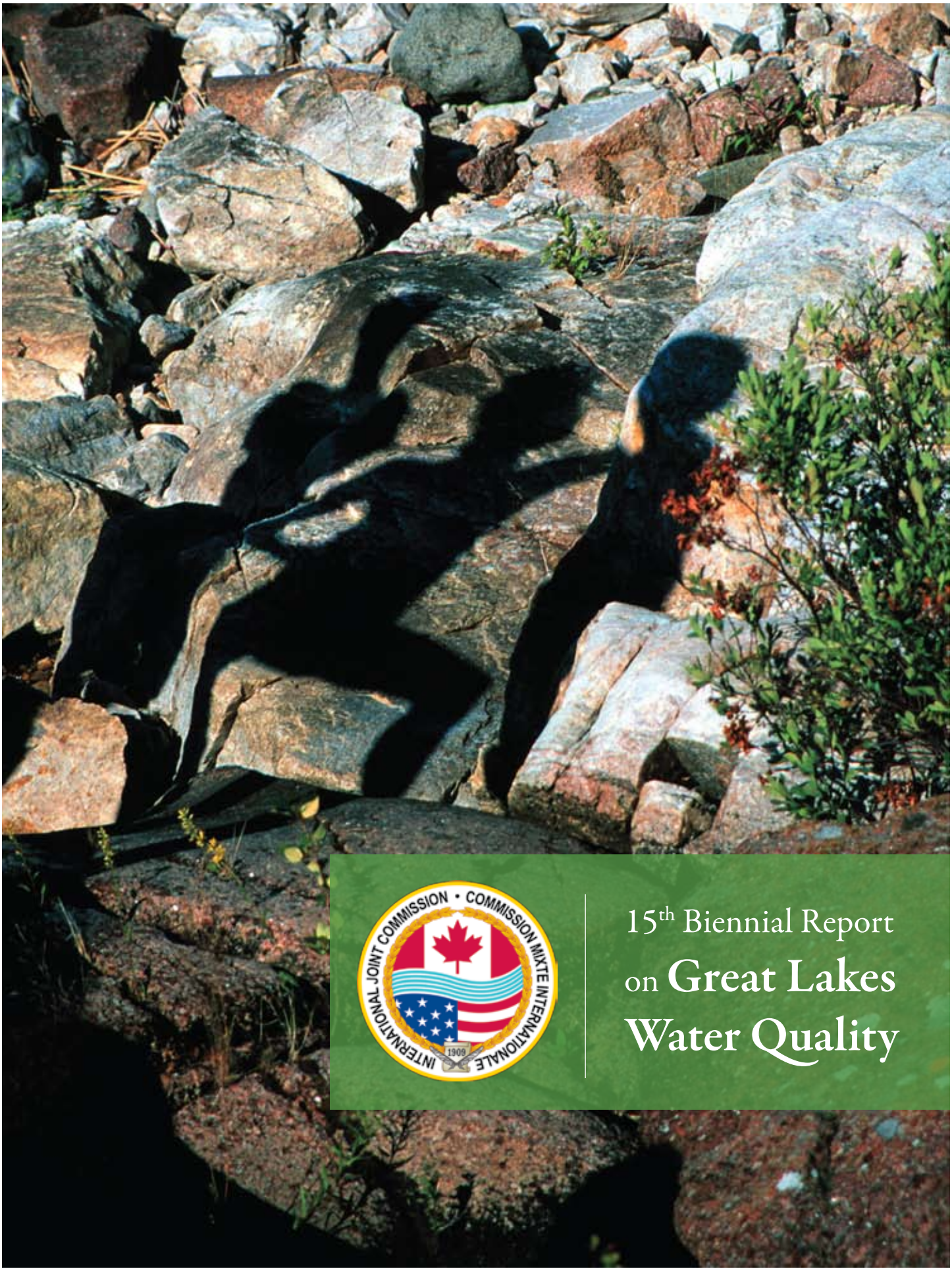

15th Biennial Report on Great Lakes Water Quality

Fifteenth Biennial Report

Prepared pursuant to the Great Lakes Water Quality Agreement of 1978 for submission to the Governments of the United states and Canada and the State and Provincial Governments of the Great Lakes Basin.

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15th BIENNIAL REPORT ON GREAT LAKES WATER QUALITY

JANUARY, 2011

INTERNATIONAL JOINT COMMISSION

CANADA AND THE UNITED STATES

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Executive Summary

Article VII of the Canada-United States Great Lakes Water Quality Agreement (Agreement) requires the International Joint Commission to report biennially to the Parties and to state and provincial governments concerning progress toward achieving Agreement objectives, and the effectiveness of programs pursuant to it. Article VII also directs the Commission to provide advice on any matter related to the quality of the boundary waters of the Great Lakes system.

In this 15th Biennial Report, the Commission addresses issues that are relevant to government departments and agencies at all levels along with other organizations with environmental responsibilities in the Great Lakes basin. These issues are particularly pertinent given the current negotiations between Canada and the United States to revise the Agreement. This document is based on the reports of work groups established by our advisory boards with additional input provided by commissioners and staff.

The focus of this report is the nearshore zone, the vital ecological link between watersheds, tributaries, wetlands, groundwater, and offshore waters of the Great Lakes. Most people live in the nearshore and get their drinking water from this zone. The nearshore also supports critical habitat for fish, invertebrate and wildlife populations. Beach closings, nuisance algal growth, the establishment of alien invasive species, and habitat loss are just some of the troublesome developments in the nearshore that act as harbingers of future changes in offshore waters.
A revised Agreement should be strengthened with explicit provisions to address threats to nearshore water quality and to prevent or reduce their impact on human and ecological health.

In a December 2007 letter to governments, the Commission concluded that water quality problems in nearshore areas have binational implications and binational cooperation is required to solve them. The Commission noted that urban and agricultural nonpoint pollution are key contributors to excessive loadings of phosphorus and need to be reduced; nutrient-control programs need to be funded and implemented; most programs to monitor phosphorus loadings terminated fifteen years ago need to be reinstated; and the significant gaps in understanding linkages between land sources, nearshore, and offshore waters need to be addressed.

The Commission recognizes the need for better accountability measures and integration of services among the many levels of government and government agencies charged with protecting the Great Lakes basin in both countries. Triennial reports, as recommended by the Commission in its 2006 advice to governments about their review of the Agreement, should be mandated to include an evaluation of the policies and programs in both countries that are intended to fulfill the governmental obligations stipulated in the Agreement.

A Nearshore Framework

Proper management of the nearshore requires adaptive management and improved governance along with management and planning at a scale that integrates watersheds with their associated lake. The Commission believes that existing governance structures could be modified to meet these challenges.

For the most part, jurisdictions and institutions are not aligned with the hydrological boundaries of the Great Lakes basin. There are multiple levels of government in two countries, bi-national organizations, and environmental nongovernmental associations with diverse legislative, programmatic, and policy tools–and all are addressing water-quality problems in the Great Lakes. Coordination and collaboration among binational institutions on nearshore zone issues have improved in recent years, but they must be further enhanced.

Greater attention must be devoted to addressing the impacts of agricultural and urban areas on Great Lakes water quality. Because the permitting and budgetary responsibility for urban development and agricultural practices is shared among all orders of government, the Commission recommends using Lakewide Management Plans (LaMPs)[1] as the geographic unit to coordinate, integrate, and implement programs. All levels of government, watershed and other environmental non-governmental organizations should be involved in each LaMP. A binational condition assessment needs to be performed to establish a baseline that roughly coincides with the timing of the revised Agreement. Within watersheds, an assessment of stressors should be undertaken prior to using analytical and diagnostic tools to assess causes of problems and determining management actions.

Eutrophication

The Commission is troubled by nearshore eutrophication, aquatic plant growth caused by excessive nutrients, which causes adverse effects on ecosystems, the economy, recreation, and human health. The reemergence of algal blooms is likely due to multiple factors, including inadequate municipal wastewater and residential septic systems; runoff from increased impervious surface areas and agricultural row-crop areas; discharges from tile drainage which result in more dissolved reactive phosphorus loading; industrial livestock operations; ecosystem changes from invasive mussel species; and impacts from climate change which include warmer water and more frequent and intense precipitation and stormwater events.

As a result, more coordinated and frequent monitoring of algal fouling is needed as is watershed-specific monitoring to test both causal hypotheses and assess management actions. More sophisticated models are needed to capture the interactions of habitat, fish community structure, and nutrient loading and work must be undertaken to understand the linkage of nearshore re- emergence of eutrophication and oligotrophication (nutrient depletion) of the offshore. The Commission recommends accomplishing the necessary monitoring and research actions via a major binational scientific effort similar to the Commission's Pollution from Land Use Activities Reference Group (PLUARG) of the 1970s. PLUARG produced a body of work instrumental in understanding and addressing nonpoint source pollution. A "PLUARG II" would improve the understanding of the resurgence of eutrophication and help managers select the wisest management actions.

In the interim, the Commission recommends that all levels of government implement actions to reduce nonpoint sources from agricultural and urbanized watershed and tributaries. The Commission recommends governments place priority on the protection and restoration of wetlands and forest lands to enhance the quality and resiliency of the Great Lakes ecosystem. These habitats are naturally effective at filtering and reducing some pollutants that affect nearshore water quality. Governments should exercise available options to prevent conversion of existing habitats to uses that could damage water quality or fish and wildlife populations, and restore habitats through conservation easements or public ownership of habitats.

[1]A Lakewide Management Plan, or "LaMP", is a plan of action to assess, restore, protect and monitor the ecosystem health of a Great Lake. It is used to coordinate the work of all the government, tribal, and non-government partners working to improve the Lake ecosystem. A public consultation process is used to ensure that the LaMP is addressing the public's concerns. (EPA, 2008)

In addition, the Commission recommends actions that mimic natural processes such as buffer strips on agricultural land, rain gardens and green roofs in urban areas, along with reducing urban sprawl and impervious surfaces. All these efforts need to be undertaken in nearshore and in all tributary watersheds. Effective efforts need to be documented and shared among potential users. In the longer term, there is a need to further develop systems that use phosphorus for desirable outcomes, such as harvesting algal biomass for biofuel.

Beaches and Recreational Water Quality

Beaches and recreational waters are critical to the economic and environmental health of the Great Lakes region and to the quality of life for residents and visitors. They provide recreational opportunities and contribute to ecosystem biodiversity and provide breeding grounds and cover for fish, birds, aquatic invertebrates and other wildlife.

Nonpoint source pollution, in particular urban and agricultural stormwater runoff, poses a much greater threat to recreational water bodies than point source pollution. More frequent and severe storm events, predicted by models of climate change, will have additional impacts.

The presence of *E. coli* bacteria and other pathogens in surface water can serve as an indicator of bacterial contamination. Nevertheless, testing can produce false positive results when fecal indicator bacteria from birds, algae and other natural populations, which have less pathogenic bacteria, are mistaken for human fecal contamination. The Commission recommends the federal governments support research into novel indicators of human fecal contamination to determine rapidly the risk to human health and increase the efficiency of decision-making for beach advisories. The Commission further recommends that governments share information on causes and best practices to improve water quality, enhance warning systems, and reduce the need for beach closings.

An efficient and timely testing method is needed to advise the public about recreational water quality. Current beach testing methodologies take 24 hours or more prior to posting beaches as unsafe for swimming. The Commission recommends that state and local governments improve public communications and issue preemptive advisories where a correlation between rainfall and elevated bacteria levels exist or when sewer overflows or other catastrophic events jeopardize public health.

Under a revised Agreement, there should be binational and nearshore standardized basin-wide surveillance and monitoring protocols along with standardized criteria for beach postings. Further, the Commission recommends that both governments designate a lead agency to establish a binational, systematic, centralized, consistent, and timely way to evaluate and report waterborne illness in the Great Lakes and to facilitate collaboration on best practices at all levels of government.

Groundwater

Groundwater recharges streams and rivers that flow into lakes, contributes to fish habitat, and supports significant ecosystem functions by maintaining stream flows and wetlands during dry periods. Groundwater's contribution to Great Lakes tributaries ranges from 48 percent in the Lake Erie basin to 79 percent in the Lake Michigan basin. In addition, an estimated 8.2 million people, 82 percent of the rural population, rely on groundwater for drinking water. Groundwater in the Great Lakes basin is of generally good quality but is threatened by chemical and biological inputs from point and nonpoint sources.

Annex 16 of the Agreement calls for both federal governments, in cooperation with state and provincial governments, to identify and control the sources groundwater contamination and to issue biennial progress reports to the Commission. This work has not been accomplished.

In 2010, Commission boards published a report describing a range of specific threats to groundwater. The report recommended actions that could be taken by all levels of government, including research, monitoring, regulation, enforcement and economic and tax incentives. Specific threats to groundwater in the basin include: pathogens, toxic chemicals, nutrients, household products, hormones, antibiotics, pharmaceuticals, and road salt. The sources of these threats include: failing septic systems, leaking underground storage tanks, hazardous waste sites, abandoned wells, leaking sanitary sewers, confined animal feeding operations, de-icing practices, landfills, land application of manure, agricultural practices, spills, atmospheric deposition, vehicle fluids, cemeteries, petroleum refineries, and injection wells.

A revised Agreement should strengthen the provisions of Annex 16 by incorporating some of these recommendations to spur implementation. In particular, efforts are needed by all levels of government to address leaking septic tanks and underground storage tanks as well as runoff from confined animal feeding operations.

Chemicals of Emerging Concern

The term "chemicals of emerging concern" refers to the recently recognized risk to human health and ecosystems from some unregulated or inadequately regulated chemicals. These chemicals are found in common household and personal care products, veterinary and human pharmaceuticals, flame retardants, and phthalates used to make plastic flexible. Wastewater treatment plants, one of the leading conveyors of these chemicals to the nearshore, are not designed to remove them.

While the Agreement has annexes that address toxic substances, none mention chemicals of emerging concern. A revised Agreement should include provisions to address this shortcoming. This revision should include the underlying principles and processes by which the Parties would prioritize categories of chemicals to address, rather than compiling a long list of specific chemicals which would rapidly become outdated. There is a need to establish coordinated monitoring programs that will provide exposure and effects information. An easily accessible repository for data also needs to be established by the governments to enable assessment of management options.

In addition, the Commission recommends that the governments provide incentives and educational programs to encourage industry, agriculture, and consumers to develop and use environmentally-friendly alternative products, thereby reducing the production and consumption of chemicals of emerging concern.

Fish Consumption

Most attention to Great Lakes fish consumption is focused on risks because contaminant levels in many species exceed current health standards. Nevertheless, fish consumption is beneficial for health because they provide a dietary source of high-quality protein and omega-3 fatty acids. The risk/benefit tradeoff of Great Lakes fish consumption is further complicated because most assessments of health benefits are based on analyses of marine fish.

"Research is needed to improve our understanding of the benefits of Great Lakes fish consumption and on optimum ways to present fish consumption information."

Diverse health impacts from some chemicals are well documented. For example, dioxins, polychlorinated biphenyls (PCBs), and chlorinated pesticides may cause cancer, affect sex determination, hormonal functions, suppress immune systems, disrupt thyroid function, and are associated with elevated risk of diabetes and cardiovascular disease. For some chemicals, children (especially at the prenatal stage of development) are more at risk than adults. Chlorinated pesticides impair neurodevelopment in children, and methyl mercury is a potent neurotoxicant to which the developing brain is more susceptible.

Research is needed to improve our understanding of the benefits of Great Lakes fish consumption and on optimum ways to present fish consumption information. The province and the states need to devote resources for more effective outreach and education campaigns, especially to those populations who traditionally consume larger quantities of fish.

Pending the foregoing activities, the Commission's workgroup has suggested the following text be included with every fish advisory: "When properly prepared, fish provide a diet high in protein and low in saturated fats. Many doctors suggest that eating a half-pound of fish each week is helpful in preventing heart disease. Almost any kind of fish may have real health benefits when it replaces a high-fat source of protein in the diet. You can get the health benefits of fish and reduce contaminants by following this advisory." The Commission also recommends that advisories disclose to women of child-bearing age that frequent fish consumption can affect fetal development and that might have a lifelong impact on intelligence and achievement.

Aquatic Invasive Species (AIS)

AIS are generally defined as introduced aquatic organisms that may cause harmful environmental, health, or economic impacts. More than 180 aquatic non-native species have been detected in the Great Lakes. About 10 percent of them are considered invasive, including sea lamprey, zebra mussel, round goby, spiny waterflea, and Eurasian watermilfoil.

AIS may degrade habitat, cause adverse effects to native species (including threatened and endangered species), disrupt food webs, and facilitate harmful algal blooms. Other impacts include degraded beaches, reduced quality of sport fishery, impaired stocks of native fish for commercial harvest, disruption to water infrastructure, lower property values, and increased public expenditures for prevention and control measures.

Once they are established, it is virtually impossible to eradicate AIS populations and very difficult to control their spread. As a result, the Commission, first and foremost, supports efforts to prevent invasions from all potential pathways.

Where prevention has not been successful, the Commission supports binational protocols for rapid response both before the AIS is detected (e.g., the Asian Carp) and if needed after an AIS has penetrated the Great Lakes. The Commission recommends consideration of the Incident Command System (ICS), an organizational structure used successfully to manage major emergencies in such areas as human and animal disease, forest pathogens and insects, invasive plants, fire management, and oil and hazardous material spills

Many of the building blocks for binational AIS rapid response are available in the Great Lakes basin, with its well-established institutional arrangements, regulatory regimes, and long tradition

of cooperation across the boundary. A revised Agreement can serve as the organizing vehicle for the development and deployment of joint protocols for effective rapid response to AIS.

A Note on Protection of Human Health

Each challenge in the nearshore zone discussed in this report has current or potential impacts on human health and enjoyment of the resources of the Great Lakes. In the past, human health concerns addressed by the governments have focused on legacy contaminants such as PCBs. While these materials remain of concern, current and emerging threats to human health include a suite of substances and problems ranging from algal blooms to little-regulated materials often found in consumer products. The Commission believes that in addition to protection of the biological, chemical and physical integrity of the Great Lakes ecosystem, the revised Agreement will be critically flawed unless it also makes explicit the goal of protecting human health.

A Note to the Reader on Recommendations in this Report:

The 15th Biennial Report contains 32 recommendations. Recommendations presented with this executive summary are organized immediately below as "Guidance to the Governments for Revisions to the Agreement" and as "Recommendations for Better Implementation of the Agreement"–with the latter to be applied under both the existing and a revised Agreement. All 32 recommendations are repeated in the body of the full report.

The Commission recognizes that the Great Lakes would benefit from governmental reforms that would assign more definitive responsibilities and timetables to various governmental entities.

RECOMMENDATIONS:

Guidance to the Governments for Revisions to the Agreement

Periodic IJC Independent Reviews

- Governments require the Commission to generate triennial reports assessing progress in achieving Agreement objectives that would include an evaluation of the policies and programs in both countries that are intended to fulfill the governmental obligations stipulated in the Agreement.

Nearshore Framework

- Explicitly recognize the importance of the nearshore; define it to include a specific distance or depth offshore and also include a specific coastal distance inland.

- Establish a nearshore framework that encompasses sound science and adaptive management in governmental programs.

- LaMPs should be used to engage a broader array of governments, agencies and programs in managing watersheds, nearshore and offshore waters of the Great Lakes Basin Ecosystem. In doing so, improve the governance linkages between RAPs, LaMPs and watershed planning and programs implementation.

- Perform a binational condition assessment of the nearshore waters of the Great Lakes using existing trend data and methods. This assessment should be nested within comprehensive basin-wide programs.

- Human health should be recognized as an additional primary goal of governmental programs designed to protect and restore the biological, physical and chemical integrity of the Great Lakes.

Eutrophication

- Develop new or improved models to improve estimates of phosphorous loadings to the Great Lakes from tributaries and other sources and use the results to establish phosphorous concentration targets for nearshore and offshore waters of the Great Lakes.

- Issue a reference to the Commission for a binational scientific investigation into the causes of the resurgence of nuisance and harmful algal growths in the Great Lakes from land-use activities and to test causal hypotheses of the linkages between land use and algal problems and associated ecosystem changes in the Great Lakes.

Beaches

- Develop standardized binational criteria, monitoring protocols and reporting for issuing and tracking beach postings and for reporting of waterborne illnesses.

Groundwater

- Retain the existing Groundwater Annex and add the following provisions:
  - o Recognize the importance of groundwater as a source of drinking water in the basin and make a high priority the protection of groundwater through monitoring, wellhead protection, well registration and abandoned well-closure programs to ensure human health.
  - o Require systematic basin-wide collection of data following standardized protocols for groundwater quantity and quality.
  - o Maintain water budgets for the basin that include major groundwater withdrawals and consumption uses, and report on trends.

Chemicals of Emerging Concern

- Develop and implement a process to identify chemicals that are a priority for binational action, consistent with national chemicals management programs; establish coordinated monitoring programs that will provide information on exposure and effects of chemicals to enable assessment of management strategies; place more emphasis on gaining knowledge and understanding of human health effects as they pertain to the major categories of chemicals of emerging concern.

- Develop provisions for monitoring chemicals of emerging concern that describe the underlying principles and processes by which the Parties identify substances and establish priorities, rather than compiling lists of substances that rapidly become out-of-date; examine and modify existing regulatory regimes to improve the response to issues posed by newly

developed and newly recognized substances; enhance binational communication, coordination, and cooperation on the design and implementation of monitoring programs and set common objectives.

Fish Consumption

- Monitor levels of omega-3 fatty acids in fish species of concern in conjunction with their ongoing monitoring of contaminant levels.

Aquatic Invasive Species

- Explicitly address the aquatic invasive species issue in a separate annex that includes improved understanding of their impacts, with provisions for, among other initiatives, a binational rapid response program.

Recommendations for Better Implementation of the Agreement

Nearshore Framework

- Ensure that the various orders of government address impacts of urban and rural areas on nearshore water and ecosystem quality, including the development of appropriate goals, targets and indictors, infrastructure improvements, and research and monitoring to track progress in sustainable land use that is protective of Great Lakes receiving waters.

Eutrophication

- Institute "no regrets" actions–measures that would be justified under all plausible future scenarios–using adaptive management to improve retention of nutrients and sediment on the land, especially in watersheds with high phosphorus loadings.

- Promote the implementation of successful "no regrets" management actions by developing, maintaining, and sharing an inventory of effective techniques and programs.

Beaches

- Conduct research on novel techniques such as microbial source tracking which would help distinguish between the various potential factors which contribute to contamination of recreation waters.

- In consultation with various orders of governments, develop testing methods to improve the scientific basis for advisory and closure decisions at Great Lakes beaches; improve early-warning communication to the public about beach advisories and closures.

Groundwater

- Designate a lead agency with responsibility for compiling and regularly reporting to the Commission on relevant research, monitoring and program information on key groundwater issues because of the importance of groundwater quality to human and ecosystem health.

- Improve training, inspection and enforcement efforts and cost-sharing of clean-up expenses from various sources, including leaking underground storage tanks, spills and leaks from oil pipelines and vehicle fluids, de-icing practices and petroleum refineries.

- Establish standards for septic systems, have them inspected periodically and require owners of them to be in compliance. Tax incentives should be provided to maintain, repair, or replace faulty systems.

- Implement and enforce more effective regulations on confined animal feeding operations to ensure proper treatment of manure and application of methods to reduce run-off and infiltration into groundwater.

- Consider grants or incentive programs as a means of ensuring maintenance and proper decommissioning of abandoned wells.

Chemicals of Emerging Concern

- Invest in communication and outreach efforts that educate consumers and provide economic incentives that encourage them to purchase more environmentally-friendly (greener) products and services, and practice safer disposal of products that contain chemicals of emerging concern.

- Provide tax, economic incentives, and educational support to encourage industry and agriculture to use and develop more environmentally-friendly and green chemistry products and reduce the design, production, and consumption of chemicals of emerging concern.

- Develop wastewater treatment technologies that improve the detection, control and removal or destruction of chemicals of emerging concern.

Fish Consumption

- Conduct research to improve the understanding of human health effects from the various chemicals found in Great Lakes fish, both singly and as a mixture of chemicals. Information on emerging chemicals of concern is of particular importance.

- Develop consistent standards for issuing fish consumption advisories that are based on consideration of both the benefits of omega-3 fatty acid consumption and the hazards from the mixture of contaminants found in Great Lakes fish.

- Improve the communication of fish consumption guidance, especially for reaching sensitive and vulnerable populations.

Aquatic Invasive Species

- Institute a consistent, coordinated approach for aquatic invasive species rapid response planning tailored to the binational dimensions of the Great Lakes-St. Lawrence River system.

- Better align research efforts with rapid response needs; establish a “technology transfer” process to convert research findings into practical application; provide for on-site scientific advice, and ensure that early detection and monitoring programs are responsive to emerging needs and feature the latest technology.

Introduction

Article VII of the Canada-United States Great Lakes Water Quality Agreement (Agreement) requires the International Joint Commission to report biennially to the federal, state and provincial governments concerning progress towards achieving Agreement objectives and the effectiveness of programs and other measures undertaken pursuant to it. Article VII also directs the Commission to provide advice and recommendations on any matter related to the quality of the boundary waters of the Great Lakes system.

For this, the 15th Biennial Report, the Commission focused on a number of issues that are relevant to government departments and agencies at all levels in both countries along with other stakeholders with environmental management responsibilities in the Great Lakes basin. This report is also particularly pertinent given the current negotiations between Canada and the United States to revise the Agreement. Findings and recommendations in this document are based largely on the work of five advisory boards established by the Commission under the aegis of the Agreement itself and the Commission's own requirements. These boards–all comprised of eminent scientists from both sides of the Canada-U.S. boundary–are the Great Lakes Water Quality Board, Great Lakes Science Advisory Board, Council of Great Lakes Research Managers, International Air Quality Advisory Board, and Health Professionals Task Force.

In many respects, the origin of this biennial report is the Commission's 2006 special report to the two federal governments with advice for their impending review of the Agreement (2006 Advice to Governments Report).[2]

In that document, the Commission recommended that the nearshore waters be given special attention because they are somewhat neglected in the current Agreement, with its main focus on offshore waters. Problems frequently become evident in nearshore waters. Beach closings, nuisance algal growth, the establishment of alien invasive species and habitat loss are just some of the symptoms of these developments, and they act as harbingers of future changes in offshore waters. The nearshore zone is a vital ecological link between watersheds, tributaries, wetlands, groundwater and offshore waters of the Great Lakes, and supports critical habitat for fish, invertebrate and wildlife populations.

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[2] International Joint Commission (IJC), 2006. *Advice to Governments on their Review of the Great Lakes Water Quality Agreement: A Special Report to the Governments of Canada and the United States* at http://www.ijc.org/php/publications/pdf/ID1603.pdf.

The nearshore is also where most people live, work and play, and its waters are the most visible and accessible to the public. The nearshore zone is also the location of drinking water intakes that provide drinking water to many of the 40 million people who live in the Great Lakes basin.

In July 2007, the Commission wrote to the Binational Executive Committee (BEC), which is comprised of senior-level representatives of government departments and agencies as well as Tribes and First Nations with responsibilities for policies and programs related to Great Lakes water quality. In its letter, the Commission stated that the lack of specifics on nearshore waters was "an issue significant enough to warrant opening the Agreement on this basis alone for substantive revisions or replacement to provide the means to address the critical science, resource management, governance and policy needs related to the nearshore waters."[3]

Recognizing the importance of the nearshore, the Commission asked its advisory boards to organize efforts under a nearshore waters framework. Members from each of the advisory boards formed work groups (as shown in Appendix 1 to the priority report on nearshore waters) to collaborate and study six important issues that are related to the nearshore: an operating framework for nearshore waters; eutrophication; beaches and recreational water quality; chemicals of emerging concern; risks and benefits of consuming Great Lakes fish; and binational rapid response to aquatic invasive species. In addition to bringing their own specialized knowledge to bear on the subjects, all of these work groups consulted with outside experts in the course of determining their findings and developing recommendations.

Preliminary reports of this joint enterprise were circulated across the Great Lakes basin during the summer of 2009 and then discussed at the Commission's Biennial Meeting and Great Lakes Conference in October of that year.[4] These documents and dialogues are the primary sources for this report, and those products were supplemented with additional research, analysis, writing, and editing by the Commission.

In addition to establishing the six work groups, the advisory groups also collaborated to produce two special reports, one on groundwater and another on impacts of urban areas on Great Lakes water quality.[5]

These latter reports were submitted to the two federal governments in early 2010, and their findings and recommendations are also reflected in this document. All of the Commission's advisory and work groups are comprised of scientific experts from academia, government and the private sector. The Commission is pleased to acknowledge their tremendous contributions towards the development of a framework for managing the nearshore which is a key step towards protecting, restoring, and maintaining the waters of the Great Lakes basin.

The nearshore zone is a vital ecological link between watersheds, tributaries, wetlands, groundwater and offshore waters of the Great Lakes, and supports critical habitat for fish, invertebrate and wildlife populations.

[3] IJC. 2009. Appendices to Nearshore Waters of the Great Lakes.
http://www.ijc.org/en/priorities/2009/reports/2009-nearshore-framework-appendix.pdf
[4] IJC 2009 Biennial Meeting Follow-up, Work Group Reports. http://meeting.ijc.org/
[5] See http://www.ijc.org/php/publications/pdf/ID1637.pdf and http://www.ijc.org/rel/pdf/impact-urban-areas-en.pdf , respectively.

A Framework For Nearshore Waters

Of the several definitions of the nearshore, the Work Group on the Nearshore Framework used the one developed in a background paper for the State of the Lakes Ecosystem Conference.[6]

The nearshore includes the relatively warm shallow areas near the shores, coastal wetlands that are dependent on lake levels, the connecting channels and virtually all of the major embayments of the system. This area is estimated to include approximately 90 percent of shallow Lake Erie, 25 percent of each of lakes Michigan, Huron, and Ontario, but only five percent of Lake Superior, which has deeper waters. The definition also describes the nearshore zone as including the land areas that are affected by the waves, wind, ice, and temperature. In general, the nearshore zone extends about 16 kilometers (ten miles) into both land and water.

Despite multiple articles and annexes referencing nearshore issues, the current Agreement lacks a cohesive nearshore focus commensurate with the importance of this ecosystem. While the nearshore is implied in many provisions of the Agreement, it is only specifically mentioned in Annexes 3 and 11. As the work group noted, "there is nothing in the current Agreement that precludes attention to water quality in the nearshore waters of the Great Lakes, but most references to the nearshore are vague and implicit."[7]

In a December 2007 letter to governments,[8] the Commission stated that nearshore water quality problems are serious in most areas of the Great Lakes and that the need to address them is clear. The Commission concluded that water quality problems in nearshore areas have binational implications and binational cooperation is required to solve them. The Commission further noted:

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[6] Summarized in *"State of the Lakes Ecosystem Conference 1996: Highlights of Background Papers,"* available at www.epa.gov/glnpo/solec/solec_1996 See also Environment Canada and U.S. Environmental Protection Agency, *Nearshore Areas of the Great Lakes*, 2009. http://binational.net/solec/sogl2009/SOGL_2009_nearshore_en.pdf and International Joint Commission, Work Group Report on Nearshore Framework, 2009. http://www.ijc.org/en-/priorities/2009/nearshore-framework.

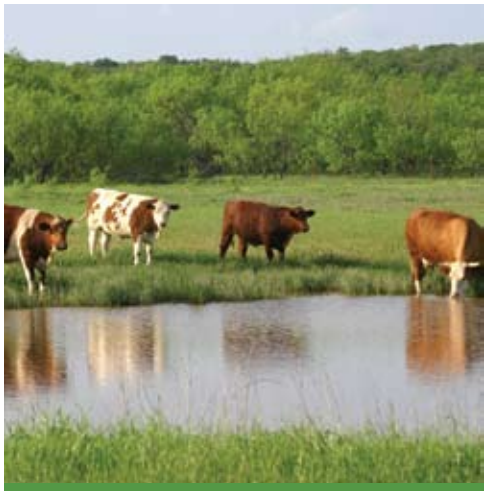
[7] International Joint Commission, Work Group Report on Nearshore Framework, 2009. http://www.ijc.org/en-/priorities/2009/nearshore-framework

[8] IJC. Appendices to Nearshore Waters of the Great Lakes. http://www.ijc.org/en/priorities/2009/reports/2009-nearshore-framework-appendix.pdf

- urban and agricultural non-point sources of pollution are key contributors to the continued and excessive loadings of phosphorus to nearshore waters and need to be reduced;
- nutrient-control programs as outlined in Annexes 3 and 13 of the Agreement need to be funded and implemented;
- most programs to monitor Great Lakes phosphorus loadings were terminated fifteen years ago and need to be reinstated;
- and there are significant gaps in understanding of the science and linkages between land sources, nearshore, and offshore waters.

Two expert consultation workshops organized by the Nearshore Framework Work Group in late 2007 and early 2008 resulted in a number of notable findings:[9]

- Institutional arrangements for addressing nearshore issues, especially in a binational context, are limited.
- Insufficient resources are being devoted to implementing agricultural and urban best management practices and managing nearshore water and ecosystem health.
- Assessing nearshore water and ecosystem health is limited by a lack of binationally coordinated documentation of land-use changes, pollutant loadings, and insufficient nearshore monitoring.
- Nearshore integrity includes protection of fish and wildlife habitat and the food web.
- Watershed-based sources of nutrients are not adequately managed to achieve Agreement goals.
- Links between airborne pollutants and nearshore degradation are poorly understood.



Agricultural nonpoint sources of pollution are key contributors to the continued and excessive loadings of phosphorus to nearshore waters.

Little support for the nearshore framework to include a new, stand-alone institutional arrangement emerged during the two nearshore expert consultations. Rather, the consensus focused on how existing institutional arrangements could be used or modified to address problems in nearshore areas. The cornerstone to improving the approach to the nearshore was deemed to be a nearshore framework that encompasses adaptive management, improved governance, management and planning at a scale that integrates watersheds with their associated lake, and explicit consideration of human health.

"The cornerstone to improving the approach to the nearshore was deemed to be a nearshore framework that encompasses adaptive management, improved governance, management and planning at a scale that integrates watersheds with their associated lake, and explicit consideration of human health."

Adaptive Management

An adaptive-management approach is particularly appropriate for the nearshore waters of the Great Lakes because the dynamic nature of the nearshore zone increases the uncertainty of achieving optimal results from applied management actions. Adaptive management is a systematic and iterative process for continually improving management actions and reducing uncertainty by learning from the outcomes of operational programs. With adaptive management, the process starts with an assessment of problems through research and monitoring (See Figure 1). Based on the assessment, management actions are designed to address the identified problems. The ecosystem is then monitored and evaluated to see how it has responded to the management actions. Based on evaluation of monitoring results, the programs are adjusted or modified or new programs are implemented in order to resolve problems and the process starts again. Consequently, adaptive management focuses on learning and adapting through partnerships of managers, scientists and other stakeholders who learn together how to create and maintain sustainable ecosystems. Programs are adjusted based on results and the process reinitiates itself.

[9] IJC. Work Group Report on Nearshore Framework, 2009. http://www.ijc.org/en/priorities/2009/nearshore-framework.

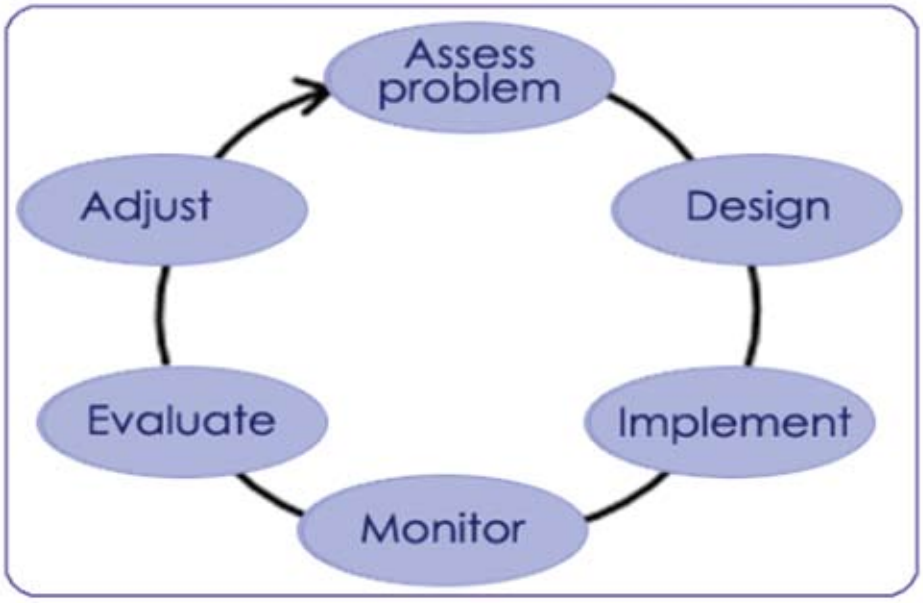


Figure 1. Diagram of the adaptive management six-step cycle.[10]

Several recent initiatives seem particularly promising for application in nearshore waters. For example, the Great Lakes Environmental Indicators (GLEI) Project is a multidisciplinary cooperative research effort with binational participation that is being overseen by the Natural Resources Research Institute at the University of Minnesota-Duluth.[11] Another collaborative adaptive management program is the Canadian Aquatic Biomonitoring Network (CABIN),[12] maintained by Environment Canada to establish a network of reference sites to help assess the biological health of freshwater in Canada.

These two research and monitoring programs in the nearshore areas of the Great Lakes illustrate the need to evolve from chemical monitoring, as emphasized in the current Agreement, to include biological and physical monitoring. The nearshore should be compared to benchmark or reference conditions, such as the CABIN approach, and an environmental status assessment that integrates the coastal zone into an indicator program, such as GLEI, that is highly suitable for reporting to resource managers, policymakers and the public.

To facilitate the tracking of progress, a binational condition assessment needs to be performed to establish a baseline that roughly coincides with the timing of the revised Agreement. The binational condition assessment should be performed using available trend data and existing technologies. Remote sensing technologies should be used to reduce costs, though some field data will clearly be needed. Indicators should be used that have existing trend data and collection regimes. Using these analytical tools to assess causes of problems, particular actions could be selected. LaMP managers would combine and coordinate watershed based activities. Following adaptive management principles, the success of management actions would be evaluated at various scales to guide subsequent management actions.

[10] U.S. Department of Interior. What is adaptive management? http://www.doi.gov/initiatives/AdaptiveManagement/whatis.html
[11] Great Lakes Environmental Indicators Project, http://glei.nrri.umn.edu/default/.
[12] Canadian Aquatic Biomonitoring Network, http://cabin.cciw.ca.

The Commission's requirement to evaluate progress toward achieving the objectives of the Agreement can in general contribute to adaptive management. The findings of this coarser review can help guide programmatic issues on a macro level. Triennial reports, as recommended by the Commission in its 2006 Advice to Governments Report, should be mandated to include an evaluation of the policies and programs in both countries that are intended to fulfill the governmental obligations stipulated in the Agreement. The report should be in two parts: 1) a synthesis of the public's views, generated by basinwide consultations conducted by the Commission and 2) the Commission's independent assessment and advice. The Commission's assessment draws heavily from a cadre of expert reviewers from our independent, scientific, and binational board members (similar to this report). By using these expert boards, the IJC contributes sound science to the process.

Governance

Another key feature of the nearshore framework is governance. Governance reforms are also required that would identify organizations with various lead responsibilities, establish cooperative partnerships, systems and approaches to better achieve components of the Agreement, and devise an evaluation scheme.

However, governance reforms are a challenge, for several reasons. For the most part, jurisdictions and institutions are not aligned with the hydrological boundaries of the Great Lakes basin. The Great Lakes drainage basin intersects 41 provincial municipalities and 287 U.S. counties. The basin can also be subdivided into 98 Canadian Fundamental Drainage Areas sub basin areas as delineated by Environment Canada and 108 U.S. Watershed Boundary Subbasin areas as maintained by the U.S. Natural Resources Conservation Service (Figure 2).

The differences between hydrological boundaries and political boundaries cause complications for two reasons. First, lake circulation patterns may result in adverse impacts from a pollution source in the nearshore area of one jurisdiction to the nearshore area of another (and also to offshore waters). Second, water flows along watershed boundaries make it difficult to manage the flow of stressors, such as sediments, nutrients, and toxic substances, which are carried in the water as they flow downstream and cross over jurisdictional boundaries. More complexity arises because Canada and the United States have diverse legislative, programmatic and policy tools for addressing water-quality problems in nearshore waters of the Great Lakes at the federal, state and provincial levels, and municipalities have their own set of programs and policies that potentially can influence the quality of nearshore waters.

Binational institutions and arrangements also need to be taken into account. The primary public institutions with a binational focus are the International Joint Commission and the Great Lakes Fishery Commission. There is also a Lakewide Management Plan (LaMP) for each of the Great Lakes.

Figure 2: The Great Lakes drainage basin showing the wide range of jurisdictions.

In addition there are many environmental non-governmental and watershed associations that make key contributions to protecting the Great Lakes and share an active involvement in nearshore issues. These include watershed councils in the United States, conservation authorities in Ontario, environmental organizations and coalitions, user groups, business/industry associations, academic research institutes, and issue-specific interest groups. Over time, such entities have assumed varying roles including education and outreach, strategic planning and priority setting, issue advocacy, coordination, basic and applied research, and related functions that collectively help shape the basin's governance regime.

To address this jurisdictional challenge and other fragmentation, processes are needed to coordinate plans, programs and activities. Coordination and collaboration among binational institutions on nearshore zone issues have improved in recent years, but they must be further enhanced to ensure the requisite efficiency, effectiveness and comprehensiveness.

Use of Lakewide Area Management Plans and the Watershed Approach

In its 2006 Advice to Governments Report, the Commission recommended improvements to the linkages between watershed planning, Remedial Action Plans (RAPs) and Lakewide Management Plans (LaMPs) for more effective results in reducing pollution on land and in tributaries, thereby better protecting Great Lakes water quality. The Commission further noted that LaMPs have been moving beyond the focus on critical pollutants called for in the Agreement (Annex 2) and have adopted a broader watershed perspective. LaMPs have the potential to be the core instrument to engage a broader array of governments, agencies and programs in the watershed and in the nearshore and offshore waters of the Great Lakes Basin.

At a smaller spatial scale, community engagement and partnerships are also required to connect lake issues to the watersheds. The watershed approach uses hydrologically-defined geographic areas to address all stressors, engaging all stakeholders strategically to achieve water resource goals.[13] The Commission recommends that a revised Agreement specify that the watershed be the geographic unit used to coordinate, integrate, and implement programs called for by the revised Agreement and set out in an action plan as described by the Commission in its 2006 Advice to Governments Report. Within watersheds, using the adaptive management approach, an assessment of stressors could be undertaken and target conditions could be set. Then using analytical and diagnostic tools to assess causes of problems, particular actions could be selected.

Ultimately, Great Lakes governments will have to decide if they want an effective watershed planning and regulatory regime to include binational support and coordination. If they do, experience at the global level could serve as a model. An example that could be followed is the approach to implementing the land-based pollution sections of the Convention on the Law of the Sea.[14] The Convention is an unprecedented attempt by the international community to regulate all aspects of the resources of the sea and uses of the ocean. The Convention covers topics such as navigational rights, territorial sea limits, economic jurisdiction, legal status of resources on the seabed beyond the limits of national jurisdiction, passage of ships through narrow straits, conservation and management of living marine resources, protection of the marine environment, a marine research regime and a binding procedure for settlement of disputes between states. Under the Convention, the United Nations Environment Program developed a series of large regional seas programs to address land-based pollution, along with rules and standards to prevent, reduce and control pollution from land based sources. Such regional programs might be an effective approach to nearshore issues.

As urban communities grow outwards away from inner cities, also known as sprawl, they have great impact the environment around them.

Addressing Urban Impacts

Greater attention must to be devoted to addressing the impacts of urban areas on Great Lakes water quality. A number of the Commission's advisory boards have focused on this matter over the past several years, and their report was submitted to governments in April 2010.[15] As urban communities grow outwards away from inner cities, there is more reliance on automobiles as the primary mode of transport, infrastructure costs to provide water and energy increase, more forested land is converted to impervious surfaces for roads, businesses, parking lots, and houses, and there is inadequate infrastructure for storm and waste water treatment. Such growth of urban areas is known as sprawl and directly or indirectly leads to increasing runoff from impervious surfaces, air deposition of contaminants, environmental byproducts of transportation, demand for water, climate change, loss of biodiversity due to habitat loss and alteration to natural hydrologic systems arising from land development. There are also serious human health impacts of urban development that result from increased exposure to air- and water-borne pollutants due to sprawl. The report provides recommendations to multiple levels of government that describe policies for sustainable urban development and smart growth.

[13] U.S. EPA. A Watershed Approach. http://water.epa.gov/type/watersheds/approach.cfm
[14] United Nations. The United Nations Convention on the Law of the Sea, Key Provisions of the Convention. http://www.un.org/Depts/los/convention_agreements/convention_historical_perspective.htm#Key provisions
[15] IJC. 2009. *The Impact of Urban Areas on Great Lakes Water Quality* at http://www.ijc.org/rel/pdf/impact-urban-areas-en.pdf.

"Explicitly recognizing human health in the Agreement as one of the key principles may make it easier to justify research and management actions along with allocation of resources by the responsible partner departments and agencies."

The report's findings and recommendation were organized under three major themes:

- urban and urbanizing areas within the Great Lakes basin have an adverse basinwide impact on natural systems;
- the impact of urban areas on Great Lakes water quality occurs at a basin scale and thus requires regional solutions; and
- the two overarching types of solutions involve transforming urban development patterns to reduce energy consumption and environmental impacts, and more immediate interventions targeted at specific causes of water quality degradation.

Since the responsibility for urban development is shared among all orders of government, the recommendations in the report are targeted not only to the federal governments of Canada and the United States but also to the state, provincial and local governments in each country. Again, using the watershed approach, LaMPs and a regional perspective seem valuable.

The Commission also recommends that governments place a high priority on the protection and restoration of wetlands and forestlands to enhance the quality and resiliency of the Great Lakes ecosystem. These habitats and systems are effective at filtering and reducing some pollutants that affect nearshore water quality. Governments should exercise their full, robust legal mandates to prevent conversion of existing habitats from uses that could degrade water quality as well as fish and wildlife populations, to restore habitats where prudent and feasible, and should undertake efforts to secure long-term or permanent easements or public ownership of habitats.

In addition, the Commission recommends the use of programs and policies that capitalize on the benefits provided by practices that mimic natural processes such as installation of buffer strips on rural agricultural land, using rain gardens and green roofs in urban areas, along with reducing urban sprawl and impervious surfaces. All these efforts need to be undertaken not just in the nearshore but also in all tributary watersheds. Effective efforts need to be documented in a database and shared among potential users. Other principles related to reducing urban runoff include reducing street width and parking and home lot sizes, and collecting runoff from road surfaces and roofs by using bioretention areas and rain gardens.[16] Smart growth principles to prevent environmental and human health impacts from sprawl are needed. Accommodating high population densities in urban areas with high rise apartment buildings as opposed to one-quarter acre lots reduces deforestation and infrastructure costs.

The Commission has not recently worked on a parallel report on the impact of agricultural runoff on nearshore water quality, but the impacts are significant, especially in those watershed that are farmed most intensively. The concepts related to preserving riparian buffers, wetlands, and forested lands will reduce agricultural runoff as well. Other impacts from agricultural runoff and means to address them are discussed in the subsequent section on eutrophication.

Human Health

The driving purpose of many Great Lakes programs conducted by all levels of government is the protection of human health. However, the Agreement hints at connections to human health but does not address the concerns about gastrointestinal illness and other health effects, such as carcinogenic, cardiovascular, reproductive, neurotoxic, immunotoxic, developmental, and endocrine-disruption effects associated with exposure to environmental stressors within the basin. Standards should be developed to protect the most vulnerable populations. Explicitly recognizing human health in the Agreement as one of the key principles may make it easier to

[16] Connecticut NEMO Program. 2009. Developing a Sustainable Community. http://nemo.uconn.edu/publications/LIDPub.pdf

justify research and management actions along with allocation of resources by the responsible partner departments and agencies. The Commission reiterates the recommendation made in its 2006 Advice to Governments Report that human health be defined in the Agreement and integrated within its goals and objectives.

Proper management of the nearshore requires a framework that encompasses adaptive management and improved governance along with management and planning at a scale that integrates watersheds with their associated lake. The framework also needs to consider urban and agricultural impacts and explicity recognize the importance of protecting human health. Using such a nearshore framework would be a key step towards protecting, restoring, and maintaining the integrity of the Great Lakes. The Commission recognizes that many scientific and policy issues in the nearshore need to be addressed by the framework while still considering the offshore. In this report, the Commission discusses several, but not all of the important issues that need to addressed within the framework: eutrophication, beaches, chemicals of emerging concern, and groundwater. It also addresses fish consumption and aquatic invasive species. Recommendations for each of these topics are provided within the report.

Nearshore Framework Recommendations

In revising the Great Lakes Water Quality Agreement, the Commission recommends that the Parties:

- Explicitly recognize the importance of the nearshore; define it to include a specific distance or depth offshore and also include a specific coastal distance inland.

- Establish a nearshore framework that encompasses sound science and adaptive management in governmental programs.

- LaMPs should be used to engage a broader array of governments, agencies and programs in managing watersheds, nearshore and offshore waters of the Great Lakes Basin Ecosystem. In doing so improve the governance linkages between RAPs, LaMPs and watershed planning and programs implementation.

- Perform a binational condition assessment of the nearshore waters of the Great Lakes using existing trend data and methods. This assessment should be nested within comprehensive basin-wide programs.

- Human health should be recognized as an additional primary goal of governmental programs designed to protect and restore the biological, physical and chemical integrity of the Great Lakes.

- Governments require the Commission to generate triennial reports assessing progress in achieving Agreement objectives that would include an evaluation of the policies and programs in both countries that are intended to fulfill the governmental obligations stipulated in the Agreement.

In addition, the Commission recommends that the Parties in implementing the Agreement:

• Ensure that the various orders of government address impacts of urban and rural areas on nearshore water and ecosystem quality, including the development of appropriate goals, targets and indictors, infrastructure improvements, and research and monitoring to track progress in sustainable land use that is protective of Great Lakes receiving waters.

Eutrophication

Eutrophication, the excessive aquatic plant growth as a result of large amounts of nutrients being released into a body of water, can have adverse effects on human health and recreation, the economy, and ecosystems. Eutrophication can cause degraded habitats and reduced populations of fish and wildlife, along with taste and odour problems in drinking water, gastrointestinal illness in swimmers, beach closings and disruptions of commercial and sport fishing. All these consequences have associated economic costs.

Eutrophication abatement efforts of the late 1970s and early 1980s constitute a principal achievement of the Agreement and serve as a model for binational cooperation on transboundary waters. As a result of policies and regulations, eutrophication was controlled for many years. In recent years, however, its most visible signs–nuisance Cyanobacteria (blue-green algae) blooms and rotting shoreline piles of the green macro-alga Cladophora–have returned to all the Great Lakes except Lake Superior. Other related observations noted by the Commission's Work Group on Eutrophication include:

- the return of Microcystis harmful algal blooms;
- dissolved oxygen depletion in the bottom waters of the central basin of Lake Erie;
- increases in the frequencies of beach postings or closings;
- botulism toxicity events re-emerging in the late 1990s and early 2000s for the first time in the Great Lakes since 1963-64;
- and "desertification" (loss of productivity) in offshore waters.[17]

The reemergence of such problems is likely due to multiple factors, which are believed to include inadequate municipal wastewater and residential septic systems; increased runoff from increased impervious surface areas and agricultural row-crop areas; discharges from tile drainage which results in more dissolved reactive phosphorus loading; industrial livestock operations; ecosystem changes from invasive mussel species; and impacts from climate change which include warmer water and more frequent and intense precipitation and stormwater events.

[17] IJC, 2009. Work Group Report on Eutrophication,. http://www.ijc.org/en/priorities/2009/eutrophication

Recent monitoring data from the Maumee River show an increasing trend of dissolved reactive phosphorus loadings over the past fifteen years.[18] While other factors may play a role, these increased loadings of dissolved phosphorus to the western basin of Lake Erie are contributing to harmful algal blooms that are now plaguing recreational users of Lake Erie and threatening the integrity of the ecosystem.

Much of the eutrophication stems from agricultural sources. Sediment loads predominantly from agricultural runoff are clearly visible from satellite photography (Figure 3). Such sediment loads are well documented to contain high concentrations of phosphorus in its soluble and reactive form that stimulates nuisance algal growths during spring and summer.[19] However, both agricultural and urban sources of nutrients and other contaminants must be addressed to remediate water quality degradation in the nearshore waters of the Great Lakes.

Wastewater treatment plants also contribute to phosphorus loading and eutrophication. Figure 4 shows the location of most of the treatment plants that operate within the boundary of the Great Lakes basin.

Figure 3. Satellite photo of Lake St. Clair, the St. Clair-Detroit Corridor, and Lake Erie taken during March, 2009 dramatically shows sediment washing off of the heavily farmed watersheds of the Thames and Sydenham rivers into Lake St. Clair and from the Maumee and Sandusky rivers into Lake Erie following winter snow melt.
Source: Great Lakes Moderate Resolution Imaging Spectroradiometer (MODIS) Imagery. http://coastwatch.glerl.noaa.gov/modis/modis.html

"While other factors may play a role, these increased loadings of dissolved phosphorus to the western basin of Lake Erie are contributing to harmful algal blooms that are now plaguing recreational users of Lake Erie and threatening the integrity of the ecosystem."

[18] National Center for Water Quality Research . http://wql-data.heidelberg.edu/
[19] Baker, D.B. and R.P. Richards. 2002. Relationships between changing phosphorus budgets and riverine phosphorus export in northwestern Ohio watersheds. *Journal of Environmental Quality* 31:96-108.
Dolan, D.M. and R.P. Richards. 2008. Analysis of Late 90s Phosphorus Loading Pulse to Lake Erie. Pages 79-96 in Checking the Pulse of Lake Erie, ed. M. Munawar and R. Heath. Aquatic Ecosystem Health and Management Society Envirovision Series.

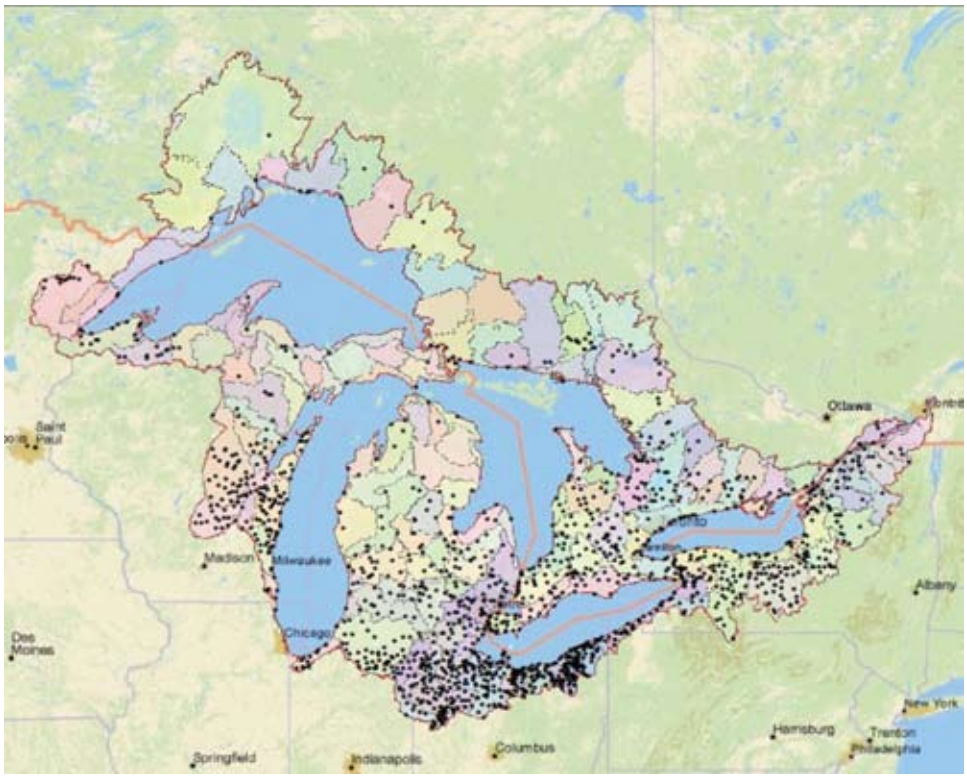


Figure 4. A preliminary evaluation of data provided by the U.S. Environmental Protection Agency and the Ontario Ministry of Environment identified 1,595 wastewater treatment facilities in the basin.

The Commission has consistently raised these concerns regarding phosphorus control and monitoring with the Parties. For instance, in its 2006 Advice to Governments Report, the Commission stated:

"The recurrence of eutrophication suggests that there is an urgent need to revisit the excess nutrient problem and the research models upon which the phosphorus reduction programs of the 1970s and 1980s were based. This includes improved monitoring of phosphorus loads from point and non-point sources..."[20]

In its December 2007 letter to the governments, the Commission noted the need to reduce phosphorus loadings to nearshore waters, to fund nutrient control programs, reinstate monitoring programs, and obtain an improved understanding of the linkages between land sources, nearshore and offshore waters.

In the Commission's view, the current situation is a consequence of past decisions to curtail nutrient monitoring and control programs. These deteriorating conditions are also indicative of the urgent need to implement strategies to address the reemergence of eutrophication as a major challenge to Great Lakes water quality, with attendant environmental, social and economic costs.

There is certainly good reason to acknowledge the achievements of the governments 20-30 years ago with respect to eutrophication control, but excessive phosphorus loading is an issue once again and must receive renewed attention along with quick and decisive action. Another concern is funding for monitoring, which needs to be reinstated.

[20]International Joint Commission (IJC), 2006. Advice to Governments on their Review of the Great Lakes Water Quality Agreement: A Special Report to the Governments of Canada and the United States at http://www.ijc.org/php/publications/pdf/ID1603.pdf.

Earlier eutrophication was directly related to inputs of phosphorus but, interestingly, total phosphorus concentrations in offshore waters are currently well below what the old models said they should be given phosphorus loading estimations.[21] This suggests that the reemergence of algal blooms is more complicated, less understood, and will require a different mix of solutions. This was apparent to the Commission as early as 2004, when it noted that "significant information gaps remain as to the recurrence of eutrophication, particularly in Lake Erie, making it difficult for policymakers to determine what actions can and should be taken to improve the lake's ecological integrity."[22] The Commission also called for more comprehensive biological investigations into the effects of aquatic invasive species, climate change and other factors, and improved measurements of phosphorus loading.

Nearshore Cladophora and other algal growth are apparently largely controlled by tributary and shoreline loading phosphorus and also by soluble reactive phosphorus which promotes algal growth more quickly than its particulate form. In addition, phosphorus concentrations may be higher in the nearshore and lower in the offshore because zebra and quagga mussels may have increased interception, retention and recycling of nutrients by the nearshore bottom dwelling community and altered the composition of particulate material exported from nearshore waters to the offshore.[23]

Other factors contribute to the complexity of the issue. For example, the size of a watershed and retention time of lake waters affects the timing and concentration of phosphorus in the nearshore zone and the potential intensity and scale of management response as well. Rainfall-induced events–such as combined sewer overflows or agricultural runoff–also have an effect.

Consistent with a nearshore zone framework, more coordinated and frequent monitoring of algal fouling (and potentially releasing algal toxins that could have a serious impact on drinking water quality) is needed, as is watershed-specific monitoring to test both causal hypotheses and assess the impact of management actions. More sophisticated models need to be developed that capture the interactions of habitat, fish community structure, and nutrient loading to make predictions about the effects of management actions. Also, more research is needed to improve our understanding of the linkage between of nearshore re-emergence of eutrophication and oligotrophication of the offshore.

Eutrophication, the excessive aquatic plant growth as a result of large amounts of nutrients being released into a body of water, can have adverse effects on human health and recreation, the economy, and ecosystems.

Given these challenges, the magnitude of the problem and the difficulties in addressing it, and the need for testing causal hypotheses and models, the Commission believes that a major binational scientific effort be undertaken. The effort should be similar to the Commission's Pollution from Land Use Activities Reference Group (PLUARG) of the 1970s and is now required to improve understanding of the underlying cause of the resurgence of eutrophication and to help develop modified programs and policies. PLUARG produced a body of work that was instrumental in advancing knowledge regarding nonpoint source pollution in the Great Lakes and elsewhere. A "PLUARG II" would improve the understanding of the causes of the resurgence of eutrophication and help managers address new agricultural practices and the degree of urban sprawl which have occurred in the past few decades.

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[21] Heckey et al. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Can J. Fish Aquat. Sci. 61: 1285-93.
[22] IJC2004. , *12th Biennial Report on Great Lakes Water Quality*, at http://www.ijc.org/php/publications/html/12br/english/report/.
[23] Heckey et al. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Can J. Fish Aquat. Sci. 61: 1285-93.

Nevertheless, despite the value of continuing to develop a better understanding of the causal relationships, the Commission believes that some steps should be taken right away in order to begin to address the problem. Hence, the Commission endorses the recommendations in the work group's report that several "no regrets" management actions be initiated at this time by all levels of government to reduce nonpoint sources from agricultural and urbanized watershed and tributaries, especially in phosphorous-sensitive watersheds (see Table 1).[24] No regrets management actions are best-bet actions that will lead to one or more improvements in the condition of eutrophic waters based on scientific understanding of cause-effect relationships.

Since the causes of eutrophication tend to be site specific, solutions require place-based actions, such as those listed in Table 1. Examples are actions to reduce phosphorus from point sources, such as sewage treatment plants, along with nonpoint sources such as urban and agricultural runoff, combined sewer overflows, and rural septic systems.[25] While such activities do not address changes to in-lake processes that alter food web nutrient processing, their collective impact across watersheds can reduce loading to any of the Great Lakes.

There is a need to further develop and evaluate systems that purposefully use phosphorus for more desirable outcomes. Solutions to nearshore zone nutrient surpluses also include controlling the dreissinids themselves or farming/harvesting algal/Cladophora biomass for beneficial purposes, such as green energy or biofuel. Effective efforts need to be documented in a database and shared among potential users by establishing an inventory of useful management practices and disseminating success stories about managing eutrophication. For the benefit of the general public, who can take important steps to help control nutrients, more user-friendly documents should be made available, and collaborating departments and agencies should develop consistent messages.

Long-term solutions to the problems associated with eutrophication will require a systems approach that balances watershed phosphorus inputs and outputs with other factors that regulate the appearance of local symptoms. There is no one management strategy that can be universally applied to all watersheds or all lakes; each is unique and solutions must be tailored to its own susceptibility to nutrient loss and the location of nutrient-sensitive waters.

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24 IJC Work Group Report on Eutrophication at http://www.ijc.org/en/priorities/2009/eutrophication
No regrets management actions are those actions that will not cause harm but there is insufficient scientific evidence to predict the degree of their effectiveness.
25 Pitois, S. et al. 2001. Source of the eutrophication problems associated with toxic algae: an overview. Journal of Environmental Health, 64: 25-32.

Table 1. No Regrets Management Actions

Reduce the use and application of phosphorus (source reduction) by promoting:

- nutrient-use planning for croplands and livestock operations;
- nutrient-use efficiency in rural and urban communities;
- promote crop fertilizer applications that are sensitive to local hydrological conditions;
- promote phosphorus soils testing to guide application rates of fertilizer and manure;
- ban or lower phosphorus in lawn fertilizers in phosphorus-sensitive basins;
- education and outreach on appropriate use of low- phosphorus fertilizers in urban settings.

Reduce discharges and runoff (management controls) by promoting:

- soil and water conservation best management practices to increase infiltration and reduce runoff and soil loss;
- promote riparian buffers to reduce runoff and phosphorus export;
- reducing wastewater treatment discharges by optimizing operations at facilities (significant reductions can be attained without significant capital inputs);
- retrofit existing stormwater management infrastructure to green infrastructure or to higher design standards;
- education and outreach to waterfront residents on septic system construction and maintenance; enhance outreach in phosphorus-sensitive basins;
- mandatory pumping of on-site septic systems on a periodic basis;
- mandatory disconnection of direct on-site septic system connections to waters of the Great Lakes.

Use adaptive management to invest more in the most cost-effective methods:

- evaluate programs designed to address urban, rural and agricultural point and nonpoint sources of phosphorus to ensure they are achieving intended results.

Modified from Report of the Work Group on Eutrophication, 2009

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Develop new or improved models to improve estimates of phosphorous loadings to the Great Lakes from tributaries and other sources and use the results to establish phosphorous concentration targets for nearshore and offshore waters of the Great Lakes.

- Issue a reference to the Commission for a binational scientific investigation into the causes of the resurgence of nuisance and harmful algal growths in the Great Lakes from land-use activities and to test causal hypotheses of the linkages between land use and algal problems and associated ecosystem changes in the Great Lakes.

In addition, the Commission recommends that the Parties in implementing the Agreement:

- Institute "no regrets" actions–measures that would be justified under all plausible future scenarios–using adaptive management to better retain nutrients and sediment on the land, especially in watersheds with high phosphorus loadings.

- Promote the implementation of successful "no regrets" management actions by developing, maintaining, and sharing an inventory of effective techniques and programs.

Beaches and Recreational Water Quality

Beaches and recreational waters are critical to the economic and environmental health of the Great Lakes region and to the quality of life for residents and visitors. Understanding the nature, extent and causes of problems at beaches and in recreational waters and the resulting solutions, are challenges that must be addressed by a coordinated nearshore zone framework.

These nearshore environments contribute to ecosystem biodiversity and provide breeding grounds and cover for fish, birds, aquatic invertebrates and other wildlife. Indeed, beach closures are one of the fourteen Beneficial Use Impairments cited in the Great Lakes Water Quality Agreement.

Beaches also provide significant recreational and associated economic opportunities. Along the many thousands of miles of shoreline, there are approximately 822 monitored beaches in the Great Lakes basin. One study reported that there were 3,000 days of beach closings and advisories in across the Great Lakes in 2005 and that a reduction of just 20 percent would result in a $130 to $190 million benefit to the region.[26]

A technical report based on information presented at the October 2008 State of the Lakes Ecosystem Conference notes that the situation is fair and unchanging in the United States and poor and deteriorating in Canada with respect to the number of health-related swimming posting (advisories or closings) days for recreational areas on the Great Lakes: "The percentage of beaches open the entire season remained nearly constant in the United States (73 percent average) and in Canada (49 percent average) from 1998-2007. The percentage of beaches closed more than ten percent of the season averaged nine percent in the United States and 42 percent in Canada during 2006-2007. Differences in the percentage of open and posted beaches between the United States and Canada may reflect differing posting criteria."[27]

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[26] The Brookings Institution. 2007. *Healthy Waters, Strong Economy: The Benefits of Restoring the Great Lakes Ecosystem*,. http://www.brookings.edu/reports/2007/0904gleiecosystem_austin.aspx

[27] See "Beach Advisories, Postings and Closures," State of the Great Lakes 2009: Technical Report, USEPA and Environment Canada, p. 167 at http://binational.net/solec/sogl2009/SOGL_2009_en.pdf. This section also includes a lake-by-lake assessment.

Since most beach users are there to swim or play in the water, state, provincial, and local governments close beach waters to protect the public from waters that do not meet safety standards. Many beaches maintain signs that describe the condition of the water at any given time (Figure 5). Respiratory and gastrointestinal illnesses as well as ear and skin symptoms can result from exposure at contaminated sites. Exposure can occur from breathing in pathogens (typically viral) from the surface of the water, ingestion, and from skin contact. Morbidity disease reports show that respiratory diseases have overtaken gastrointestinal illnesses as the most common water-related diseases.

Figure 5. Indiana Department of Environmental Management's sign for beach at East Chicago, Indiana. This picture was taken in May 2010 just prior to beach opening season. Photo credit: Meredith Nevers, U.S. Geological Survey.

Causes of degraded water quality

Point sources of contamination–from industrial discharges and wastewater treatment facilities, for example–contribute to degraded water quality. However, it appears that nonpoint source pollution, in particular stormwater runoff, poses a much greater threat to the integrity of recreational water bodies.[28] One study of South Shore Beach in Milwaukee concluded that the high *E. coli* level were from local sources of pollution and rarely affected by regional contamination events such as sewage overflows.[29] Bacterial source tracking studies revealed that the elevated levels of *E. coli* from the swimming area were attributed to the large ring-billed gull and waterfowl populations and storm water runoff and that much of it was coming from the parking lot that drained into the lake. Similar findings were made during studies of inner city beaches on Lake Ontario in Hamilton and Toronto that used microbial source tracking methods to demonstrate that the main source of *E. coli* in nearshore beach water was wild birds.[30] However, another study on recreational water contamination in southeastern Lake Huron demonstrated that the dominant source of *E. coli* in lake water samples was agriculture, which supplied about 60 percent of the bacteria to the lake, whereas human sources provided only about three percent.[31]

Nonpoint source pollution generally results from agricultural and urban storm water discharges, precipitation, atmospheric deposition, drainage, seepage, or hydrological modification. Nonpoint source pollution can include excess fertilizers, herbicides and insecticides from agricultural lands and residential areas; oil, grease and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes and faulty septic systems. [32]

Faulty On-Site Waste Treatment Systems (OWTS) are also a problem. In the upper Great Lakes, for example, the most attractive sites for waterfront homes and cottages have high water tables for part of the year and soils that are not suitable for the OWTS that are installed on these properties. Poor maintenance of OWTS is also a matter of concern. A compounding issue is that much of the lower Great Lakes basin is highly urbanized with extensive and aging infrastructure.

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[28] Jensen, E.T. and S.L. McLellan (2005). Beach Closings: Science versus Public Perception. Action Bioscience.
http://www.actionbioscience.org/environment/jensen_mclellan.html

[29] McLellan, S. L., and A. K. Salmore. 2003. Evidence for localized bacterial loading as the cause of chronic beach closings in a freshwater marina. Water Research 37: 2700-2708.

[30] Edge et al. 2007. Experience with the antibiotic resistance analysis and DNA fingerprinting in tracking faecal pollution at two lake beaches. *Water Science and Technology*. 56:51-58.

[31] Kon et al. 2009. Repetitive element polymerase chaing reaction analysis of Escherichia coli isolates from recreational waters of southeastern Lake Huron. Canadian Journal of Microbiology. 55:269-276.

[32] U.S. EPA. 2010. What is Nonpoint Source Pollution. http://water.epa.gov/polwaste/nps/whatis.cfm

In particular locales, leaking municipal sewer lines may be a significant source of contamination of groundwater which ultimately affects the quality of recreational waters.[33] Climate change models indicate the Great Lakes will experience more severe and frequent storm events. These include short but intense precipitation events (micro-bursts), which have the potential to erode beachheads, mobilize materials within the watershed and impair water quality. These high precipitation events often result in sewer overflows that contribute raw or partially treated sewage to the lakes and rivers, leading to elevated *E.coli* counts and subsequent beach postings.[34]

Need for better and timelier indicators

Public beaches are often posted as unsafe for swimming because of elevated *E. coli*. levels. Most of the hundreds of strains of *E. coli* are relatively harmless and cause illnesses only when consumed in high numbers.[35] However, the presence of *E. coli* bacteria in surface water can result from sewage and wastewater pollution; moreover, *E. coli* may be an indicator that other pathogens are present. It is generally much simpler, quicker and safer to analyze for an indicator organism, than for the entire suite of individual pathogens.

Beach sand may contain far more *E. coli* and parasites than beach water does, and it could be that exposure to the sand might cause gastrointestinal illnesses.

Nevertheless, testing can produce false positive results when fecal indicator bacteria from birds, algae and other natural populations, which have less pathogenic bacteria, are mistaken for human fecal contamination. Thus, existing testing protocols can lead to unnecessary closures of beach recreational waters. Another issue is that some beach sand may contain far more *E. coli* and parasites than beach water does, and it could be the exposure from the sand that could cause gastrointestinal illness. Wild birds are now thought to be responsible for much of the contamination of beach sand. Research into novel techniques (such as microbial source tracking) would help distinguish between the various potential factors which contribute to contamination of recreation waters [36] and would increase the efficiency of the decision-making process for beach advisories.

There is still a significant lag between monitoring, analysis and notification, and devising systems to inform the public of problems in a timely way remains a challenge. Current beach testing methodologies take 24 hours or more prior to posting beaches as unsafe for swimming. As metropolitan areas continue to grow in the basin, larger numbers of people will be using nearby beaches. An efficient and timely testing method is needed to advise the public about recreation water quality at busy beaches to prevent water-based illness. The Commission recommends that state and local governments issue preemptive advisories where a correlation between rainfall and elevated bacteria levels exist or when sewer overflows or other catastrophic events jeopardize beach safety. [37]

Furthermore, communication of beach closure decisions needs to be improved. For convenience but also for optimum health protection, the public should be informed of conditions before arriving at the beach and encountering warning signs. In addition, announcement of closure decisions should specify whether it is the water or the beach that is unsafe, or both. The public

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[33] Dorfman and Rosselot, 2009. Testing the Waters A guide to Water Quality at Vacation Beaches. Natural Resources Defense Council. http://www.nrdc.org/water/oceans/ttw/ttw2009.pdf

[34] For information on pollution from municipal sources, see International Joint Commission, *14th Biennial Report on Great Lakes Water Quality, August 2009,* at http://www.ijc.org/php/publications/pdf/ID1631.pdf.

[35] Kon et al. 2009. Repetitive element (REP)-polymerase chain reaction (PCR) analysis of Escherichia coli isolates from recreational waters of southeastern Lake Huron. *Canadian Journal of Microbiology* 55:269-276.

[36] Stoeckel, D. M. and V. J. Harwood. 2007. Performance, design, and analysis in microbial source tracking studies. *Applied and Environmental Microbiology* 73:2405-2415.

[37] Dorfman, Mark and Kirsten Sinclair Rosselot. 2009. Testing the Waters. A Guide to Water Quality at Vacation Beaches. Natural Resources Defense Council. http://www.nrdc.org/water/oceans/ttw/ttw2009.pdf

needs to understand why the beach is closed and what they can do to reduce the frequency of closures.

Some positive steps have been taken along these lines. Michigan, Indiana, and Wisconsin state agencies post current beach closures, and additional information on their respective beaches is also available on a Great Lakes Information Network web site. [38] Other jurisdictions in both Canada and the United States should emulate this practice and consider establishing a joint, binational web site with basin-wide information on beach conditions and recreational water quality.

Need for basinwide standards and criteria

The effective management of beaches across the Great Lakes basin is further complicated because there are so many federal, state, provincial and local authorities, and because they often use different monitoring approaches, standards and criteria for issuing beach advisories and closing beaches.

Under a new Great Lakes Water Agreement, binational and nearshore standardized basin-wide surveillance and monitoring protocols in conjunction with preventive risk management strategies would enable binational standardized criteria for beach postings. Further, the Commission recommends that federal governments designate a lead agency to establish a binational, systematic, centralized and timely way to evaluate and report waterborne illness in the Great Lakes and to facilitate collaboration on best practices at the local, regional, state, provincial and federal levels.

Recent actions suggest that these objectives are highly feasible. Under the U.S. Great Lakes Regional Collaboration, for example, wider use is being made of predictive models to provide more timely advisory information as well as a standardized sanitary survey for a more systematic approach to finding and correcting beach contamination problems.[39] In Canada, under the auspices of the Great Lakes St. Lawrence Cities Initiative, mayors and provincial ministers have committed to work together to protect the health of beaches and coastal areas by creating a new network that brings experts together to share information and best management practices.[40] As the Commission's Work Group on Beaches and Recreational Water Quality suggested, "What would help further would be the designation of a focal point on the U.S. side and the Canadian side, each of whom could pull together what is happening on the local, regional, state, provincial and federal levels."[41]

The Commission is pleased to note success stories at the local level. For example, the city of Racine, Wisconsin has almost completely eliminated beach advisories as a result of stormwater management improvements, a constructed wetland, changes in beach grooming and other strategies, which are now being implemented in other cities.[42]

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[38] Great Lakes Beach Cast. http://great-lakes.net/beachcast/bw.html (current beach conditions)
[39] Great Lakes Regional Collaboration. 2010. Beach Project Initiative.
http://www.glrc.us/initiatives/beaches/index.html.
[40] Great Lakes St. Lawrence Cities Initiative. 2010. Great Lakes – Great Beaches & Coasts.
http://www.glslcities.org/initiatives/great-beaches.cfm.
[41] Ibid.
[42] Kinzelman et al. 2009. "Success of science-based best management practices in reducing swimming bans: A case study from Racine, Wisconsin, USA,: in Aquatic Ecosystem Health and Management 12(2) 187-196.

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Develop standardized binational criteria, monitoring protocols and reporting for issuing and tracking beach postings and for reporting of waterborne-illnesses.

In addition, the Commission recommends that the Parties in implementing the Agreement:

- Conduct research on novel techniques such as microbial source tracking which would help distinguish between the various potential factors which contribute to contamination of recreation waters.

- In consultation with various orders of governments, develop testing methods to improve the scientific basis for advisory and closure decisions at Great Lakes beaches; improve early-warning communication to the public about beach advisories and closures.

Groundwater

"Significantly, Annex 16 is the shortest in the Agreement, and no biennial reports have ever been issued on the topic. In the Commission's view, this reflects the relative lack of attention groundwater has received, even though it is clear that human and ecosystem health in the Great Lakes basin cannot be protected without protecting ground-water resources."

Groundwater consists of water that infiltrates the land surface, flows underground for varying distances, and then discharges to a stream or lake. Through this process, groundwater recharges streams and rivers that flow into lakes, contributes to fish habitat and supports significant ecosystem functions by maintaining stream flows and wetlands during dry periods.

In the Great Lakes basin, groundwater is the source of drinking water for 8.2 million people, including 82 percent of the rural population. It also provides 43 percent of agricultural water and 14 percent of industrial water in the basin and is vital to the quantity and quality of Great Lakes water and its tributaries. Groundwater contribution to Great Lakes tributaries ranges from 48 percent in the Lake Erie basin to 79 percent in the Lake Michigan basin, and its total volume is approximately equivalent to Lake Michigan (4168 km^3).[43]

Groundwater in the basin is of generally good quality but is threatened by chemical and biological inputs from point and nonpoint sources. Since contaminated groundwater is a source of surface water contamination, Annex 16 (Pollution from Contaminated Groundwater) was added to the Agreement. This annex calls for actions to identify existing and potential sources of contaminated groundwater affecting the Great Lakes, map hydrological conditions in the vicinity of existing and potential sources, develop a standard approach and procedures for sampling and analysis, and control the sources of contamination and the contaminated groundwater itself. Progress in implementing the annex is to be reported to the Commission every two years.

Significantly, Annex 16 is the shortest in the Agreement, and no biennial reports have ever been issued on the topic. In the Commission's view, this reflects the relative lack of attention groundwater has received, even though it is clear that human and ecosystem health in the Great Lakes basin cannot be protected without protecting groundwater resources.

An important contribution to improving the understanding of the impact of groundwater on the quality and quantity of Great Lakes water was made by the Commission's Great Lakes Science Advisory Board which, in conjunction with the Council of Great Lakes Research Managers and the Health Professionals Task Force, issued a report assessing a range of specific threats to groundwater in the basin.[44] The report recommended actions that could be taken by federal,

[43] Groundwater in the Great Lakes Basin, 2010 at http://ijc.org/php/publications/pdf/ID1637.pdf.
[44] Ibid.

state, provincial, and local governments, including research, monitoring, regulation, enforcement, financial support, and economic and tax incentives. Local governments were also encouraged to increase source-water protection, conservation measures and requirements for on-site wastewater treatment.

Threats to Groundwater Quality

Groundwater in the basin is of generally good quality but is threatened by chemical and biological inputs from point and nonpoint sources and the effects of many independent local management decisions have consequences on the basin's water resources at a much larger scale. This is probably the most profound change in the understanding of groundwater resource management since the Commission's advisory boards began evaluating groundwater resources.

Specific threats to groundwater in the basin include: pathogens, toxic chemicals, nutrients, household products, hormones, antibiotics, pharmaceuticals and road salt. The threats are generally localized but occur in all jurisdictions and affect the basin's water resources at a regional scale. The sources of these threats include: failing septic systems, leaking underground fuel storage tanks, hazardous waste sites, abandoned wells, leaking sanitary sewers, confined animal feeding operations, de-icing practices, landfills, land application of manure, agricultural practices, spills, atmospheric deposition, infiltration of vehicle fluids, cemeteries, petroleum refineries and injection wells. Other activities affecting groundwater include road kill carcass burial, pit and quarry operations, water bottling operations and ethanol production.

The thirteen technical annexes in the Science Advisory Board's report elaborate on all of these issues.[45] In the Commission's view, a revised Agreement should strengthen the provisions of Annex 16 by incorporating the report's recommendations to spur implementation. A few of the major issues and recommendations are included here.

Overall, 90 percent of water-borne pathogenic disease outbreaks are attributable to water systems supplied from groundwater, and more than half of these illnesses may be due to viruses. The primary cause is human fecal waste coming from malfunctioning septic tank or seepage bed systems and from leaking sanitary sewers. Bacteria mostly originating from human sewage, animals and animal manure are also of concern.

Septic systems frequently leak and have been considered to be the primary cause of nonpoint source groundwater pollution in Michigan. For example, sales records from Wayne and Washtenaw County in Michigan showed failure rates of about 20 percent.[46] Door County Wisconsin is requiring all systems to be inspected and requiring all failed systems to be replaced by the landowner. In British Columbia, the owner must keep up maintenance to keep their warranty valid.

Septic systems frequently leak and have been considered to be the primary cause of nonpoint source groundwater pollution in Michigan.

There are more than 148,000 leaking underground storage tanks (LUST) in the eight Great Lakes states out of the 612,000 identified underground storage tanks.[47] A U.S. federal LUST Trust Fund was establshed in 1986 to oversee and enforce clean-up actions. The fund is financed through a 0.1 cent per gallon tax on the sale of motor fuel, but that is only a minor contributor to the amount spent by states. Estimates of the number of underground storage tanks in Ontario vary from 30,000 to 60,000, and it is estimated that 20 percent of them are leaking.[48] Petroleum

[45] Ibid.
[46] Ibid.
[47] U.S. EPA 2007. FY 2007 End-of-Year Activity Report. http://www.epa.gov/OUST/cat/ca_07_34.pdf
[48] Alsip, R. 1993. Leaking Tanks, leaking profits. Canadian Banker. 100:46-48.

products and additives are generally the major concern, while leaking solvents are also a serious issue. Health effects include damage to vital organs and to the immune, respiratory, and reproductive systems and cancer. Ontario has required all underground storage tanks to be registered and either upgraded or removed to meet new spill protection equipment guidelines.[49] Canada has also implemented Storage Tank Systems for Petroleum Products and Allied Petroleum Products under the Canadian Environmental Protection Act of 1999 to protect soil and groundwater from contamination on federal and aboriginal lands.[50] The states should be provided more funding from the LUST Trust Fund to improve training, inspection, and enforcement efforts.[51] Other potential approaches to the problem include secondary containment (such a double-walled system), biannual leak detection inspections, and a requirement that polluters should be required to pay for cleanups.[52]

The regulation of concentrated animal feeding operations should ensure proper treatment of manure and application of methods to reduce runoff. Regulations should also address carcass burial along with land application of septage (partially treated waste pumped from a septic tank) and manure. Abandoned well programs are required to avoid aquifer cross contamination and prevent the access of contaminated surface water to groundwater. Grants or incentive programs could be considered as a means of ensuring maintenance and proper decommissioning of abandoned wells.

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Retain and improve the Groundwater Annex with the following provisions:
  - Recognize the importance of groundwater as a source of drinking water in the basin and make a high priority the protection of groundwater through monitoring, wellhead protection, well registration and abandoned well-closure programs to ensure human health.
  - Require systematic basin-wide collection of data following standardized protocols for groundwater quantity and quality.
  - Maintain water budgets for the basin that include major groundwater withdrawals and consumption uses, and report on trends.

In addition, the Commission recommends that the Parties in implementing the Agreement:

- Designate a lead agency with responsibility for compiling and regularly reporting to the Commission on relevant research, monitoring and program information on key groundwater issues because of the importance of groundwater quality to human and ecosystem health.

- Improve training, inspection and enforcement efforts and cost-sharing of clean-up costs from various sources, including leaking underground storage tanks, spills and leaks from oil pipelines and vehicle fluids, de-icing practices and petroleum refineries.

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[49] Carter 2006. Dealine for removal or upgrade of Ontario's fuel storage tanks fast approaching *Charity Law Bulletin* No. 88., http://www.carters.ca/pub/bulletin/charity/2006/chylb88.htm

[50] Environment Canada. 2008. Storage Tank Systems for Petroleum Products and Allied Petroleum Products. http://www.ec.gc.ca/rs-st/

[51] General Accounting Office. 2003. Recommendations for Improving the Underground Storage Tank Program. http://www.gao.gov/new.items/d03529t.pdf

[52] Sierra Club. 2005. Leaking Underground Storage Tanks: A Threat to Public Health & Environment. http://www.csu.edu/cerc/documents/LUSTThreattoPublicHealth.pdf

- Establish standards for septic systems, have them inspected periodically and require owners of them to be in compliance. Tax incentives should be provided to maintain, repair, or replace faulty systems.

- Implement and enforce more effective regulations on confined animal feeding operations to ensure proper treatment of manure and application of methods to reduce runoff and infiltration into groundwater.

- Consider grants or incentive programs as a means of ensuring maintenance and proper decommissioning of abandoned wells.

Chemicals of Emerging Concern

"The threat is not just to Great Lakes biota, but also to humans via consumption of drinking water from the lakes and upstream wells and from consuming fish."

The term "chemicals of emerging concern" (CESs) has come to define the emerging awareness of the presence in the environment of many unregulated or inadequately regulated chemicals used by society that may pose a risk to the health of humans and ecosystems. For the most part, CECs enter the Great Lakes in the nearshore via sewage treatment plant discharges or combined sewer overflows. While the Agreement has a number of annexes[53] that, in whole or in part, address toxic substances, none specifically mentions chemicals of emerging concern. A revised Agreement should include policies to address this critical shortcoming.

Tens of thousands of industrial substances are currently in use in the United States and Canada. Yet, relatively few of them have regulations governing their release into the environment, and historically, a large percentage has not been thoroughly evaluated for their effects on human health and the environment. When toxic substance laws came into effect, the vast majority (by volume) of these products were "grandfathered" into regulated commerce, and the burden of demonstrating their risks and demonstrating the need for action fell on government agencies. Even when regulatory criteria do exist, they were developed based on the best available science at the time and may neglect important considerations for which there were scientific data gaps, such as bioconcentration via different pathways and consideration of other toxicity endpoints.

Both federal governments are currently immersed in the process of screening and assessing these existing chemicals. Some of these unregulated or insufficiently regulated chemicals are accumulating in sediments, fish, birds and other aquatic life. The threat is not just to Great Lakes biota, but also to humans via consumption of drinking water from the lakes and upstream wells and from consuming fish.

In this context, chemicals of emerging concern include those that (a) just gained entry into the environment (new to commerce or a new formulation, nanomaterials or other chemicals) and (b) are newly characterized as a result of increases in their concentrations or because of improvements in the instrumentation and analytical abilities to detect these chemicals in air, water, sediment, or biota.[54] Many categories are now found in the Great Lakes (See Table 2).

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[53] U.S. Canada Great Lakes Water Quality Agreement of 1978, as amended by protocol in 1987; annexes 10 - 14; http://www.ijc.org/en/activities/consultations/glwqa/agreement.php

[54] International Joint Commission. Work Group Report on Chemicals of Emerging Concern. http://www.ijc.org/en/priorities/2009/chemicals

Table 2. Categories of Chemicals of Emerging Concern Detected in the Great Lakes

Synthetic Musks
Fluorinated Surfactants
Brominated Diphenyl Ethers
Other Flame Retardants
Alkylphenol Ethoxylates
Chlorinated Paraffins
Phthalates
Pharmaceuticals, Veterinary Drugs and Personal Care Products
Current Use Pesticides

However, chemicals of emerging concern are often present in consumer products and may be released into the Great Lakes from multiple, dispersive and nonpoint sources. The need to focus not just on reducing emissions from industrial processes, but to also reduce emissions from the use and disposal of products, poses new challenges for protecting the Great Lakes.

Sources of Chemicals of Emerging Concern

Often, the original source is a particular product, including pharmaceuticals, fabrics, plastic toys, and sunscreen. The exact pathways by which chemicals of emerging concern reach the Great Lakes are not always well understood. Pathways and categories include wastewater treatment plant discharges, sewage overflows (cosmetics, pharmaceuticals, and possibly, nanomaterials), agricultural runoff (pesticides and veterinary products), landfill leachate, and long-range atmospheric deposition. Substances from such products are a source of contamination that may pose a potential threat to the health of the Great Lakes. The nearshore is particularly vulnerable because most loading occurs in that zone, especially because wastewater treatment plants are not designed to destroy or remove chemicals of emerging concern and are among the leading conveyors of these contaminants to the Great Lakes.

Monitoring

While ongoing monitoring efforts are recognized and valued, there has been limited surveillance for many chemicals of emerging concern in the Great Lakes. This reflects the constraint on government resources, the focus of existing resources on legacy pollutants, and the fact that capabilities to detect and analyze many contaminants in environmental media are available for a small fraction of chemicals in current use.

Provisions for monitoring chemicals of emerging concern should be included in a revised Agreement. There is a need to establish coordinated and aligned monitoring programs (combination and alignment of existing programs, augmentation of existing programs as well as new programs) that will provide exposure and effects information of chemicals to enable assessment of management strategies. Given the size of the chemical enterprise, the extent to which it is woven into the fabric of society and the backlog of unexamined chemicals, a new approach is needed that does not rely on resource-intensive, chemical-by-chemical risk assessments in which government, at great public expense, bears the burden of proof.[55]

"Market and regulatory tools are needed to motivate investment by industry in green chemistry and in the use, design, and production of safer chemicals and materials."

Future monitoring programs also should strive for a balance between a targeted design (critical path analysis with sampling in locations near obvious discharges that are expected to have higher concentrations) and statistically defensible spatial sampling in locations which will enable the definition of representative concentrations in the basin. A common, transparent, and easily accessible repository for data also needs to be established by the governments.

Management and Control

At the same time, optimal risk management strategies have to be identified. Useful approaches may include pharmaceutical return programs, education of medical professionals to reduce prescription rates, incentives for green drug manufacturing and improving technologies for the treatment of drinking water and wastewaters.[56] At this stage, however, there seems to be inadequate information available to determine the most effective strategies.

Hormones, antibiotics and pharmaceuticals and agriceuticals generated from concentrated animal feeding operations are transported in water and soil.[57] Little is known of the environmental fate of the tons of physiologically active steroid hormones that are released. Current regulations to mitigate inputs of chemicals of emerging concern need to be strengthened and include assistance to enable compliance from farm operators.

A revised Agreement should include a description of the underlying principles and processes by which the Parties would identify substances and establish priorities, rather than compiling a specific list of substances as such lists rapidly become out of date.

New policies need to be developed that reduce the design, production and consumption of chemicals of emerging concern. Green chemistry principles advocate the use of chemical research and chemical engineering to promote the design of products and processes that minimize the use and generation of hazardous substances. These approaches could provide non-toxic alternatives that are more readily degraded in natural systems. Market and regulatory tools are needed to motivate investment by industry in green chemistry and in the use, design, and production of safer chemicals and materials.

Consumer education can lead to "greener" purchasing decisions and wiser use and safer disposal, for instance, putting unused pharmaceuticals in the trash as opposed to the sewer system. Governments can invest in communication and outreach efforts that build awareness of the environmental implications of societal actions and activities.

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[56] Marsalek, U. 2008. Pharmaceuticals And Personal Care Products (Ppcp) In Canadian Urban Waters: A Management Perspective. In: Dangerous Pollutants (Xenobiotics) in Urban Water Cycle Springer Publ. (Petr Hlavinek, Ongjen Bonacci, Jiri Marsalek and Ivana Mahrikova Eds.) Pages 117-130

[57] Shore, L.S. and A.Pruden, Amy (Eds.) 2009. Hormones and Pharmaceuticals Generated by Concentrated Animal Feeding Operations Transport in Water and Soil Series: Emerging Topics in Ecotoxicology, Vol. 1 2009

[57] Wilson MP, and MR Schwarzman. 2009 Toward a New U.S. Chemicals Policy: Rebuilding the Foundation to Advance New Science, Green Chemistry, and Environmental Health. Environ Health Perspect 117(8): doi:10.1289/ehp.0800404

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Develop and implement a process to identify chemicals that are a priority for binational action, consistent with national chemicals management programs; establish coordinated monitoring programs that will provide information on exposure and effects of chemicals to enable assessment of management strategies; place more emphasis on gaining knowledge and understanding of human health effects as they pertain to the major categories of chemicals of emerging concern.

- Develop provisions for monitoring chemicals of emerging concern that describe the underlying principles and processes by which the Parties identify substances and establish priorities, rather than compiling lists of substances that rapidly become out-of-date; examine and modify existing regulatory regimes to address issues posed by newly developed and newly recognized substances; enhance binational communication, coordination, and cooperation on the design and implementation of monitoring programs and set common objectives.

In addition, the Commission recommends that the Parties in implementing the Agreement:

- Invest in communication and outreach efforts that educate consumers and provide economic incentives that encourage them to purchase more environmentally-friendly (greener) products and services, and practice safer disposal of products that contain chemicals of emerging concern.

- Provide tax, economic incentives, and educational support to encourage industry and agriculture to use and develop more environmentally-friendly and green chemistry products and reduce the design, production, and consumption of chemicals of emerging concern.

- Develop wastewater treatment technologies that improve the detection, control, removal and destruction of chemicals of emerging concern.

Risks and Benefits of Eating Great Lakes Fish

The first Beneficial Use Impairment (BUI) identified in Annex 2 of the Agreement is "restrictions on fish and wildlife consumption."[58] As a result of recommendations developed by the Commission, the BUI is deemed to exist when contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife, and the contaminant levels are due to contaminant input from the watershed. Not surprisingly, therefore, most attention to Great Lakes fish consumption is focused on risks.

However, many studies of fish, especially from marine environments, have shown that they contain several important nutrients, such as high-quality protein, vitamins, minerals and beneficial omega-3 fatty acids, and that fish consumption may provide a number of health benefits. These benefits include reduced risks of heart disease, diabetes and other chronic and inflammatory illnesses. At the same time, contaminants in fish can make consumption harmful to human health.

Canadian and U.S residents in the Great Lakes basin, along with visitors and other consumers of Great Lakes fish, seek information to assess the tradeoffs between the risks and benefits of consuming fish to make healthy food choice decisions. In the Great Lakes basin, this challenge to assess the tradeoffs is especially complicated because most assessments of health benefits are based on analyses of marine fish. However, there has been some recent research on the health benefits of eating fish from the Great Lakes.

[58] Under Annex 2 of the Agreement, an Area of Concern is defined as a geographic area (in the nearshore zone) that fails to meet the Agreement's objectives where such failure has caused or is likely to cause impairment of beneficial use or the area's ability to support aquatic life. Annex 2 also defines a beneficial use impairment (BUI) as a change in the chemical, physical, or biological integrity of the Great Lakes system sufficient to cause any of 14 specific outcomes.

Sources of Contamination

Fish contamination results largely from toxic chemicals that reach the Great Lakes from several sources, including discharges from wastewater treatment facilities, atmospheric transport and deposition of combustion sources, and urban and agricultural runoff. Another source is contaminated sediments which remain in tributaries and nearshore waters but can be stirred up by streamside development, violent storms, and dredging. The persistent bioaccumlative chemicals are believed to pose the greatest risk to humans and include methyl mercury, polychlorinated biphenyls (PCBs), dioxins/furans and chlorinated pesticides such as DDT and its metabolite, DDE. The impacts of combinations of chemicals in fish also need to be taken into account, since health effects are usually assessed on the basis of individual chemicals.[59]

When toxic chemicals are in the water, they can be absorbed by fish through their gills. Predatory fish acquire additional exposure and are at more risk because any chemicals in prey they consume bioaccumulate in their tissues. Since humans are also unable to metabolize and excrete these substances efficiently, eating contaminated fish over time can cause accumulation of these chemicals to a level at which they may cause adverse health effects. In general, individuals and groups or subpopulations that consume more fish for cultural or subsistence reasons are at greater risk, especially if the fish come from a more polluted region.[60]

The varieties of adverse health impacts from the chemicals that are of greatest concern have been documented. For example, PCBs, dioxins, and chlorinated pesticides such as dioxins, DDT and DDE may cause cancer, impact sex determination and hormonal function, suppress immune system function, disrupt thyroid function and are associated with elevated risk of diabetes, and cardiovascular disease.[61] For some chemicals, children (especially at the prenatal stage of development) are more at risk than adults. The chlorinated pesticides impair neurodevelopment in children,[62] and methyl mercury is a potent neurotoxicant to which the developing brain is more susceptible than in adults.[63]

Sport fish from lakes Michigan, Ontario and Huron have been found to have the highest levels of PCBs, DDT and dieldrin. Sport fish from Lake Superior have the highest levels of toxaphene and those from Lake Ontario have the highest levels of mirex.[64] Each of these chemicals is rated as a probable human carcinogen and also has a variety of non-cancer adverse health effects.[65]

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[59] See "Combination Effects of Chemicals," *Science for Environmental Policy: DG Environment News Alert Service,* European Commission at http://ec.europa.eu/environment/integration/research/newsalert/pdf/21si.pdf.
[60] Cole, D.C., Kearney, J., Sanin, L.H., Leblanc, A., and Weber, J.P. (2003). Blood mercury levels among Ontario anglers and sport-fish eaters. *Environmental Resources* 95:305-314.
IOM (Institute of Medicine). (2007). Committee on Nutrient Relationships in Seafood, (2007); Seafood Choices: Balancing Benefits and Risks. ISBN: 978-0-309-10218-6. Mahaffey, K.R., Clicker, R.P., and Jeffries, R.A. (2008) Adult women's blood mercury concentration vary regionally in USA: Association with patterns of fish consumption (NHANES 1999-2004). *Environmental Health Perspectives* doi:10.1289/ehp.11674. Available at http://dx.doi.org/ ;
[61] This statement is derived from several papers and multiple authors cited in the IJC, 2009, Workgroup report on Benefits and Risks of Great Lakes Fish Consumption. http://www.ijc.org/en/priorities/2009/fish-consumption
[62] Torres-Sanchez, L., Rothenberg, S.J., Schnaas, L., Cebrian, M.E., Osorio, E., del Carmen Hernandez, M.,Garcia-Hernandez, R.M., del Rio-Garcia, C., Wolff, M.S., and Lopez-Carrillo, L. (2007). In utero p,p- DDE exposure and infant neurodevelopment: a perinatal cohort in Mexico. *Environmental Health Perspectives* 115:435-439.
[63] Rice, D.C. (2008). Overview of modifiers of methylmercury neurotoxicity: Chemicals, nutrients and the social environment. *Neurotoxicology* 29:761-766.
[64] Rice, D.C. (2008). Overview of modifiers of methylmercury neurotoxicity: Chemicals, nutrients and the social environment. Neurotoxicology 29:761-766.
[65] Environment Canada and U.S. EPA, 2009. Contaminants in Sport Fish, Indicator 4201. http://www.epa.gov/solec/sogl2009/4201sportfish.pdf

The Ontario Ministry of the Environment (in collaboration with the Ontario Ministry of Natural Resources) and U.S. states and tribes have monitored contaminant levels in edible parts of fish, and issued consumption advisories for Great Lakes fish since the 1970s. Currently, Great Lakes fish consumption advisories exist due to these contaminants: dioxin, PCBs, methyl mercury, toxaphene, chlordane, and DDT.[66]

The Commission's Work Group on the Risks and Benefits of Great Lakes Fish Consumption considers two contaminants, methyl mercury and PCBs, to be of particular concern because of their known toxicity and because of the level of these chemicals found in Great Lakes fish.[67] It noted that important approaches to managing risk identified to date include issuing consumption advisories on methyl mercury and PCBs, directing efforts toward controlling sources of continuing contamination (such as coal-fired power plants), and remediating contaminated sediment.[68]

Both countries have had ongoing, long-term efforts to monitor contaminant levels in top predator fish species (walleye in Lake Erie and lake trout in other Great Lakes). Further, both Environment Canada and U.S. EPA maintain top-predator fish samples, which provide an opportunity to perform retrospective analyses and examine long-term trends. These monitoring data have been invaluable in raising public awareness of the potential health threat from contaminated fish and encouraging governmental action to prohibit activities that produce certain noxious chemicals.

Benefits of eating fish

Fish prepared and eaten with little or no added fat provide a dietary source of high-quality, easily digestible protein that is relatively low in saturated fats (which may cause heart disease and other ailments). A key benefit of eating fish is the consumption of longer-chain omega-3 fatty acids, which are polyunsaturated and beneficial. Omega-3 fatty acids are major components of neuronal, retinal, and cardiac muscle membranes. Humans with low levels of omega-3 fatty acids are more likely to have numerous health concerns, including cardiovascular and inflammatory diseases and impaired neurological development of fetuses and children.[69]

Omega-3 fatty acids can be obtained from multiple other food sources, for example, dark green leafy plants, canola and linseed oils, and walnuts. Eggs, milk, and cheese have been enriched with fatty acids by supplementing animal and poultry diets with fish oils.[70] Yet, western lifestyles and food preferences in general result in low consumption of omega-3 fatty acids as measured in the U.S. population[61] and among pregnant women in Canada.[72]

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[66] Huang, X., Hites, R.A., Foran, J.A., Hamilton, C., Knuth, B.A., Schwager, S.J., and Carpenter, D.O. (2006). Consumption advisories for salmon based on risk of cancer and non-cancer health effects. Environmental Research 101:263-274 [66] Environment Canada and U.S. EPA, 2009. Contaminants in Sport Fish, Indicator 4201. http://www.epa.gov/solec/sogl2009/4201sportfish.pdf

[67] See the report at http://www.ijc.org/en/priorities/2009/reports/2009-fish-consumption.pdf.

[68] Sunderland, E.M. (2007). Mercury exposure from domestic and imported estuarine and marine fish in the U.S. seafood market. Environmental Health Perspectives 115:235-242. Del Gobbo, L., Archbold, J., Eckley, C., Robson, M., Diamond, M., and Vanderlinden, L. (2009). Mercury and Omega-3 fatty acid concentrations of fish sampled from markets in Toronto: consumption scenarios balancing risks and benefits for childbearing women. Canadian Journal of Dietetic Practice and Research.

[69] Simopoulos, A .P., 2008. The importance of the omega-3 fatty acid ratio I cardiovascular disease and other chronic diseases. Experimental Biology and Medicine. 233:674-688.

[70] Hargis, P.S., Van Elswyk, M.E., and Hargis, B.M. (1991). Dietary modification of yolk lipid with menhaden oil. Poultry Science 70:874-883.

[71] Rice, D.C. (2008). Overview of modifiers of methylmercury neurotoxicity: Chemicals, nutrients and the social environment. Neurotoxicology. 29:761-766.

[72] Innis, S.M. and Friesen, R.W. (2008). Essential n-3 fatty acids in pregnant women and early visual acuity maturation in term infants. American Journal of Clinical Nutrition 87:548-557.

There are only a few studies with data on the content of omega-3 fatty acids in freshwater fish from the Great Lakes System. One study examined fish in Lake Superior[73] and another looked at fish in Lake Superior and Lake Erie.[74] These reports reveal that several common fish species in Lakes Superior and Erie contain concentrations of omega-3 fatty acids that are comparable to those in fatty marine fish. There is, however, considerable need for more information on levels of omega-3 fatty acids in fish from Lakes Huron, Michigan and Ontario.

Progress has been made in understanding the risks and benefits of consuming fish and notifying the public of the current state of information. Yet, more information is needed. Several researchers have sought to understand and/or quantify the benefits versus risks of consuming fish, but the analysis is particularly challenging.[75] For its part, the Work Group identified a few major needs: quantifying human blood levels of those contaminants known to have adverse health effects; quantifying levels of omega-3 fatty acids in Great Lakes fish, especially from Lakes Huron, Michigan, and Ontario, and examining fish consumers' medical history, blood chemistry and neurobehavioral responses.

In the meantime, fish consumption advisories are issued by Ontario and all the U.S. Great Lakes states. More and more, however, they seem to be available primarily online. This may pose a challenge, particularly for individuals that eat a lot of fish but do not have regular access to the Internet. Conventional signs at fishing sites are still needed. Further research is required to improve the presentation of information to individuals so that they can make informed fish consumption decisions. It does seem clear, though, that both the province and the states need to devote resources to comprehensive outreach and education campaigns.

Pending the foregoing activities, the jurisdictions should help consumers to make more informed decisions by developing a general statement that would accompany every fish consumption advisory about the benefits of eating fish. The Commission's Work Group has suggested the following text: "When properly prepared, fish provide a diet high in protein and low in saturated fats. Many doctors suggest that eating a half-pound of fish each week is helpful in preventing heart disease. Almost any kind of fish may have real health benefits when it replaces a high-fat source of protein in the diet. You can get the health benefits of fish and reduce contaminants by following this advisory."

"... reports reveal that several common fish species in Lakes Superior and Erie contain concentrations of omega-3 fatty acids that are comparable to those in fatty marine fish. There is, however, considerable need for more information on levels of omega-3 fatty acids in fish from Lakes Huron, Michigan and Ontario."

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[73] Wang, Y.J., Miller, M., Perren, M., and Addis, P.B. (1990). Omega-3 fatty acids in Lake Superior fish, Journal of Food Science 55:71-73

[74] Holub, B. (2009). Omega-3 fatty acid contents of Great Lakes fish; unpublished research prepared for the IJC.

[75] Foran, J.A., Good, D.H., Carpenter, D.O., Hamilton, M.C., Knuth, B.A., and Schwager, S.J. (2005). Quantitative analysis of the benefits and risks of consuming farmed and wild salmon. Journal of Nutrition 135:2639-2643.

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Monitor levels of omega-3 fatty acids in fish species of concern in conjunction with their ongoing monitoring of contaminant levels.

In addition, the Commission recommends that the Parties in implementing the Agreement:

- Conduct research to improve the understanding of human health effects from the various chemicals found in the Great Lakes fish, both singly and as a mixture of chemicals. Information on the emerging chemicals of concern is particularly important.

- Develop consistent standards for issuing fish consumption advisories that are based on consideration of both the benefits of omega-3 fatty acid consumption and the hazards from the mixture of contaminants found in Great Lakes fish.

- Improve the communication of fish consumption guidance, especially for reaching sensitive and vulnerable populations.

Aquatic Invasive Species (AIS)

Alien, non-native, or non-indigenous species are species that do not naturally occur within an area and that have usually arrived in the area as a result of human intervention (whether deliberate or accidental). Many non-native species do not pose any immediate risk and may even provide benefits.[76] Invasive species, on the other hand, are non-native species that have the potential to cause harm to the environment, human health or the economy.[77] The term Aquatic Invasive Species (AIS) can be used to describe aquatic plants, animals and microscopic organisms that produce harmful impacts[78] and are generally synonymous with alien aquatic invasive species.

More than 180 non-native aquatic species have been detected in the Great Lakes basin.[79] The roughly 10 percent of these species that are known to be invasive have caused well-documented environmental, economic and human health impacts. Some of the AIS presently in the system and of particular concern include the sea lamprey, zebra mussel, quagga mussel, Eurasian ruffe, round goby, spiny waterflea, Viral Haemorrhagic Septicaemia (VHS), and Eurasian watermilfoil.

AIS may cause numerous ecological impacts. They may degrade habitat, cause adverse effects to native species, especially threatened and endangered species, disrupt food webs, and facilitate harmful algal blooms. Socio-economic impacts associated with establishment of AIS include reduced use and recreation of degraded beaches and swimming areas, reduced quality of sport fishery, impaired stocks of native fish species for commercial harvest (e.g., sea lamprey impacts on lake trout), disruption to water infrastructure (i.e., clogging intake and discharge pipes, costs of retrofitting), damages to submerged equipment and structures (including boat hull fouling), lowered property values, increased water user costs, regulatory compliance, and AIS prevention and control costs.

The Sea Lamprey is an example of an AIS of serious concern.

[76] Environment Canada . 2010. Invasive Alien Species in Canada. http://www.ec.gc.ca/eee-ias/default.asp?lang=En&n=C4637128-1Alien.
[77] Federal Register. 1999. Executive Order 13112. February 8, 1999, Presidential Documents. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=99-3184-filed.pdf
[78] Work Group Report on Binational Aquatic Invasive Species Rapid Response Policy Framework, at http://www.ijc.org/en/priorities/2009/reports/2009-invasive-species.pdf.
[79] National Oceanic and Atmospheric Administration. 2010. Great Lakes Aquatic Nonidigenouse Species Information System. http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html

AIS prevention and control in the Great Lakes system is a challenge given the large number and diverse nature of pathways, the large number and unique characteristics of individual AIS, and the immensity of the system. Transport in the ballast water of transoceanic commercial vessels is believed to be responsible for approximately 55 percent to 70 percent of the non-native species becoming established in the Great Lakes since the opening of the St. Lawrence Seaway in 1959.[80] Other pathways of AIS introduction (both intentional and unintentional) include the aquaculture industry, aquarium trade, live food fish industry, recreational boating, sport fish stocking, bait bucket transfers, canals and waterways, and various horticultural practices.

Once established in the waters of the Great Lakes basin, it is virtually impossible to eradicate AIS populations, and very costly and difficult to limit or control their spread. As a result, the Commission, first and foremost, supports efforts to prevent invasions and spread from all potential pathways. The Commission is pleased that in recent years, the primary focus has been on preventive measures as the "first line of defense." An array of prevention initiatives have been developed at the state, provincial, and international levels. Since 2006, the rate of discovery of new non-native speices has declined for several reasons, including the implementation and enforcement of mandatory ballast water management regulations by Canadian, U.S., and St. Lawrence Seaway authorities.[81]

Presently, all Great Lakes states and provinces have some form of AIS prevention and control plan in place. Furthermore, various entities (e.g., the Aquatic Nuisance Species Task Force in the U.S. and the Great Lakes Panel on Aquatic Nuisance Species with members from both countries) have been actively engaged in promoting the development and implementation of state/provincial/regional comprehensive management plans addressing AIS prevention and control. The Great Lakes Panel has worked closely with all eight Great Lakes states and two provinces to promote a consistent and coordinated approach using panel meetings, specialty workshops, model planning and legislative guidance, among other instruments.

While the Commission supports efforts to prevent invasions and spread from all potential pathways, prevention measures are not foolproof, and other strategies are required. For those events where prevention was not successful, the Commission supports binational protocols for rapid response to new threats both before the AIS is established (e.g., the Asian Carp) and if needed after an AIS has penetrated the Great Lakes

[80] National Oceanic and Atmospheric Administration. 2010. Great Lakes Aquatic Nonidigenouse Species Information System. http://www.glerl.noaa.gov/res/Programs/glansis/docs/great-lakes-list.xls

[81] MacIsaac, H. (2009). Can We Predict (and Prevent) Aquatic Invasions? Abstract. 16th International Conference on Aquatic Invasive Species, Montreal, Canada, April 19-23. Deneau, M., Bailey, S., Jean, L., Wiley, C. (2009). Have the New Ballast Water Regulations and Inspection Program Reduced the Risk of NIS Introductions for the Laurentian Great Lakes? Abstract.16th International Conference on Aquatic Invasive Species, Montreal, Canada, April 19-23.

Rapid Response and Early Detection

Several rapid response and early detection initiatives have been developed at the state, provincial, federal and international levels. The need for a well-defined and universally-accepted protocol for rapid response has been demonstrated in recent years with efforts to eradicate populations of Northern Snakehead carried out in Maryland, New York, and Arkansas. Recently, several agencies collaborated to establish an Asian Carp Control Strategy Framework.[82] The framework includes electrical barriers that were built by the U.S. Army Corps of Engineers with input from numerous other agencies and experts from many different disciplines. Another Asian Carp collaborative project was to treat an area with rotenone when the barrier was shut down for maintenance, in December 2009 (Figure 6). Genomic technologies can be used to detect VHS across a large region at a level of effort compatible with common environmental monitoring programs.[83] The threat of VHS makes it reasonable to recommend adding pathogen surveillance during routine monitoring.

Figure 6. Responders prepare to apply rotenone treatment to prevent passage of Asian Carp through the electrical barrier while it is turned off for maintenance in December 2009. Numerous organizations, from multiple jurisdictions, including some from Canada, conducted this operation in the Chicago Sanitary and Ship Canal. The effort demonstrated how a large scale rapid response could be organized to prevent establishment of AIS following early detection. Photo credit: Bill Bolen, USEPA.

[82] Asian Carp Control Strategy Framework. May 2010. www.asiancarp.org/Documents/AsianCarpControlStrategyFrameworkMay2010.pdf

[83] Bain MB, Cornwell ER, Hope KM, Eckerlin GE, Casey RN, et al. (2010) Distribution of an Invasive Aquatic Pathogen (Viral Hemorrhagic Septicemia Virus) in the Great Lakes and Its Relationship to Shipping. http://www.aquacircle.org/images/pdfdokumenter/efterret10/VHS_USA_journal_pone_0010156.pdf

Currently there is concern with the apparent lack of connection between AIS research initiatives and the pragmatic needs of rapid response practitioners. Enhanced coordination between these two communities is needed to improve alignment of research efforts with rapid response needs, establish a "technology transfer" process to convert research findings into practical applications, provide for on-site scientific advice, and ensure that early detection and monitoring programs are responsive to emerging needs and feature the latest technology. Ready access to relevant expertise and methodologies, perhaps through formal involvement of researchers in the rapid response organizational structure, is appropriate.

Communication and coordination becomes more difficult when more than one country is involved. Therefore, a binational policy framework for rapid response to AIS will be required, and will need a set of common principles to lay the foundation for consistent and cooperative policies in both nations. This is a central need for an effective unified binational framework for responding to an AIS incident.

The report of the Commission's AIS Work Group report identifies several "institutional dimension" challenges of binational rapid response. In general, agencies tend to be hesitant to take on leadership responsibilities in the absence of a clear legislative directive or funded mandate. Another challenge is harmonization to remove inconsistencies in legislation, policies, and programs so that all relevant parties approach rapid response with a consistent set of goals and objectives. Compromise and negotiation may be needed to achieve shared policy goals.

A revised Agreement can serve as the organizing vehicle for the development and deployment of binational rapid response protocols. A model for rapid response could be the Incident Command System (ICS), an organizational structure used to manage major emergencies in such areas as human and animal disease, forest pathogens and insects, invasive plants, fire management, and oil and hazardous material spills. ICS "is a standardized emergency response management construct designed to provide an organizational structure for incident management. It is an 'all hazard – all risk' approach to managing crisis response operations for emergencies of all sizes, as well as non-crisis events."[84] ICS was successfully used for the Arkansas Snakehead and the Asian Carp eradications. A variation of ICS, the Unified Command System can be an effective mechanism for integrating a multi-agency command structure suited to binational response.

The success of a binational AIS rapid response plan will be a function of both its public profile and its structural and operational characteristics. The planning effort must be sanctioned at the highest political levels, and the AIS threat must be declared-and publicly regarded-as an emergency. Structural characteristics (i.e., how relevant parties are organized to provide rapid response functions) and operational characteristics (i.e., what those functions are and how they are performed) must be clearly articulated and based upon successful past experiences. Recently, experiences with the spread of Bighead and Silver Carp in the Mississippi River basin, Northern Snakehead and invasive aquatic plants such as Hydrilla and Eurasian watermilfoil have helped garner public support for action and demonstrate the value of a rapid response protocol for AIS. The Parties should develop policy and regulations based on the rapid response framework provided in Table 3.

[84] Patient Tracking. A portal resource for communities. http://www.comcare.org/Patient_Tracking/IPTI- Glossary.html#I

Institutional arrangements in the Great Lakes basin can contribute to a successful rapid response effort at the binational level. For example:

- The basin has a highly developed and sophisticated institutional structure that includes an array of binational public and nongovernmental entities.

- These institutional arrangements include AIS-specific entities (e.g., Great Lakes Panel on Aquatic Nuisance Species) with a long-standing focus on issues associated with rapid response.

- Public agencies in the basin have a history of working cooperatively on Great Lakes issues, both at the domestic and binational levels.

- Basin institutions have decades of experience with AIS prevention and control (both successes and failures), as well as with rapid response associated with other issues (e.g., oil and hazardous spill response).

Thus, many of the "building blocks" for binational AIS rapid response planning are presently available, given the basin's well-established institutional arrangements, existing binational agreements/ mechanisms, legal/regulatory regime, policies, programs, and tradition of binational cooperation. Harmonizing and assembling these elements, while identifying and addressing unmet needs, will expedite the planning process.

Recommendations

In revising the Agreement, the Commission recommends that the Parties:

- Explicitly address the aquatic invasive species issue in a separate section that includes improved understanding of their impacts, with provisions for, among other initiatives, a binational rapid response program.

In addition, the Commission recommends the Parties in implementing the Agreement:

- Institute a consistent coordinated approach for aquatic invasive species rapid response planning tailored to the binational dimensions of the Great Lakes-St. Lawrence River system using a rapid response framework.

- Better align research efforts with rapid response needs; establish a "technology transfer" process to convert research findings into practical application; provide for on-site scientific advice, and ensure that early detection and monitoring programs are responsive to emerging needs and feature the latest technology.

Table 3. Framework for rapid response policy and regulations

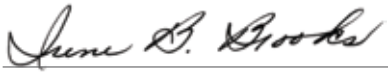
- Binational rapid response will be mandated by a formal agreement between the two nations, such as the Great Lakes Water Quality Agreement, and well grounded in national implementing legislation.
- A lead agency will be designated in each country to carry out AIS rapid response, with a responsibility to coordinate with its counterpart in the other country.
- The discovery of potentially harmful AIS in the boundary waters between Canada and the United States will be recognized as an urgent environmental threat that can affect the biosecurity of both nations.
- Response to the discovery of AIS will be handled the same as other national emergencies such as disease outbreaks and natural disasters that call for a unified multi-agency command structure.
- Pre-designated AIS rapid response on-scene commanders will be identified and assigned responsibility for specific geographical regions/watersheds.
- Memoranda of Understanding will be established to clarify jurisdictions and facilitate movement of personnel and equipment.
- Two Federal AIS rapid response funds will be established.
- A binational group will be designated to convene periodic binational rapid response drills, and to report on progress.
- A consistent approach to AIS rapid response will be used in all boundary water regions on a watershed basis.
- Hotlines and incentives for rapid reporting of AIS discoveries will be established and coordinated.
- Existing public outreach and education programs will enlist the support of anglers, commercial fishers, hunters, naturalists, and recreational boaters to detect, report, and if possible, turn in suspected AIS specimens.
- Response plans will be worked out with orders of governments in consideration of the rights of property owners.
- Appropriate methods to eradicate different AIS threats will be pre-approved for rapid deployment.
- The Great Lakes Fishery Commission will be requested to consider serving as a convening authority for binational rapid response planning operations, response exercises and reporting on the state of binational rapid response readiness.
- The IJC will address the effectiveness of rapid response policy in shared watersheds on a periodic basis.

Modified from Workgroup Report on Aquatic Invasive Species Rapid Response Policy , 2009.

Signed this seventh day of January, 2011 as the Fifteenth Biennial Report of the International Joint Commission pursuant to the Great Lakes Water Quality Agreement of 1978.

Lana Pollack
U.S. Co-Chair

Joseph Comuzzi
Canadian Co-Chair



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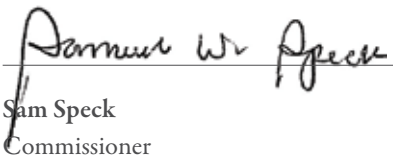

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