly and could be justified as being minor exceptions within the aggregated implementation strategy. As such, trade-offs between implementation strategies should be based upon the willingness to fund implementation of each component task as a function of the anticipated benefits attained (greater accuracy in decisionmaking).

The Enhanced Implementation Strategy provides at least fifty percent greater benefits to the decision process than that provided under the Selective Implementation Strategy as determined through the relative value assessment process contained in Appendix K. This strategy provides the most optimized mix of monitoring, analysis, modeling and information integration than all other plans other than the Full Implementation Strategy. It does represent a substantially aggressive and ambitious vision, which would require an established infrastructure to exist within federal agencies and collaborating regional and state interests to be implemented rapidly. In many cases, it could be challenging to meet the objectives outlined under each of the 59 tasks under this strategy within a 10-year project schedule.

(4). Biohydrological Information System – Full Implementation Strategy

The results of the Cost Effectiveness and Incremental Analyses tests, as described in Appendix K: *Cost Evaluations and Risk Assessments,* do not show that the Full Implementation Strategy to be less cost effective than any other strategy for any of the 59 requisite tasks of the integrated biohydrological information system. As such, trade-offs between implementation strategies should be based upon the willingness to fund implementation of each component task as a function of the anticipated benefits attained (greater accuracy in decisionmaking).

The Full Implementation Strategy provides 5-times the benefits of the Minimum Investment Strategy, 2.5-times the benefits of the Selective Implementation Strategy and about 50% more benefits than the Enhanced Implementation Strategy. The cost of this strategy ($1.64 B) is likely too prohibitive, however.

Meanwhile, some tasks under this strategy may not be implementable within a 10-year time period. For example, Task 2 (the most expensive individual task) for this strategy calls for the generation of high-resolution three-dimensional geological mapping of groundwater resources for over 2,200 1:24,000 scale quadrangles. The quantity of this work effort is staggering in that there may not be enough geologists available in the government, private sector or in university training to accomplish this work within the desired 10-year time period. Similar circumstances may surround other tasks where existing qualified manpower resources may be inadequate to be directed towards accomplishing the desired results within the desired timeframe.

Furthermore, the Full Implementation Strategy would entail direct measurements of all major water withdrawals from the groundwater, surface water and open lake sources. Such an ambitious initiative will likely not be societally acceptable, if a substantial burden for these monitoring costs is to be borne by private citizens and corporate concerns. In addition, these tasks also would require either voluntary reporting or mandatory requirements with compliance measures that could be underestimated within this report.

7. Summary of Coordination and Comments

In the fall of 2002, project staff initiated compilation of the biohydrological information inventory and identified project stakeholders and a process for coordinating study activities and consulting with the states, Canadian provinces, Indian tribes and U.S. and Canadian federal agencies with a mandate or identified interest in the study.

On April 3, 2003, project staff convened a meeting of project stakeholders at National Oceanic and Atmospheric Administration (NOAA's) Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan. The purpose of the meeting was to introduce the study to representatives of federal agencies (and other important stakeholders) within the region, review the preliminary inventory of physical, ecological and biological information, and discuss information system needs. The participants suggested some fundamental changes in the way the information was to be organized, and recommended the implementation of a focus group approach for reviewing individual data sets within categories.

Between May and October 2003, project staff convened a series of conference calls to provide an opportunity for U.S. federal agency representatives and other stakeholders to comment on draft data sets and preliminary implementation plans. These conference calls were set up to address issues presented in the study appendices. Suggestions and corrections from stakeholders have been incorporated into this report.

The names and contact information for agency representatives engaged in the development of this report can be found in Appendix L: *Project Background*.

8. Closing

This document was developed to produce an inventory of available Great Lakes water resource data, identify what future additions or improvements would be very advantageous to the existing data sets, and anticipate the general benefits (and beneficiaries) of creating a comprehensive Great Lakes Biohydrological Information Database.

However, in light of the different strategic options identified in this work, there is no fully applicable analysis tool or system in existence that can adequately and defensibly recommend any one of the strategies over another. Although the Decision Support System identified earlier in this work is an analysis tool, it does not provide an adequate measure for comparing the value of data types that may be needed for water management decisions. The use of a "trade off analysis" generally weighs benefits vs. impacts in a qualitative fashion, however, the various strategies need to be analyzed quantitatively. This investigation would need to include a benefit/cost analysis to fully justify whether future funding under a particular strategy would be prudent and beneficial.