CHAPTER 1
EXECUTIVE SUMMARY

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1.1. WATER RESOURCES MANAGEMENT DECISION SUPPORT SYSTEM PROJECT

1.1.1 THE GREAT LAKES AND RESOURCE DEMANDS

The Great Lakes, their connecting channels and the St. Lawrence River collectively comprise the world's largest body of fresh surface water, which provides the region's eight states and two provinces with an abundance of high quality fresh surface water. The Great Lakes system contains 6.5 quadrillion gallons (24.6 quadrillion litres) of fresh surface water, 20 percent of the world's supply. The Great Lakes influence and are inseparably linked to the region's environmental health, economic well being and quality of life as they play an important role in advancing and sustaining the regional and national economies. The Great Lakes system, however, is a fragile ecosystem, and even minor physical, chemical or biological changes to the system can have individual and cumulative effects with lasting implications for the conservation, protection and wise use of the resource.

In many areas of North America, existing sources of water are being stressed by withdrawals and diversions from aquifers, lakes, rivers and reservoirs to meet the needs of cities, farms, homes and industries. The water rich region of the Great Lakes-St. Lawrence River has been relatively immune from serious water shortages and water supply problems. However, as population and economic growth in the Great Lakes-St. Lawrence River basin has occurred, in-basin water uses have increased and are projected to continue (Tate and Harris, 1999). Communities within Great Lakes jurisdictions that are situated just outside Great Lakes basin surface water boundaries also have looked to basin water sources as a supply source. As other regions encounter difficulty meeting their water needs, the Great Lakes system has increasingly been viewed as a potential source of high quality freshwater to meet these non-basin needs. Implications of this increased interest present a significant challenge for Great Lakes water policy makers and resource managers.

1.1.2 WATER RESOURCES MANAGEMENT DECISIONMAKING

As scientists, managers and policymakers gain an increased understanding of the range and complexity of issues surrounding the region's needs and demands for high quality fresh water, they are increasingly relying on data, information and technology to answer difficult questions and inform their research. Decision support systems are becoming an important tool in the fields of water resources science, planning and management. A Decision Support Systems (DSS) is a broad concept that typically involves both descriptive information systems as well as standard, prescriptive optimization approaches. It may be defined as 'any and all data, information, expertise and activities that contribute to option selection' (Andriole, 1989).

The Great Lakes Commission and its project collaborators initiated this project, titled *Toward a Water Resources Management Decision Support System for the Great Lakes,* in August 2000 in response to the increasing need for data and information on Great Lakes-St. Lawrence River water resources and the governors' and premiers' renewed attention and commitment to Great Lakes water resources management. This multi-year initiative has involved the compilation and synthesis of information on the status of Great Lakes water resources, current water uses, and ecological impacts of individual and cumulative water withdrawals.

The impetus for this project can be traced to a statement issued by the Council of Great Lakes Governors in late 1999 that provided a set of principles for a stronger water resources management framework for the region. Through this statement, which built upon the Great Lakes Charter of 1985 and led to the development of the Great Lakes Charter Annex in 2001, the governors and premiers agreed that a durable, simple, and efficient water management regime is needed to protect the resource and retain decisionmaking authority within the basin. Although work under the Water Resources Management Decision Support System (WRMDSS) project commenced before the signing of the Charter Annex and the establishment of the Charter Annex working groups, the two efforts have been interconnected and WRMDSS project work has supported Annex implementation.

1.1.3 PROJECT OUTCOMES

This project has produced several major products, which singly and collectively strengthen water quantity decisionmaking processes. Chapters 2 through 9 describe project outcomes in detail. Chapter 2 provides a report introduction, Chapters 3 through 7 describe specific project activities and outcomes, Chapter 8 looks at information and communications and Chapter 9 synthesizes project work. Findings and recommendations of the report provide valuable information for guiding the next steps. This report, and its many associated components, provide a wealth of information about the water resources and associated policies related to the Great Lakes-St. Lawrence basin. Appendices, which include the full text of reports summarized in this document, are attached in CD-ROM form and are available at http://www.glc.org/wateruse/wrmdss.html.

1.2. CHAPTER 3: STATUS ASSESSMENT OF GREAT LAKES-ST. LAWRENCE RIVER WATER RESOURCES

Chapter 3 provides a summary of the efforts of the Status Assessment of Water Resources Technical Subcommittee and includes descriptions of the hydrology of the Great Lakes, the process for measuring levels and flows, and the uncertainty associated with measurements of levels and flows. This assessment lays the groundwork for a decision support system that is applicable to a broad range of variables and geographic areas ranging from small sub-basins (e.g., a single tributary) to the entire Great Lakes-St. Lawrence system. The chapter also recommends improvements to current monitoring activities that will enhance decisionmaking processes.

Although a significant amount of hydrologic monitoring occurs in the Great Lakes basin, current monitoring targets specific needs that do not fully address the needs of the Annex's decisionmaking standard. Several agencies collect Great Lakes hydrologic data and calculate levels and flows, and often use distinct methods to collect data and calculate flows. Data are not available for all flows on a binational basis; coordination on its collection and analysis is inadequate. Potential problems include the diversity of hydrologic data and information sources, inconsistencies in metadata, lack of compatibility with geographic information systems for some data, and limited accessibility to data on the Internet.

Decisionmakers do not always understand or consider the variability of the hydrologic system and the limitations of hydrologic measurements. All levels and flows are variable in the short and long-term and at many spatial scales. Also, all measurements and calculations are inherently uncertain. However, most reported flows are long-term averages at large spatial scales, and associated data uncertainties are not reported and often not calculated.

Uncertainties associated with measurements of levels and flows hinder the ability to assess effects from withdrawals on a system-wide level. Even though the effects of a withdrawal on levels and flows cannot currently be detected by measurements, existing models can accurately predict the effects of withdrawals on connecting channel flows, lake levels, or hydroelectric production.

On a sub-watershed scale, sufficient streamflow and groundwater data are available in many areas of the basin to predict effects of in-stream and groundwater withdrawals. Only large-scale groundwater withdrawals are likely to be detected in streamflow, but this ability depends on the scale of withdrawal relative to the scale of baseflow. Standard approaches are available to collect the hydrologic information needed to make decisions on in-stream and groundwater withdrawals.

1.2.1 RECOMMENDATIONS

Chapter 3 offers the following recommendations:

1. Develop common data standards and common reporting practices for hydrologic data and information relevant to the Annex.
2. Evaluate current monitoring networks within the context of the Annex, after a decisionmaking standard is agreed upon.
3. Develop a single Internet gateway that accesses primary data sources and provides consistent data and metadata by way of a geographic information system.
4. Systematically evaluate current streamflow gaging so as to (1) quantify uncertainties, (2) identify optimal locations for new gauges, if needed, and (3) recommend a core minimum and optimal network of gauges that will meet decisionmaking needs.

5. Develop a robust method to calculate streamflow for ungaged areas that (1) makes use of statistically significant physical characteristics of the watershed and (2) calculates an associated uncertainty for the flow.
6. Develop a preliminary groundwater flow model for the Great Lakes basin that (1) incorporates known groundwater divide locations, (2) identifies and prioritizes data needs, and (3) identifies locations and quantities of groundwater discharge directly to the Great Lakes.
7. Develop coordinated binational calculations for the entire Great Lakes basin using common data standards and models.
8. Develop a basin-wide standard model to calculate precipitation directly on the lake surface that makes use of existing weather radar data and that incorporates calculations of uncertainty.
9. Develop a basin-wide standard model to estimate evaporation from the Great Lakes that makes maximum use of remote sensing technology and that incorporates calculations of uncertainty.
10. Develop a common set of standards for calculating flow and a "best approach" for each connecting channel that includes calculations of uncertainty.
11. Develop a common set of standards for calculating flow and a "best approach" for each diversion that includes calculations of uncertainty.
12. Support the continued maintenance and enhancement of the Great Lakes water level gauging network.
13. Secure agency commitments to core, long-term, geographically distributed monitoring needed to implement the decision standard.
14. Continue development and refinement of system-wide hydraulic models, so that effects of proposed withdrawals and the uncertainty of the effects can be predicted.
15. Develop common standards for collecting and analyzing the hydrologic information that is necessary to make decisions and that is suitable for predicting ecological impacts.
16. Incorporate an understanding of variability and uncertainty in levels and flows into the decisionmaking process.

1.3. CHAPTER 4: INVENTORY OF WATER WITHDRAWAL AND USE DATA AND INFORMATION

Chapter 4 describes the outcomes of the work of the Water Withdrawal and Use Technical Subcommittee. This work includes the assessment of state and provincial water use data collection programs, the functionality of the Great Lakes Regional Water Use Database, and consumptive use accounting. The role of demand forecasting in regional water resources management is also examined. The agreements made through the Great Lakes Charter are used as a yardstick to measure the progress made in water use data collection and the contribution of that data to water resources management activities.

Several conclusions from the assessment of state and provincial water use data collection programs can be made. Many areas of state/provincial programs can be further developed and coordinated to improve regional water management. Most jurisdictions collect some data at or below the Great Lakes Charter established 100,000 gallon (380,000 litre) per day threshold, but the ability of several jurisdictions to collect and report water use data for all water use categories is lacking. About half of the members of the Water Withdrawal and Use Technical Subcommittee feel their jurisdiction is able to fulfill the Charter data collection and reporting requirements in both legislative/regulatory authority and implementation effort for almost all water use categories. The other half tends to feel that their jurisdiction has relatively strong legislative/regulatory authority but weak implementation efforts. Jurisdictions that have mandatory

reporting requirements built into their programs seem to be more effective than those that do not, due to the more stringent requirements and the availability of enforcement mechanisms.

Progress has been made in the area of water use data collection and reporting since the Great Lakes Regional Water Use Database became operational in 1988, but the database has limited utility as a management tool due primarily to constraints in the data collection and reporting programs at the state/provincial level. Data submitted to the database is aggregated for multiple facilities, estimated in many cases, reported at an annual interval and in some jurisdictions, focused solely on surface water. This level of data quality is inadequate for identifying annual, or seasonal, trends of water use with the reasonable confidence needed for demand forecasts and other planning activities.

The status of consumptive use accounting for the Great Lakes basin is similar to that of the water use data collection. Consumptive use calculations are inadequate for providing meaningful and defensible consumptive use information because they rely on estimations that are based on partially estimated water withdrawal and use data. Current evidence does not validate consumptive use coefficients, and jurisdictions do not generate comparable data with the current use of various coefficients.

Demand forecasting also provides a useful water resources management tool to inform water resources planning activities at the regional, jurisdictional and local levels. Forecasts generate crucial information on where water demand is likely to increase and where financial and other resources may need to be applied to help address these priority areas. Although demand forecasts are a useful tool, they suffer from lack of financial and programmatic support at the jurisdictional level. Without knowing what and where future demand is likely to be, planners and policymakers have difficulty developing and implementing effective and comprehensive water management programs that include elements such as water conservation and drought contingency planning.

1.3.1 RECOMMENDATIONS

The following recommendations are offered in Chapter 4:

1. Develop state/provincial legislative and programmatic authority with adequate funding and technical support to carry out the water withdrawal and use commitments in the Great Lakes Charter and Charter Annex.
2. Evaluate the effectiveness of the database in supporting the decisionmaking process and adjust the collection of data to meet decisionmaking needs.
3. Provide a more uniform and consistent base of data and information through the state/provincial water use data collection and reporting programs to facilitate comparison and evaluation.
4. Develop reporting requirements for incorporation into state/provincial water use data collection and reporting programs.
5. Revise and upgrade the Great Lakes Regional Water Use Database on a regular basis to make it a more useful planning tool.
6. Establish authority to require consumptive use reporting that emphasizes reliable and accurate data by water use sector in state/provincial programs.
7. Utilize the same consumptive use coefficients, adopted by all jurisdictions, for each water use category.
8. Develop regular water demand forecasts to provide effective planning at the state/provincial level.
9. Develop a uniform regional approach to demand forecasting.

1.4. CHAPTER 5: WATER CONSERVATION IN THE GREAT LAKES-ST. LAWRENCE REGION

Under the direction of the subcommittee on water withdrawal and use, the water conservation research presented in Chapter 5 was undertaken through a survey of state and provincial water use and conservation programs and written materials on conservation best management practices. This research supports a region-wide commitment to "environmentally sound and economically feasible water conservation measures" for a new decisionmaking process developed under the Great Lakes Charter Annex, which is needed so the region can show that it uses water wisely and that it is capable of making fair decisions on water withdrawal proposals.

This new emphasis on water conservation is a major shift from past water management practices, which have not relied heavily on conservation in water supply planning because of the reliable supply of fresh surface water in the Great Lakes. Water conservation and responsible water use may provide a viable solution to current shortages in some communities experiencing water supply problems, but even in those areas with abundant water, conservation measures may increase efficiencies, lead to lower costs and provide ecological benefits. In particular those areas identified as having particular ecological and hydrological sensitivities will benefit from targeted water conservation efforts.

Several Great Lakes states and provinces have the authority to implement basic water conservation programs at the jurisdictional level, but these programs vary widely in scope and content, and are usually part of state and provincial drought contingency plans. Many efforts also occur at the local level. However, programs and models to promote coordination of regional water conservation efforts are lacking. Elements of all the state, provincial and local programs could be considered in development of regional guidance for a more comprehensive and coordinated approach to water conservation.

In support of state, provincial, municipal and other efforts, 15 types of water conservation practices detailed in the chapter, ranging from financial incentives to technological improvements, provide effective water conservation approaches that can be built upon through further research.

1.4.1 RECOMMENDATIONS

The following recommendations are found in Chapter 5:

1. Develop and implement a uniform and consistent regional approach to water conservation that addresses the Charter Annex requirement of "environmentally sound and economically feasible."
2. Develop model guidance for state/provincial water conservation programs.
3. Conduct research and establish an information clearinghouse on best management practices for water conservation by individual water use sectors.
4. Develop and update state/provincial drought contingency plans.
5. Develop specific water conservation provisions as part of state/provincial water management programs.
6. Undertake an economic analysis showing the financial benefits of water conservation.
7. Conduct research and establish an information clearinghouse on BMPs for water conservation by individual water use sectors.
8. Develop a regional information/education program on the need for water conservation in the Great Lakes-St. Lawrence region.

1.5. CHAPTER 6: ECOLOGICAL IMPACTS ASSOCIATED WITH GREAT LAKES WATER WITHDRAWALS

Chapter 6 provides an assessment of the individual and cumulative ecological impacts of water withdrawals based on the work of the Inventory of Information on Ecological Impacts Subcommittee. This chapter describes: a) the development of a list of "essential questions" (aided through an Experts Workshop) regarding potential ecological impacts that should be addressed in reviewing water withdrawal proposals; b) a literature search and analysis; and c) an inventory of existing models. The subcommittee compiled an inventory of the data and knowledge base and tools available for applying a regional resource-based decisionmaking standard (required by Directive #3 of the Annex), and in doing so identified the gaps in understanding and assessment capabilities. The compiled information has led to the identification of research and data collection priorities that would increase certainty for decisionmakers who are faced with proposals for new or increased Great Lakes basin water withdrawals.

The Experts Workshop resulted in the development of a reasonably good outline for how to assess potential ecological impacts of water withdrawals. Participants identified many essential questions that must be considered to fully assess the ecological impacts of water withdrawals. The questions vary in complexity, from basic questions about the location of the withdrawal, to questions related to potential cumulative impacts of multiple water withdrawals and other stressors. The literature review and model inventory highlighted a large knowledge base to support this assessment. Selected past and ongoing research studies and existing modeling tools have provided useful resources to answer some of the essential questions.

These project activities also highlighted many information and understanding gaps, and unresolved policy issues that limit the practical implementation of the Annex. The literature offers few practical approaches for addressing questions that relate to cause-effect relationships and cumulative impacts of changes in levels and flows, although some studies could guide the establishment of monitoring protocols and agendas for scientific research. A key observation from the literature review is that the lack of integrative modeling tools currently confounds the assessment of cumulative ecological impacts from multiple stressors. This observation is supported by the outcome of the model review, that there is no single model that can, by itself, quantify the range of potential ecological impacts of a particular water withdrawal scenario.

Continued research and data collection are necessary for more certain assessment of cumulative ecological impacts of water withdrawals/diversions. However, these understanding and data gaps cannot be allowed to slow progress toward building and applying tools for supporting the decisionmaking process. The region should move forward in addressing the scientific questions as well as the policy and management aspects of implementing a basin-wide water resource protection and conservation ethic.

1.5.1 RECOMMENDATIONS

Chapter 6 presents the following recommendations:

1. Review and refine the list of "essential questions" developed by the project to ensure their comprehensiveness and feasibility in a decision support framework.
2. Direct future funding for research and development in this area at "data mining" the existing studies for both qualitative and quantitative stress-response relationships in this subject area. After mining the existing data, identify information gaps, and design targeted studies to collect the needed data and information.
3. Focus priorities for research and data needs on ecological impacts on identifying sensitivities through the development of indicators and thresholds that allow a determination of "no significant adverse impacts" in Directive #3.

4. Synthesize and model the quantitative relationships between water withdrawals/diversions in various types of Great Lakes ecosystems (large lakes, inland lakes, streams and rivers, groundwater) and potential ecological impacts of those water uses. Develop linked model frameworks for selected water withdrawal scenarios by building on the existing model inventory.
5. Incorporate predictions of regional climate change, population growth, demand forecasting, and land use changes in assessments of water withdrawal impacts.
6. Improve data to address time and space scale issues in making cause-effect assessments.
7. Incorporate an understanding of variability and uncertainty in levels and flows into the decisionmaking process.
8. Include some level of monitoring the system's response to water withdrawal activities as a means of "post-auditing" the decision and providing data and information for updating assessment tools.

1.6. CHAPTER 7: RESOURCE IMPROVEMENT STANDARD FOR WATER RESOURCES PROJECTS

Chapter 7 describes the analysis of issues and potential application of a "resource improvement" concept, which was done under the direction of the Inventory of Information on Ecological Impacts Technical Subcommittee. This work supports development of a new regional water resources decisionmaking standard, as outlined in Directive #3 of the Great Lakes Charter Annex, which is partly based on "an Improvement to the Waters and Water-Dependent Natural Resources of the Great Lakes Basin."

A focus group conference call with members of the WRMDSS project and the Annex Water Management Working Group determined the scope for this work and provided input on how the new standard would be interpreted and applied. Limno-Tech, Inc. prepared a briefing paper that explores this scope of work through ten case studies that have resource improvement-related applications. A workshop convened by the Great Lakes Commission in July 2002 provided a forum for further discussion of a resource improvement standard, and focused on four questions in the briefing paper associated with the standard's definition, interpretation and application.

Project activities have provided helpful information on the development and application of a resource improvement standard. The "resource improvement standard" concept has been interpreted and applied in many other settings, and these approaches inform the Annex process, but are not adequate for providing a model that meets the needs of the Annex.

Development of the resource improvement standard will require further defining and interpreting Directive #3 terminology; making operational the four Directive #3 principles; and addressing application issues, including assigning a spatial/temporal scale and accommodating prospective cumulative impacts. Resource improvement measures should all be directed toward a common end point, or goal, and should work from a common baseline for measurement. Specification of the goals, objectives, and baseline conditions should be developed within a state and province-based "Great Lakes Restoration Plan." Consideration must be given to both the design of an appropriate methodology, and the data, information and resource requirements to support the standard and its measurement. The resource improvement standard needs to be built based on specific scientifically sound guidance, along with flexible accommodations for the uniqueness of individual proposals.

1.6.1 RECOMMENDATIONS

Chapter 7 offers the following recommendations:

1. Develop the following in the interest of identifying data, information and evaluation requirements for water withdrawal assessments: a) precise definitions for terms in Directive #3 of the Annex;

b) guidance on the application of spatial and temporal dimensions of "resource improvement"; and c) a science-based evaluation methodology that presents acceptable procedures for assessing withdrawal proposals (from individual and cumulative standpoints) in the interest of measuring the "improvements" associated with the attendant conservation, enhancement or restoration activity. Many of the same data and knowledge base needs identified in Chapter 6 for assessing significance of resource impacts are also needed for assessing resource improvements.

2. Provide additional attention to the case study approach to resource improvement standard application. Ongoing work on a suite of projects supported by the Great Lakes Protection Fund should be carefully reviewed and augmented, as needed, by additional "scenarios testing" that leads to efficient and cost-effective methodologies for implementing the resource improvement standard.

1.7. CHAPTER 8: INFORMATION AND COMMUNICATIONS

Chapter 8, "Information and Communications," broadly defines, describes, and presents examples of a decision support system (DSS) and communication tools that could assist the decisionmaking process. The chapter systematically lists the key points to consider when integrating data and information into a water resources DSS. These key points include the promotion, development and implementation of data and information standards, the variability of hydrologic and hydraulic data in density, resolution, scale and temporal characteristics, and the improvements in computer modeling and associated visualization tools. The chapter gives an overview of evolving technologies, such as Internet, real time data, metadata and GIS technology that may contribute significantly to water resources decisionmaking.

The chapter elaborates on the definition of a DSS as "any and all data, information, expertise and activities that contribute to option selection" (Andriole, 1989). It describes the primary function of a DSS as to support and promote an informed debate where a plurality of goals and interest, conflict resolution, and consensus building must be simultaneously addressed. Decision support systems have been utilized worldwide to assist in resource management planning and decisionmaking. The chapter describes a few operational decision support systems used for water resources management.

The chapter lists and describes various information dissemination and communication tools that can be applied to a future DSS. These tools include the Internet, intranet portals, online GIS, and meetings and conferences. Last, the chapter discusses various DSS framework options and describes potential the operation of a DSS. For example, one component of a DSS might be an interactive software program that walks the user through the entire decisionmaking process. The software program would link the user – at appropriate stages – to relevant scientific data and information such as water use data, consumptive use information, relevant literature, essential questions to elicit an assessment of ecological impacts, computer models and other tools.

1.7.1 RECOMMENDATIONS

The following recommendations are offered in Chapter 8:

1. Develop integrated and interoperable Internet web pages to facilitate the exchange, distribution and access to all applicable data and information used for water resources management.
2. Develop metadata to accompany all geospatial and temporal data used in the water resources decision support system.
3. Incorporate a robust communications strategy into the water resources decision support system, involving Internet technologies; email and on-line discussion groups; and meetings, conferences and symposia.

4. Hold a workshop/forum, or a series of meetings, focused on the design of interrelated information and communications tools as the first step in developing these tools for the decision support framework.

1.8. CHAPTER 9: PULLING IT ALL TOGETHER: PROJECT SYNTHESIS

With the conclusion of this effort to inventory and assess available water resources data and information, state and provincial water resources policy experts, managers and decisionmakers will begin to grapple with how project findings and recommendations can be applied to a decision support system called for under the Charter Annex. Key issues in meeting future water resources data and information needs include: the definition of scale and extent of the prospective problem; the cumulative nature of withdrawals over space and time; groundwater; and ecological impacts.

1.8.1 MEETING FUTURE DATA AND INFORMATION NEEDS

Much of the data that is currently available adequately meets the needs for which it was originally intended. As decisionmaking needs evolve, however, data and information that are collected and reported may be inadequate to meet new needs. This points to the need for proactive planning and the implementation of programs that can accommodate changing needs.

Any decision support toolkit needs to be as robust as possible to weather the "test of time," and to accommodate changes in the quantities of the region's water resources, due to changes in uses of the water and water dependent resources of the Great Lakes-St. Lawrence system. Unanticipated ecological stressors will likely arise, complicating the region's ability to manage the resource effectively. On top of these likely changes, technologies will continue to evolve, some at a very rapid pace. Climate variability is the norm for the region, and long-term climate change due to anthropogenic influences may also occur and will be accompanied by varying ranges of water levels and quantity. Socioeconomic and human health issues and changes in social preferences and scientific understanding will also need to be included in the water resources decisionmaking process.

Developing and working through plausible water withdrawal and use scenarios provides a valuable process for evaluating where data needs and gaps exist and how, or if, decisionmaking can occur without pieces of information. A workshop was conducted under this project to help discriminate the full range of data and information needs related to the hydrology and hydraulics of the Great Lakes system, water withdrawal and use data, ecological effects from water projects and potential cumulative impacts associated with different types of water projects.

1.8.2 APPROPRIATE SCALES FOR WATER RESOURCES ASSESSMENT

One of the greatest challenges to water resources professionals involved with managing the waters of the Great Lakes is how to answer the questions, "how sensitive is the Great Lakes system to impacts associated with water withdrawals and diversions, and at what level can those impacts be ascertained?"

As knowledge and understanding of groundwater resources, ecological impacts and cumulative impacts have increased, the realization has emerged that impacts will be most discernable at the sub-watershed level. This has created a need to reexamine the way that the region evaluates water withdrawal proposals with decisions based not solely from a system-wide point of view but rather from the perspective of how projects will impact the water and related land and biological resources at the local sub-watershed level.

The utilization of hierarchical (or nested) watershed designs in support of water withdrawal decisionmaking is one approach that enables opportunities to analyze conditions at multiple scales of resolution. Each scale is important to understand the system and the relationship between supply, use and ecological impacts.

Understanding the sensitivities tied to the varying characteristics of watersheds will be important to developing informed water resource management decisions. Size, shape, slope, elevation, density of channels, channel characteristics (depth/width), vegetation, land use, soil type, hydrogeology, lakes, wetlands, artificial drainage, water use, ecology, etc., represent some of the important characteristics of a drainage basin. These natural and anthropogenic factors will influence the ecologic and hydrologic sensitivities of watersheds, which could be used to categorize watershed according to their individual sensitivity to water withdrawals or diversions.

1.8.3 CUMULATIVE IMPACTS

Cumulative impacts refer the way an action has an incremental influence on the environment over time and space. These impacts can occur individually, but often are enhanced through the collective effect of several actions (40 Code of Federal Regulations). Cumulative impacts occur both as hydrological and ecological effects of water withdrawals and a host of other stressors. At this point in time, the region is becoming more aware of the importance of cumulative impacts, but mechanisms for fully measuring these impacts have not yet been developed. The issues surrounding cumulative impacts are complex, and recommendations have not yet been developed that link this topic with water withdrawal data and information needs.

1.8.4 GROUNDWATER DATA AND INFORMATION

A better understanding of the role of groundwater in the hydrologic cycle and the contributions of groundwater to surface water levels and flows have elevated the importance of protecting of the region's groundwater resources from impacts associated with new and increased water withdrawals.

On a system-side scale, the amount of groundwater that discharges directly into the Great Lakes and connecting channels is small relative to other flows into the Great Lakes and is not measured. Groundwater also discharges to the Great Lakes and connecting channels indirectly by way of tributary streams. Groundwater that discharges to streams supports in-stream ecosystems by maintaining base flows and moderating water temperatures and is especially important for maintaining water quality during periods of low flows.

With regard to data and information needs and requirements, much is still unknown about the region's groundwater resources. On a sub-watershed scale, sufficient streamflow and groundwater data are available in some, but not all, areas of the basin to predict the likely effects of in-stream and groundwater withdrawals. Expansion of tributary stream gauging and groundwater monitoring networks will be critical, if the water resources decision support system is expected to support investigations in areas which have been heretofore "data poor." Also, the need exists for a basin-wide groundwater flow model.

1.8.5 ECOLOGICAL IMPACTS

The need to consider the ecological impacts associated with water withdrawals has placed new demands on scientists and managers who have traditionally approached water resources projects mostly from a hydraulic/hydrologic standpoint. As ecological impacts have begun to be considered in greater detail, needs have increased to better understand how collective impacts from multiple projects and cumulative impacts from single or multiple projects over time affect the resource to be protected.

As the region's understanding of the complexities of the Great Lakes-St. Lawrence system have improved, concerns have been expressed regarding the effects of water withdrawals to the Great Lakes basin ecosystem, particularly in the near-shore zone, where biota appears to be more likely to be affected by water withdrawals. Also, impacts of withdrawals are most likely to be discernable at the local, sub-watershed level.

Another consideration is that water withdrawals may be only one factor "or stressor" present in certain watersheds that contribute to the measurement of impacts to aquatic ecosystems. The impacts of a single withdrawal may not be measurable, but combined with other factors, such as land-use changes, may create a level of impact that causes harm to one or more components of the aquatic ecosystem.

1.8.6 PROCEEDING WITH THE DECISIONMAKING PROCESS

Overall, this project has shown that while much relevant water resources data and information pertaining to water withdrawal and use proposals and their impacts exists, there is also a lack of some critical data and information that the scientific, management and policy community considers to be fundamental to the region's ability to make scientifically sound decisions regarding water withdrawals, uses and exports.

The data and information that is considered relevant to water resources planning and management is likely to never all be available. Even with available data, understanding the uncertainties associated with available data and information in many cases can be as critical as the information itself.

Improving the base of data related to water withdrawal and use, surface water and groundwater resources and ecological/biological effects will not be easy, requiring substantial, long-term commitment on the part of all units of government (state, provincial and federal). To maximize the effectiveness of data collection processes, current data collection and monitoring programs, such as the State of the Lakes Ecosystem Conference (SOLEC) indicator suite, should be exploited.

As progress is made in resolving data or information shortfalls, decisionmakers should evaluate projects using the best available data, information, tools and decision support options available at the time, recognizing the uncertainties associated with these resources.

1.9. REFERENCES

Andriole, S.J. (1989). *Handbook of decision support system*. Philadelphia: TAB Books Inc.

40 Code of Federal Regulations. 1508.7

Tate, D. M. and Harris, J. 1999. Water Demands in the United States Section of the Great Lakes Basin, 1972 - 2021. GeoEconomics Associates. Unpublished background document prepared under contract to the U.S. Section of the International Joint Commission. Washington, D.C. 61 p.

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PREFACE

This report provides the comprehensive research, findings and recommendations resulting from the project, *Toward a Water Resources Management Decision Support System for the Great Lakes* (WRMDSS), supported by the Great Lakes Protection Fund and pursued by the Great Lakes Commission and its collaborators. The project's purpose was to compile and synthesize information on the status of Great Lakes water resources, current uses and ecological impacts of water withdrawal and use in preparation for the development of a regional water resources management decision support system that will facilitate scientifically sound decisionmaking.

The Commission's involvement in this important project is an outgrowth of its long-term interest and involvement in Great Lakes water resources management activities and in response to the Commission's mandate to "promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes basin." (Article I of the Great Lakes Basin Compact)

This report is a product of the Great Lakes Commission with significant input and collaboration from numerous project partners that comprised a Project Management Team (PMT), Stakeholders Advisory Committee (SAC) and three technical subcommittees (TSCs). The findings and recommendations of this report address identified data and information gaps and needs, and provide valuable information for guiding the next steps in the process of developing an effective decision support system. The recommendations presented in the report were discussed and agreed to, unless otherwise noted, by the Project Management Team and the Stakeholders Advisory Committee.

This project work, which occurred between August 2000 and November 2002, has supported the ongoing efforts of the Great Lakes governors and premiers through the Council of Great Lakes Governors, which in 1999 set out principles to create a stronger water resources management framework for the region. These principles were further developed in 2001, after the commencement of the WRMDSS project, through the June 2001 signing of the Great Lakes Charter Annex. This WRMDSS report provides regional leaders with much of the information they will need to further develop a water resources decisionmaking process and an associated decision support system.

This written report, and the project's many associated components, provide a wealth of information about the water resources and associated policies related to the Great Lakes-St. Lawrence basin. The report appendices, which include the reports generated by the project, are attached in CD-ROM form and are available at http://www.glc.org/wateruse/wrmdss.html.