CHAPTER 8
INFORMATION AND COMMUNICATIONS

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8.1. THE NEED FOR SCIENTIFICALLY SOUND INFORMATION

A recurring finding of this project is that there is a lack of data and information that members of the scientific, management and policy community consider to be fundamental to scientifically sound and legally defensible decisionmaking regarding the withdrawal, use and export of Great Lakes water resources. Additionally, numerous recommendations are contained in this report that address specific improvements that are needed in accounting of the waters of the Great Lakes – St. Lawrence system, monitoring water uses across the region and assessing prospective impacts on the region's ecological resources.

Under this WRMDSS project, existing data and information have been assembled and characterized, and gaps have been identified. The next step in this endeavor is to organize this information in such a way that resource managers and decisionmakers can have ready access to them. Directive #5 of Annex 2001, calls for "a decision support system that ensures the best available information."

In signing the Annex, the governors and premiers also stipulated that the "design will include an 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 decision support system." The Annex 2001 implementation process is moving forward, and a governor/premier-appointed Working Group is focusing on the development of binding agreements and associated implementing documentation. Accurate, consistent, well-documented and easily accessible data and information should be the architectural foundation of the decision support system.

The design of the decision support system will need to be a collaborative effort involving representatives from all likely decisionmakers as well as information providers and shareholders. Further, the information systems that support the decisionmaking process will need to be designed to provide for wide public access. Recent developments in Internet technologies have proven to be essential components in this endeavor. Perceptions of equitability are almost always affected by the openness of the process and the ability for all participants to reach independent, and frequently common, conclusions from the same available information.

8.2. THE INFORMATION BASE OF THE DECISION SUPPORT SYSTEM

Some key points to consider about data and information in the water resources decision support system are:

We will likely never have access to all of the data and information that is considered relevant to water resources planning and management; hence, decisions will be made with best-available information.

Data and information standards will need to be promoted, developed and implemented as necessary; metadata (detailed records about datasets) will become increasingly important to assure that information is accurately interpreted and used in decisionmaking, especially considering that all information has inherent uncertainties;

Hydrologic and hydraulic data vary in density, resolution, scale and temporal characteristics; assessing changes in the water resources of a headwater of a watersheds is substantially different than looking at water resource characteristics on the Great Lakes; this information must be structured, managed and delivered at various "nested" scales and temporal formats;

Improvements in monitoring of water withdrawals and uses throughout the region will coincide with a need for increased sophistication in database design and maintenance and will require commensurate commitments to metadata production;

Scientifically sound data and information on the ecological conditions and trends are being collected under compatible programs and should be exploited to the fullest extent possible; binational monitoring programs that are evolving to implement the State of the Lakes Ecosystem Conference (SOLEC) indicator suite are the best example of this point;

Improvements in computer modeling of complicated physical, chemical and biological processes and associated visualization tools may play a crucial role in the decision support system; connectivity between computer models should demand greater attention; and

Technological advancements in interoperable computer networks, geographic information systems (GIS) and wireless communications will create significant opportunities for seamless and virtual information exchange between political jurisdictions, albeit with inherent cooperation costs.

8.3. EVOLVING TECHNOLOGIES

When considering decision support system options, it is important to understand the way communications and technology advances have contributed to changes in water resources decisionmaking since the signing of the Great Lakes Charter in 1985. Some of the changes include the following:

The Internet – In large part, the Internet is the most significant technological advance of the last decade. Information is disseminated almost instantaneously across this backbone to almost all shareholders of a system, being limited only by their abilities to afford the nominal investment in computing power, bandwidth and network connections. Advances in Internet functionality should be expected to continue unabated for the foreseeable future. It is safe to say that the Internet will be the cornerstone for data and information access for the water resources decision support system.

Electronic Communications and Compatibility – The explosion of the cellular communication industry, along with improvements in land-line functionalities, is continuing to transform business processes. The advent of the "email revolution" cannot be overstated as well for the same period. Both of these new technologies provide wide access to data and information managed centrally or in a distributed fashion.

Real Time Data – Over the same period, advances have been made in automated and instantaneous dissemination of data from remote sampling locales. Almost all water level gaging systems utilized in the

region are equipped with some mechanism for instantaneous interrogation and/or satellite or radio-frequency data relay. Access to real-time data drives many of the hydropower, commercial navigation, municipal, industrial and agricultural users in the Great Lakes – St. Lawrence River system.

Integrated Data Collection – Positional and temporal detail has been tremendously improved over the last 15 years. It is now the norm to collect water level data from gaging sites at 6-minute intervals and at mobile sampling locations with sub-meter accuracies using data provided by inexpensive backpack or hand-held Global Positioning System (GPS) units.

Data Consistency, Uniformity and Display – Although it appears that significant shortfalls exist related to data and information standardization, substantial progress has been made on many fronts to allow disparate users to exploit water resources data and information. For example, streamflow data is available on the Internet for the next day for all sampling sites in the eight Great Lakes states. Gaps in water use inventories are identified and reporting is becoming more uniform and repetitive. Complex processes can now be simplified by computer models and visualized due to advancements in computing and Internet resources.

Metadata - Substantial progress has been made in defining data content standards for many crucial GIS data themes; nevertheless, a substantial investment of human resources into production of metadata for other data types is needed. Metadata in the broadest sense is the "history" of the data, including source, scale, accuracy, processing steps, etc. The power of distributed data access, real-time web mapping applications, timely computer simulation modeling and many other prospective applications are compromised if metadata are incomplete and not comprehensive.

GIS – Geographic Information System (GIS) technology has evolved steadily with advances in desktop computing power, network bandwidth, distributed processing and relational database management tools. The current state-of-the-science is focused on developing large-scale multi-jurisdictional "web-mapping" functionalities. Web mapping frequently involves multiple cooperative data serving nodes, focused on delivering products to clients using common Internet browsers (i.e., Internet Explorer, Netscape). It is likely that the information needed to support water resource decisionmaking will exploit this technology.

Information Overload - With all of technological advances noted above, it is becoming increasingly frequent that extracting information from data is an art-form. Considering that this phenomenon will continue, it will be critical to invest suitable resources in a careful system-engineering assessment of the problems associated with data access/storage/retrieval.

In the immediate future, technological advances will continue. Investments are being made in new wireless and fiber optic delivery mechanisms that should provide resource managers, shareholders and interested citizenry with improved abilities to acquire data and information across the Internet in an efficient manner. Increases in computer storage capacities will also occur, but likely will be matched by increased data volumes. Increased computing speeds will continue to promote improvements in physically based computer models and visualization tools.

These technological advances should promote a more open environment for resource management protocols with the public. Although security considerations are likely to increase, effective "work-arounds" are likely to be found. The level of sophistication of resource management decisions should improve, with improved abilities to ingest vast quantities of data and information, digest this information, and extract applicable options to the problems at hand. Further, managers should be able to more effectively plan for the future, set reasonable targets, develop metrics, monitor progress and achieve desired results.

8.4. EXAMPLES OF OPERATIONAL DECISION SUPPORT SYSTEMS

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 decision support process can consist of three phases of decisionmaking: *information gathering, options design,* and *choice.* The information-gathering phase typically involves identifying problem situations, causes and effects and interrelationships. The information gathering system can play a vital role in coordinating decision situation analysis through its ability to integrate and explore data and information from a wide range of sources. In the option design phase, the DSS typically supports decisionmakers in the development of possible alternatives that reflect competing interests and objectives and evaluation criteria to be employed. Lastly, the choice phase depends upon the decisionmaker's preferences with respect to the importance of the evaluation criteria. DSSs can vary radically from highly deterministic and rule-based formulae to highly interactive and participatory approaches.

The objective of a computer based decision support system for water resources management is to improve planning and decisionmaking processes by providing useful and scientifically sound information to the actors involved in these processes. In addition, it is most effective in the context of collaborative decisionmaking. GIS, expert or knowledge-based systems, and other analytical and modeling techniques have been used to help scientists, decision and policy makers to understand the complexity of physical and biological systems.

Numerous efforts to implement decision support systems at a regional or watershed level have been designed for research applications and demonstration purposes. Most common DSSs have been developed to assess the impact of utilization of natural resources and to evaluate the impact of agricultural, industrial and land use activities on the environment. Other DSSs have been applied to potential contamination problems and site suitability problems based on maximization of multiple criteria and minimization of threshold (constraint) values. Popular DSSs-based software packages, such as, IDRISI GIS, STELLA, ExpertChoice and a number of ESRI extensions are designed for users to evaluate a decision problem through a multiple criteria decisionmaking (MCDM) process. This common approach allows the user to assess the relationships between a set of objectives and associated attributes. Many of the software packages are becoming "web-enabled", allowing for wider access and even multi-player gaming exercises.

What makes the framework of DSS as a support of resource management and planning so innovative is that it attempts to create an information framework that will be able to suit the information, communication and technical needs of project planning. In addition, it can support and promote an informed debate where a plurality of goals and interests, conflict resolution, and consensus building must be simultaneously addressed. By the definition above, the Great Lakes Water Resources DSS should include a strong information framework that integrates a range of current technologies.

A DSS framework for water resources management has been applied for the management of Lake Ellesmare in New Zealand and is described in Gough and Ward (1996). This framework was used to identify different levels of decisionmakers and stakeholders and 'learn' about differing perceptions on existing lake management problem. Through the process of concentrating on information gathering and consultation with affected parties, the framework allows emphasis on improving the process of decisionmaking and establishing criteria for measuring 'good' and 'effective' outcomes.

From the perspective of a multi-jurisdictional decision support system, the Colorado River Decision Support System (CRDSS) has been a fully operational decision support system that provide Colorado agencies, water users and managers a better means for organization, assessing and evaluating a wide range of information and alternative strategies on reservoir and river operating policies, impacts of water flows and allocation of water resources. Designed by Riverside Technology, the CRDSS allows

decisionmakers to analyze historical and real-time hydrologic data, run hydrologic simulation models and water rights allocation models and study the effects of potential decisions. The primary component of CRDSS is the HydroBase database that includes streamflow, climate, water rights, diversions, well permits, dam safety and land use data. These criteria can be used in the consumptive use model to calculate the amount of water used by different users. The results from scenario models are central to determining present and future uses of water. Allowing all applications to use the same, consistent information, this data centered approach ensures data integrity, minimizes data redundancy and enforces entity relationships (Bennett et al. 2001). This aspect of a decision support system is crucial for a distributed, collaborative user environment.

To address the ecological-economic paradox of river basin management, the Quebec Ministry of Environment developed GIBSI, an integrated modeling system prototype, to evaluate the impacts of municipal, industrial, forestry, and agricultural projects on the water quality and yield of a river basin (Rousseau et al, 2000). Comprising of a relational database management system, GIBSI has the ability to use both spatial and attribute data (e.g. digital elevation model, meteorological data, soil database, gauge station locations, simulation results, quantitative and qualitative data associated with administrative units, livestock production, crop management, etc.) to generate scenarios that reveal water quality and flow regime to the watershed assessments of the ecological integrity of running waters.

An operational DSS has also been implemented in the Great Lakes watershed. RAISON (Regional Analysis by Intelligent Systems ON microcomputers), which has been developed at the National Water Research Institute of Environment Canada, is a system designed to help decisionmakers, managers and advisors to locate relevant information for toxic chemicals in the Great Lakes basin (Lam and Swayne, 1993; Lam et al., 1995; Booty et al., 2000). The system consists of several layers of computational modules: database, spreadsheet, GIS layer, statistics, expert system, contouring, spatial visualization and graphs. Data on toxic chemicals of concern can be inputted into the database table for further statistical analysis or optimization modeling. It integrates data, text, maps, satellite images, and other knowledge input with a combination of spatial algorithms, models and statistics to generate specific scenarios.

The essence of developing a DSS is to integrate data, information and knowledge from different sources for the purpose of improving the decisionmaking process. However, there are a series of obstacles that hinder the development and adoption of an integrated decision support system in water resource management.

Quality of Data - One of the main obstacles is data collection. Large amounts of raw data from different sources (i.e. water levels, river flow, air temperature, precipitation, metrological parameters) and in different formats must be verified and often converted into a format suitable for the proposed system. In some instances, geospatial layers that are produced by multiple agencies with different positional accuracy and geocoding systems make them difficult to be integrated into the system. This issue exemplifies the well-known problem of data interoperability and consistency.

System and Hardware Maintenance – Experiences have shown that when dealing with large set of data types from different sources, it is important to carefully design database tables and their fields in the initial phase of the project. The maintenance aspect of the support system requires data to be up-to-date; the system will be useless without it. The development of a DSS should be considered as a continuous process instead of a one-time development project. The system should be able respond to the current needs, stakeholder interests and future demands.

Leadership and Management – The function of leadership and management is to set achievable goals and objectives. In order to sustain the value of the investment, both leadership and organization setting must be committed to achieve those goals. Another critical aspect of leadership is coordination and communication between different agencies across jurisdiction. There are many examples of DSSs and each has its own merits. The objective of developing a decision support system for water resources management in the Great Lakes basin requires the collaboration between stakeholder and interest group.

Emphasis should be placed on the importance of the DSS as being a communication tool that will provide an *information infrastructure* and *information framework* for multiple users to make informed decisions based on the best available data collected.

8.5. INFORMATION DISSEMINATION OPTIONS

The manner in which a broad range of disparate information is displayed and presented will be key to the success of the water resources decision support system.

Clearinghouse node – The Clearinghouse is a decentralized system of servers located on the Internet, which contain descriptions of available digital data. These descriptions are known as metadata and they are collected in a standard format to facilitate query and consistent presentation across multiple participating sites. The Clearinghouse uses readily available Web technology for the client side to query, search, and presentation of search results to the Web client. By utilizing a standard for method of query, search and presentation of data, the Clearinghouse allows individual agencies, consortia, or geographically defined communities to band together and promote their available digital spatial data.

Integrated and interoperable web pages – By promoting the availability, quality, and requirements for digital data through a searchable on-line system, it is essential to have integrated and interoperate web pages that provide a standard data and information dissemination mechanism to different target audiences.

Data warehouses - A Data Warehouse is a database designed to support decisionmaking in organizations. It is batch updated and structured for rapid online queries and managerial summaries. This component is also the most critical element of the system. The intention of data warehouses is to store historical and consolidated data (e.g. flow records, water levels, meteorological parameters) into a common format.

Distributed networks - The reliance of multiple sources and types of data in water resource applications requires a network to retrieve data sources from different data holdings. A distributed network functions closely with a clearinghouse node. Servers may be installed at local, regional, or central offices, dictated by the organizational and logistical efficiencies of each organization.

All Clearinghouse servers in a distributed network are considered "peers" within the Clearinghouse activity -- there is no hierarchy among the servers -- permitting direct query by any user on the Internet with minimum transactional processing and to minimize duplication of effort in the collection of expensive digital spatial data and foster cooperative digital data collection activities.

Distributed GIS mapping – An open GIS architecture should be able to assess multiple forms of data. Users of geospatial data need to share data effectively and efficiently. Web-based GIS, acting as visualization mechanism, will allow users to access various source of geospatial data from multiple data clearinghouses.

8.6. ENHANCING COMMUNICATIONS

An important part of the WRMDSS project has been the development of effective "communications tools" to provide access to available data and information. Below is a description of these tools and approaches and how they may be applied in a future decision support system.

- **Internet** - A Great Lakes Water Use Website has been a centerpiece of project activity and has been finalized with electronic versions of project products and an online regional water use database. The site is extensively linked through, and prominently highlighted on the Great Lakes Commission-managed Great Lakes Information Network (GLIN). GLIN is a well-known Internet clearinghouse for data and information in the Great Lakes-St. Lawrence region. GLIN supports the hydrometeorological station directory and coordinated hydrologic/hydraulic data from a binational

federal coordinating body. GLIN also provides significant contributions to the water resources management community via its GLIN-News feature, an electronic "clip service" which monitors numerous print, radio and television media coverage of Great Lakes issues on a daily basis. GLIN also provides email discussion forums for targeted groups and topics. This function would likely be important to support the needs of the regions governmental agencies during decisionmaking deliberations.

- **Intranet Portal** – An "intranet portal" can be envisioned as an internal communication tool including only state and federal regulatory agencies (and others by design), which is designed to provide security and privacy for confidential information exchange and deliberations. In some respects intranet functions are currently available to the WRMDSS project team via listservs and community email addresses. The intranet portal can also be useful for researchers who need to coordinate ongoing and prospective projects with colleagues and to feed the decision support system process for policymakers and managers. There will likely be a need for establishment of a variety of intranet groups, focused on specific objectives, to facilitate the operation of the water resources decision support system.
- **On-Line GIS** - The Great Lakes Commission also supports new web-based GIS functionalities in support of the International Joint Commission (IJC), the U.S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA). The GLIN website is currently working on developing the framework for a regional metadata clearinghouse and web-mapping applications. The GLIN website could provide an effective Internet presence for a coordinated and distributed GIS for the water resources decision support system.
- **Conventional "Hard Copy" Dissemination** - The Great Lakes Commission's *ADVISOR* newsletter has been used to disseminate project update information/announcements to more than 3,500 policymakers, managers, researchers and other interested parties. Additionally, hard copy versions of some products (i.e., water use database report) have been published and publicized and made available to all interested parties. A special *Advisor* insert, summarizing project results and directing readers to project products will be prepared for the November/December 2002 edition. Hard copy products will continue to be the "medium-of-choice" for many entities in the region to keep current with issues associated with water resources decisionmaking and should be factored into the future decision support system.
- **Meetings and Conferences** - The Semiannual and Annual Meetings of the Great Lakes Commission have been used to report on progress, receive feedback and release interim and final reports. This has been a convenient and cost effective dissemination vehicle given that many of the participants in the WRMDSS project attend these meetings. Project findings and recommendations will likely be presented and discussed at other related meetings and conferences where Great Lakes issues are discussed. Face-to-face communication should continue to be a major vehicle for information dissemination and coordination of decisionmaking and as such also needs to be explicitly designed into the water resources decision support system.

These communication tools are proven to be effective; further work is necessary to refine them in an integrated fashion to satisfy the needs of decisionmakers, scientists, policy analysts, and other interested parties. An initial approach to the development of many of these tools should be to hold a workshop and/or forum focused on the design of the intranet suite to complement information exchange and communications provided through current Internet offerings.

An intranet workshop/forum would introduce decisionmakers to available data and information resources and new modeling and visualization tools. This would demonstrate their value as decisionmaking tools and guidance. The workshop would convene researchers engaged in projects addressing water quantity

management issues and, in particular, ecological assessment with the objective to facilitate communication, and to promote the transfer of research outcomes into policy and management applications for Annex 2001 implementation. The workshop would allow for identification of the components of the intranet service that will maximize value to prospective users; design the larger-scale research forum; and discuss the broader range of activities/initiatives needed to better coordinate research and maximize policy/management applications. The forum could address topics such as information exchange/technology transfer; science/policy linkages; a review of progress toward Annex 2001 implementation; data and information management goals; and mechanisms to maximize research coordination and policy/management applications over the long-term.

Development of an intranet suite coupled to GLIN would allow the science, policy and management communities to access relevant Annex 2001 documentation (e.g., research results, policy documents); review and comment on draft materials; post upcoming event notices and other relevant information; and otherwise communicate on matters of shared interest. The site could be used to facilitate discussions and document exchange between the Annex 2001 Working Group, DSS project personnel and working groups, Great Lakes Protection Fund researchers, and other relevant parties. This would greatly enhance the critical, information-sharing component of the DSS and, in so doing, strengthen Annex 2001 implementation and contribute to Annex 2001 commitments. Development of the intranet suite in connection with GLIN would ensure its long-term maintenance and availability, due to a commitment of the Great Lakes Commission in its mandate to promote sound public policy decisions on water quantity management issues.

8.7. INFORMATION AND COMMUNICATIONS IN A DECISION SUPPORT FRAMEWORK

Prior to the selection and implementation of the decision support system, managers, scientists and decisionmakers must have the opportunity to review and evaluate alternative decision support frameworks – or models – that organize critical, yet disparate, data and information in a way that will foster science-based evaluation of withdrawal proposals. Decisionmakers should be presented with multiple alternative decision support frameworks, and be fully involved in associated testing and evaluation. The groups charged with conducting the initial research, review and assessment of different options should not advocate for a single, specific alternative, but provide the forum by which the decisionmakers (i.e., the Annex Working Group) can reach their own conclusions on which option or suite of options best meet the needs of the region.

An example of one component of a decision support system might be an interactive software program that walks the user through the entire decision process. Among others, this might include an overview of Great Lakes water resources and associated management efforts (with graphics); an introduction to the water withdrawal application process and associated Great Lakes Charter and Annex 2001 documentation; a flow chart of the process; visual displays (e.g., clickable maps and GIS displays) of the area(s) of interest; and extensive linkages to all relevant science-based data and information, evaluation models and related resources. As the water withdrawal applicant/evaluator is "walked through" the process, the software program would link the user – at appropriate stages – to relevant scientific data and information. This would include all key data sets and other products of the WRMDSS project, such as water use data by basin, jurisdiction and sector; consumptive use information; relevant literature (peer-reviewed and "gray") on ecological impacts; essential questions to elicit an assessment of ecological impacts; computer models and other tools (e.g., GIS) that can be employed to evaluate withdrawal proposals; and data/information concerning the application of a resource improvement standard.

8.8. RECOMMENDATIONS

1. **Commitments should be made by all federal, state and provincial governments across the Great Lakes – St. Lawrence River system to cooperate fully in the development of 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. **Development of metadata should be stressed by all parties to accompany all geospatial and temporal data used in the water resources decision support system; complete metadata should benefit decisionmaking by facilitating information discovery, networked GIS mapping, and assessment and consideration of information uncertainties.**
3. **The water resources decision support system should intrinsically factor in a robust communications strategy, likely reliant upon existing and emerging Internet technologies; email and on-line discussion groups should be viewed as key components of the decision support system, along with applicable meetings, conferences and symposia focused on information coordination and continued system development.**
4. **An initial step in the development of interrelated information and communication tools should be to hold a workshop/forum, or a series of meetings, focused on the design of these tools for their use in the decision support framework.**

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