CHAPTER 9
PULLING IT ALL TOGETHER: PROJECT SYNTHESIS

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9.1. INTRODUCTION

The results of this two-year effort, which commenced in August 2000 have been compiled and presented in this report in a manner to ensure immediate use and benefit to the Great Lakes states and provinces and other relevant water resources agencies. As this project has progressed and the process of gathering and assessing information has unfolded, the project collaborators have come to realize that while much is known about the complex nature of Great Lakes-St. Lawrence River water resources, much more still needs to be known to advance scientifically-based decisionmaking.

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. "Pulling it all together" means taking the inquiry to the next, critically important level: understanding and applying the uncertainties associated with the water resource and its ecological effects; filling key data and information gaps; and designing interoperable and integrated communication, data management and assessment tools.

9.1.1 USING DATA AND INFORMATION TO INFORM DECISIONMAKING

The main charge to the project partners in the conduct of this project was to assess the status of current data and information and to identify gaps and needs associated with these data. This latter part of the charge by its very nature assumes somewhat of a negative posture by focusing on what is lacking versus what is available. In the writing of the overall report, a challenge has been to present a balanced discussion and not adopt a "glass half empty" approach when critically looking at the complex issues surrounding data and information useful for decisionmaking. It is equally necessary to point out those areas where ample, high quality data exist and where systems and institutions are in place to guarantee that this data continues to be generated into the future. 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 does not mean that agencies and jurisdictions lack the commitment or have been negligent in meeting these needs, but rather points to the necessity of proactive planning and the implementation of programs that can accommodate changing needs of the resource and related decisionmaking.

9.1.2 FOCUSING ON FUTURE NEEDS

The emphasis of historical regional agreements pertaining to water quantity management have focused predominantly on decisionmaking related to bulk removals of water from the Great Lakes proper or larger tributaries to the Great Lakes. As needs have changed and as the understanding of the resources to be protected has improved, several emerging and related priorities have shifted the emphasis of how scientists and managers approach water resources management issues.

1. The issue of scale has taken on greater importance. 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.
2. 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.
3. 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.
4. 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.

Along with these issues, future needs can be met by building on current data collection processes. Water use data and information can assist the region in anticipating future demands and planning for these demand increases or decreases. 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.

9.2. THE IMPORTANCE OF SCALE IN THE ASSESSMENT OF WATER RESOURCES DATA AND INFORMATION NEEDS AND GAPS

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?" These questions are extremely complicated due to a variety of factors, one of which is that the Great Lakes are no longer an entirely natural system. Changes to the Great Lakes-St. Lawrence River system, primarily for navigation, hydropower, and riparian purposes, have permanently altered the natural levels and flow regimes of the system. Diversions (both incoming and outgoing); construction of locks, dams and controlling works; and dredging and riparian encroachment in the interconnecting waterways have created changes that are orders of magnitude greater than any changes that might occur from small-scale withdrawal, diversion or export projects, even when considered collectively (sum of impacts associated with multiple projects) or cumulatively (the impacts from a single or multiple projects over time). In addition, major changes have occurred in natural hydrologic/hydraulic streamflow regimes due to largely irreversible land use modifications such as timber cutting, agricultural and transportation development and residential expansions, to name a few prime examples. Being able to discriminate between the effects of each of these "forcing functions" will be crucial, if the water resources decision support system is to be effective.

9.2.1 HYDROLOGIC SCALE ISSUES

As noted in Chapter 3, the variability of the hydrologic system and the limitations of hydrologic measurements are factors that need to be considered in any decision support process and in the assessment of watershed sensitivities. All hydrologic and hydraulic phenomena are variable both temporally and spatially and can be treated at different scales of time and space, depending on the hydrologic problem under consideration. However, most of these data are reported as long-term averages at large spatial scales, with no direct measure of uncertainty. As a consequence, different hydrologic problems may have different space-time scales. This is particularly applicable to the water withdrawal issue. For instance, a withdrawal of a certain amount of water from a large water body could have very different consequences from that of a withdrawal of the same amount of water from a small water body or stream.

Most hydrologic issues are analyzed within a given drainage basin or watershed. A watershed is the area that diverts all runoff to the same drainage outlet. Watershed boundaries rarely coincide with territorial or jurisdictional boundaries (Singh, V.P., 1992). A watershed can be of almost any size, from that of a small parking lot to as large or larger than the entire Great Lakes basin. Large watersheds such as the Great Lakes basin are usually broken down into smaller drainage basins to suit the requirements of a particular problem. For example, in the case of the Great Lakes basin, this can be broken down into the watersheds of each individual lake (e.g. Lake Ontario, Lake Erie, etc.). These lake drainage basins can be further broken down to the river and stream level, such that, the Grand River basin in Ontario is a sub-watershed of the Lake Erie basin, which is a sub-watershed of the Great Lakes basin.

The ordering of these watersheds begins at the largest level of the watershed. For example in Canada, the Great Lakes Basin would be considered the primary or 1st level watershed. Individual lake watersheds (i.e. Lake Superior) would be considered a secondary or 2nd level watershed, the sub-watersheds of the individual lakes would be considered tertiary or 3rd level watersheds and so on. In the United States, the U.S. Geological Survey (USGS) has a hydrologic unit classification system, similar to the hydrologic watershed classification of Canada. The first level of classification divides the United States into 21 regions, one of which is the Great Lakes basin (Region 4). The second level of classification divides the 21 regions into 222 sub-regions. A sub-region includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area. The third level of classification subdivides many of the sub-regions into accounting units. These 352 hydrologic accounting units nest within, or are equivalent to, the sub-regions. The fourth level of classification is the cataloging unit, the smallest element in the hierarchy of hydrologic units. A cataloging unit is a geographic area representing part of all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature.

These basin levels should not be confused with the Horton-Strahler stream-ordering scheme (Horton, 1945; Strahler, 1957), which increases numerically from headwater streams. The system of stream ordering is a method of numbering streams as part of a drainage basin network. The smallest unbranched mapped tributary is called first order; the stream receiving the tributary is called second order, and so on. Tributaries which have no branches are designated as of the first order, streams which receive only first-order tributaries are of the second order, larger branches which receive only first-order and second-order tributaries are designated third order, and so on, the main stream being always of the highest order.

9.2.2 ASSESSING IMPACTS AT THE SUB-WATERSHED LEVEL

This report has repeatedly stated that the consequences of various water withdrawals or diversions are not equal across the basin and that the impacts of a withdrawal or diversion would most clearly be identified and discernable at a sub-watershed level. The mandate of this report and that of Annex 2001 is to address the impacts of any water withdrawal from anywhere within the Great Lakes basin to the water resources of the Great Lakes-St. Lawrence system. In addition to the impacts to the Great Lakes themselves, the impacts at a localized scale, such as a 3rd or 4th level watershed, must also be considered. Potentially serious and substantial impacts occurring at the local level that are not identified and considered may have regional implications both immediately and in the future. For example, a water withdrawal from a stream of a 4th level watershed may not have measurable impacts to the overall levels and flows of the Great Lakes system. However, if examined on the sub-watershed scale, the withdrawal may be shown to reduce flow in that stream to the point where it has jeopardized the habitat of an endangered species. The impact to this species could have regional, and binational implications.

The utilization of hierarchical (or nested) watershed designs in support of water withdrawal decision making 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. The Canada/Ontario Water Use and Supply Project has been implementing these structures to better understand water use and supply and ecological impacts at the various scales (Figure 1).

Figure 1. Conceptualization of nested watersheds

The nested watersheds start with the entire Great Lakes basin catchment, move through individual Great Lake catchments through to third level (tertiary) and fourth level (quaternary) watersheds. With each move to a more detailed resolution, increasing details can be captured and represented. Individual withdrawals can be assessed at a local level to identify water availability, existing usage and ecological impacts based on the know sensitivities of the local watershed.

The movement outward in resolution through this nested structure enables use, supply and impacts to be aggregated to better assess both individual and cumulative impacts. The impacts within the lower level watersheds can be carried through to the higher levels.

While the importance of scale is a key issue, the understanding of the varying characteristics of watersheds is also important. 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. A watershed may be relatively uniform in terms of one characteristic, but quite different in terms of others and these characteristics may have different variability and combinations of variability. Further complicating the issue is the fact that the quality and quantity of water resources can vary substantially within the Great Lakes basin. The amount of precipitation, evaporation, runoff etc., can vary significantly even over relatively small spatial scales. Groundwater discharge to streams can be as low as 10 percent of the streamflow to as high as 80percent of the streamflow (Piggott, et al. 2001). The uniformity of groundwater flow over time can also vary significantly amongst watersheds, as can the type of land use and types of water uses. Both these natural and anthropogenic factors will influence the ecologic and hydrologic sensitivity of a watershed.

Understanding these sensitivities will be important to developing informed water resource management decisions. For example, understanding the physical characteristics of a watershed, the current surface and groundwater supplies, the current water uses, and ecological requirements of the system could help to characterize each watershed in terms of it's individual sensitivity to water withdrawals or diversions. Water conservation strategies, for example, might then be more useful if targeted on highly sensitive watersheds that are already stressed by over use. A categorization of watersheds in terms of their sensitivities may be a first step towards providing the context within which water management decisions are made.

9.3. THE IMPORTANCE OF GROUNDWATER DATA AND INFORMATION RELATED TO WATER RESOURCES DECISIONMAKING

The issue of scale is also important as it relates to the availability and use of groundwater resources in the Great Lakes-St. Lawrence system. 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 important for maintaining water quality especially during periods of low flows.

At the sub-watershed level, groundwater discharge may be important to aquatic ecosystems; however, a literature search conducted under this project did not find research results on the relation of groundwater to aquatic ecosystems in the Great Lakes proper or their connecting channels.

With regard to data and information needs and requirements there is still much that is unknown about the region's groundwater resources. For instance, each aquifer that contributes groundwater to the Great Lakes or their tributary streams has a potentiometric surface. This surface is similar to the earth's surface in that it has groundwater divides that are analogous to watershed divides. Groundwater on one side of the divide flows towards the Great Lakes; groundwater on the other side flows away from the Great Lakes. Only a part of the Great Lakes region and only some of the aquifers have mapped potentiometric surfaces and groundwater divides. In the remainder of the region, the area that contributes groundwater to the Great Lakes is unknown. It is known however, that there are groundwater contributions into the Great Lakes that do not coincide with the watershed boundaries for tributary streams.

On a sub-watershed scale, sufficient streamflow and groundwater data are available in many areas of the basin to predict the likely effects of in-stream and groundwater withdrawals. For many other areas however, these data are unavailable. Expansion of tributary stream gaging 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, there is a need for a basin wide groundwater flow model that would provide information to support decisions on proposed groundwater withdrawals in the U.S. and Canada.

Reliable groundwater supplies continue to be readily available to the majority of the Great Lakes basin's population. However, in some localized cases, inadequate groundwater supplies or groundwater of poor quality has caused local water supply shortages. For example, Monroe County, Michigan, located in the southeast corner of the state, relies on groundwater for drinking water and irrigation, but aquifers have been depleted due to quarry operations. Oakland and Macomb Counties, also in southeastern Michigan, likewise have recently experienced aquifer depletion due to low rainfall, higher than normal temperatures and rapid residential development. The interest in protecting groundwater resources has heightened as a result of these and other examples of localized groundwater shortages. In addition, the recent construction and operation of the Perrier bottling plant near Muskegon, Michigan has brought this issue to the forefront of public discussion. The groundwater issue and "better understanding its role in the Great Lakes basin" is also an identified priority under Directive #6 of the Great Lakes Charter Annex. These examples point to the need to consider the importance of groundwater when developing a regional water resources decision support system framework.

9.4. IMPORTANCE OF DATA AND INFORMATION TO ASSESS ECOLOGICAL AND CUMULATIVE IMPACTS OF WATER WITHDRAWALS

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. Again, this issue is important as it relates to the scale issue discussed above. Chapter 3, which focuses on the issue of uncertainty regarding the ability to measure components of the Great Lakes water balance points out that on a lake-wide scale, uncertainties in flows, and to a lesser regard levels, dwarf knowledge of a potential withdrawal of the Great Lakes.

While the region has been struggling with its ability to discern impacts from small withdrawals on a system-wide scale it will be at the local, sub-watershed level where impacts are likely to be most discernable. Also, it the collective and cumulative effects of multiple withdrawals or single or multiple withdrawals over time that creates the need to better understand the ecological impacts associated with water withdrawals.

It is in the near-shore areas, where biota appear to be more likely to be affected by water withdrawals, rather than those organisms, which inhabit the deeper portions of the Great Lakes _ . However, fish and other aquatic organisms that live in these deeper areas may be dependent on near-shore areas, for food, spawning habitat and other purposes. Also, water withdrawals may be only one factor "or stressor" present in certain watersheds that contribute to the measurement of impacts to the aquatic ecosystem. The impacts of a single withdrawal may not be measurable, but together with other factors (such as land-use changes) may collectively and cumulatively create a level of impact that causes harm to one or more components of the aquatic ecosystem.

Better and more site-specific data and information on the ecological effects associated with water withdrawals are needed to support a regional resource-based decisionmaking standard (being developed under Directive #3 of the Annex)., Activities pursued under this project highlight many data and information needs and understanding gaps, and unresolved policy issues that may limit the practical implementation of the Annex. The literature reviewed under the project 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 shed some light on 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 no single model 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 ecological impacts (particularly cumulative effects) of water withdrawals and diversions. However, these understanding and data gaps cannot be allowed to slow progress toward building and applying tools for supporting the decisionmaking process.

To develop a resource improvement standard as required under Directive #3 of the Annex, there is no current approach in another setting that offers a single model that meets the needs of the Annex. However, a suite of linked models can be used to address management questions for different withdrawal scenarios. To further develop the resource improvement standard concept, terminology in Directive #3 needs to be further defined and interpreted.

9.5. THE USE OF SCENARIOS/CASE STUDIES TO EVALUATE DATA AND INFORMATION

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. Two scenarios evaluation exercises were convened under the WRMDSS project that helped scientists, managers and policymakers focus on key issues related to the region's ability to evaluate water withdrawal and use proposals. One scenario evaluation exercise was convened by the Water Withdrawal and Use Technical Subcommittee (TSC 3) on September 10-11, 2001 and was designed as a tool to assist in the identification of water withdrawal and use data and information needs. Building upon this exercise, a project-wide scenarios evaluation workshop was held on May 15-16, 2002, which was designed to bring the full range of interests and expertise to bear on the evaluation of three distinct mock water projects. This workshop also aimed to inform the discussion of 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. An additional purpose of the workshop was to evaluate the data and information needs and availability to inform the Annex 2001 implementation process and to begin to conceptualize informational components and characteristics for an effective decision support system.

Some of the observations and ideas generated at the workshop are useful to show how scenarios/case study examples can be used to enhance understanding of data and information needs and requirements. A sample of the important observations from the May 15-16 workshop are presented below:

- The ability of current data and the state of science to inform cumulative impact assessments is limited and will likely be a weak link in the development and application of any decision support system.
- The relationship between hydrologic changes and ecological impacts, particularly related to cumulative impacts in the near shore zone is not currently well known. For instance,

data coverage for wetlands is incomplete, inconsistent, and non-periodic, making it impossible to monitor changes over time.

- When considering a decision support system, decision standards, data collection programs and modeling efforts should be applicable to decisionmaking both on large (entire basin) and small (sub-watershed) scales.
- Socioeconomic and human health issues as well as changes in social preferences, technological capacity, and scientific understanding should be accommodated in the water resources decisionmaking process.
- Dedicated and long-term monitoring programs are currently lacking and will be a valuable tool to assess the successfulness of any decisionmaking process in reaching predetermined goals.
- Demand forecasting will be a useful tool to provide guidance to any decision support system.

The scenario process can be used to further identify data needs and gaps, and to identify viable processes for decisionmaking.

9.6. LOOKING INTO THE FUTURE: OTHER ISSUES INFLUENCING WATER RESOURCES DECISION SUPPORT

The work of the WRMDSS project has addressed a host of past and current issues that need to be addressed prior to initiating work on detailed system design of any integrated decision support system. Research, management and policy activities also need to be "future oriented" to anticipate changes that could occur in the near and intermediate future that might significantly affect how water resources decisions are made and the data and information requirements to support the evolving decisionmaking process. 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. Brief discussion of these issues follows: Climate variability is the norm for the region, not the exception. Long-term climate change due to anthropogenic influences may also occur and will be accompanied by varying ranges of water levels and quantity.. New advances in climate prediction and risk assessments will assist managers in anticipating these effects.

- Substantial changes in land uses will continue. Residential property development will reduce agricultural lands and urban re-development will continue to be a societal objective. Agricultural changes are likely to continue into more selective "niches," requiring significant changes in local water demands. Recreational opportunities will continue to transform the landscape (e.g., golf course development) and recreational boating will put pressure on greater controls of water levels throughout the system.
- Municipalities have been expanding water treatment capabilities as a major infrastructure investment. Service areas are expanding regularly. Substantial changes have occurred in the bottled water and related beverage industries. Societal shifts from tap water to bottled water could likely continue, causing ever-increasing interests in the exportation of the region's water resource as a commodity.

- A number of ecological stressors will continue, and in some cases may increase in relevance. Impacts of new exotic or invasive species can (and will) complicate the region's ability to discriminate between causes and effects, particularly in the indicator wetland environments. Coastal wetlands are also highly impacted by adjacent land use changes, hardening of nearby shorelines and changes in sediment supplies.
- The technological advances experienced in the last decade should not be expected to diminish. Investments in new wireless and fiber optic delivery mechanisms will provide scientists, resource managers, water users and concerned citizenry with greater abilities to ingest data and information in an efficient manner. Increases in computer storage capacities will also likely occur, to match the increased data volumes that are expected. Increased computing speeds will make integrated products dealing with resource management issues more user friendly.
- These technological advances continue to push resource management protocols into the public arena. Public involvement in the decisionmaking process will only increase because of these technological improvements. The level of sophistication of resource management will also likely improve. Managers will have the ability to ingest vast quantities of data and information, digest this information, and extract applicable options to the problems at hand. The manager can have a system engineering perspective for problem solving. Further, resource managers will be able to more effectively plan for the future, set reasonable targets, develop metrics, monitor progress and achieve desired results

9.7. SUMMARY AND CONCLUSIONS

One of the outcomes of this WRMDSS project is the realization that while there exists much relevant water resources data and information pertaining to water withdrawal and use proposals and their impacts, there is also a lack of some critical data and information that the scientific, management and policy community considers to be fundamental or foundational to the region's ability to make scientifically sound decisions regarding the withdrawal, use and export of Great Lakes water resources. There are numerous recommendations throughout this report addressing the need to improve the quality and quantity of this data and information.

This being said, there are some concluding points to be made regarding the importance of data and information to guide water resources decisionmaking:

- Scientists, managers and decisionmakers will likely never have access to all of the data and information that is considered relevant to water resources planning and management;
- Understanding of the uncertainties associated with available data and information in many cases can be as critical as the information itself;
- Data needed for decisionmaking on hydrologic and hydraulic processes throughout the system have varied characteristics. For instance, sub-watershed level analyses will likely require denser spatial and temporal detail than assessments conducted on the open-lakes or for the interconnecting waterways;
- The region has a pressing need to improve its ability to collect and report accurate, consistent and uniform water withdrawal and use data;
- 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 commitment on the part of all units of government (state, provincial and federal);

- The commitment to improve this base of data will not be short-term but ongoing and will require the political will and dedicated and ongoing support for programs over time;
- Scientifically sound data and information are being collected under highly compatible programs and should be exploited to the fullest extent to reduce costs. The best examples are the binational monitoring programs that are evolving to implement the State of the Lakes Ecosystem Conference (SOLEC) indicator suite.
- As progress is made in resolving data or information shortfalls, regional water resources management decisions will still need to be made. 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.