

North American Great Lakes Experience: Management Issues and Challenges

Jon MacDonagh-Dumler, Great Lakes Commission, Ann Arbor, Michigan, USA.
Victoria Pebbles, Great Lakes Commission, Ann Arbor, Michigan, USA.
John Gannon, International Joint Commission, Windsor, Ontario, CA.

Introduction

The North American Great Lakes constitute the largest system of fresh surface water on the face of the earth (Figure 1): over 244,000 square kilometers of surface water; 520,000 square kilometers of drainage area; and, a combined volume of nearly 23,000 cubic kilometers. Individually, the five Great Lakes are among the fifteen largest freshwater lakes in the world. With more than 17,000 kilometers of shoreline, including its thousands of islands, this ecosystem extends some 3,500 kilometers from the westernmost shores of Lake Superior to the Atlantic Ocean (Figure 2). The lakes provide daily drinking water to two-thirds of its' 40 million residents. Domestic and commercial uses of lake water consume nearly four trillion liters daily. Water dependent industry - such as heavy manufacturing, agriculture, recreation and tourism, and sport and commercial fishing - are all multi-billion dollar a year industries (Table 1).

Figure 1. Great Lakes-St. Lawrence River System (GLIN, 2003)

Table 1. Great Lakes Physical Features and Population (Fuller and Shear, 1995)

The profile of the human geography and economy of the Great Lakes region is quite significant and serves to underscore its numerous management challenges (Kling et al., 2003). Residing within the political jurisdictions of the eight Great Lakes states and province of Ontario are more than 60 million people with more than half of them located in the Great Lakes drainage basin itself. This in-basin population comprises 20 percent of the U.S. population and 60 percent of the Canadian population. Population growth was nearly nine percent in the Great Lakes states and over 12 percent in Ontario in the last decade. There are many major cities located on Great Lakes shorelines, including: Buffalo, Chicago, Cleveland, Detroit, Hamilton, Milwaukee, Toledo, Toronto, and Windsor.

Figure 2. Great Lakes System Profile (GLIN, 2003)

The regional economy is quite large and diversified with manufacturing, services (including tourism and recreation), agriculture, forestry, and government sectors. The Great Lakes binational region forms the industrial heartland of North America with total production in 2000 of nearly \$2 trillion (USD), which is only exceeded by the gross domestic production of the United States and Japan. In 2000, Canada derived more than 50 percent of the value of manufacturing shipments from Ontario alone and, in the U.S., six of the Great Lakes states

contributed greater than 25 percent to the total manufacturing value added. Significant industrial growth began about 1850 and relied upon resource extraction through mining, harvesting timber and low-cost shipping on the lakes. For example, the huge steel mills of Gary (Indiana), Pittsburgh (Pennsylvania), and Cleveland (Ohio) obtained iron ore from northern Minnesota that was shipped down the lakes. These same commercial shipping routes carried steel products to Detroit and Chicago for further processing into finished consumers goods, such as automobiles and farm equipment. With this infrastructure in place, the region maintains significant shipping ports that serve large freighters carrying goods and commodities, such as grain, soybeans, coal, iron ore, from both in-basin and out-of-basin areas of the U.S. Midwest and Canada. These shipments are worth billions of dollars; in addition, the businesses that service this activity generate \$3 billion (USD) in yearly business revenue and employ more than 60,000 people.

Agriculture figures prominently in the Great Lakes region producing more than 25 percent of the total value of US agricultural products, which includes about half of the nation's corn and soybeans. Similarly, the Canadian side of the Great Lakes basin produces nearly 25 percent of total agricultural output with aggregate economic value in Ontario exceeding all other provinces except Alberta. Forestry operations are significant in some locations but overall contribute less regionally. For example, in the last decade the Ontario forest products industry employed more than 90,000 people while generating more than \$15 billion (CdnD). In 2000, Wisconsin alone employed 74,000 workers in pulp, paper, and wood products manufacturing which generated more than \$18 billion (USD).

More recently, diversification into a variety of service sectors has created one of the largest components of the regional economy, which includes many tourism, recreation, and environment-related enterprises. Water related amenities on and near the Great Lakes represent the major recreation and tourism attraction in middle America. For example, more than two million tourists visited the Indiana Dunes National Lakeshore and Sleeping Bear Dunes National Lakeshore (Michigan) in 1999. In 2001, provincial parks in Ontario drew a total of more than 11 million visitors from Point Pelee (on Lake Erie) to Lake Superior. In addition, smaller inland lakes attract many in northern Michigan, Minnesota, Ontario, and Wisconsin. And in winter, downhill and cross-country skiing, and snowmobiling draw large numbers of visitors. On the U.S. side more than 15 million people engage in fishing, hunting, or wildlife watching activities bringing in \$18.5 billion (USD) annually. Similarly, travel and tourism in Ontario generated more than \$20 billion (CdnD) in 2000.

More broadly, the Great Lakes region must be seen and understood in terms of numerous competing socio-economic, political and environmental characteristics and issues. All who live in the region are stewards of a finite resource that must be managed sustainably. In a certain sense, the residents are also participants, directly or indirectly, in a very large scale institutional experiment reconciling economic and geo-political boundaries with hydrologic ones. Though the experiment began little more than a century ago, the successes and failures in governance and resource management that are learned in the region will likely have global applications. Therefore, the Great Lakes might also be described as the largest freshwater laboratory for institutional experimentation on the face of the earth.

The Evolution of Regional Governance

Experimentation with government institutions is an ongoing process with a long and storied history for both Canada and the United States. By way of proxy for both, the following outline is provided to reveal the major features of evolving government institutions that affected resource management; in this outline five successive eras are described (Donahue, 1996).

Since the founding of the nation in the late 1700s waterways have provided vital transportation routes to compensate for a lack of roads. The very first commercial canal project was led by George Washington, the first president. Competing state interests between Maryland and Virginia initially indicated limits to state sovereignty and began to frame federal/state relations.

The “Resource Development” Era - circa 1780-1850

Water resource project were development oriented, with transportation as a major emphasis and were generally designed to overcome the limitations of the physical system, such as with the poor road system. In 1797, a rudimentary lock was constructed at what is now Sault Ste. Marie, Michigan. This project was followed by the Erie Canal in 1825; the Welland Canal in 1828; the Chicago River locks in 1848. These projects had a single objective: structural development and so comprehensive planning was the exception rather than the rule during this era.

The “Transition” Era - circa 1850-1900

Permanent, multi-jurisdictional institutions were established which had expansive water resources development responsibilities. For example, the federal Rivers and Harbors Act of 1852 created regional institutions for navigation improvements, bank stabilization and flood control. Structural changes and development of water resources systems largely characterized this era through federal legislation that created government institutions with broad powers. In the Great Lakes region, health crises along with economic opportunities accelerated the development toward this new paradigm of resource management. For example, outbreaks of typhoid and cholera in the late 1890s in Chicago resulted in a project that reversed the flow of the Chicago River from Lake Michigan southwest into the Mississippi River basin.

The “Federal Leadership” Era - circa 1900-1950

This era was characterized by strong federal legislation, and consequently federally dominated water management institutions, an acceptance of comprehensive planning, and much debate on the role of regional governance in the U.S. system of federalism (vis-à-vis sharing power over water resources with the states). The 1920s and 1930s saw the federal government embrace and dominate the practice of comprehensive basin planning. For example, in the Great Lakes region the federal government negotiated the International Boundary Waters Treaty of 1909 with Great Britain. A new institution was created to implement the terms of the treaty: the International Joint Commission which reflected the multi-objective, multi-jurisdictional emphasis on governance.

The “River Basin” Era - circa 1950-1985

A fourth era emerged with still greater federal powers and unprecedented institution building at the river basin level. But it also asserted federal/state partnerships and state stewardship responsibility for water resources through the establishment of river basin commissions, such as the Great Lakes Basin Commission. It also emphasized environmental protection and resource management, as opposed to development. The shift from federal dominance to state empowerment also continued with the 1954 creation of the Great Lakes Fishery Commission, a binational agency with strong state and provincial involvement, and the 1955 creation of the Great Lakes Commission, an interstate compact agency founded in both state law and Congressional consent legislation.

This era began to end in 1981 by executive order of the president, which dismantled the institutions established under earlier federal legislation - the Water Resources Planning Act. In addition, federal power over water resources was becoming further entrenched with implementation of the Federal Water Pollution Control Act of 1972. Counterbalancing these developments, however, the Council of Great Lakes Governors was formed in 1982 indicating that, at least in the Great Lakes, there was a new state stewardship ethic emerging.

The “New” Era - circa 1985- Present

The present era of resource management has seen the transition from a top-down, command and control, government dominated approach to a bottom up, partnership-based, inclusive one. A number of developments, which have sometimes been contradictory, appear to explain this transition. These developments include:

- The “new federalism” philosophy of the Reagan Administration which viewed water resources issues largely as concerns of the states either singly or collectively;
- The current downsizing and “re-invention” of the federal government, prompted by efficiency concerns and budgetary constraints;
- A “kinder and gentler” federal government that has tempered its regulatory emphasis with voluntary compliance and partnership characteristics;
- A rising ethic of self determination, stewardship and collaboration among states; and
- Relentless efforts of “grass-roots” non-governmental organizations to empower communities and individuals.

Collectively, these influences have had a profound impact on regional water resources management. The evolution in governance can be characterized as follows:

Sustainable Use Vulnerabilities

“There are two basic and quite different bilateral Great Lakes issues: lake levels and water quality.” In 2003, many Great Lakes managers and researchers would agree with this statement, which was in fact published twenty years ago (Carroll, 1983). Notwithstanding progress in addressing issues of water quality and lake levels over the past two decades, water quality and lake levels continue to dominate the Great Lakes policy and management arenas. Anthropogenic and natural ecological processes that degrade water quality or stymie its improvement and those that do or potentially can result in changes in the quantity of water sustained in each of the five lake basins and their connecting channels continue to threaten the sustainable use of the Great Lakes.

Threats to Water Quality

Point Source Discharges

Historically, the primary threats to water quality came from municipal and industrial “point source” discharges. Sewage from residences, shops and workplaces was discharged untreated or minimally treated into Great Lakes tributaries and the lakes themselves. Paper, steel, automobile and other manufacturing industries that have historically dominated the regional economy released their leftover chemical cocktails and sludges, into the land, water and air.

A suite of federal environmental legislation on both sides of the border was part of a maturing environmental movement that began alongside other social movements in the 1950s and 60s. On the U.S. side, major federal laws were established to control pollution from these point sources to the water directly and indirectly from the air and land. These included the Federal Water Pollution Control Act Amendments of 1972 (known as the Clean Water Act), the Clean Air Acts of 1970 and 1977 and the Resource Recovery and Conservation Act of 1976. Canada similarly passed federal environmental laws, including the Canada Water Act of 1970, albeit with a very different approach (Carroll, 1983).

Programs to address point source discharges have met with relative success over the past several decades, (particularly in the area of phosphorous, but also due to sewage treatment plants and other control measures) exposing the significance and ubiquity of non-point sources of pollution (runoff and air deposition) as well as historic contamination. Today, the biggest threats to Great Lakes water quality come from a variety of non point sources of pollution.

Nonpoint Source Discharges from Land Use Activities

1. Urban Development and Runoff

One of the most significant land use issues in the Great Lakes region is the continuing growth of major metropolitan areas and sprawl of residential areas and other development (Pebbles, 2001). Since World War II, the human footprint on the land around the Great Lakes has been transformed by a major shift in land development patterns from high-density urban development to low-density suburban and development. This shift reflects that of the nation at large and has

happened at a rate unparalleled in American history. Over several decades, the Great Lakes went from being a region of distinct cities, towns and rural areas to one of metropolitan areas dominated by suburbs comprised of strip malls and segregated bedroom communities connected by vast amounts of wide lane roads and boulevards. The causes and consequences of sprawling development are the subject of much discourse and debate. Several elements aspects of urban runoff contribute it as a threat. One is erosion from construction activities that involves removal of vegetation, soil compaction/grading and development. The impacts of development are exacerbated by the extent of impervious cover that occurs with sprawling development patterns that result in extensive impervious land cover in the form of roads, parking lots, sidewalks and rooftops. Impervious cover threatens water quality by preventing rain and snow from slowly filtering into the ground and instead redirecting it rapidly and directly to drains and streams, increasing the frequency and severity of flooding and erosion along the way and degrading stream and riparian habitat. Although all development results in some impervious cover, low-density nature of sprawl results in the need for more roads rooftops and parking lots to connect shops, homes and workplaces and house automobiles necessary to get there. The “green” areas around these low-density developments rarely compensate for the impervious cover as the land is compacted and where revegetation occurs, it usually involves lawns and selected ornamental shrubs and trees that have much less water absorption and filtering capacity than the grasses, trees and shrubs that existed on the land prior to development.

Pollutants from urban and suburban activities that end up in runoff are as varied as the types of human activities. They include oil and grease from automobiles, surface decay, pesticides and herbicides from home yard care, household cleaning products and pet wastes. The threat of these pollutants is exacerbated with high levels of impervious surface that block infiltration—one of nature’s foremost abilities to deal with pollutants.

2. Agricultural Runoff

Agriculture is a leading economic activity in all of the Great Lakes states and its footprint around the Great Lakes basin is significant, representing 24 percent of the basin or 25 percent of the land base (Thorp et al., 1997). Although seemingly more benign than industrial manufacturing, the impacts from agricultural practices are more insidious and can stake a significant claim in the degradation of Great Lakes water quality. The shift from agriculture to agribusiness that also occurred during the middle of the 20th century was characterized by heavy use of chemicals and nutrients to fend off pests, resist disease and ensure highest possible yields. There was little to no regard to the impacts of indiscriminate use of pesticides—in the home or on the field—until the release of “Silent Spring” in 1962, the seminal book which challenged and ultimately changed the way pesticides and other chemicals are used and managed in the U.S. The impact of agriculture is related to the type and extent of agricultural land uses and management practices. About 65 percent of the basin’s farmland is cropland (Thorp et al., 1997). While cropland uses its share of chemical and nutrient inputs, and contributes to soil erosion and sedimentation, there is increasing attention to threats from livestock operations. Although livestock operations occupy a significantly smaller footprint, the growing concentration of animals per farm, inadequate manure management and the potential for waterborne pathogens from concentrated livestock operations is a growing concern. Regulations have recently emerged to address nutrient management from livestock operations, but their impact on ecosystem or water quality

improvement is still uncertain. While agricultural practices happen on the ground in the region, international trends in agricultural production and commodity pricing influence local practices.

3. Farmland Conversion

Although agricultural practices can and often do degrade water quality, agriculture also has attributes that can contribute to and enhance ecosystem integrity. This is an important consideration in light of other major competing land uses, particularly urbanization. In contrast to urban development where the impacts are essentially irreversible, agriculture does hold promise for practices that have stewardship and productivity in mind. Contour farming, conservation tillage, the use of buffer strips, integrated pest management and other methods that reduce agriculture's negative impact on the environment hold promise for agriculture as an industry that can preserve land and open space where the hydrologic cycle can occur unimpeded. The same cannot be said for urban development. Once land is developed for roads or housing, it may change function or form, but it remains essentially urban. Actively farmed orchards and crops allow water to filter into the land and provide cover for some animals, functions which are enhanced by the practice of employing buffer strips or conservation easements. Importantly, farmland left fallow will eventually revert to a natural state with little to no long term consequences for ecological integrity.

The expansion of metropolitan areas referenced above goes hand-in-hand with farmland conversion. This phenomenon is particularly significant in the Great Lakes Basin where nearly two-thirds of the farmland is located within 31 miles (50 kilometers) of medium and large cities (GLC, 1996). As urban areas expand, surrounding agriculture and open space lands pay the price. Farmland loss in the U.S. portion of the Great Lakes Basin between 1982 and 1997 was more than 4 million acres, representing nearly 49 percent of the total farmland loss for the eight Great Lakes states during this period. The rate of loss is disparate across the region and the basin, since some jurisdictions (e.g., states/provinces) have relatively small basin land areas (e.g., Illinois) and others have less farmland in their portion of the basin (e.g., Minnesota). Whether looking at figures specific to the basin or the entire 8-state, 2-province region, the trend of farmland conversion over the last two decades is staggering. Between 1981 and 1997 more than 12.6 million acres of farmland were converted to other uses—a surface area larger than the size of lakes Erie and Ontario combined (Pebbles, 2001).

The urbanization and farmland conversion cycle places the agriculture at serious risk. Remedies must not only reduce urban sprawl, but also maintain viable agricultural economies at the local and regional levels.

4. Combined Sewers and Storm Sewer Overflows

Older urban areas built with combined sanitary (household sewage and industrial wastes) and storm sewer systems allow untreated sewage to bypass treatment and go directly into surface waters when treatment facilities are inundated during storm events. This “combined sewer overflow” is a serious threat to water quality and the sustainability of coastal areas from ecological and socio-economic standpoints. Separate sanitary sewer systems can also experience untreated discharges related to wet weather events, known as “sanitary sewer overflows” or

SSOs. These can be caused by excessive inflow and infiltration, inadequate maintenance, and insufficient wet weather transport capacity. SSOs and untreated CSOs can contain pathogens that lead to beach closures and human health concerns, as well as oxygen demanding substances that can lead to low dissolved oxygen levels. Untreated CSOs discharges may also contain industrial pollutants (USPC, 2002). Toronto still has 71 CSOs that remain and is developing a Wet Weather Master Plan and Wet Weather Flow Management Strategy for the City that will include by-laws, policies, projects, programs, a monitoring plan, an implementation plan and funding mechanisms to eliminate CSOs and SSOs, and institute a number of other water quality improvement measures (Toronto). Milwaukee is also meeting the challenge of reducing CSOs and SSOs. Since 1994, both sanitary and combined sewer overflows have been reduced from an annual average of about 70 to about 2.5 occurrences largely due to the construction of Inline Storage, or Deep Tunnel System. The system combines horizontal and vertical circular shaft constructions; since its inception in 1994 it is credited with preventing more than 227 overflows and capturing about 40 billion gallons of diluted wastewater (Milwaukee). While circumstantial evidence indicates that CSOs and SSOs continue to be a problem in other parts of the Great Lakes, there is no basinwide assessment of the threat.

5. Contaminated Sediments

Contaminated sediments from historic economic activities are perhaps one of the most unique yet serious ecological threats to the Great Lakes. Even after serious cleanup efforts began in the late 1960s, little attention was paid to the toxics concealed on the bottom of the lakes and their tributaries. The first priority was to stop the discharge of new contaminants, and little concern was paid to sediments. It was not until the early 1980s that environmental problems caused by sediment contamination began to generate interest. Decades worth of heavy metals and toxic organic chemicals mixed with the particles of rock, soil, and decomposing wood and shell have collected in the sediments of the rivers and harbors in the Great Lakes Basin. US EPA's Great Lakes program identifies polluted sediments as the largest major source of contaminants to the Great Lakes food chain, including each of the 43 Areas of Concern (AOC) designated under the U.S.-Canada Great Lakes Water Quality Agreement (see below). Over 2,000 miles (20%) of the Great Lakes shoreline are considered impaired because of sediment contamination and fish consumption advisories remain in place throughout the Great Lakes and many inland lakes. On the U.S. side of the border, sediments have been assessed at 26 Great Lakes locations and over 1,300,000 cubic yards of contaminated sediments have been remediated over the past 3 years. However, the challenge is so great sediment remediation is not yet complete at any US AOC (US EPA). In 2002, the U.S. Congress passed the Great Lakes Legacy Act, which authorizes \$270 million over five years from fiscal years 2004 to 2008. The Act authorizes \$50 million per year for "Projects" which may include: site characterization, assessment, monitoring, remediation, and/or pollution prevention, \$3 million per year for technology research, and \$1 million per year for public information programs.

Threats to Water Quantity and Lake Levels

The hydrology and "water balance" of the Great Lakes basin has been altered by human diversions, regulatory structures, urbanization, dredging, filling and other human activities over the last 200 years or so. Major diversions have shifted some flows from the Lake Michigan

watershed to the Illinois River/Mississippi River drainage system. And another diversion brings water from the James Bay/Hudson Bay watershed into the Lake Superior basin. Also, the International Joint Commission oversees regulatory structures at the outflow of Lakes Superior and Ontario to help control water levels in those lakes. Various large scale proposals to remove water from the Great Lakes have been around for almost a century, but received little attention. Heightened interest in Great Lakes basin diversions resulted in two policy responses in the 1980s. First, in 1985 the Great Lakes governors and premiers signed a binational good faith agreement known as the Great Lakes Charter, which established a series of principles and procedures for managing Great Lakes water resources. In 1986, the US Congress included a provision in the Water Resources Development Act (Section 1109) that prohibits any new or increased diversion of Great Lakes water without the approval of the Great Lakes governors.

Due to changes in regional leadership, uneven public interest, and inconsistent support for water management programs, the binational management framework called for in the Great Lakes Charter never fully matured (GLC, 2003). The deficiencies of the framework came to the limelight in the late 1990s when an Ontario-based company was issued a permit to withdraw Lake Superior water with the intent of establishing an overseas market for bulk water export. The Great Lakes community was caught by surprise, renewing a flurry of regional interest and activity in water resource management. In 2001, Canada amended its Boundary Waters Treaty Act to prohibit bulk water removals from the Great Lakes and set in place a licensing regime for dams and other public water works projects (GLC, 2003). Basinwide, the Great Lakes governors and premiers signed the Great Lakes Charter Annex in 2001 to reaffirm their commitment to the 1985 Great Lakes Charter and set forth a revised set of principles for Great Lakes water management. The Great Lakes Commission engaged in a two-year basinwide collaborative effort to assess Great Lakes water resource information and management and develop a framework for a Water Resources Decision Support System (WRDSS) for the binational Great Lakes-St. Lawrence River system.

The final WRDSS report released in June 2003, *Toward a Water Resources management Decision Support System for the Great Lakes-St. Lawrence River System*, provides a detailed assessment of data and information needs—a critical component for a completed decision support system—and suggests next steps for a complete WRDSS. It is now up to the governors and premiers to take the necessary next steps for establishing the legal and institutional mechanisms necessary for a functioning and effective Great Lakes water resources management framework and decision support system.

Threats to Ecosystem Integrity

To be sure, activities and events that threaten water quality and/or quantity are also threats to ecosystem integrity. Fortunately, the Great Lakes region has benefited from an institutional and legal focus on water quality and quantity as part of ecosystem integrity. The variety of other ecosystem stressors and threats and responses to them lists in the dozens, from soil erosion and sedimentation to air deposition of air toxics, to oil spills to information gaps, insufficient funding and institutional inertia. However, no discussion of threats to the Great Lakes system would be valid without mentioning the ongoing threat and impact of aquatic invasive or nuisance species.

1. Aquatic Nuisance Species

More than 140 nonindigenous, or invasive, species have become established in and around the Great Lakes since the 1800s (IAGLR, 2002). Due in large part to increases in the volume of shipping traffic, the introduction of new invasive species has increased dramatically over the past 50 years. More than 87 nonindigenous aquatic species have been accidentally introduced into the Great Lakes in the 20th Century alone. Once introduced, invasive species must be managed and controlled, as they are virtually impossible to eradicate.

In a recent study, the U.S. General Accounting Office looked at economic impact of invasive species in the U.S., the management plans of the National Invasive Species Council, efforts of the U.S. and Canadian federal governments to prevent introductions in the Great Lakes via ballast water of ships, and, finally, coordination of Great Lakes management efforts between the two countries (USGAO, 2002). The study found that current efforts are not adequate because: (1) some ships entering the Great Lakes carry residual water in their ballast tanks that later become mixed with, and subsequently discharged into domestic waters; and, (2) ballast water exchange procedures do not appear to be effective at removing or killing organisms in ballast tanks and there no standards nor fully effective technologies available to ensure protection of Great Lakes waters.

Policy, Legislative and Institutional Responses

Binational cooperation on the issue of water began well before the U.S. national environmental movement of the 1960s with the 1909 U.S.-Canada Boundary Waters Treaty. The Boundary Waters Treaty established the International Joint Commission (IJC)—a binational body to prevent and settle disputes over the use of waters shared by the U.S. and Canada and was a landmark in Canada-U.S. cooperation, paving the way for Great Lakes-specific efforts. The IJC is comprised of six commissioners, three U.S.-appointed and three Canadian-appointed. It is supported by a complex organizational structure of more than 20 boards and reference groups made up of experts from the U.S. and Canada, including the Great Lakes. While the treaty includes a provision to protect the boundary waters from pollution, it was not enough to address the growing water pollution problems in the Great Lakes.

In 1964 the two governments forwarded a reference to the International Joint Commission (IJC) requesting it to determine whether the Great Lakes were polluted and what could be done to remediate them. An important outcome of the reference was the recognition that federal legislative efforts to address water quality on either side of the border were inadequate to deal with the multijurisdictional complexities of the Great Lakes as a binational resource shared by two federal governments, eight states, and two provinces and thousands of local governments. In 1972, the U.S. and Canada signed the Great Lakes Water Quality Agreement, which calls on the Parties (the U.S. and Canada) *“to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes ecosystem.”* Signed by President Nixon and Prime Minister Trudeau, the Agreement does not have treaty status, but is a binational executive agreement that commits Canada and the United States to specific actions to protect and enhance water quality.

The Great Lakes Water Quality Agreement not only addressed the water quality issue, but perhaps equally important, the issue of multiple fragmented jurisdictions. To this end, the Agreement established the IJC Great Lakes regional office (the only IJC regional office) which has specific responsibilities for providing technical support, coordinating programs and monitoring implementation of the two federal governments under the Agreement. The IJC has established a Great Lakes Water Quality Board and a Science Advisory Board to carry out its mandate under the Agreement.

Prior to 1972, the IJC investigations only held public hearings on specific topics; otherwise, these were carried out in private because only the governments could give permission to release "internal communications . . . by boards, committees". Under the 1972 Agreement, public involvement increased; the Research Advisory Board (RAB) of the IJC sponsored a workshop to consider means to enhance public participation. The RAB's Standing Committee on Social Sciences, Economic, and Legal Aspects met in 1975 and established seventeen public advisory panels for the *Pollution from Land Use Activities Reference* Group study (PLUARG). The PLUARG study followed up the 1964 Lower Great Lakes Reference on the lower Great Lakes and St. Lawrence River; the latter study led to the Great Lakes Agreement of 1972. Eventually, PLUARG resulted in over 100 published reports. Hundreds of citizens and local officials were involved in the 17 advisory panels. The involvement of the public during the course of PLUARG generated three long term results: (1) those involved brought diverse backgrounds and interests from across the basin; (2) local involvement developed a the outline of a framework for the Remedial Action Plan process; and, (3) recommendations from the public advisory panels shaped the decision agenda of the IJC itself (Botts and Muldoon, 1983).

In addition, the PLUARG enhanced scientific understanding of nonpoint and land-based sources of pollution to the Great Lakes by showing that the problem originated from many sources; in other words, Great Lakes water quality problems were an air problem, a land runoff problem, a contaminated site problem, and possibly a human health problem. It also provided the basis for the ecosystem concept of water resource management and stewardship which was eventually incorporated into the GLWQA.

The Agreement was revised in 1978 to establish more comprehensive and stringent water quality objectives with a greater ecosystem focus. It was amended again in 1983 and further in 1987, the latter amendment committing the two governments to develop and implement Remedial Action Plans (RAPs) for 43 Geographic Areas of Concern (AOC) within the Great Lakes where beneficial uses were threatened or impaired. Though the Agreement is an executive agreement between the two federal governments and does not have treaty status, it has been incorporated into federal, state and provincial law on both sides of the border. Cleaning up AOCs and developing Lakewide Management Plans to reduce pollutant loadings for each Great Lake with a binational shoreline (i.e., not Lake Michigan), has become a major focus of binational ecosystem management efforts in the Great Lakes (Hildebrand et al., 2002).

Complementary binational program responses have emerged under the Great Lakes Water Quality Agreement, including:

- A biennial ecosystem conference to report on the State of the Great Lakes based on a series of established ecological indicators

- A binational toxics strategy to address persistent toxic substances
- A framework to coordinate relevant federal, state and provincial agency activity in cleaning up AOCs shared by Ontario and Michigan; and
- A program to eliminate point source discharges of persistent bioaccumulative toxic substances into Lake Superior

Canada and the United States have also been working cooperatively on Great Lakes fisheries issues since 1955 through the Great Lakes Fishery Commission (GLFC), which was established under a Canada-U.S. Convention on Great Lakes Fisheries. The Convention is an international treaty that has been incorporated into federal law on both sides of the border. The Fishery Commission is focused on ways to improve and perpetuate fisheries resources of the lakes, develop and coordinate fishery research programs, and develop measures to manage the parasitic sea lamprey (Great Lakes Panel, 1996). The Fishery Commission's Strategic Vision for the First Decade of the New Millennium (2001 through 2010) focuses on three areas: 1) Healthy Great Lakes Ecosystems; 2) Integrated Management of Sea Lamprey; and 3) Institutional /Stakeholder Partnerships (GLFC, 2001).

The eight Great Lakes states themselves have been working collaboratively on basinwide ecosystem management issues through the Great Lakes Commission (GLC) since 1955. The GLC is an interstate compact agency founded in state and federal law and comprised of state officials, legislators and governors' appointees from the eight Great Lakes states. The GLC was established to guide, protect and advance the common interests of the eight Great Lakes states in areas of regional environmental quality, resource management, transportation and economic development. The status of Great Lakes provinces (Ontario and Quebec) was elevated from observer to associate member in 1999, reflecting the GLC's anticipated evolution to a fully binational state-provincial agency. The GLC staffs over a dozen issue-specific task forces and advisory committees to address the variety of ecosystem priorities and special projects being undertaken by the Commission at any given time. Dredging, aquatic nuisance species, soil erosion and sedimentation, wetlands monitoring, oil spill prevention, air toxics and online information sharing are just some of the ongoing task forces and regional initiatives managed by the GLC.

Also concerned with basinwide issues on the U.S. side is the Council of Great Lakes Governors, a non-profit organization whose members include the governors of the 8 Great Lakes states, which was formed in 1983 to coordinate stewardship of the region's economy and environment. Among the Council's most notable cooperative binational ecosystem management initiatives is the 1985 Great Lakes Charter. The Great Lakes Charter is a good-faith agreement of the Governors and Premiers of the Great Lakes basin to express their shared concern over water supply and use issues, which sets up the Council to oversee implementation of a binational process to review water use patterns and consider diversion and consumptive use proposals under the terms of the Charter.

A series of programs to reduce discharges from point sources has allowed both countries to claim success with controlling pollution from the most prominent sources. The region's simultaneous decrease in manufacturing (Testa, 1991) that reflected larger national and global economic trends might have resulted in fewer active industrial polluters. By the late 1990's the major threats to

the Great Lakes water quality were nonpoint source discharges, but non-point sources and historic contamination.

Lessons Learned: Research

Formality and Informality

Research on the Great Lakes has benefited from the lakes being binationally shared between the United States and Canada. The formal agreements, including the Great Lakes Water Quality Agreement and the Convention on Great Lakes Fisheries, provide binational communication mechanisms for the development of research needs and recommendations. These functions are performed by the Science Advisory Board and the Council of Great Lakes Research Managers under the Great Lakes Water Quality Agreement and the Board of Technical Experts under the Convention on Great Lakes Fisheries. Research needs and future directions are developed through panels, conferences, and workshops organized by the Great Lakes Commission, or by funding agencies, including the National Science Foundation (Johnson, 2003), the Great Lakes Protection Fund, or by private foundations. The multidisciplinary International Association for Great Lakes Research (IAGLR) performs an important function in communicating research results on the Laurentian Great Lakes, and other large lakes of the world, through its annual Great Lakes Conferences and Journal of Great Lakes Research. Recognizing that scientific information is often too technical for decision-making, IAGLR is currently engaged in a project to strengthen the connection between Great Lakes science and policy with initiatives on urban nonpoint source pollution and aquatic invasive species (see <http://www.iaglr.org/scipolicy>).

In addition to these formal arrangements, it is important to recognize the role of informality to the vitality and relevance of Great Lakes research to resource management issues and problems. A secondary benefit of the conferences, workshops, and task forces created by the above-mentioned and other formal institutional arrangements is the role they provide as a communication forum for researchers to get to know one another. Collegial relationships are developed and often evolve into collaborative research between individuals who share expertise, enjoy each other's company, and look forward to working together. Another strength of Great Lakes research is that researchers often informally call meetings among themselves, outside of the formal institutional arrangements and without directives from program administrators. For example, when the zebra mussel invaded the Great Lakes in the 1980's, U.S. and Canadian scientists met and developed a research needs document that later evolved into the work of Great Lakes Aquatic Nuisance Species Panel. More recently, the informal Lake Erie Millenium Network was formed by U.S. and Canadian researchers and managers to develop research plans and share research results through conferences and workshops on the rapidly changing Lake Erie ecosystem.

Academia and Government

Research programs are conducted by academic institutions and State, Provincial, and Federal government laboratories both in the U.S. and Canada. There is no strict division of responsibility between academic and government research on the Great Lakes. In general, academia is better

adapted to conduct pure research and more quickly respond to new and emerging issues. While government programs give more emphasis to applied research focused on resource management, policy needs, and long-term research and monitoring. On the surface, there is a complementary and mutually reinforcing relationship between academic and government research in the Great Lakes. In reality, reductions in funding and personnel has resulted in academic and government research spending an inordinate amount of time competing for shrinking Great Lakes science dollars. Under these circumstances, the weaknesses in Great Lakes research coordination become more apparent, resulting in calls to strengthen the Great Lakes research agenda (Thomas & Cooley, 1996; Krantzberg, 1997; Matisoff, 1999).

Disciplinary and Interdisciplinary

Much of Great Lakes research has been driven by environmental crises. Research focused heavily on single issues including eutrophication during the 1960's and 1970's; toxic contaminants in the 1980's; and invasive species during the 1990's (McNaught, 1993). There will always be a need for more research emphasis in some disciplines research, for example, more research is needed into the economic valuation of environmental benefits (Cangelosi, 2001). The greater challenge facing the Great Lakes research community is to plan, coordinate, and conduct multidisciplinary research to better understand the structure and function of the Great Lakes basin ecosystem in this new millennium. Environmental conditions in the Great Lakes are rapidly changing and it is becoming increasingly difficult for research to provide information useful for guiding Great Lakes resource management and policy towards environmental protection, restoration, and sustainable uses of the Great Lakes region. In particular, there is need for more multidisciplinary research interaction in the Great Lakes between limnology and fisheries; water and watersheds; and environment and economics. The Great Lakes community has been a leader in espousing an ecosystem approach to research and management but is still challenged to advance the ecosystem approach from concept to practice (Christie et al., 1985; Hartig et al., 1995).

Monitoring

Environmental monitoring is extremely important for detecting emerging issues, assessing the effectiveness of regulatory and resource management programs, assessing progress in restoration efforts and determining status and trends in ecosystem health. Yet, monitoring is often criticized for not measuring the right parameters and for collecting too much data without sufficient attention to synthesis and reporting. Many of the afore-mentioned lessons learned on Great Lakes research also applies to monitoring.

Governments and academia are both involved in monitoring in the Great Lakes with the majority conducted by the former. Formal binational monitoring agreements, such as the Great Lakes International Surveillance Plan (GLISP) under the Great Lakes Water Quality Agreement, are necessary but have faced serious shortcomings in implementation. In addition to formal monitoring plans, it is important to recognize more informal data sets that have been maintained by academic and government scientists; such data sets become invaluable in monitoring and interpreting ecosystem changes often unrelated to the purpose for which the data were originally collected. A shift in emphasis is well underway in Great Lakes monitoring from water and

sediment chemistry (pollutants and algal nutrients) to more integrative, multidisciplinary approaches, including atmospheric deposition and biological indicators of ecosystem health (Gannon et al., 1986). Results of monitoring efforts in the Great Lakes are reported at the biennial State of the Lakes Ecosystem Conference (SOLEC; see <http://www.binational.net>) for the environmental management community and at annual lake committee meetings for the fishery management community (see <http://www.gllfc.org>). Currently, there is considerable interest from Great Lakes researchers and management to improve planning, integration, and coordination of Great Lakes monitoring to better understand status and trends of ecosystem changes and responses to stressors. As for research, there is a history of good binational communication and cooperation on Great Lakes monitoring, but a new level of improved coordination is required to advance scientific understanding and influence environmentally sustainable economic development of the Great Lakes basin ecosystem in this new millennium.

Lessons Learned: Institutions and Governance

Institutional Arrangements for Advancing Sustainability

Lake resource management in the Great Lakes basin, as practiced by early European immigrants, focused on single resource extraction activities, such as timber. Through successive eras, these practices have evolved to multi-objective, multi-media and multi-disciplinary planning and management that strives to balance environmental and economic prosperity goals (Donahue, 1996). Innovation in ecosystem management is now guided by “sustainability” concepts, such as that advocated by the Brundtland Commission: a state at which today’s society is able to meet its needs without compromising the ability of future generations to meet their own needs (WCED, 1987). Indeed, much has been learned regarding environmental and economic sustainability within the framework of Great Lakes institutions. There are now recognized, and presented below critical actions which could help to ensure that further evolution within institutions is encouraged for the advancement of sustainable management practices (Donahue, 2002).

- **Characterize the roles, relationships and gaps on the “institutional ecosystem.”**

Continued evolution of this very complex system of institutions will be enhanced through understanding the interactions of the multitude of government and non-government entities, organizations and other interests. Ongoing study of the roles and relationships among these stakeholders is one of the essential elements to sustainable basin governance.

- **Creative use of informal institutional arrangements.**

As noted earlier, much of the “institutional infrastructure” for Great Lakes resource management has been created through laws, treaties, conventions, compacts and formal agreements. These formal institutions are costly to create and maintain. Other alternative relationships, in the form of non-binding, “good faith” agreements among the relevant parties should be carefully explored where advantages, such as flexibility, are desirable.

- **Design institutions that “learn.”**

Once an institution has been established to address a crisis or problem it becomes vulnerable to problems, such as irrelevance or inefficiency as the problem is ameliorated or eventually

solved. However, if the institution is designed to “learn” and adapt to its changing context then it is capable of responding to emerging issues, such as aquatic nuisance species, climate change, water export, energy transmission infrastructure, or the assertion of stewardship by First Nations and tribal authorities. Lake management institutions must be designed not only for a “crisis response,” but also to “anticipate and prevent” emerging problems.

- **Translate regional governance lessons to other international/global contexts.**

Great Lakes management institutions can learn from the successes and failures of other regions of North America and the world (e.g., Baltic Sea). Science provides a model for translation and sharing of knowledge on such issues as air deposition of toxic substances, the introduction and spread of aquatic nuisance species, and the origins and impacts of climate change. Applying this model to the governance arena would be helpful.

- **Integrate science and policy throughout lake management institutions.**

Related to the recommendation just discussed, the science community appears to lack relevance knowledge that could be applied to resolving policy issues. Moreover, institutional managers appear to ignore or discount scientific evidence in establishing their policies. Thus, there is a need to strengthen communications between scientists and decision makers regarding relevant and helpful knowledge while also providing feedback on solutions that do or do not work.

- **Develop an ecosystem view of the impact of institutional change.**

As lake management institutions evolved in the Great Lakes basin they often did so in response to a crisis or singularly focused objective. Other needs went unmet or were ignored. There is the need to carefully consider the Great Lakes institutional ecosystem to achieve a more orderly, objective and reasoned approach that addresses long-term governance needs.

- **Develop a clear, coherent and consensus-based understanding of “sustainability.”**

As a concept, “sustainability” provides a point of reference for many decision makers in the Great Lakes. While the broad definition provided by the Bruntland Commission is instructive, a coherent understanding is lacking which compromises its applicability and usefulness. A consensus-based working definition is needed to inform management and policy processes.

Benchmarks and Audit Processes of Institutional Performance

In order to gauge progress toward ecosystem management goals it is necessary to identify indicators, or benchmarks of ecosystem health. For example, in 1993 the International Joint Commission established an Indicators for Evaluation Task Force (IETF, 1996a) to identify ecosystem indicators for assessing progress under the Great Lakes Water Quality Agreement. The IETF report also extensively documented similar efforts by others (IETF, 1996b). In particular, the U.S. Environmental Protection Agency and Environment Canada have jointly sponsored and coordinated the State of the Lakes Ecosystem Conference (SOLEC, 2002) that serves their agencies program needs as well as those of many resource managers throughout the basin. Clearly, these efforts are fundamentally important to ensure that ecosystem restoration and

protection programs are properly focused and effective. However, many institutions and government programs are lacking performance benchmarks for their processes.

- **Expand mechanisms of accountability among regional institutions.**

To enhance efficiency, effectiveness and responsiveness of regional, multi-jurisdictional institutions, mechanisms of accountability should be expanded, including the use of performance measures, benchmarks, and enhanced public profile and interaction.

- **Incorporate an audit process into basin governance initiatives.**

Audit procedures that thoroughly assess management program activities can realize two important benefits. First, audits enhance efficiency and effectiveness by identifying and correcting problems with the program approach or implementation. They also document accomplishments in achieving the priorities of resource managers and the public. These procedures should be included in basin governance initiatives, including post-audits to identify lessons learned for management future initiatives.

Research on Institutions and Governance

Moving the notion of sustainability along the path from concept to application requires research on in the past, the nexus between Great Lakes institutions and regional governance issues have not been examined closely. Progress on developing sustainable approaches to ecosystem management requires more attention to research on these problems; specifically:

- **Enhance understanding of the institutional and governance relationships affecting the physical and socio-economic dimensions of the Great Lakes ecosystem.**

A recurring need of government policies is to integrate environmental and economic goals in a manner that is sustainable for the ecosystem and also transparent in the design and operation of institutions. The physical characteristics of the basin have been extensively studied and incorporated into institutional design whereas socio-economic characteristics have not. Further research into both the physical and socio-economic dimensions, and how their characteristics translate into institutional practice is clearly needed.

- **Careful research of existing governance mechanisms, the relationships among them, and their role in advancing ecosystem management goals.**

Any research program that would aim to strengthen or otherwise revise the roles and responsibilities of institutions must not only examine those already in place, it should identify unmet needs for new institutions and characterize the differences between them. The first step is “mapping” the institutional ecosystem, as recommended above.

- **Evaluate the contributions and potential roles of First Nations/ tribal authorities.**

Current basin governance sometimes includes tribal authorities in a variety of planning and policymaking mechanisms. At the same time, First Nations are increasingly asserting their role in these activities. Their formal representation on basin institutions is presently limited at best, as is their status as signatories to basin agreements. Thus, it is clear that policy research on these emerging First Nations/ tribal authority interests in basin governance is needed.

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Figure 1. Great Lakes-St. Lawrence River System (GLIN, 2003)
Available online at the GLIN Map Gallery: <http://www.great-lakes.net/gis/maps/>



Figure 2. Great Lakes System Profile (GLIN, 2003)
 Available online at the GLIN Map Gallery: <http://www.great-lakes.net/gis/maps/>

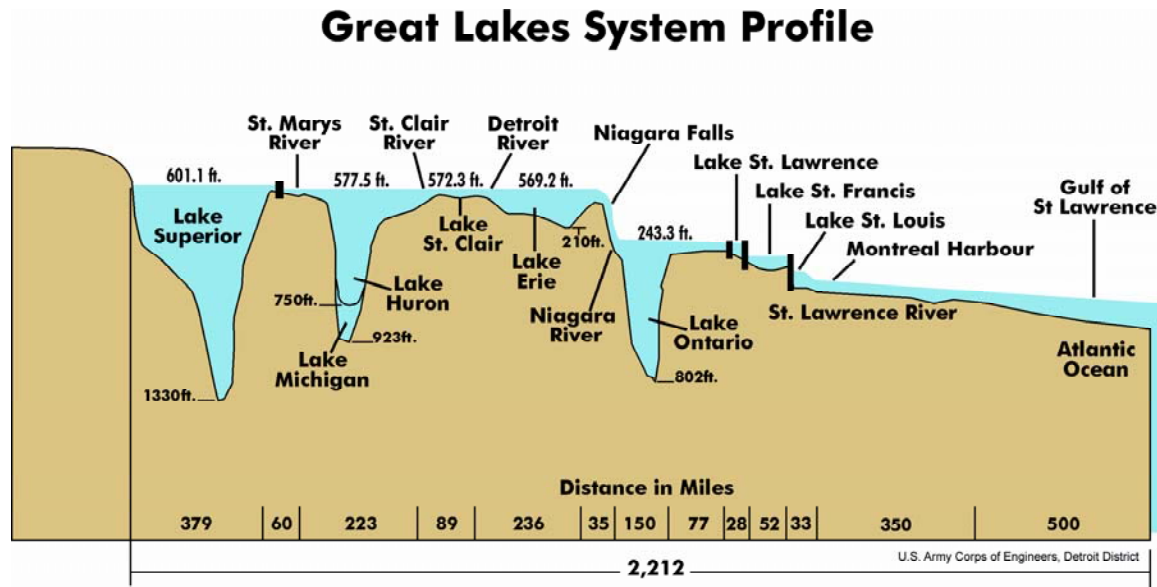


Table 1. Great Lakes Physical Features and Population (Fuller and Shear, 1995)

		Superior	Michigan	Huron	Erie	Ontario	Totals
Elevation^a	(feet)**	600	577	577	569	243	
	(metres)	183	176	176	173	74	
Length	(miles)*	350	307	206	241	193	
	(kilometres)	563	494	332	388	311	
Breadth	(miles)*	160	118	183	57	53	
	(kilometres)	257	190	245	92	85	
Average Depth^a	(feet)**	483	279	195	62	283	
	(metres)	147	85	59	19	86	
Maximum Depth^a	(feet)*	1,332	925	750	210	802	
	(metres)	406	282	229	64	244	
Volume^a	(cu. miles)*	2,900	1,180	850	116	393	5,439
	(km³)	12,100	4,920	3,540	484	1,640	22,684
Water Area	(sq. mi.)*	31,700	22,300	23,000	9,910	7,340	94,250
	(km²)	82,100	57,800	59,600	25,700	18,960	244,160
Land Drainage Area^b	(sq. mi.)*	49,300	45,600	51,700	30,140	24,720	201,460
	(km²)	127,700	118,000	134,100	78,000	64,030	521,830
Total Area	(sq. mi.)*	81,000	67,900	74,700	40,050	32,060	295,710
	(km²)	209,800	175,800	193,700	103,700	82,990	765,990
Shoreline Length^c	(miles)*	2,726	1,638	3,827	871	712	10,210 ^d
	(kilometres)	4,385	2,633	6,157	1,402	1,146	17,017 ^d
Retention Time	(years)**	191	99	22	2.6	6	
Population	Totals	607,121	10,057,026	2,694,154	11,682,169	8,150,895	33,191,365
Outlet		St. Marys River	Straits of Mackinac	St. Clair River	Niagara River/Welland Canal	St. Lawrence River	

Notes:

- ^a Measured at Low Water Datum.
- ^b Land Drainage Area for Lake Huron includes St. Marys River. Lake Erie includes the St. Clair-Detroit system. Lake Ontario includes the Niagara River.
- ^c Including islands.
- ^d These totals are greater than the sum of the shoreline length for the lakes because they include the connecting channels (excluding the St. Lawrence River).

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