CHAPTER 3 *Contents*

Environmental Fate

Biological Activity

3.3.5 January 23, 2001 Meeting Conclusions

3.4 UNDERSTANDING THE INTERACTION OF GROUND WATER AND SURFACE WATER IN THE GREAT LAKES BASIN

3.4.1 Ground Water Issues Related to the Great Lakes

Quantity

Quality

Ecosystem

3.4.2 Identified Research Needs

Effects of Land-use Change

Ground W ater and Ecosystems

Estimating Consumptive Use

Discharge and Recharge

Recommendation

3.5 UNDERSTANDING THE LONG-TERM IMPACTS OF WATER LEVEL FLUCTUATIONS, DIVERSIONS AND CONSUMPTIVE USES IN THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

3.5.1 Effects of Climate Change and Great Lakes Watershed Hydrology

3.5.2 Research Needs for Wetlands

3.5.3 Coastal Development Including the Evaluation of Riparian Shore Properties and Dredging

3.5.4 Human Ability to Regulate Water Levels and Assessments of Long-term Impacts of Water Level Fluctuations on Ecosystem Integrity

3.5.5 Common Databases for Environmental and Shoreline Interests, Water Use and Better Tools to Project Future Uses

3.1 INTRODUCTION

The Council of Great Lakes Research Managers (Council) serves as the International Joint Commission's (IJC) principal advisor on research programs and needs. The Council's purpose is to enhance the ability of the IJC to provide effective leadership, guidance, support and evaluation of Great Lakes research as it applies to the provisions of the Great Lakes Water Quality Agreement. The

Council's responsibilities include:

• promoting effective communication and collaboration between researchers and agencies in Canada and the United States;

• encouraging researchers to share their findings;

• compiling a summary of current and planned research programs related to the Great Lakes Water Quality Agreement, particularly those called for by Annex 17;

• identifying and prioritizing research needs to identify gaps and encourage the U.S. and Canadian governments, the parties to the Agreement, to shift funding toward studies directly relevant to the Agreement's purpose; and

• reviewing the impact of research recommendations made by itself, the Great Lakes Science Advisory Board, the Great Lakes Water Quality Board and the IJC.

Membership is evenly divided between representatives from the United States and Canada, consisting of individuals managing federal, state and provincial research programs and representatives from academic institutions and private industry. Binational members representing the Great Lakes Fishery Commission and the International Association for Great Lakes Research also sit on the Council.

The Council and Great Lakes Science Advisory Board engaged in a methodical evaluation of emerging issues to identify priority issues for the 1999-2001 priority work cycle. *(See section 2.4 of the Great Lakes Science Advisory Board chapter for a detailed process description.)* Six priority issues were identified for investigation of research needs: ecological impacts of changing demographics; impacts of water level fluctuations; emerging contaminants including pharmaceuticals; ground water; alien invasive species; and emergence of new pathogens. One additional issue identified as an area of shared interest between the Council and Science Advisory Board was the need for an integrated Great Lakes observing and monitoring system. As a result of this shared interest, the two groups formed a joint subcommittee to address this issue.

The Council evaluated each issue by forming subcommittees to `scope out' each issue. The process of scoping involves: 1. determining the current level of scientific knowledge on a priority issue; 2. identifying gaps in knowledge; and 3. ranking research needs to fill those gaps.

Five of these issues were examined and the results provided. Further

discussion, study and workshops are planned regarding the emergence of new pathogens and the need for an integrated Great Lakes observing and monitoring system. These future activities are discussed in sections 3.8.3 and 3.8.4 respectively.

The Council of Great Lakes Research Managers would like to acknowledge the efforts of all of those who, although they were not official members of the Council, made a significant contribution to the report. Many participated as invited experts at Council meetings, authored special reports, served as alternate representatives and provided valued support. They include: Jacinthe Leclerc, Bill Cibulas, Heraline Hicks, Rao Manam, Dan Todd, Sheridan Haack, Sergei Chenyak, Allegra Cangelosi, Walter Rast, Joseph Gilbert, Tom Crane, John Gannon, John Freidhoff, Bill Booty, Dave Dolan, Miriam Diamond, Ken Drouillard, Russ Kreis, Heather Morrison, Jan Ciborowski, Lisa Tulen and Giovanna Stasiuk.

3.2 ECOLOGICAL IMPACTS OF CHANGING DEMOGRAPHICS WITHIN THE GREAT LAKES BASIN

3.2.1 Background

The Great Lakes basin is home to 33.5 million people, with approximately 8.5 million in the province of Ontario and the remaining 25 million distributed among the eight Great Lakes states. Population density is highest in the southern part of the basin and around lakes Michigan, Erie and Ontario. The greater Toronto metropolitan area, located on Lake Ontario, accounts for almost half of the Canadian basin population, whereas approximately 80 percent of the U.S. basin population is located in its 11 largest metropolitan areas.

Human beings are the single largest source of stress to the Great Lakes basin ecosystem. Understanding how human populations may change over future decades may help environmental managers anticipate and deal with emerging environmental problems that result from changing demographics.

The many forms of development, such as industrial, commercial, residential, agricultural and transportation-related activities, carry specific, significant and cumulative impacts for the natural world and particularly Great Lakes water quality. These activities take place throughout the basin, but their most immediate and direct impact on the Great Lakes appears to be on lands proximate to the lakes themselves and their tributary waters. Land use in coastal areas is changing in response to the region's evolving economy and industrial restructuring, as well as to the relentless forces of urban sprawl. The aesthetic and recreational attraction of the shore also is

spurring renewed public appreciation and use of this asset, whether it be an urban waterfront or remote location. Mining and forestry activities, on the other hand, which are concentrated in the northern half of the basin, are likely to remain relatively stable into the future.

Although there has been some improvement to air pollution from industrial sources, air quality, especially ground level ozone, affecting living organisms in the nearshore ecosystem is a major concern. As urban transportation systems become more energy intensive, this problem could intensify. Increasing greenhouse gas releases continue to pose a challenge, as more and more vehicles congest roads transporting people to and from work at ever increasing distances.

3.2.2 Urban and Rural Development Land Uses

Urban Sprawl

The most significant development issue in the Great Lakes region is the continuing growth of major metropolitan areas and the virtually uncontrolled sprawl of low-density, residential areas and other development. The detrimental consequences of these trends are well known. The population-related generation of pollution, higher transportation and residential energy use, increasing encroachment on agricultural lands and natural areas, and burdensome physical infrastructure requirements portend an unsustainable future.

Today, urban sprawl is the predominant pattern of development on both sides of the border. Land-use projections for the state of Michigan, for example, indicate that a state population increase of less than 12 percent may result inasmuch as an 87 percent increase in new developed land by the year 2020. A six percent population increase in southeastern Michigan alone is expected to result in a 40 percent increase in land consumption during this same period.

Land and water availability, lower wage scales, transportation access, proximity to new residential markets and other cost/service factors have accelerated sprawl. The central city anchor for rail transportation, multi-story factories, and apartment life has given way to interstate truck transport, one-story industrial buildings, sprawling office parks, and a house and lot of one's own. An ongoing pattern of tax-based subsidies to developers by municipal governments, eager to see growth at any cost, has to date served to constrain market forces that could reverse this trend.

There has been a significant trend toward the extensive construction of

seasonal, second homes and recreational cottages. This trend is now shifting toward permanent residences in rural areas as the leading edge of the baby boom generation approaches retirement age. The emerging trend toward multiple careers over one's lifetime and more home-based work for the new `information' generation allows greater workplace mobility.

Land classified as farmland, which includes cropland, woodland and permanent pasture categories, declined in the Great Lakes basin by more than 1.83 million hectares (4.52 million acres) or 9.6 percent between 1981-82 and 1991-92. Much of this land conversion has taken place near the metropolitan population centres, but the phenomenon is occurring in more remote rural areas where residential, commercial, industrial and transportation development pressures also exist. Land consumption caused by sprawling development has been a dominant post-war trend and, in some places, has eliminated important wildlife habitat and good agricultural land.

If significant levels of farmland conversion continue in the Great Lakes basin, the agricultural production base will decline, and with it, the agrifood sector of the economy. With nearly two-thirds of basin cropland located within 50 kilometres of medium-sized cities and large metropolitan areas, efforts to preserve farmland may also help to contain sprawling development patterns and improve sustainability.

Brownfields

The economy of the Great Lakes region is completing a transition from heavy manufacturing to a more diverse and increasingly service-oriented economy. This restructuring has resulted in a surplus of vacant industrial locations that require environmental cleanup before they can again become productive. Referred to as `brownfields,' these vacant or inactive industrial or commercial properties were once thriving manufacturing operations and have now become blighted areas of neglect and often have known or suspected soil or water contamination problems. These properties pose a unique opportunity and challenge for the development industry, government environmental agencies and the banking industry, which must weigh the financial rewards of new development against the increased cost and potential environmental liability of providing loans to those undertaking redevelopment of these sites. New development is rejected for many reasons, including cleanup costs and lingering uncertainty over liability issues, thus encouraging such development to migrate to outlying undeveloped areas or greenfields.

The retreat of industry from its traditional location along the nearshore presents new opportunities for waterfront and

harbour redevelopment as communities become involved in grass-root efforts to `take back the waterfront' for public and commercial uses. Redevelopment of these former industrial sites also presents new opportunities for high-technology manufacturing, commercial service, residential construction and leisure activity or some mix of these for tomorrow's economy.

Redeveloped brownfields represent opportunities to make urban areas more efficient by utilizing existing infrastructure. Impact fees and development charges, which developers pay for the cost of new infrastructure for development, may also serve as an incentive for the redevelopment of brownfields. A surcharge on these fees could be scaled and put into a brownfields redevelopment fund for that purpose. This approach would forestall sprawl and development in rural areas by encouraging greater use of metropolitan sites. Alternatively, a portion of the tax increment from new metropolitan development could be used to purchase open, green space or, in the case of farmland, the purchase of development rights.

Hardening of the Landscape and Stream Degradation

Impervious or `hardened' surfaces, such as roads, parking lots, sidewalks and rooftops, block rain from recharging ground water and drinking water supplies, impair the ability of natural systems to cleanse runoff and protect wetlands and nearshore biota from contaminants, increase the potential for flooding and erosion, and contribute to the degradation of streams and lakes. Stream degradation caused by development is a classic example of both long-term cumulative environmental change and the difficulty of responding to such change. For example, of the more than 63,000 hectares (156,600 acres) that comprise metropolitan Toronto, only one-quarter remains agricultural, vacant land or open space.

Another form of hardening takes place along the lake shores and tributaries when shoreline residents act to protect their real estate from wave and flood damage by hardening the shoreline with concrete, gabion and other shoreline covering. Extension of shoreline protection, sometimes coupled with piers and abutments, alters natural functions along the shoreline. This has been the case for much of the north shore of Lake Ontario and has led to the permanent loss of once productive beaches.

3.2.3 Agricultural Land Uses

About one-third of the land in the Great Lakes basin is used for agriculture, with usage concentrated in the southern half of the basin. Nearly three-quarters of the basin's agricultural land is on the U.S. side. There is a trend toward fewer, but larger farms with more intensive crop production, declining livestock numbers and less land overall in agricultural production. From 1981 to 1992, basin farmland declined by almost 10 percent and cropland by almost six percent. The conversion of agricultural land to development, in addition to other global and continental competitive pressures, is causing a shift of agricultural activities to areas with less productive soils, shorter growing seasons and greater distances to major

markets.

Increasing environmental awareness among the public and farmers is resulting in a growing market for pesticide-free agricultural produce. At the same time, farmers are switching to environmental conservation practices, such conservation tillage, integrated pest management, and better manure management techniques. The ramifications of an emerging trend to greater dietary substitution of fruits and vegetables instead of animal products, in response to the apparent health risks associated with meat products, have yet to be felt to any significant extent. One consequence may be greater produce farming at the edge of cities as increasingly sophisticated consumers demand more locally grown and fresher vegetables.

3.2.4 Conclusions

Rapid population growth, intensive industrial and agricultural activity and sprawling urban development have resulted in significant stress to the nearshore ecosystem of the Great Lakes. Nearshore waters continue to be polluted, and in some cases have become severely contaminated, from sanitary sewage, industrial toxic substances and urban and agricultural runoff.

Wetlands and other natural habitat areas within the nearshore ecosystem are under threat of destruction and alteration by increasing urban sprawl and second-home cottages. Finally, shoreline protection and other shore hardening caused by development have interfered with natural shoreline processes and, in some cases, resulted in the irreversible loss of beaches.

Notwithstanding recent attention to more intensive forms of urban development, development throughout the basin continues to be predominantly land-intensive urban sprawl. By contrast, high-density intensive development facilitates the

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economic viability of public transit as an efficient alternative to the private automobile for commuters. Urban communities with higher population densities typically require less costly municipal infrastructure, such as sewers and roads, use less water and energy, and create less pollution. As a result, taxation to pay for municipal services may be significantly lower, making higher-density communities more competitive from that perspective.

Reduced use of natural resources generally implies reduced pollution and stress on ecosystems, including the nearshore ecosystem. Urban sprawl has contributed to the loss of some of the best farmland in the basin, as housing and other development replaces agriculture. Farming that shifts to lower

productivity soils and at greater distances from final markets is less efficient and more resource-intensive. In addition, urban sprawl promotes the clearing and conversion of natural habitat lands, including wetlands.

Finally, marketplace incentives that would promote more sustainable development, such as full cost, user-pay development charges or impact fees, are inconsistently applied by different jurisdictions. At the same time many jurisdictions believe they should compete for the short-term jobs and tax revenues that come from new development. Direct and indirect subsidies for new development through the public provision of roads, water and sewage treatment facilities mask the real long-term economic and environmental consequences of urban sprawl and continue to favour unsustainable development.

3.3 EMERGING CONTAMINANTS AND PHARMACEUTICALS IN GREAT LAKES WATERS

3.3.1 Background

The Great Lakes Water Quality Agreement charges the governments of the U.S. and Canada, the parties to the Agreement, to "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem." In particular, Annex 1 addresses persistent toxic substances in several organic and inorganic chemical classes and Annex 10 charges the Parties to maintain lists of known or potential "hazardous polluting substances" with a risk of being discharged to the Great Lakes ecosystem. The main focus of the Parties has been on these priority persistent and hazardous pollutants. However, chemicals specifically listed in the Agreement and its annexes constitute only a portion of the greater discharge of substances into the Great Lakes. Recently, other industrial chemicals, known to mimic various endocrine functions, have received attention. Little attention, however, has been given to several, more diverse groups of substances that are now being detected with greater frequency in waters both regionally and world-wide. This includes pharmaceutical agents and the bio-active ingredients in a wide variety of personal care products.

In the last 10 years, several studies from Europe have reported the detection of several prescription and non-prescription drugs and household products in sewage treatment plant effluents, surface water and ground water (Buser 1998, Buser 1999, Herberer 1997, Holm 1995, Stan 1994). First thought to be only isolated occurrences, as more investigations are done and the detection limits lowered, the range of substances detected has expanded and now encompasses the full gamut of prescription and non-prescription drugs and numerous household and personal care products

(Halling-Soorenson 1998, Richardson 1985).

3.3.2 Widespread Use and Lack of Regulation

Over the past several decades, while attention has been focused on the many priority pollutants, this wide variety of substances have been overlooked. However unfortunate, this is in keeping with the lack of environmental regulation for most of these substances and acknowledges that, chemically, many of them are quite different from the persistent pollutants.

Amounts used

Many of these chemicals are typically not regulated or monitored in the environment. Also, few requirements exist for reporting total amounts manufactured, distributed, used or disposed of by the either the manufacturer or consumers. This also reflects the proprietary nature of these substances and the numerous consumer formulations in use today. The `sudden' detection of these contaminants is basically an increased awareness of their previously overlooked presence.

Another reason for their increasing detection is the acknowledgment of their widespread and ever increasing use. As urban and suburban populations continue to increase in number and, in turn, their use of these substances, it is more likely they will appear more frequently in impacted water supplies (Raloof 1998, 2000). The National Research Council recently reviewed this topic (NRC 1999) and, similarly, a report was recently released documenting an increase in the use of antibiotics in humans and in animal agriculture, and calling for more judicious use of antibiotics, especially in reference to an increasing resistance to many of them (Mellon 2001). The public health implications of this problem is being addressed by a U.S. task force on antibiotic resistance (CDC 2000).

Disposal

Another reason as to why these compounds are now being detected is the inconsistent regulation of their disposal. Although the disposal of almost all these compounds is well-regulated as industrial wastes during the manufacturing process, little attention has focused on their consumer-based, household disposal. Many chemicals, such as pharmaceuticals or fumigants used in households, reach sewage treatment plants where little is understood about their removal and destruction, and where there are no monitoring requirements for these specific constituents. In other cases, chemicals may reach surface and ground waters as runoff from

environmental applications, such as the use of antibiotics in confined animal feed operations or fruit tree agriculture, and from the constituents found in suntan lotions, insecticides or repellants found in personal care products.

In the absence of monitoring for these constituents in runoff or in surface or ground water, it is difficult to ascertain their presence and the potential degree of impact from various sources. Similarly, there is no requirement that these substances be monitored in source or finished drinking water.

Monitoring Occurrence

Initial reports from Europe found chemicals from a wide number of groups of substances in surface water and sewage treatment plant effluents (Halling-Soorenson 1998, Daughton 1999). Because of their reportedly low concentrations and chemical differences from the priority pollutants in the Great Lakes Water Quality Agreement, analysis for many of these substances is not yet routine, which complicates establishing simple monitoring programs. To date, only a few reports have appeared documenting their presence in North American waters. However, in 1999, the United States Geological Survey's (USGS) Toxic Substances Hydrology Program began a national reconnaissance for selected emerging contaminants (USGS 2000). This program is analyzing surface and ground water samples taken from a network of streams and wells across the U.S. for the substances listed in Table 1.

Current U.S. Geological Survey Activities

The Toxic Substances Hydrology Program of the USGS has implemented a national reconnaissance to provide baseline information on the potential environmental occurrence of select `emerging contaminants.' More information on this program is available at their web site at http://toxics.usgs.gov/regional/emc.html (USGS 2000). Target analytes are in three categories: human and veterinary pharmaceuticals; industrial and household wastewater products; and sex and steroidal hormones. During 1999, a network of 100 stream sites was sampled, representing a wide variety of geographical and hydrogeological settings. The streams represent basins that fall into four general categories: intense urban activities; intense livestock production; mixed land use; and control streams. The sampling points were located in 24 states throughout the U.S. An additional 55 sites were sampled in 2000 to confirm and expand results. To determine if emerging contaminants are being transported to ground water, 45 wells located in 16 states were also sampled during 2000. As part of this study, locations were sampled that are tributary to the Great Lakes in Michigan, Ohio and Wisconsin. The samples are being analyzed at USGS research laboratories that are developing, and/or refining the laboratory methods to measure these compounds to very low levels, less than one part per billion (ppb). Results are anticipated to be released in mid- to late-2001. This reconnaissance will provide: 1. the first nationwide assessment of the occurrence of these emerging environmental contaminants in streams and ground water; 2. a focal point for development and testing of new laboratory analytical methods for measuring compounds in environmental

samples at very low, sub-ppb levels; and 3. a basis for design of more systematic

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monitoring programs for emerging environmental contaminants.

For several years, USGS has offered analysis of various compounds that can occur in wastewater and may indicate the possibility that other emerging contaminants may be detectable. These compounds include detergent metabolites, antibiotics, caffeine, cotinine, cholesterol, coprostanol, fumigants and other substances listed in Table 1.

3.3.3 Ecological and Human Health Impact

It must be recognized that a substantial number of these substances are manufactured to intentionally be biologically active, although at concentrations and in formulations that vary greatly from those detected in water. Since many pharmaceuticals are originally intended to suppress or kill infectious agents, or modify human physiology, their potential presence in water must be taken seriously. Also, it is reasonable to assume that they may have similar effects on unintended organisms, either directly or indirectly. Just as many industrial chemicals have been found to have unintended biological activity after being studied in a wider range of tests, it is not surprising that a number of these substances have had unintended biological effects.

Intended Pharmacologic and Toxicologic Activity

Many of the substances considered were developed because they have specific pharmacologic mechanisms that address certain important health issues. Although these same substances may also have unintended effects in humans, known as side effects, their use is considered to be an acceptable risk because of the profound life-saving and life-sustaining intended effects. However, their potential biological activities usually have not been taken into consideration concerning disposal into sewers and water systems.

Two cases in point are the antibiotics and the estrogen-like compounds. The widespread use of antibiotics, particularly in confined animal feed operations and accounting for the major use of this group of substances, has been the subject of wide debate (Mellon 2001) and the focus of a U.S. task force (CDC 2000). It is thought the lack of monitoring of their use and disposal is part of the supposed cause of resistant bacteria, an unintentional outcome of their intended use. The case with estrogen-like substances is more complex. The use of estrogen-like substances is increasing with little consideration given to their disposal. It is likely that in our water systems, they can have direct actions based upon their structures that go beyond

their intended use. Furthermore, a large group of other substances also reportedly have estrogen-like effects. These, and other substances now thought to have some estrogen or endocrine-like activity, could be having unintended actions on unintended audiences.

Another concern is the little understood result of combined or cumulative activity of very small amounts of these separate, but pharmacologically similar substances when in the presence of each other. The possibility of additive or synergistic effects for substances with similar or related mechanisms of action are not at all understood. More needs to be known about the levels of exposure that may be occurring and the activity of these substances in other organisms and ecosystems (Boudou 1997).

Relative Activities and Concentrations

A major aspect of this issue is the relative concentration in the source of exposure (water) compared to what might be a typical concentration range in humans leading to a desired biological effect. For humans we might attempt to use the concentrations found during normal therapeutic use. The concentrations found in a few selected locations in the environment and their normal therapeutic (blood) concentrations are provided for some representative substances in Table 2. It is important to note that many of these substances do not usually bioaccumulate in humans, designed appropriately so, such that their chemical structure allows the human body to eliminate them over a short period of time. However, numerous factors, such as the potential for bioaccumulation, especially in other species, and the amount of uptake from such an exposure, would be required in order to accurately assess the potential for relative harm from a given source. Factors, such as accumulation potential, length of exposure, greater sensitivity or unexpected biological effects could easy modify the therapeutic range (biological endpoint) and thus the relative concentration.

The relative concentration between the two columns in Table 2. is in a range of 100 to 1000 times higher in blood (in order to produce a therapeutic effect) versus the water concentrations detected in the few isolated studies to date. This does not take into consideration a wide array of factors that might effect these two values and their relative ranges, but does indicate that a two to threefold order of magnitude might exist in humans for the specific examples given here. Such a simplified risk assessment is indeed very basic and although it may suggest that a safety factor may exist, not enough data exists at this time to be able to justify any solid conjecture. Also, this two to threefold order of magnitude may only exist for the effects in humans, while other impacted species may show a greater susceptibility for a biological endpoint of toxicity and thus a smaller relative range between the exposure and biological-endpoint

concentrations.

Ecological Activities

Beyond the intended actions and uses of these substances in human populations, due consideration must be given to their impact on other parts of the Great Lakes ecosystem. There is no doubt that exposure to low levels of some substances can have profound effects on other groups of organisms (Boudou, 1997). Besides the recently acknowledged reports of the development of antimicrobial resistance to an increasing number of antibiotics (CDC 2000), a few reports have shown that aquatic organisms are being affected in streams in North America following exposure to previously unsuspected pollutants (Raloof, 1998, 2000). Further evaluation of the occurrence and activity on other species is needed.

Public Health Impact

It is clear that past experiences with the priority pollutants must help shape an appreciation of the potential implications of these new chemical substances. Unfortunately we have little information on which to base any projections about the ultimate fate or long-term effects on humans or other parts of the ecosystem.

3.3.4 Research Goals

Further understanding of the extent of this problem will require action in three major areas. First, greater attention must be drawn to the problem such that an accurate assessment of the current status of these substances in Great Lakes waters can be done. This would be accomplished primarily through more monitoring of various water systems. Secondly, we must obtain a better understanding of the fate of these substances in soil and sediment and in waterways and water systems. Finally, after a better understanding is obtained of the levels of these substances in Great Lakes waters, further evaluations of the pharmacologic and toxicologic activities must be done to permit some estimation of the risks involved to exposure at those levels.

Monitoring

The primary goal of early efforts must be to assess the extent of the problem by doing accurate and thorough monitoring of possible routes of exposure. Since these substances can be substantially different, chemically, from the standard priority pollutants, methods for monitoring them can be considerably more complex and the amount of time necessary to analyze them increased. Establishing a unified approach to determining levels may require standardization of techniques and coordination of resources. As noted earlier, USGS currently has the only current ongoing monitoring program in place to begin to assess the presence of these substances in our waters (USGS 2000). A few studies have been reported by various groups at a symposium in Canada (personal communication).

Environmental Fate

Another difficult aspect of assessing the impact of these substances is determining their environmental fate. These substances may be entering water from a number of points, including sewage treatment plant effluent. The breakdown of these substances in the environment, often referred to as metabolism within organisms, and in the sewage treatment plant is not well understood because of the chemical complexity of these substances. Even less is known about their binding characteristics to the parts of the environment where they are most likely to come in contact or the likelihood that they may bio-accumulate in some organisms. The extent of their binding is important in determining their fate as well as the extent of exposure to

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exposed organisms.

Biological Activity

Although the biological effects of some of these substances is well studied in man, their intended target in many cases, little is known about long-term exposures to low levels, the susceptibility of sensitive populations and the effects on other organisms. Certain water-based organisms are likely to be the most impacted by long-term exposure. However, until the extent of the exposures or levels can be estimated, little can be done to estimate the risks associated with the presence of these substances in the environment.

3.3.5 Recommendation

The Council recommends the following to the IJC.

• Based on the information found in section 3.3 of the *1999-2001 Priorities and Progress under the Great Lakes Water Quality Agreement,* recommend to the Parties that the following areas of research and action be implemented regarding emerging contaminants and pharmaceuticals in Great Lakes water:

a. examine inputs to and outputs from wastewater and drinking water treatment plants to determine if emerging contaminants are present;

b. determine the effective levels, biotic indicators and degradation times for the emerging contaminants; and

c. identify viable options for wastewater and drinking water treatment plants to remove those chemicals identified as potential threats to human health and the ecosystem.

(These conclusions may be best placed into action by framing them within the three research goals defined in section 3.3.4 for addressing the issue of emerging contaminants.)

3.4 UNDERSTANDING THE INTERACTION OF GROUND WATER

AND SURFACE WATER IN THE GREAT LAKES BASIN

Recently, there has been a renewed interest in and a

growing number of questions regarding the relation
ship of ground water to the Great Lakes. Understanding the interaction of ground water and surface water in the Great Lakes basin is essential to natural resource managers and scientists. In many ways, ground water and surface water are closely linked and need to be thought of as a single resource. Wise management of water resources in the Great Lakes requires an understanding that ground water is a large component of the Great Lakes water budget. Decisions that affect the quantity or quality of ground water discharge to tributary streams and coastal wetlands also affect the quantity and quality of water in the Great Lakes and the health of the Great Lakes ecosystem.

Both the International Joint Commission and the Great Lakes Protection Fund have supported recent research and white papers summarizing many of the significant issues regarding ground water and the Great Lakes. Holtschlag and Nicholas (1998) provide estimates of indirect ground water discharge to the Great Lakes via tributary streams using streamflow records from the United States. Grannemann and Weaver (1998) present an annotated bibliography of selected references regarding ground water discharges directly to the Great Lakes. Grannemann and others (2000) summarize the major ground water issues in the Great Lakes region and identify information needs and research issues. Finally, ground water issues are highlighted by the IJC in its *Protection of the Waters of the Great Lakes*, including specific recommendations to the governments for ground water research.

The following summarizes ground water issues, including a reiteration of the research and information needs, and provides a prioritization and emphasis of those needs that are not widely recognized. The research needs are quite broad and encompass virtually all areas of the science of ground water hydrology.

3.4.1 Ground Water Issues Related to the Great Lakes

Quantity

Ground water enters the Great Lakes as either direct or indirect discharge. Direct ground water discharge is flow directly into a lake through the lake bottom. Indirect ground water discharge is flow into a lake by way of a tributary stream.

Most ground water discharged to the Great Lakes is indirect. Indirect ground water discharge ranges from 42 percent of the basin water supply for Lake Ontario to 22 percent for Lake Erie, excluding connecting channel flows. Ground water discharge to streams ranges from more than 75 percent of the total streamflow in Michigan to less than 40 percent in Ohio. Like streamflow, the amount of indirect ground water discharge is variable during the year, generally reaching a maximum in March or April and a minimum in August or February.

Lake Michigan is the only Great Lake for which there is enough information to estimate direct ground water discharge. There, it accounts for approximately five percent of the inflow budget. Direct ground water discharge to the remaining Great Lakes is most likely a smaller part of their inflow budgets.

The amount and timing of ground water discharge is affected by natural geologic and climatic conditions and by land use. Ground water discharge is usually greatest in undisturbed watersheds where subsurface materials are coarse and precipitation is high. Where land uses restrict recharge, such as in urban areas, ground water discharge is significantly reduced. Where land uses lower ground water levels, such as by pumping or by means of drainage tiles and ditches in agricultural areas, ground water discharge also is significantly reduced. In areas where ground water discharge is reduced, streams may have little or no flow during summers or other dry periods.

Quality

Ground water has a significant effect on the quality of water in streams tributary to the Great Lakes and on coastal wetlands by transporting natural and anthropogenic substances to them. In agricultural and urban areas of

the Great Lakes basin, contaminants on the land surface become dissolved in ground water and eventually flow into streams, wetlands and the Great Lakes. This widespread, diffuse flow of contaminants by way of ground water is a type of nonpoint source contamination. Pesticides and nutrients, such as nitrate and phosphorus, are the principal nonpoint source form of pollution that reaches the Great Lakes by way of indirect ground water discharge to tributary streams and coastal wetlands.

Annex 16 of the Great Lakes Water Quality Agreement specifically addresses the flow of contaminated ground water to the Great Lakes. Annex 16 is generally interpreted as applying to point sources of contamination from specific sites, such as Areas of Concern. However, the language of Annex 16 does not exclude consideration of nonpoint source contamination via direct or indirect discharge.

Ecosystem

The Great Lakes ecosystem is closely tied to the biologic viability of tributary streams and coastal wetlands. The biologic viability of these, in turn, is largely dependent upon the quantity and quality of both surface runoff and ground water discharge.

Ground water discharge is a significant determinant of the biologic viability of tributary streams and coastal wetlands. In undisturbed areas, ground water discharge throughout the year provides a stable inflow of water with consistent dissolved oxygen concentration, temperature and water chemistry. Where land uses significantly reduce ground water flow to a stream, reaches of the stream or wetlands may lose their biologic viability. Likewise, where land uses add contaminants to a stream or wetland, they also may become unviable.

3.4.2 Identified Research Needs

The IJC, in its report, *Protection of the Waters of the Great Lakes*, makes the following recommendation.

Governments should immediately take steps to enhance ground water research in order to better understand the role of ground water in the Great Lakes basin. In particular, they should conduct research related to:

• unified, consistent mapping of boundary and transboundary hydrogeological units;

• a comprehensive description of the role of ground water in supporting ecological systems;

• improved estimates that reliably reflect the true level and extent of consumptive use;

• simplified methods of identifying large ground water withdrawals near boundaries of hydrologic basins;

• effects of land-use changes and population growth on ground water availability and quality;

• ground water discharge to surface water streams and to the Great Lakes, and systematic estimation of natural recharge areas; and

• systematic monitoring and tracking of the use of water-taking permits, especially for bottled water operations.

These recommendations are broad and generally include recommendations found in other reports cited in at the beginning of section 3.4. Depending upon the definition of research, some recommendations may not be considered research. For instance, the methods and approach to mapping hydrogeologic units are well developed and the lack of available maps is due to lack of funding for mapping, not a lack of understanding of how to map hydrogeologic units. Similarly, tracking bottled water operations does not constitute a research need.

There is a serious lack of research and information on ground water issues that encompass virtually all areas of the science of ground water hydrology. This research should be given high priority funding, given the direct impact of ground water quality on more than 20 percent of the basin's human population and a large biological community.

The Council has identified four specific research needs that have received little attention and should receive priority for research funding.

Effects of Land-use Change

Land use affects recharge rate and distribution, the amount and timing of ground water discharge to surface water bodies, and the quality of ground water, primarily via nonpoint source pollution. Where land use includes ground water pumping, such as for drinking water or irrigation, ground water may be subject to competing uses. There is only a limited amount of research on the relationship of ground water quality to land use and virtually none on how land use affects recharge or discharge to surface water, therefore research is needed on these topics. There is a substantial amount of research and case studies related to ground water availability and competing uses, therefore, research on these topics is not a priority.

Ground Water and Ecosystems

Research focusing on the relationship of ground water and ecosystems is

rare. Little is understood about the complex relationship among ground water, Great Lakes levels and coastal wetlands. While there is some research showing the importance of ground water in the hyporeic zone of streams, little is known about this relationship to stream and Great Lake ecosystems. The majority of Great Lakes fish spend some of their life in tributary streams dominated by ground water flow and it is important to understand these relationships.

Estimating Consumptive Use

Consumptive water use rarely has been measured. It is typically estimated by coefficients of loss. There are two main consumptive uses -- irrigation and drinking water. The losses in irrigation are to evapotranspiration and incorporation into crop moisture content. The losses in drinking water are for public water systems where the water pumped from aquifers is discharged to streams, rather than aquifers, after treatment. These may not constitute a loss to the water balance of the Great Lakes, but they do constitute a loss from the ground water flow system and the beneficial discharge of ground water to surface water bodies. Irrigation consumptive uses have been measured by some field studies and models to estimate losses have been developed by researchers. Losses via drinking water systems have not been estimated, but can be readily estimated from water use data for public water supplies. These latter losses are important only for ecological implications, not for water balance

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calculations.

Discharge and Recharge

Ground water discharge to streams and the Great Lakes has been the subject of recent papers. However, the estimates of discharge to streams incorporate many broad assumptions and actual research is limited. Direct ground water discharge to the Great Lakes and coastal wetlands is poorly known and systematic research to estimate this discharge does not exist. While ground water is recharged everywhere in the watershed, except portions of lakes and streams, some parts of the watershed have much higher rates of recharge than others. These areas need to be systematically identified so appropriate measures can be taken to preserve them.

Recommendation

The Council recommends the following to the IJC.

• Recommend to the Parties that the highest priority research funding be directed to the following ground water research needs listed in priority order:

a. research on the effects of land-use changes and population growth on ground water availability and quality;

b. development on a comprehensive description of the role of ground water in supporting ecological systems;

c. development of improved estimates that reliably reflect the true level and extent of consumptive use; and

d. research on ground water discharge to surface water streams and to the Great Lakes, and a systematic estimation of natural recharge areas.

3.5 UNDERSTANDING THE LONG-TERM IMPACTS OF WATER LEVEL FLUCTUATIONS, DIVERSIONS AND CONSUMPTIVE USES

IN THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

The management of physical resources is a challenging

problem given the complex diversity of interests.

Lake level regulation for the sole or balanced benefit of traditional interests, such as the riparian property, hydropower and navigation, has caused unintended adverse impacts on wetlands, plant communities, fisheries and wildlife. Water use and withdrawals from the Great Lakes system can have serious economic and ecosystem impacts that would also be difficult to reverse.

Based on the concerns of the existing interests and the unintended omission of the ecosystem interest in the current regulation plans and water diversion practices, the Council of Great Lakes Research Managers has identified topical issues that require further research, and recommended actions to be implemented by the governments. The research areas recommended for study primarily pertain to Great Lakes water quality. Because of lake regulation, water use and diversions significantly alter water quality and the ecosystem, it is essential to have research topics and priorities that link the water quality and quantity. The research needs are broadly classified as

follows.

3.5.1 Effects of Climate Change and Great Lakes Watershed Hydrology

There is a need for obtaining Global Climate Model Scenarios from meteorologists that provide plausible climate scenarios. These are used in generating hydrologic scenarios for testing alternative regulation plans and for the study of long-term impacts on the ecosystem. Methodologies should be developed to forecast water supplies to the lakes for use in testing alternative regulation plans. It is recommended that a system simulation model be developed to include the Great Lakes - St. Lawrence River and downstream tributaries, including the Ottawa River. All natural effects should be taken into account including isostasy, a natural process that impacts lake levels throughout much of the Great Lakes basin. This effect is superimposed on all other causes of lake level change and needs to be accounted for. There is also a need for developing a simula

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tion model to define the pre-project conditions for areas downstream of Lake St. Francis.

3.5.2 Research Needs for Wetlands

There is a general consensus among environmental scientists that the frequency and amplitude of high and low lake levels should be increased to more closely approximate natural conditions and reduce the environmental impacts of regulation. Similar recommendations call for establishing acceptable high and low lake level constraints with more variability in water levels between years. Potential responses of wetland plant communities to increased variability were compared with current regulation plans. This comparison showed some improvement in increasing the area of wetland subjected to both flooding and dewatering conditions and thus increased habitat diversity. Such recommendations from environmental scientists were based on topography of a limited number of actual field sites. The development process for the plan was unable to address the seasonality problem, in which many wetlands remain dewatered during the spring spawning season, because the topography information was not suited to the task. Additional shoreline bathymetry data are needed to provide a broader base for development and testing of alternative regulation plans that better serve to provide diverse habitat in wetlands. The shallow water environment is most susceptible to impacts from water level regulation.

Research indicates that plant communities at elevations not dewatered

since the low-level period of 1964 had the lowest species diversity and were dominated by several submersed species. The areas that were alternately flooded and dewatered more frequently were found to be rich in species and had the greatest wetland taxa. Exaggerated wintertime drawdowns result in springtime water levels that are too low to flood wetlands, reducing fish access to wetlands for spawning in the spring.

Monitoring of wetland sites should be based on the potential for critical spawning habitat for fish, such as northern pike that enter wetlands in early spring, and requires detailed topographic data at wetland sites.

Data needs to be collected to determine the impacts of fluctuating lake levels on plant communities at representative sites around the Great Lakes that are subjected to different flooding and dewatering histories.

3.5.3 Coastal Development Including the Evaluation of Riparian Shore Properties and Dredging

The following actions should be given priority for assessing the long-term impacts of lake level fluctuations on the shoreline.

• The stage-damage relationships used in previous IJC reference studies should be reevaluated based on consid-eration for storm wave effects and storm damage surveys.

• The Lake Michigan shoreline erosion model should be expanded to include all the lakes.

• Data bases for waves, shoreline classification at one kilometer resolution, and recession rates should be developed for all the lakes.

• Research must be conducted to determine the relationship between water level and erosion, flood potential and wetland delineation.

• The long-term impacts of dredging and disposal of sediments must be determined.

3.5.4 Human Ability to Regulate Water Levels and Assessments of Long-term Impacts of Water Level Fluctuations on Ecosystem Integrity

There is a need for establishing the limits of regulation, for the two lakes that are currently regulated, without any additional control structures in the system. Once a new regulation plan criteria is established and found acceptable by all interested parties, including environmental interests not originally included in the current regulation plans, new upper and lower

level limits on Lake Superior and Lake Ontario must be reestablished. Accordingly, the limits of our control of the system must be identified.

Water supplies outside the historical range, including climate change scenarios, need to be analyzed to determine the limits of human ability to influence the system. For this purpose, a tested and calibrated system-wide model for the watershed as described is essential.

3.5.5 Common Databases for Environmental and Shoreline Interests, Water Use and Better Tools to Project Future Uses

There is an essential need for good field survey data, shoreline bathymetry and topography of the Great Lakes - St, Lawrence River system at an increased number of wetland sites. Additionally, data is needed on plant communities, fish accessibility to wetland habitat, shoreline geomorphology, riparian property values, and bluff heights and slope.

Data bases need to be developed for obtaining pertinent information related to demographics, marinas (physical layout, operation of facilities and required drafts), water intakes and shore wells. State-of-the-art data collection techniques, such as airborne laser-survey techniques, geographic positioning systems (GPS) and geographic information systems (GIS) are suggested.

Common data bases would serve a number of analyses including wetlands, fish habitat and plant community, recreation boating, and shoreline erosion and riparian property damage. An inventory of currently available geospatial data and development of a common framework for geospatial data are needed to define the required resolution and extent of data.

This recommendation agrees with 1981, 1985 and 1999 reference studies on diversions and consumptive uses carried out for the International Joint Commission that indicated further research needs in this area. A centralized, binational database for all diversions, withdrawals and consumptive uses based on a uniform method needs to be developed and maintained. All researchers on Great Lakes water uses could use this dynamic database for cumulative impact assessment.

For example, the Great Lakes Commission is authorized to maintain the Water Use Database Repository without the provision of adequate legal and funding mechanisms. Such databases require continual update and support,

and need adequate funding to be retained as a viable resource. The data base repository should be linked to a host of forecast models for different types of water use. Water use forecast models that were used in past studies require revisions based on recent trends in manufacturing, agriculture, economy, demographics and scenarios for climate changes. In the same context, these forecast models should consider the effects of water demand management pressures, such as changes in water pricing strategies. An evaluation model should also be a part of this package to determine the cumulative impacts from economic and environment points of view.

A decision support system providing an effective framework for formulating and implementing water quantity management policies and programs is needed. Such a system must be multi-jurisdictional and socially acceptable with due consideration for present and future demands. It must be flexible enough to accommodate uncertainty, yet rigid enough to yield decisions that are both scientifically sound and legally defensible. Current jurisdictional capabilities for the compilation and analysis of water use data need to be assessed in light of present and anticipated needs.

Any new management regime ultimately developed to exercise decision-making authority will undoubtedly require a more comprehensive, consistent and timely approach to data gathering and analysis within and across all basin jurisdictions.

3.5.6 Recommendation

The Council recommends the following to the IJC.

• Recommend to the Parties that the following broad areas of research and action be implemented as they pertain to Great Lakes water quality:

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a. research the effects of climate change and develop a simulation of Great Lakes watershed hydrology;

b. develop research needs for wetlands;

c. research coastal development including the evaluation of riparian shore properties and impacts of increased dredging;

d. research the human ability to regulate water levels and assessments of long-term impacts of water level fluctuations on ecosystem integrity; and

e. develop a common database for environmental and shoreline interests, water uses and better tools to project future uses.

3.6 ALIEN INVASIVE SPECIES RESEARCH

3.6.1 Introduction

There are more than 160 nonindigenous species in the Great Lakes, with more discovered every year. Numerous studies have documented the serious environmental and economic consequences associated with alien invasive species (AIS), also referred to as aquatic nuisance species (ANS), becoming established in the Great Lakes. Although many vectors for transporting AIS have been identified, it is widely agreed that the discharge of ballast water from ships entering the Great Lakes from other regions of the world poses the greatest threat. Many different agencies and organizations have recognized and identified actions that should be taken to address the problem. These include the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety, U.S. Coast Guard, IJC's Great Lakes Water Quality Board, Great Lakes Fishery Commission, Great Lakes Panel on Aquatic Nuisance Species, Aquatic Nuisance Species Task Force Ballast Water and Shipping Committee, Great Lakes Commission, Council of Great Lakes Governors, provincial governments, and non-governmental organizations, such as the Northeast-Midwest Institute. There has been significant progress in several areas, however, the majority of research has been focused on ecology, restoration and outreach rather than on establishing standards and preventing new introductions.

The IJC's Great Lakes advisory boards recognize the introduction of AIS as a top priority issue. A great deal of effort has been put forth to monitor activities and target value-added contributions to the process of closing the door on new introductions. Over 22 U.S. and Canadian federal agencies have participated in workshops and meetings, chartered committees and have dedicated resources to address this problem. The Council participated in the November 2000 discussions on ballast water and AIS sponsored by the Great Lakes Water Quality Board in Québec City, Québec and heard further presentations about research needs during its own January 2001 meeting in Windsor.

The Council fully supports the effort put forth by the Water Quality Board to explain current issues, concurs with the board's recommendations for research leading to short- and long-term practical solutions and the need for immediate action. The Water Quality Board's recommendations regarding AIS can be found in section 1.2.

The need for communicating and coordinating AIS research is more important than ever. During the upcoming year, as part of its analysis of overall Great Lakes research and monitoring needs, the Council will review invasive species research needs and funding requirements. The resulting

guidance document will provide more concise guidance and sound recommendations to the IJC regarding what the Parties should budget for additional research. The Council will also continue to promote collaboration and effective communications between researchers, agencies and governments though its web-based research inventory database.

3.6.2 Strategic Planning

In a joint report with the Great Lakes Fishery Commission issued in September 1990, the Commissions made the two following specific recommendations regarding research.

• The United States and Canada ensure, in cooperation with shipping and other interests, that a major applied research and development program is established that devises and tests improved measures for the exchange and/or treatment of ballast water.

• The governments of the United States and Canada work together to foster and encourage long-term strategic research on all dimensions of the exotic species problem.

A considerable amount of research is being done on nonindigenous species, particularly in the United States. Current entries in the Council's Research Inventory indicate an annual amount of more than $42 million (U.S.) expended on research studies that include nonindigenous species research since 1999. This represents approximately 13 percent of the total expenditures on research entered into the inventory for that period. Recognizing that participation in the Research Inventory is incomplete, this would represent a low estimate of actual expenditures. A summary of historic funding levels for aquatic nuisance species programs for U.S. agencies can be found on the Northeast-Midwest Institute's web site. It lists budget data for the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, Department of the Interior, U.S. Coast Guard, and the Environmental Protection Agency. Between 1992 and 2000, more than $80 million (U.S.) was allocated to these five agencies for ANS programs. Although this figure includes salary funds, it does not include additional funds provided in the National Sea Grant or Great Lakes Environmental Research Lab budgets from 1996 to 2000 for ANS programs. A May 2001 Great Lakes Panel on Aquatic Nuisance Species report indicates that in 2000, $3.1 million was expended by National Sea Grant with $2.2 million going to research and $0.9 million to outreach programs.

The Uniform National Discharge Standards (UNDS) program for liquid discharges from U.S. military vessels includes ballast water discharge

research. In this program, with the U.S. Navy as the lead, 25 discharges were identified that will require marine pollution control devices (MPCDs). The UNDS rule making process aims to establish MPCD performance standards and regulations governing the design, construction, installation and operation of MPCDs. Although interested states have been involved in the UNDS effort since its inception, and the Navy is involved with the Ballast Water and Shipping Committee of the Aquatic Nuisance Species Task Force, this effort has not facilitated establishment of commercial ballast water discharge standards. This appears to be mainly due to assigning ballast water discharge controls a lower priority than other discharges addressed by UNDS. The total cost for research, development, procurement and installation of MPCDs for 169 naval surface ships is estimated to be $318 million. If commercial and military programs were harmonized, these resources could be leveraged to speed development of ballast water control standards to benefit both the commercial and military sectors.

On the international level, as active members of the International Maritime Organization, both Canada and the U.S. will benefit from the results of Global Ballast Water Management program research. This is a three year, $10.2 million (U.S.) initiative using funds from the Global Environment Facility deployed through the United Nation's Development Programme, to enable the International Maritime Organization to assist developing countries to tackle the transfer of harmful aquatic organisms in ships' ballast water. This program should be completed in May 2003.

Recent and ongoing studies in the Great Lakes include the Great Lakes Ballast Demonstration Project, the Michigan Department of Environmental Quality project to test the effectiveness of biocides, and the $1.7 million (U.S.) project to sample and assess the threat from ships declaring no ballast on board.

With this amount of research activity, it has been questioned why the problem has not been solved in more than 10 years. There are three primary reasons:

• the problem is immense and requires a broad spectrum of research;

• there is currently no readily available `off the shelf' treatment technology providing a suitable alternative to ballast water exchange for all vessel types; and

• there is a tendency toward research into the effects and control of alien invasive species already present in the system rather than toward prevention of new introductions.

The Great Lakes Panel on Aquatic Nuisance Species noted the lack of emphasis on prevention of new introductions in its 1996 policy statement *Research Guidance for the Prevention and Control of Nonindigenous Aquatic Nuisance Species in the Great Lakes*. The Panel reported that 1995 research data indicated, "53 percent of all projects received examined the ecosystem effects of species already present, while only 5 percent of the

total expenditure was on prevention of introductions." This percentage has slightly increased over the past six years, but there is plenty of room for improvement. The National Sea Grant

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College Program report *Aquatic Nuisance Species Report An Update on Sea Grant Research and Outreach Projects 2000* lists 62 projects for FY 1999 and 2000. Of these ANS projects, five list the primary focus as "ballast" and three as "prevention." This represents approximately 13 percent of the total, with 87 percent of the projects focusing on ecology, restoration and outreach.

As the IJC and Great Lakes Fishery Commission did in 1990, the Great Lakes Panel on Aquatic Nuisance Species pressed for a strategic planning effort in 1996, recommending measures to strengthen the current research infrastructure, both in the U.S. and Canada. These included the following recommendations.

• Develop a national research strategy for nonindigenous aquatic nuisance species that is interjurisdictional in scope and contains three fundamental goals that operate simultaneously: prevention of new introductions; control of already introduced species and restoration of the aquatic ecosystem; and recognize research needs identified in state management plans for aquatic nuisance species.

• Develop an overarching coordinated action plan or regional policy agreement, including short- and long-term agendas, to ensure commitment to collective multi-jurisdictional action on ANS prevention and control. This may include commitment for interjurisdictional cooperation in prevention and control; development of consistent state and provincial laws and programs; sharpened delineation between agency roles and responsibilities; establishment of a regional emergency response team; and establishment of a center for invasive species control.

In its *Eighth Biennial Report on Great Lakes Water Quality* published in June 1996, the IJC again emphasized the need for a strategic approach stating, "A basinwide, binational strategy should be developed to prevent further introductions by any route of potentially harmful species."

Responding to this need, the U.S. and Canadian governments commissioned a study by the National Research Council Marine Board of the National Academy of Sciences, which published its report *Stemming the Tide* in July 1996. Based on recommendations from the marine board, the two governments set forth a binational research strategy and was included in their binational *1996-1997 Report on Great Lakes Water Quality* by the Department of Fisheries and Oceans Canada Science Directorate, Canadian

Coast Guard, Transport Canada Marine Safety and U.S. Coast Guard. This report recognized the importance of near-term treatment options for vessels with no ballast on board (NOBOB). It also addressed urgent requirements to review the safety of ballast exchange in current ship designs and to develop practical measures for confirming exchange in addition to measuring salinity. This strategy was developed by U.S. and Canadian federal agencies, taking into account the associated work being sponsored by the Great Lakes Protection Fund, the Michigan Office of the Great Lakes and other agencies around the world. In addition, the report stated that the agencies would facilitate studies of filtration included in the Great Lakes Ballast Water Demonstration Project, and the Canadian Department of Fisheries and Oceans and Michigan Department of Environmental Quality studies of certain biocides. Research in these areas has been funded and is underway.

Several other documents have been published to provide direction to research programs. The Great Lakes Panel on Aquatic Nuisance Species made sound recommendations in 1996 and again in 1998 on research needs and how to strengthen the research infrastructure both in the U.S. and Canada. In March 2001, they published the Great Lakes Ballast Water Management Policy Statement. This plan also represents a strategic, binational effort that sets goals and identifies short- and long-term research needs.

How much will additional research cost? This question has not been fully answered. The Great Lakes Commission identified over $37 million (U.S.) in funding requirements for AIS in its draft report *The Great Lakes Program to Ensure Environmental and Economic Prosperity - Great Lakes Commission Priorities to "Restore the Greatness."* This report recommended over $10 million annually for ballast technology development and demonstrations, however more specific requirements must be identified and prioritized.

3.6.3 Research and Monitoring Needs and Priorities

The U.S. Coast Guard noted the absence of sufficient applied research in several key areas in a Federal Register notice dated April 2001, in particular the lack of data on the effectiveness of ballast water exchange (BWE):

"Currently, the actual "effectiveness" of BWE is not well resolved ... The more finely resolved approach based on effectiveness profiles across taxonomic groups for major types of vessels would require an as yet undeveloped data set on BWE effectiveness across major ship classes and biotic groups. This approach would require a focused research effort to identify the data gaps and conduct the necessary experiments ... Standards based on the capabilities of the best available technology will also require a significant amount of additional work, as most existing systems are still in preliminary phases of development. Significantly, for standards based on either BWE or best available technology, important decisions will need to be made concerning the specifics of standardized testing protocols."

A summary of research recommendations from the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety and U.S. Coast Guard, the Great Lakes Regional Panel on Aquatic Nuisance Species, the Northeast-Midwest Institute, and the Great Lakes Commission is found in Appendix 1. These recommendations indicate many areas of common concern, notably in the areas of standards development and prevention.

Recommendations

The Council recommends the following to the IJC.

• Recommend that the Parties place an emphasis on the immediate implementation of current AIS research recommendations proposed by the Great Lakes Water Quality Board and other advisory panels.

• Recommend that the Parties give priority support and funding to well-focused, applied research needed to establish ballast water discharge standards and prevent new introductions of AIS.

• Recommend that the Parties provide resources for a binational coordination of efforts to ensure that a mutually acceptable ballast water discharge standard is developed and that unnecessary duplication of efforts is eliminated.

During the coming year, the Council's Research and Monitoring Needs and Priorities subcommittee will further examine current research recommendations and look at studies in progress in order to identify funding requirements. In this way, the Council can provide recommendations to the IJC regarding the total commitment of funding they should seek from Canada and the United States to fill critical research gaps and eliminate the threat of new introductions of alien invasive species.

3.7 FRAMEWORKS FOR MODELLING ECOLOGICAL CHANGE

IN THE DETROIT RIVER - LAKE ERIE CORRIDOR

Background

In 1997, the Lake Erie Task Force recommended that the Council of Great Lakes Research Managers bring together modelers and resource managers to address the development of a model for Lake Erie. Based on this recommendation, the Council hosted the *Great Lakes Modelling Summit: Focus on Lake Erie*, March 27-28, 1999 during the International Association of Great Lakes Research conference at Case Western Reserve University in Cleveland, Ohio. This workshop examined the feasibility of building an aquatic ecosystem model for Lake Erie that could examine the ecosystem-level effects of multiple stressors acting in concert.

Workshop

Building on this work, the Council hosted another modelling workshop to coincide with the *Lake Erie in the Millennium- Progress and New Issues* binational conference held March 28-29, 2001. This workshop built on the previous modelling summit, but focussed on the western basin of Lake Erie and more specifically on the Detroit River - Lake Erie system.

First, a roundtable discussion was conducted on *The Influence of the Detroit River on the Lake Erie Ecosystem.* Participants

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identified key features and tests necessary to evaluate the question, "What is the likely role of Detroit River remediation on the Lake Erie ecosystem?"

During the afternoon, the Council held a modelling workshop titled *Frameworks for Modelling Ecological Change in the Detroit River Lake Erie Corridor*. This workshop provided modelers with an opportunity to comment on how well the measurements and experimental proposals made during the roundtable session would fit into a modelling framework. The proceedings provided background on previous efforts and took note of important observations made at *The 2001 Lake Erie in the Millennium* conference.

An example of the discussion included, in particular, the fact that total phosphorus levels in the lake appear to be going up and whether this observation is the result of increased loadings of phosphorus to the lake or of changes in in-lake processing of phosphorus loads. It was noted that the

future challenge for modelers is to take observations, such as phosphorus concentration trends, and convert them into quantitative hypotheses that can be tested within a modelling framework. Informed decisions could then be made on what should be done and what priorities should be made in order to improve the system.

It was noted that the initial question, "What is the likely role of Detroit River remediation on the Lake Erie ecosystem?" is a very generic management question. Using a model to address this question requires modelers to become more specific and address questions such as the following.

If we want to remediate the Detroit River so as to improve Lake Erie as well:

• Where should we focus?

• Where should we start?

• Where should we spend our money?

• How can specific potential remediation alternatives be simulated within a modelling framework?

The point was made that as research tools, models are an integral part of the scientific method. It was stated that:

"Models serve as a means of quantitatively synthesizing process experimental results and theory along with field observations into a whole system hypothesis-testing tool. With complex ecosystems, it becomes virtually impossible to measure ecosystem structure and functioning at the scale necessary to test hypotheses strictly with data; this is where system-level models have great value. While we can never really simulate the entire ecosystem, we can mathematically reproduce our conceptual model of the key processes and feedback as a means of testing system response to conditions that may exist but for which we do not have empirical experience. The great value of models used in this research mode is the knowledge gained when they "fail". In this way gaps in our data or understanding are indicated. Then we can iterate between monitoring/experimentation and model application in order to build our understanding of how the ecosystem responds to external stimuli.

The challenge of course, is establishing a management model and a research model in the single framework. Often, the demands for spatial and temporal and kinetic (or process) resolution in a research model may be very different than a management model. For example, a management model for PCB's might just look at total PCB's. However, this is generally not appropriate for a research study. For research purposes, we might want to look at the behavior of some of the PCB congeners individually. These things make it a challenge to address both a management and a research model question in the same program."

The following specific modelling questions were addressed and related to the overall theme of modelling ecological change in the Detroit River Lake Erie corridor:

• What types of models and approaches are most appropriate to complement the suite of measurements previously proposed?

• Can one model address all of the issues of concern? If multiple approaches are warranted, which ones best fills the gaps?

• What important compartments and state variables may have been omitted?

• Is the proposed geographic extent of sampling sufficient?

• Will the proposed measurements generate the types of data sufficient to create a mass budget or mass balance model?

• What temporal and spatial resolution of sampling is appropriate and what time frame should be considered?

• Can the physical and biological processes be sufficiently integrated?

• What resources, such as monetary or collaborative would be necessary to undertake a suitably sensitive and general model?

Conclusions and recommendations from the workshop are as follows.

• Models need to test a hypothesis that incorporates both a research and management need.

• Toxicokinetic models need to be coupled with hydrology models by using appropriate technologies such as a geographic information system (GIS).

• Modelers need to incorporate people and human influences into their models.

• Demographics will influence the direction of Great Lakes research in the future including loss of expertise and lack of recruitment of Great Lakes researchers.

• Current monitoring in the Detroit River is insufficient to develop appropriate models that can make predictions or merely explain current state of the Detroit River- Lake Erie system.

• A loss of representative sampling in the Detroit River, `sampling erosion,' has resulted in biased data.

• The system needs to be considered as a corridor, including the area from the head of the St. Clair River, Lake St. Clair, Detroit River and Lake Erie.

• Sharing data and models with the public can create advocacy for models.

• Upstream and downstream monitoring, appropriate detection limits and up-to-date intensive monitoring to develop loadings should be reinstated.

• The cost of modelling is relatively small portion, 10-12 percent, of the total project cost compared to other remediation project costs and can ensure the quality assurance of remediation.

• Peer review and validation of models is important and a `battle of the models' would help to review and critique proposed models for the corridor.

The full transcript of workshop proceedings will be published as a separate document and made available on the Council's web page. http://www.ijc.org /rel/boards/cglr

3.8 ONGOING INITIATIVES AND NEW ACTIVITIES

3.8.1 The Great Lakes - St. Lawrence

Research Inventory

The Great Lakes - St. Lawrence Research Inventory is an important tool for the Council of Great Lakes Research Managers to gauge research activity in the region. The Research Inventory is an Internet-based, searchable database that collects and disseminates information on research programs relevant to the Great Lakes Water Quality Agreement. Since 1985, the Council has continuously gathered descriptions of research programs from its members, as well as from external agencies and institutions. Previous to the Council's efforts to track Great Lakes research, the Research Advisory Board, which became known in 1979 as the Great Lakes Science Advisory Board, conducted research reviews in 1975, 1976, 1978 and 1982. In 1995, the Council took advantage of the Internet to extend its data collection efforts and increase the consistency and availability of this information through the web. The inventory allows Great Lakes researchers to identify similar studies, network, share experiences

and increase efficiency. It also enables the Council to examine the impact and adequacy of research as stipulated by the Agreement, to reveal the interrelationships between research disciplines and to link research to policy questions. The Council hopes to promote the transfer of information on research programs to basin policymakers, resource managers and the public.

The inventory currently has 650 projects listed representing approximately $140 million U.S. ($214 Million CDN) in research expenditures and is accessed between 200 and 300 times per month. During this priority cycle, the Council took steps to improve data analysis capability and to capture data on environmental economics research studies. The Council is also pursuing improvements to inventory usability to speed updates, incorporate on-line queries and interactive features, simplify database maintenance, automate updates and provide faster access to key information for on-line users.

3.8.2 Science Vessel Coordination

The Fifth Annual Great Lakes Science Vessel Coordination Workshop, sponsored by the Council, was held in Windsor, Ontario, January 22-23, 2001. The workshop produced a strong turnout from both science vessel operators and managers and provided a productive exchange of views and helped promote enhanced communication, cooperation and the more efficient and cost effective use of the Great Lakes science vessel resources.

Breakout sessions were held with three primary groups, the Scientist and Managers, Upper Lakes, and Lower Lakes committees. Institutional and administrative requirements, program development and coordination, advocacy and coalition building, and communications and information sharing were discussed.

Recommendations from this meeting include:

• sharing of shipyard experiences and developing a list of preferred shipyards;

• development of a Great Lakes science vessel brochure to recognize current coordination efforts and to promote greater awareness of this initiative among scientists and the public;

• completion of a staffing survey to compile vessel manning data; and

• incorporation of data regarding laboratory equipment and services into the Research Vessel Inventory.

In addition to this effort, the Council funded an update to the Research Vessel Inventory to better organize data and to provide for improved links to individual vessel web sites. More information on the Research Vessel Inventory is available on the Internet. http://www.buffalostate.edu/~csboats/index.htm

3.8.3 Integrated Great Lakes Observation and Monitoring

In its *Tenth Biennial Report on Great Lakes Water Quality*, the IJC recommended that the Parties develop and implement a binational information policy employing advanced technology to support implementation of the Great Lakes Water Quality Agreement. This followed recommendations from the Great Lakes Science Advisory Board in the *1997-1999 Priorities and Progress under the Great Lakes Water Quality Agreement* report on a coupled Great Lakes Observation and Modelling System.

Based on these recommendation and a 1998 U.S. national program for Sea Floor Observatories established by the White House as a Presidential Initiative to be implemented through the National Undersea Research Program of NOAA; the Council studied the concept of developing the Great Lakes into `instrumented ecosystems' where fish and zooplankton populations are tracked, 3-dimensional current structures mapped, and *in situ* chemical and physical analyzers, optical systems and biomonitoring systems gather real time data via remote monitoring (V. Klump). In 2000, the National Research Council set out a plan to approach the problem and recommended that the National Science Foundation build ocean observatories. The report, *Illuminating the Hidden Planet the Future of Seafloor Observatory Science*, by the Committee on Seafloor Observatories's Ocean Studies Board, includes many well-supported findings and recommendations. This report is available on the Internet. http://books.nap.edu/books/0309070767/html/R1.html

The Great Lakes Science Advisory Board and the Council formed a joint subcommittee in 2001 to sponsor a workshop exploring the potential of the Great Lakes basin as a pilot area for initial testing and deployment of this technology. This workshop is scheduled for Fall 2001 and will lay the foundation for further plans and recommendations to the IJC on this important new initiative.

3.8.4 Emergence of New Pathogens

The serious risks posed by aquatic invasive species are much better

understood than the risks posed by the introduction of viruses, bacteria and protozoans. Infectious agents, capable of causing illness in humans or animals, are commonly referred to as pathogens and considered in a separate category from nonindigenous species. Researchers in the Chesapeake Bay area have measured an average of approximately 2 million bacteria and twenty million viruses per milliliter of ballast water from ships entering that waterway. Similar measures may be expected from samples taken from ships entering the Great Lakes system. It

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is estimated that between 500 to 600 foreign flag vessels enter the Great Lakes each year. Seaway-size bulk carriers have a ballast capacity of about 20-40 percent of the weight of the cargo, typically from 2 to 4 million gallons (7.6 to 15.2 billion milliliters) of ballast water. Consequently the number of microorganisms delivered to the Great Lakes basin in ballast water is astronomical. The majority of these microorganisms are not pathogenic and occur naturally in aquatic ecosystems, however the environmental risks associated with global transport of ballast water microbes are not well understood.

A number of pathogens in Great Lakes waters have been identified over the past decade, including cryptosporidia, giardia, cyclospora and E. coli. Another pathogen that is always of potential concern is cholera, ever-present in waters elsewhere in the world.

At the present time, the full impact on human health from some of these pathogens has been only explored as it relates to isolated outbreaks. Typically, little is known about their long-term presence, viability and impact on other Great Lakes organisms and ecosystems. Further examination of these issues to better understand and predict their implications, as pertains to the Great Lakes waters, may be warranted in upcoming meetings and symposia. Accordingly, this topic was identified as an emerging issue of concern and the Council plans to scope out this issue in detail during the upcoming priority cycle.

3.8.5 Research and Monitoring Needs and Priorities

At its January 2001 meeting, the Council formed a subcommittee on Research and Monitoring Needs and Priorities. The Council believes that the Great Lakes `family' of agencies should help the regions elected officials articulate the needs of the basin more effectively to secure funding to solve the many problems facing the region. Many have taken note of the funds recently appropriated by the U.S. Congress for restoration of the

Florida Everglades and cleanup of the Chesapeake Bay. All agree that the problems facing the Great Lakes region are equally challenging and deserve the same level of support. The Council agreed that the Florida Everglades model is a good one, but is focused primarily through one agency. The Chesapeake Bay model is also good, but it is focused primarily on one issue -- eutrophication. In the Great Lakes, the challenge is to reach consensus amongst many agencies and many issues.

The Council's charge to this committee is to go beyond the identification of emerging issues and to identify research and monitoring needs and their associated funding requirements. This will enable the Council to provide sound advice to the IJC on what level of funding is really needed for the governments to address these problems. The Council has invited members of the Science Advisory Board and the Water Quality Board to participate on the subcommittee so that a strong consensus may be forged. A report on priorities and funding requirements is to be provided before the end of 2001.

3.9 COUNCIL MEMBERSHIP FOR 1999 - 2001

United States Members

Dr. Stephen B. Brandt, Co-Chair

Director, Great Lakes Environmental Research Lab.

National Oceanic and Atmospheric Administration

2205 Commonwealth Blvd.

Ann Arbor, Michigan 48105-2945

Dr. Joseph V. DePinto

Limno-Tech, Inc.

501 Avis Drive

Ann Arbor, Michigan 48108

Dr. Christopher T. DeRosa

Director, Division of Toxicology

CDC/Agency for Toxic Substances and Disease Reg.

1600 Clifton Road, N.E., Mail Stop E-29

Atlanta, Georgia 30333

Dr. James M. Haynes, Director

Professor of Biological Sciences

Center for Applied Aquatic Science and Aquaculture,

Department of Biological Sciences

SUNY College at Brockport

Brockport, New York 14420-2973

Mr. Paul Horvatin

Senior Advisor
U.S. EPA-GLNPO

77 West Jackson Street

Chicago, Illinois 60604

Dr. Thomas C. Johnson

Director, Large Lakes Observatory

University of Minnesota

Duluth, Minnesota 55812

Mr. Jan A. Miller

U.S. Corps of Engineers

Great Lakes & Ohio River Division

111 North Canal Street

Chicago, Illinois 60606-7205

Mr. James R. Nicholas

Michigan District Chief

Water Resources Division

U.S. Geological Survey

6520 Mercantile Way, #5

Lansing, Michigan 48911-5991

Dr. Jeffrey M. Reutter

Director, Ohio Sea Grant College Program

Ohio State University, Research Center

1314 Kinnear Road, Room 1541

Columbus, Ohio 43212

Dr. Nancy Milton

Great Lakes Science Center,

U.S. Geological Survey

Biological Resources Division

1451 Green Road

Ann Arbor, Michigan 48105

Canadian Members

Dr. Harvey Shear, Co-Chair

Regional Science Advisor

Environment Canada

4905 Dufferin Street

Downsview, Ontario M3H 5T4

Mr. Vic Cairns

Great Lakes Laboratory for

Fisheries and Aquatic Sciences

Dept. Of Fisheries and Oceans, CCIW

867 Lakeshore Rd., P.O. Box 5050

Burlington, Ontario L7R 4A6

Dr. Patricia Chow-Fraser

Department of Biology

McMaster University

1280 Main Street, West

Hamilton, Ontario L8S 4K1

Dr. Steve Clarkson

Bureau of Chemical Hazards

Environmental Health Center, Health Canada

Tunney's Pasture, Building 8

Ottawa, Ontario K1A 0L2

Dr. Lynn Cleary

Director, Information Management

and Dissemination Section

Environment Canada, Centre Saint-Laurent

105 McGill, 7th Floor

Montréal, Québec H2Y 2E7

Mr. Dale Henry

Atmospheric Studies, Science and Technology

Ministry of Environment

135 St. Clair Ave. W., 12th Floor

Toronto, Ontario M4V 1P5

Mr. Dean M. Jacobs

Walpole Island First Nation Heritage Centre

R.R. #3

Wallaceburg, Ontario N8A 4K9

Ms. Cheryl Lewis

Ontario Ministry of Natural Resources

Fisheries Research Section

300 Water Street, 3rd Floor

North Tower

Peterborough, Ontario K9J 3C7

Mr. Karl Schaefer

Great Lakes and Corporate Affairs Office

(Economics Section)

Environment Canada, Ontario Region

Canada Centre for Inland Water

867 Lakeshore Rd., P.O. Box 5050

Burlington, Ontario L7R 4A6

Binational Members

Dr. Christopher I. Goddard

Executive Secretary

Great Lakes Fishery Commission

2100 Commonwealth Blvd. Ste. 209

Ann Arbor, Michigan 48105-1563

Dr. Gail Krantzberg

International Association for Great Lakes Research

Great Lakes Strategic Coordinator

Ministry of the Environment

135 St. Clair Ave. West, 11th Floor

Toronto, Ontario M4V 1P5

Commission Liaisons

Dr. Kay Austin

International Joint Commission

United States Section

1250 23rd Street NW, Suite 100

Washington, D.C. 20440

Ms. Ann MacKenzie

International Joint Commission

Canadian Section

234 Laurier Ave., West, 22nd Floor

Ottawa, Ontario K1P 6K6

Secretary

Mr. Mark Burrows

Secretary (July 2000 - present)

International Joint Commission

Great Lakes Regional Office

100 Ouellette Avenue, 8th Floor

Windsor, Ontario N9A 6T3

Former Members

The following also served on the Board during the 1999-2001 biennial cycle. Their contributions are gratefully acknowledged.

Dr. Gregory Smith

U.S. Geological Survey

Dr. Val Klump

Center for Great Lakes Studies

Dr. Russsell A. Moll

Director, Michigan Sea Grant

Dr. Fred Edgecombe

Canadian Plastics Industry Association

Mr. Richard MacDonald

United Nations University

Ms. Charlotte Bastien

Environment Canada, Centre St. Laurent

Former Secretary

Mr. Douglas Alley

(Acting Secretary June 1999-July 2000)

International Joint Commission

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Appendix 1. Summary of Recommendations Regarding

Research Needs Associated with Non-indigenous Invasive Species Control Measures

1996-1997 DEPARTMENT OF FISHERIES AND OCEANS CANADA SCIENCE DIRECTORATE, CANADIAN COAST GUARD, TRANSPORT CANADA MARINE SAFETY, AND THE U.S. COAST GUARD BINATIONAL PLAN

Source: 1996-1997 Report on Great Lakes Water Quality by Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety, and the U.S. Coast Guard.

(242) The Binational Plan to Support the

Comprehensive Research Strategy

The purpose of the plan, quite simply, is to fill in those critical elements of the overall strategy which are not being adequately addressed at the present time, within the limits of the competence, funding, and political direction of the agencies, taking advantage of opportunities for collaboration with other agencies and organizations also doing work on these issues.

(242.1) Specific Projects to be Developed by the Agencies

Based on a review of the work in progress and the outstanding issues which need to lie addressed as soon as possible, the agencies have agreed to pursue the following priority projects.

• Evaluation of Exchange. Within this general project, two critical issues need to be addressed:

Review of the safety of pump-down exchanges, specifically their effect on hull integrity and ship stability, for all relevant classes of vessels, including both large vessels calling at North American saltwater ports, and smaller but narrower vessels entering the St. Lawrence Seaway. This subproject should include historical comparisons of hull cracking in Seaway vessels in order to attempt to distinguish hull cracks which may be caused by pump-down exchanges since the beginning of the Great Lakes regime and hull cracking which is caused by other factors (design, age, loading practices). Because of the initial study already conducted by the Canadians, this subproject is an excellent candidate for formal US/Canadian

collaboration.

Development of tests and protocols for confirming exchange, beyond the current salinity tests used in the Great Lakes. Two types of tests are needed (and both are likely to be an important part of any North American or worldwide regime). 1. A relatively simple and real-time field test, which can be used on board a vessel by both the vessel operators and the government agencies, to provide a reasonable indication that an adequate exchange has been conducted before a vessel enters port or discharges ballast. 2. A scientifically reliable and legally enforceable test, which may well not be real-time, to allow both scientific validation of any regime and punitive enforcement action against violators of a mandatory regime.

• Near-Term Captions for NOBOB. Prompt action is needed to deal with the problems presented by the NOBOB, which constitute a significant gap in both the Great Lakes regime and any national or world-wide regime. Within this general project there are three SUBPROJECT which are most likely to lead to solutions in the near future.

Better evaluation of the threat posed by the slop and sediment in the bottom of the NOBOB, specifically including evaluation of the practicality and effectiveness of short-term operational measures such as the "partial exchange" or "swish and spit" in controlling the organisms in the slop and sediment. Because of the initial testing already conducted by the Canadians, this subproject is an excellent candidate for formal US/Canadian collaboration.

Hydrodynamic modelling of feasible tank retrofits making it possible to conduct flow-through exchanges, specifically including retrofits which would make it possible to conduct top-down flow-through exchanges on NOBOB. This subproject would address both the NOBOB problem and the problem of safety constraints on pump-down exchanges on all vessels.

Tests of the feasibility and effectiveness of heating the slop and sediment on NOBOB. which may be practical through simple shoreline injections of heated water due to the relatively small quantities of water involved. Because of the initial study already conducted by the Canadians, this subproject is an excellent candidate for formal US/Canadian collaboration.

• Realistic cost comparisons of the competing options. We need rigorous, credible, and consistent economic analysis of the competing options, including filtering, follow-on treatments associated with filtering such as UV, heat in its various modes, plausible biocides, and various configurations for tank retrofitting and redesigns. This economic analysis is essential to the development of any real-world regulatory regime.

(242.2) Other Projects Supported by the Agencies

The specific projects listed above are the critical needs which are not being currently addressed by other projects, which are within the current funding guidance to the US Coast Guard, and which allow for some formal collaboration with the Canadian agencies. In addition, the agencies will offer whatever support they can to other work taking place in the Great Lakes region:

• The Great Lakes Ballast Demonstration Project, which is studying filtering, and has now, expanded to study pathogens in ballast water, (See Appendix I.) This project has already received some funding from the US Coast Guard, and significant funding from the Great Lakes Protection Fund. At this time, the US Coast Guard is actively assisting that project in taking samples from foreign vessels in Messina.

• DFO and Michigan Office of the Great Lakes studies of certain biocides. Within the limits of the funding guidance to the US Coast Guard, which is restricted in this respect, the agencies will work together to facilitate any intergovernmental approvals and held tests which may be appropriate to test the effectiveness and environmental acceptability of limited applications of biocides in NOBOB vessels entering the Great Lakes.

GREAT LAKES PANEL ON

AQUATIC NUISANCE SPECIES

Source: Policy Position of the Great Lakes Panel on Aquatic Nuisance Species, Research Guidance for the Prevention and Control of Nonindigenous Aquatic Nuisance Species in the Great Lakes. Adopted December 4, 1996.

1996 Recommendations

Recommendations on ANS research gaps and needs have been classified by six research categories adopted by the Great Lakes Panel on Aquatic Nuisance Species as well as the national ANS Task Force.

Biology and Life History

• Perform a timely literature review and translation of information on all newly introduced species to eliminate duplication of research.

• Determine and prepare potential range maps for all new introduced species in a region.

• Prepare risk assessments to determine impacts on native species.

• Study genetic characterization of invaders and source populations.

Control and Mitigation

• Increase education and research activities for alternate control options and eradication of aquatic nuisance species.

• Develop a model plan for eradication of a nonindigenous aquatic nuisance species that outlines the necessary procedures to be undertaken in the event of a new invasion.

• Improve documentation and transfer of private sector research.

• Enhance bioengineering of species-specific pathogens.

• Develop and examine containment options for species already present.

• Explore the technical feasibility of integrated pest management (I'M). I'M integrates various control measures and examines the economic benefits versus costs in determining whether control is beneficial.

Ecosystem Effects

• Enhance/maintain monitoring programs to establish pre-invasion data on native species and to provide a better understanding of the community structure in the Great Lakes region. This will allow for more informed decision making on potential control options in the event of an invasion of a nonindigenous aquatic nuisance species.

• Determine the ecosystem response (environmental and social) to the control/containment of nonindigenous aquatic nuisance species.

• Develop the theory of ecosystem resilience toward the establishment and dominance of nonindigenous aquatic nuisance species.

• Develop more reliable ecosystem models to assist management in making decisions on mitigation of impacts or on the control of established nonindigenous aquatic nuisance species, if control is possible.

Prevention of Introductions

• Identify, understand and perform risk assessments of pathways, next likely invaders (including pathogens), and likely sources of origin for new invasions.

• Identify maritime transportation routes that have demonstrated or have the potential capability to advance the spread of aquatic nuisance species. Develop and evaluate prevention and control options, including exploring ballast water management technologies.

• Examine current legislation regulating the importation of nonindigenous aquatic nuisance species to ensure proper prevention and control measures are in place (e.g., aquarium and pet trade industry, aquaculture).

Socioeconomic Considerations and Analysis

• Estimate the economic costs of current and historical damage (physical, biological, industrial, recreational, ecosystem) to the Great Lakes caused by the invasion of nonindigenous aquatic nuisance species.

• Estimate the costs and benefits (economic and social) of adopting new prevention and control technologies, including an examination of ways to minimize these costs to the affected industry.

• Utilize the concept of biological pollution when referring to the introduction of nonindigenous aquatic nuisance 4 species.

Spread of ANS Populations

• Identify, understand and perform risk assessments of potential dispersal pathways within the Great Lakes region.

• Monitor and review federal, state and provincial laws and regulations to ensure that prevention and control measures address all pathways of concern (e.g., aquaculture, aquarium, pet trade) in a consistent manner from one jurisdiction to the next. Gaps and inconsistencies should be resolved accordingly.

• Prepare potential range maps for species already present.

• Institute programs in the U.S. and Canada for early detection and reporting with incentives for participation.

• Require containment guidelines for all research projects handling aquatic nuisance species (public and private sector research).

• Examine dispersal barriers i.e., choke points to control the spread of established populations (e.g., Chicago River).

Strengthening the Research Infrastructure

• Develop a national research strategy for nonindigenous aquatic nuisance species that is interjurisdictional in scope and contains three fundamental goals that operate simultaneously: prevention of new introductions, control of already introduced species, and restoration of the aquatic ecosystem as well as recognize research needs identified in state management plans for aquatic nuisance species.

• Develop an overarching coordinated action plan or regional policy agreement (with short and long-term agendas) to ensure commitment to collective multi-jurisdictional action on ANS prevention and control. This may include commit

ment for interjurisdictional cooperation in prevention and control; development of consistent state/provincial laws and programs; sharpened delineation between agency roles and responsibilities; establishment of a regional emergency response team; and establishment of a center for invasive species control.

• Develop and institute pre-clearance regulations for the importation of aquatic shipments (fish, plants). This would ensure that cargo is inspected for nonindigenous aquatic nuisance species before it leaves its destination.

• Increase interest/concern about other less highly publicized species by designating them as aquatic nuisance species or by identifying them as regional priorities for prevention and control.

• Institute a national program for early detection and reporting with incentives for participation.

• Develop and link ANS research databases nationally and internationally on the Internet to foster better communication among researchers.

• Enhance communication on ANS issues between scientists and Sea Grant agents as well as the general public.

• Continue research on ANS by reauthorizing the federal Nonindigenous Aquatic Nuisance Prevention and Control Act (National Invasive Species Act of 1996) and adequately appropriating funds. Research priorities should reflect the recommendations of the national ANS Task Force and/or the Great Lakes Panel on Aquatic Nuisance Species and other relevant organizations.

1998 Recommendations

Source: Policy Position of the Great Lakes Panel on Aquatic Nuisance Species. A Binational Canadian-United States Ballast Water Research Strategy. Adopted February 1998.

To advance implementation of its December 1996 policy position, the Great Lakes Panel on Aquatic Nuisance Species recommends that its member agencies and organizations support the following research action plan.

• **Evaluation of Exchange**

Review the two technical reports on the safety of ballast pump-down exchanges for all relevant classes of vessels, including both large vessels calling at North American saltwater ports, and smaller but narrower vessels

entering the St. Lawrence Seaway. Perform studies to determine hull stress, bending moment, seakeeping characteristics and overall safety of exchange. Evaluate potential increase in fatigue cycles to hull components due to additional ballast exchanges at sea.

Develop and support ongoing efforts to develop field-type tests and protocols that confirm that ballast exchange has taken place at sea. Two types of tests should be considered, including: 1. A simple and real-time field test to be used on board a vessel by both the operators and applicable government agencies. 2. A scientifically reliable and enforceable test to allow both scientific validation and enforcement action.

• **Evaluate Near-Term Options for NOBOB Vessels**

Evaluate the threat posed by slop and sediment in the bottom of NOBOB as well as the practicality and effectiveness of short-term operational measures such as "partial exchange," or a "swish and spit," in controlling organisms in the slop and sediment. Support demonstration projects to validate these and other relevant methods.

Conduct modelling to evaluate flow-through methods (top-down and bottom-up) for effectiveness of water and sediment displacement and potential biological effectiveness. Evaluate the costs of retrofitting existing systems for the two alternatives as well as the costs of incorporating changes into new ships at the design stage. Support demonstration projects of the alternatives to validate results.

Support studies for shipboard heating or shoreline heating of smaller quantities of water and "hot shotting" individual tanks. Provide realistic refit costs for both shoreline and shipboard systems and provide realistic vessel delay times to perform the operation ashore.

• Biocide Studies Relevant U.S. and Canadian agencies and organizations should work together to assure efficient consideration of permit applications for field tests of potential biocide treatments for ballast residuals. Studies must demonstrate that candidate chemicals can be stored and disposed of in an environmentally sound manner and break down into environmentally sound, harmless byproducts before any discharge into the Great Lakes.

• Support of Ongoing Research U.S. and Canadian agencies and organizations are encouraged to support and participate in initiatives (e.g., Great Lakes Ballast Demonstration Project, and Canadian Dept. of Fisheries and Oceans and Michigan Office of the Great Lakes biocide research) that examine specific approaches to ballast water management or critical,

associated needs.

March 2001 Recommendations

Source: March 2001 Great Lakes Panel on Aquatic Nuisance Species Policy Statement on Ballast Water Management.

Technology Options and Research Needs

• Evaluate ballast water management practices and treatment technologies, including ballast water exchange, in terms of crew safety, effectiveness, real-world technical viability, environmental acceptability, economic feasibility, practicality and enforceability.

• Evaluate how vessel structure, age, operating conditions, crew capabilities and other factors affect ballast water technologies and management approaches.

• Consider the use and effectiveness of combinations of ballast water treatments.

• Assess the effectiveness of best management practices and non-chemical treatment methods (e.g., ultraviolet treatment) for ballast water management.

• Develop protocols for the use of biocides as a treatment option for ballast management, particularly in regard to NOBOB, and evaluate their use in terms of environmental implications; effectiveness; physical effects on vessels; health and safety risks; and consistency with the stated policies of federal, state, provincial and regional Great Lakes-St. Lawrence entities.

• Evaluate the potential of shore-based ballast water treatment facilities at critical chokepoints in the Great Lakes-St. Lawrence system as one component of a ballast water management program.

• Implement full-scale application on commercial vessels of promising ballast water management/treatment technologies that have shown potential in demonstration projects to minimize ANS discharges.

• Develop and implement a ballast water sampling program using water quality and/or biological criteria as benchmarks to measure improvements that occur with various treatment methods.

Research Funding and Coordination

• Establish secure, dedicated, long-term, federal funding that will provide sufficient support for research, ballast water sampling and monitoring, and demonstration projects for ballast water management practices and technologies.

• Develop and utilize mechanisms to expedite sharing and widespread dissemination of results, such as a single Internet site, that cross-links research topics with projects, researchers and funding organizations.

Management of NOBOB

• Evaluate the potential for NOBOB to introduce and spread ANS and assess the economic and environmental risks such introductions pose. Include in this evaluation identification of all life stages of organisms, including resting stages and cysts, that are present in NOBOB.

• Determine the utility, environmental implications and desired duration of short-term management approaches to NOBOB, including partial exchange, best management practices, and physical and chemical treatment.

• Evaluate, in conjunction with the marine industry and federal authorities, long-term approaches including technological alternatives, new ship design and other management options that address the ANS problems associated with NOBOB.

Estimation of Costs and Economic Impacts

• Evaluate the costs of retrofitting existing vessels and incorporating ballast water treatment technologies into new vessels.

• Compare the potential environmental impacts and economic costs of ANS invasions against the cost of development and implementation of ballast water treatment measures.

• As promising management options/technologies are identified by research, assess the potential implementation costs to guide development at the full-scale level.

• Examine the potential to modify trade patterns of lakers and ocean going vessels in the Great Lakes-St. Lawrence system to minimize the discharge of foreign ballast. Evaluate the potential economic impacts of ballast water measures in terms of varying vessel types, types of commodities and volume, differing ballasting systems and alternative transportation modes.

• Examine the economic impacts of requiring all ships to stop at a certain point for ballast water treatment (e.g., shoreline treatment).

• Identify and evaluate options to mitigate the financial burden of ballast water management requirements for the shipping industry (e.g., tax credits, federal funding).

Assessment of Human, Fish and Wildlife Health Risks from Pathogens

• Assess the nature and scope of the public health risks posed by potential ballast water pathogens.

• Conduct a fish and wildlife pathogen risk assessment to expand knowledge of this issue.

• Assess the nature and scope of public health risks already present in the waters of the Great Lakes-St. Lawrence system as a framework by which to compare/assess shipborne risks.

NORTHEAST-MIDWEST INSTITUTE

Source: January 23, 2001 Presentation by Allegra A. Cangelosi to Council of Great Lakes Research Managers: *Characterizing Biological Effectiveness of Ballast Water Treatment: Options and Case Examples.*

General Conclusion

"We Should Design Early Research on Ballast Treatments Collaboratively to Determine Meaningful Evaluation Benchmarks and Treatment Objectives."

Conclusions

• Bioeffectiveness of treatment technologies is influenced by properties of organisms (e.g. morphology and regrowth potential), water (physical/chemical), and ships (operational/structural).

• Each technology will have strengths and limitations relative to critical parameters.

• Early studies should help define critical parameters and overall treatment objectives, so that later studies can efficiently "profile" bioeffectiveness of proposed treatments.

General Issues for Collaborative Investigation

• What should our treatment objectives be, especially with respect to microbes?

• At what scale (and for which organisms) do pilot research findings become predictive of shipboard performance?

• Will operative morphological/physical/ chemical features in one geographic region predict treatment effectiveness on organisms of another assemblage/geographic region?

A Common Metric?

• How do we measure success (mortality vs. inactivation, percent reduction

vs. absolute concentrations)?

• How do we incorporate retention effects (e.g. die-off, regrowth)?

• How do we predict the fate of moribund plankton once discharged into the receiving system?

GREAT LAKES COMMISSION

Great Lakes Commission Priorities to "Restore the Greatness" (Working Draft) (Posted on GLC web page March 2001).

Selected Priority Actions

• Reauthorization of the National Invasive Species Act (NISA): to strengthen national and regional programs and develop ballast management standards and regulations consistent with recommendations of the Great Lakes Commission and the Great Lakes Panel on Aquatic Nuisance Species.

• Implement Comprehensive State Management Plans (NISA, Sect. 1204): to partner with Great Lakes states on critically important prevention and control programs $5.0 million annually to the Great Lakes states through the U.S. Fish and Wildlife Service.

• Support the Great Lakes Panel on Aquatic Nuisances Species (NISA, Sect. 1203): to ensure effective, efficient and well coordinated regional prevention and control programs $0.3 million annually to the Great Lakes Commission through the U.S. Fish and Wildlife Service.

• Ballast technology development and demonstrations: to address a leading vector for invasive species (commercial vessels in ballast or "no ballast on board" status) $3.0 million annually for each of several federal agencies/facilities with special expertise: Great Lakes Environmental Research Laboratory (National Oceanic and Atmospheric Administration), Great Lakes Science Center (United States Geological Survey), and Great Lakes Sea Grant Program (through the National Sea Grant Program); and $1.2 million annually to the U.S. Coast Guard

• Public facility research and development: to complete the design, construction and evaluation of a dispersal barrier in the Chicago Sanitary and Ship Canal, and undertake related control activities $3.0 million annually to the U.S. Army Corps of Engineers.

• Sea lamprey barriers: to dramatically reduce infestations with an emphasis on nonchemical alternatives $3.0 million annually to the U.S. Army Corps

of Engineers.

• Best Available Technology on commercial vessels: to secure authorizing language for a program to support retrofitting of commercial vessels to eliminate/reduce infestations and spread $25.0 million annually to the U.S. Coast Guard.