Great Lakes Monitoring Inventory and Gap Analysis

Highlighting Monitoring Activities and Recommendations for Addressing Shortfalls and Improving Monitoring Coordination in the Great Lakes Basin

Prepared by

Great Lakes Commission
Eisenhower Corporate Park
2805 South Industrial Hwy., Suite 100
Ann Arbor, MI 48104
Phone: 734-971-9135
Fax: 734-971-9150
Email: glc@glc.org
Web: www.glc.org
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Acronyms

AIRS	Aerometric Information Retrieval System
BEC	Binational Executive Committee
DDT	Dichlorodiphenyltrichloroethane
EC	Environment Canada
GLNPO	Great Lakes National Program Office
GLOS	Great Lakes Observing System
IADN	Integrated Atmospheric Deposition Network
NOAA	National Oceanic and Atmospheric Administration
PAH	Poly-aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
SOLEC	State of the Lakes Ecosystem Conference
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOC	Volatile Organic Compounds

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EXECUTIVE SUMMARY

The Great Lakes Monitoring Inventory and Gap Analysis, funded through a grant from the Joyce Foundation, is the first attempt to develop a comprehensive binational inventory of monitoring programs in the Great Lakes basin and evaluate current levels of monitoring efforts against regional monitoring needs. Working with federal, state/provincial, and local organizations, the Great Lakes Commission developed a comprehensive database of descriptive information on current monitoring programs in the Great Lakes basin. In total, information describing more than 600 monitoring programs is contained in the Great Lakes Monitoring Inventory.

Following the initiation of the Great Lakes Monitoring Inventory and Gap Analysis project, the Binational Executive Committee (BEC), a committee composed of the U.S. Environmental Protection Agency (US EPA), Environment Canada, state agencies, tribal authorities, and other representatives, requested the development of a framework for a similar regional monitoring inventory effort. The Great Lakes Commission participated in the BEC planning meetings, and, in addition, scheduled several coordination meetings of its own. In order to avoid duplication of effort, it was agreed that all data collected through the Great Lakes Commission and BEC inventory efforts would be mutually exchanged.

Results of the Great Lakes Monitoring Inventory indicate that the majority of sampling programs are found at the state/provincial level, followed by federal government, local government, university, nongovernmental organizations and private organizations. In total, 521 programs were reported for the U.S. portion of the Great Lakes basin, with 123 programs reported for the Canadian portion of the basin. Results indicate that while state agencies manage the largest percentage of reported U.S. monitoring programs, the majority of Canadian monitoring is conducted by the Canadian federal government. The combined U.S. and Canadian monitoring inventory results indicate fairly even geographic distribution of monitoring efforts across the Great Lakes. Results of the monitoring inventory will be available to Great Lakes resource managers and the general public through a web-based, fully searchable database.

A core set of Great Lakes monitoring needs was established to serve as the foundation for analyzing gaps and overlaps in Great Lakes monitoring programs. Indicators established under the U.S.-Canadian State of the Lakes Ecosystem Conference (SOLEC) process were used to identify basinwide monitoring needs, divided into twenty-one monitoring categories for the Great Lakes basin. These include fish consumption, drinking water, beach safety, air, water quality, sediment quality, soil quality, groundwater, climate/weather, fish population health, wildlife ecology, aquatic invasive species, benthic and invertebrate ecology, coastal wetlands, plant ecology, habitat and community, atmospheric deposition, nutrient management, land use, erosion, and urban issues. Details of the gap analysis findings are found throughout the report and are summarized below. Most of the findings below focus on gaps in the overall, regional monitoring system. Please read individual sections of the report to gain a complete picture of the extent of monitoring in the Great Lakes basin.

Highlights from the Gap Analysis Findings

1. Fish Consumption
    - While the U.S. EPA follows procedures established by the SOLEC indicator for measuring contaminants in sport fish through boneless, skin-on fillets of the dorsal muscle, the Ontario Sport Fish Contaminant Monitoring Program tests contaminant levels from skin-off dorsal fillets.

- The Ontario program includes both dioxin and dioxin-like PCB contaminant levels for establishing fish consumption restrictions while counterparts in the U.S. rely solely on dioxin-like PCB analysis. This discrepancy in analysis methods could limit the usefulness of these data for a Great Lakes basinwide evaluation.

2. Drinking Water
   - Most drinking water monitoring is directed at evaluating treated drinking water systems. Due to the high cost of this type of monitoring, few resources are available for monitoring surface water sources. More resources may need to be directed at monitoring surface drinking water sources to get an accurate understanding of the health of the ecosystem.
   - Most states and provinces test well-water when installing wells, but subsequent testing of wells is not generally conducted for single family users. The Great Lakes basin would benefit from development of a targeted program to monitor high-risk private, single-family, well-water systems.
3. Beach Safety
   - While standards are defined at the federal level, states have been given a certain degree of autonomy to design their own monitoring programs to meet their specific needs. This has lead to a decentralization of beach monitoring activities resulting in somewhat inconsistent, disjointed monitoring efforts and beach advisory postings. While each program collects *E. coli* data, the number of sampling sites and frequency of monitoring vary considerably among states and local agencies.
4. Air Monitoring
   - There are concerns about possible network reductions due to budget cuts to ambient air monitoring programs. Concurrently, there are discussions of implementing new U.S. national standards that may require more stringent monitoring efforts. With current levels of funding it may not be possible to maintain an effective network of ambient air monitoring stations.
5. Water Quality
   - While the cost of monitoring increases each year, the level of governmental funding dedicated to water quality monitoring remains the same. The result is a continuous decrease in monitoring efforts in order to stay within previously set budgets. More effort needs to go toward allotting financial resources based on current monitoring needs rather than previously set limits.
   - Michigan's Clean Michigan Initiative bond funding system is a good example of an innovative funding source. Because of this funding system, Michigan has the resources necessary to maintain a comprehensive water quality monitoring program. This type of funding system may serve as a good example for other states and provinces seeking additional financial resources.
   - There is limited data on toxic chemical concentrations in offshore waters of the Great Lakes. It is important to note that toxic chemical concentrations are also measured via indirect methods, such as in sediments and fish tissue. More investigation is needed to determine if the benefits of monitoring the toxic chemical concentrations in water is worth the added expense when similar data are being collected in sediments and fish.
6. Sediment Quality
   - Results of the monitoring inventory also indicate that while there is a considerable amount of issue-driven sediment sampling, more baseline sediment monitoring may be needed. Currently there is little guidance on baseline sampling for open waters and nearshore areas of the basin. To successfully address SOLEC indicators, specific monitoring guidelines may need to be developed in this area.
7. Soil
   - Currently, no SOLEC indicator specifically calls for soil monitoring. To develop baseline data on soil characteristics and the potential environmental impacts of alternations, SOLEC

participants may want to consider adding an indicator to address soil composition and contamination.

- The U.S. Department of Agriculture National Resources Conservation Service manages the Soil Climate Analysis Network (SCAN). This program is the only U.S. basinwide program collecting real-time soil moisture and temperature locations in the Great Lakes basin. A need for additional sampling locations has been identified and consequently SCAN is seeking to expand its network.

8. Groundwater
    - More resources need to be directed toward monitoring groundwater discharges in the region. No specific groundwater discharge monitoring programs were reported to the inventory.
    - The USGS gauging station program monitors surface water, groundwater, and water quality extensively across the U.S. portion of the basin. Funding for many of these sampling locations comes from sources outside of USGS, such as state agencies and universities. Due to federal, state, and nongovernmental budget cuts, funding for this important program is threatened.
9. Climate/Weather
    - Overall monitoring for the climate change indicators appears to be quite complete, but the continuing need for this monitoring should be emphasized to those with budgetary oversight to ensure that monitoring coverage continues.
    - A considerable amount of weather related data is collected at land-based stations. While 47 marine buoys are present, they are not as widespread as land-based stations. These differences in spatial coverage may lead to accuracy differences between land and marine temperature models.
10. Fish Population Health
    - A Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state and provincial organizations, has been developed to address fisheries related issues. This partnership framework is a strong example of effective coordination and collaboration and may be used as a model for other areas of Great Lakes monitoring.
    - The Canadian Department of Fisheries and Oceans' Great Lakes Fish Contaminants Surveillance Program has been collecting important fish contaminant data since 1977. Funding for this program was cut in the spring of 2005. This has created a gap in regional fish contaminant monitoring and interrupts one of the few Great Lakes long-term fish contaminant monitoring programs capable of documenting trends and changes in the Great Lakes basin.
    - Results of the inventory indicate that more fish habitat monitoring is needed in the Great Lakes basin at both the federal and state/provincial levels in order to fully address SOLEC indicators.
11. Aquatic Invasive Species (AIS)
    - The region would benefit from development of a scientifically-based early detection monitoring program. This early detection monitoring strategy should be coupled closely with a rapid response program. This type of monitoring program, which would enable regional managers to effectively and efficiently detect invasions, is important when considering the limited funds currently available.
    - The region would benefit from a coordinating body to organize and record AIS monitoring and management activities. A binational AIS monitoring office is needed to serve as a central location for coordinating monitoring activities and serve as a central resource for AIS related monitoring data.
12. Coastal Wetlands
    - Wetland ecosystem health is seen as a high priority in the region, but additional resources may be needed to reach short and long-term goals set forth by the Great Lakes Strategy released in December 2005 as part of the Great Lakes Regional Collaboration (GLRC). Implementation of a monitoring plan from the Great Lakes Coastal Wetlands Consortium, consisting of scientific and policy experts drawn from U.S. and Canadian federal agencies, state and provincial agencies, nongovernmental organizations, and other interest groups, will address most of these

goals. In addition, implementation of state wetland monitoring plans called for by the U.S. EPA Office of Wetlands, Oceans, and Watersheds may require additional resources.
- A comprehensive inventory of coastal wetlands has been completed, and landscape level changes can be computed at a coarse scale, but there are currently no programs to regularly update the individual wetland boundaries.
- There are numerous efforts to restore coastal wetlands, but no programs appear to be tracking restoration success basinwide.

13. Wildlife Ecology
    - Results indicate that Natural Heritage Inventory Programs and related biological community surveys may collect data needed to evaluate the nearshore species diversity indicator. Two potential limitations are:
        - Datasets are primarily land-based; and
        - The scope may not be focused enough.
    - Wildlife managers in the region and SOLEC decisionmakers should re-evaluate the wildlife monitoring needs of the Great Lakes basin to determine how best to fill in potential monitoring gaps and coordinate individual species monitoring programs.
14. Benthic and Invertebrate Ecology
    - General monitoring for benthic macroinvertebrate abundance and diversity may be sufficient (except in the Lake Superior basin), but native species may be overlooked.
    - Zooplankton and phytoplankton are regularly collected at only eleven sites throughout the basin. Also, monitoring for *Diporeia* and *Hexagenia* is limited to only a few programs in single lake basins. These programs need to be expanded if a better understanding of the population dynamics of these species is desired.
    - There are a number of programs monitoring mussel populations, but further investigation is needed to determine if this provides an adequate thorough enough investigation into these sensitive native species whose population viabilities are threatened.
15. Plant Ecology
    - Forest age-class and forest successional stage data collection appears to be limited.
    - Little monitoring data are available regarding insect or disease monitoring in terrestrial plant communities.
    - A number of SOLEC indicators need to be further defined in order to properly assess data availability.
16. Habitat and Community
    - A standardized habitat classification map for the entire Great Lakes basin would be highly useful for bringing habitat monitoring together for a basinwide assessment and for focusing stewardship efforts.
    - The Illinois Department of Natural Resources Critical Trends Assessment Program provides a strong example of using species and habitat occurrence data as a foundation for assessing habitat conditions and ecological health. Expansion of this type of program throughout the entire Great Lakes basin would improve availability of important habitat quality information.
17. Atmospheric Deposition
    - The Integrated Atmospheric Deposition Network (IADN) appears to be the only program collecting information on the parameters necessary to evaluate SOLEC's Atmospheric Deposition of Toxic Chemicals indicator. A potential limitation of IADN lies in the distribution of sampling stations and in the corresponding activities at each station.
    - The necessary spatial frequency of sampling locations remains unknown. Atmospheric monitoring of dioxin and mercury is particularly costly, so more research should be conducted to determine the appropriate spatial distribution of atmospheric deposition sampling locations.
18. Nutrient Management

- Additional effort should be made to compare results from nutrient and pesticide management programs (i.e., rates of growth in implementation) with direct monitoring of nutrients and pesticides in surface waters.

19. Land Use
    - Potential limitations to the USGS National Land Cover Characterization Project and the NOAA Coastal Change Analysis Program (C-CAP) are the time periods between dataset development, the spatial resolution of the imagery, and the level of detail of the classification system.
    - A more detailed analysis, focused on evaluating specific GIS data needs and availability, should be conducted to identify specific gaps or overlaps in land use and land cover data.
20. Erosion
    - Comprehensive coastal erosion monitoring programs like Pennsylvania's Bluff Recession Monitoring project and Ohio's Lake Erie Coastal Erosion Study are valuable examples of coastal erosion monitoring. It would be useful from a basinwide perspective if other states and provinces in the basin were to implement such monitoring programs.
21. Urban Issues
    - Results indicate that wastewater treatment programs are focused primarily at the local and municipal level. The focus of the Great Lakes Monitoring Inventory did not make it possible to evaluate wastewater treatment monitoring efforts, because the inventory focused primarily on federal and state programs. Additional effort is needed to fill in these informational gaps in the inventory.

Conclusions and Recommendations

The Great Lakes Monitoring Inventory and Gap Analysis is the first comprehensive resource developed to report on monitoring activities in the basin and how these activities meet previously set goals to assess and protect the environmental health of the Great Lakes basin. Recommendations have been developed based on results from the inventory and the analysis of gaps and overlaps in monitoring efforts. In addition, the draft report was circulated to Canadian and U.S. monitoring organizations throughout the basin and Commission staff held conference calls with a broad array of monitoring technical staff as part of the review process. Recommendations are divided into two categories: recommendations for improving the Great Lakes basin monitoring network and recommendations for conducting future inventory update efforts.

Monitoring Community Recommendations

These recommendations, based on the results of the monitoring inventory and gap analysis, are general recommendations directed at improving the monitoring network in the region.

1. Form coordinating bodies to organize monitoring efforts in key issue areas. Formation of such coordinating bodies was suggested as a necessary element for effective management of monitoring efforts. An example of such a partnership can be seen in the Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state and provincial organizations, that has been developed to address fisheries related issues. This partnership framework is a strong example of effective coordination and collaboration and may be used as a model for other areas of Great Lakes monitoring.

2. Encourage regular discussions among individuals managing similar monitoring programs. There is currently limited interaction between program managers managing similar monitoring efforts in different parts of the Great Lakes basin within a number of monitoring areas. Conference calls

conducted as part of this project led to a number of sideline discussions among program managers about the discrepancies of individual monitoring protocols across the basin. These types of open discussions will increase coordination and collaboration across monitoring programs, leading to more comparable datasets to evaluate basin wide trends.

3. The monitoring inventory should be used by the SOLEC indicator working groups as a resource for information on monitoring efforts currently taking place in the region. Currently there is no systematic process in place for identifying monitoring efforts that address each SOLEC indicator. The Great Lakes Monitoring Inventory and Gap Analysis provides the foundation for identifying relevant monitoring efforts. During the next review of SOLEC indicators, reviewers should examine the inventory and this report to better document monitoring programs under each indicator.

4. Evaluate monitoring needs, costs, and current regulations prior to establishing funding levels. Funding levels should be based on resources needed to meet previously set monitoring objectives and regulatory requirements. Funding levels also need to account for constantly changing monitoring costs.

5. Monitoring programs need to be assessed for compatibility. Reporting on SOLEC indicators requires an assessment of programs collecting data and a comparison of results across these programs. In many cases, monitoring for a given indicator is accomplished by a number of programs at various organizations, and often for purposes other than reporting for basinwide indicators. Before summarizing data together from these disparate datasets, it is critical that a compatibility analysis be conducted to determine if the monitoring methods, data analysis and reporting elements are comparable between programs. If they are not, steps should be taken to better coordinate programs to allow for direct comparison and aggregation of data.

6. Federal and state monitoring mandates should respond more directly to regional basinwide monitoring needs. Many of the programs included in the inventory are national in scope and are designed to meet national objectives. Often, these objectives are not compatible with the informational needs of the Great Lakes or other regions. Regional offices of federal agencies need to work to encourage program administrators to allow greater discretion and flexibility to address regional needs. Similarly, state and provincial and critical local or nongovernmental programs need to have the flexibility to be altered to address regional information needs. Without this flexibility, data generated by more narrowly defined monitoring programs may not be useable in a regional context, resulting in monitoring inefficiencies or ineffectiveness.

7. Encourage regional and local level participation at planned monitoring coordination meetings. Regional and local agencies perform a great deal of monitoring in the basin, as the results from the monitoring inventory demonstrate. Their experience and data can be extremely valuable to basinwide monitoring coordination efforts and, if included, could lead to greater monitoring efficiency and effectiveness. Monitoring program managers at state/provincial and key local or nongovernmental organizations should be included in monitoring coordination meetings and conferences so that they can take part in monitoring network design.

8. Short-term, small-scale monitoring programs should be balanced with basinwide monitoring initiatives. Monitoring is needed at a variety of levels to address numerous objectives. Both small-scale and basinwide monitoring programs are taking place widely across the basin. Each of these levels of monitoring can provide a great deal of value, and when analyzed in conjunction with one another to provide a deeper understanding of the Great Lakes ecosystem. The Great Lakes monitoring community needs to engage in a direct assessment of monitoring needs and capacities

to determine how best to balance the needs for narrowly targeted monitoring with the needs for broad-based, long-term monitoring. When data are not compatible and cannot be made to be compatible, the region needs the ability to set priorities between competing needs.

9. State and regional monitoring programs should better utilize citizen-based or volunteer resources. The monitoring inventory includes a number of examples of citizen or volunteer-based monitoring programs. Often these programs are designed to raise the public's awareness of environmental issues, but in many cases, the programs include thorough quality assurance designed to generate credible data. The vast availability of volunteer resources should not be overlooked, as they may provide a cost-effective way to collect broad-scale status and trends data. State/provincial, regional, and federal programs should assess the viability of using volunteer data to enhance the effective monitoring breadth of their programs.

Great Lakes Monitoring Inventory Improvements

The value of the Great Lakes Monitoring Inventory is directly tied to its accuracy and completeness. Development of a comprehensive monitoring inventory is a large-scale, regional effort that takes into account many factors, including participation by the full range of monitoring organizations, as well as information accuracy and completeness. The authors of this report made extensive efforts to collect complete information on the full range of monitoring programs in the basin; however, as the first attempt at an initiative of this scale, it is likely that a number of programs were overlooked. In order to improve the utility and the validity of this tool and the associated recommendations for improving monitoring coverage and coordination, steps need to be taken to ensure that the Great Lakes Monitoring Inventory accurately and completely reflects monitoring activities in the Great Lakes basin.

The following is a list of recommendations for addressing potential gaps in the monitoring inventory data collection efforts.

1. More detailed information is needed on monitoring efforts in the Canadian portion of the Great Lakes basin. . At the time of completion of this report, the representation of Canadian programs in the Great Lakes Monitoring Inventory is limited. The Binational Executive Committee (BEC) monitoring inventory development team focused primarily on collecting information on Canadian monitoring programs, while the Great Lakes Monitoring Inventory focused primarily on U.S. monitoring activities. This split was made to avoid duplication of effort. It was agreed that all program information collected by both parties would be mutually exchanged. The lack of Canadian monitoring program information in the Great Lakes Monitoring Inventory may be the result of several factors, including 1) the BEC inventory timeline for data collection did not correspond to the Great Lakes Monitoring Inventory timeline; 2) a more passive data collection effort was employed by the BEC monitoring inventory; or 3) limited monitoring efforts in the Canadian portion of the basin. It should be noted that the Canadian entries that have been submitted into the inventory lack the depth needed to analyze monitoring efforts in sufficient detail. This makes it difficult to perform a valid comparison across monitoring efforts in both Canada and the United States in many cases.

2. The completeness and accuracy of the monitoring inventory needs to be regularly evaluated by the Great Lakes monitoring community. While every attempt was made to include all current monitoring programs in the monitoring inventory, programs may have been missed or incompletely represented. A thorough review was conducted prior to publication of this report but it will be important to regularly review the inventory throughout its life so that entries remain current and new programs are added.

3. More information on specific monitoring locations is needed. While programs were asked to submit specific sampling station locations, a minority of program managers provided this level of detail. The result is that the geographic analysis included in the gap analysis is based in large part on general geographic descriptions. The analysis would be much improved with a complete set of monitoring locations included for each program in the database. As the inventory is updated, it is important that particular emphasis be placed on obtaining monitoring location information.

4. More information is needed on the funding sources that support monitoring programs. This information is necessary to perform an accurate and complete analysis of current funding patterns, reliability of these funding sources and funding needs to address monitoring gaps. While the authors of this report attempted to analyze the reliability and sustainability of funding for monitoring in each analytical section of the gap analysis, in most cases, the funding information was too incomplete to draw realistic conclusions. As the inventory is updated, it is important that emphasis be placed on documenting funding sources and amounts for each monitoring program.

5. Program descriptive information needs to be expanded. For many monitoring program entries, only a subset of the requested information was submitted or available. Much of the information contained in the database was collected from public resources and this information is incomplete. These information gaps were described in each section of the gap analysis. It is important to complete entries for those programs in the inventory with missing information.

6. Active, ongoing data collection efforts should be continued through the Binational Executive Committee monitoring inventory effort. As noted above, the entire database of monitoring programs collected through this initiative was shared with the BEC monitoring inventory team. As the parties to the BEC have been called upon to complete this inventory and use it for further planning and coordination of monitoring activities, it may be incumbent upon the BEC's representative agencies to continue management of the inventory.

7. The Binational Executive Committee Monitoring Inventory field list should be expanded. Expansion of the field list included in the BEC inventory is necessary to capture important elements associated with monitoring efforts, many of which have been captured by the Great Lakes Monitoring Inventory effort. Some of these include funding source, budget, sampling protocol, sampling parameters, sampling station locations, and staff description. Without this information, it is difficult to use the BEC inventory for assessment or coordination purposes.

Conclusions

The Great Lakes Monitoring Inventory includes hundreds of important monitoring programs that each contribute to our overall knowledge about the Great Lakes ecosystem. Each program, in its own way, enhances the effectiveness of resource management in the region. However, few of these programs are designed to yield broad information about the status and trends of Great Lakes resources as a whole. This gap analysis illustrates many, but not all, of the gaps in environmental monitoring at the basinwide level. It is imperative that the monitoring community and the resource managers they serve seek ways to coordinate and combine their knowledge so that Great Lakes resources may be effectively managed as an integrated system. In this way, the monitoring community may make the whole system truly greater than the sum of its parts.

Great Lakes Monitoring Inventory and Gap Analysis

Highlighting Monitoring Activities and
Recommendations for Addressing Shortfalls and
Improving Monitoring Coordination in the Great Lakes Basin

Section I. Introduction

The Great Lakes basin, the largest freshwater system in the world, contains more than 20 percent of the world's freshwater supply and more than 95 percent of the surface freshwater found in the United States. The more than 30 million people who live in the Great Lakes basin – roughly ten percent of the U.S. population and 30 percent of the Canadian population -- benefit from the drinking water, transportation, power, recreation and other benefits provided by the lakes. The Great Lakes watershed encompasses all of the state of Michigan as well as parts of Illinois, Indiana, Minnesota, New York, Ohio, Pennsylvania, Wisconsin and the Canadian provinces of Ontario and Quebec.

As population growth and industrialization pressures increase, the Great Lakes basin faces increasing environmental threats. Currently many efforts are underway to document and monitor the environmental health of the basin. While the Great Lakes basin benefits from the efforts of a multitude of monitoring and data collection agencies and organizations, there remains a great deal of additional progress required in the area of monitoring program coordination and collaboration. This need has been highlighted in recent years by the increasing demand for a more holistic and regionally consistent assessment of the health of the Great Lakes.

In a recent report, the U.S. Government Accountability Office (GAO) concluded that monitoring strategies in the basin are not coordinated in such a way to ensure effective use of limited resources available.[1] The report also states that, at the time the report was released in September 2004, there was no centralized repository of information on monitoring activities. Furthermore, it stated that without such information it is difficult to coordinate existing data and determine what additional information is needed to establish baseline conditions and assess progress toward restoration goals.

The Great Lakes Regional Collaboration (GLRC) is a wide-ranging, cooperative effort to design and implement a strategy for the restoration, protection and sustainable use of the Great Lakes. In 2003, the Great Lakes governors identified nine priorities for Great Lakes restoration and protection. Since their release, these priorities have been adopted by the Great Lakes mayors, the Great Lakes Commission and other Great Lakes leaders. These priorities form the organizing principle for the Great Lakes Regional Collaboration Strategy. The Great Lakes Regional Collaboration Strategy, unveiled in December 2005, specifically addressed the need for improved regional observing and monitoring systems in a chapter developed to Indicators and Information section of the GLRC strategy. The Great Lakes Monitoring Inventory provides a key building block for developing such an observing and monitoring system. Coordination with initiatives such as the Great Lakes Observing System (GLOS), an integrated observing system being developed to provide critical real-time data to the region, will further enhance data coordination and collaboration efforts.

Up to this point, an inventory of monitoring programs for the entire Great Lakes basin had not been developed. This has constrained coordination and collaboration potential among agencies both nationally and binationally. With no centralized location for monitoring program information, there has been a lack of data sharing and aggregate analysis at the basin level. Efforts have been undertaken, primarily within

individual lake basins, to coordinate data collection efforts, but until now little has been done to develop a basis for an information network focused on the Great Lakes basin as a whole.

However, one basinwide initiative deserves specific mention for its attempts to define the informational needs in the basin and develop a framework for monitoring coordination and consistent basinwide reporting. The State of the Lakes Ecosystem Conference (SOLEC), co-developed and organized by Environment Canada and U.S. EPA, is an effort to bring scientists and ecosystem managers together from across the basin to develop indicators of Great Lakes health in response to requirements in the Great Lakes Water Quality Agreement. More than a series of biennial conferences, this process has set the stage for developing a cohesive monitoring network for the basin. As described in the methodology sections below, the SOLEC indicators form the basis of the monitoring needs assessment required for an effective gap analysis. The network of SOLEC participants also provided this project with points of contact for obtaining information to complete the monitoring inventory. Further information about the SOLEC process is provided in the Needs Assessment section.

The *Great Lakes Monitoring Inventory and Gap Analysis* is the first attempt to develop a comprehensive binational inventory of monitoring programs in the Great Lakes basin and evaluate the current level of monitoring effort as they pertain directly to regional monitoring needs. By surveying federal, state, local, university, and nongovernmental organizations, a database of active monitoring programs was developed and will serve as a central location for monitoring program information for the Great Lakes region. Results of the monitoring inventory will be available to Great Lakes resource managers and the general public through a web-based, fully searchable database.

Section II. Project Overview

In 2002, The Joyce Foundation funded the Great Lakes Commission to initiate the Great Lakes Monitoring Inventory and Gap Analysis project. Working with federal, state/provincial, and local organizations, the Commission developed a comprehensive survey of current monitoring programs in the Great Lakes basin. The Great Lakes Monitoring Inventory contains a variety of descriptive characteristics, including, but not limited to, contact information, program description, parameters, geographic characteristics, program funding, and data collection procedures. With funding provided by the U.S. Environmental Protection Agency – Great Lakes National Program Office (GLNPO), the inventory was developed into a web-based, searchable resource. The inventory can be viewed at www.glc.org/monitoring/greatlakes/.

Using the results of the monitoring inventory and a list of monitoring needs derived from the SOLEC indicator list, monitoring gaps and overlaps based on geographic coverage, program content, and agency coordination were identified. Management recommendations were developed based on the results of the gap analysis to highlight opportunities for improving monitoring effectiveness and coordination in the Great Lakes basin. Specific recommendations for improving monitoring coverage and coordination across the Great Lakes basin were developed by Commission staff, with advice from a cross-section of monitoring experts. The analysis and recommendations will be distributed in a variety of forms to resource managers, federal and state legislators, and the general public.

Section III. Monitoring Inventory

A. Methods

The Great Lakes Commission worked with federal, state/provincial, and local organizations to develop a binational inventory of current monitoring programs in the Great Lakes basin. A project advisory group was created to provide input to the Great Lakes Commission staff. The group was comprised of representatives from U.S. and Canadian government, university, and nongovernmental organizations. This group was called upon to advise on the development of the database structure for the monitoring inventory, the monitoring organization contact list, and preliminary monitoring program inventory. This group was also called upon to provide input on the completeness and accuracy of the monitoring inventory and gap analysis.

The initial list of monitoring organizations and programs was based largely on results from previous monitoring inventory efforts and input from the project advisory group. For this project, monitoring was defined as any active, ongoing project collecting data used to detect environmental changes over time. The inventory effort focused exclusively on active monitoring programs; therefore, what may appear to be missing information may in fact be a discontinued program. Monitoring organizations were initially contacted via email and asked to submit descriptive information about their monitoring programs via an online survey located at http://glc.org/monitoring/greatlakes/inventory_gl.html. Telephone interviews, email, and Internet searches were also used to encourage responses and fill in missing information. The online survey remained open for more than eight months and remains active to facilitate further data collection. The information submitted to the inventory was supplied voluntarily by program managers or other individuals with knowledge about the programs in the survey. To maintain quality control and assurance, a quality assurance project plan (QAPP) was developed for the inventory and gap analysis. A copy of the QAPP can be obtained upon request.

It should be noted that the scope of the data collection effort changed slightly during the course of the project. Following the initiation of the project, the Binational Executive Committee (BEC), which is made up of representatives from U.S. and Canadian government agencies, environmental groups, industry, academia, and community groups requested the development of a framework for a similar regional monitoring inventory effort. Commission staff participated in all planning meetings coordinated under BEC's auspices, and, in addition, scheduled several additional meetings. These meetings were designed to reach agreement on the regional needs of a monitoring inventory and to coordinate the inventory's content and development requirements. Additionally, the meetings sought to determine the best strategy for developing and distributing an inventory, avoid duplication of effort, and meet the needs of basin resource managers. After making several unfruitful attempts to synchronize data collection efforts and develop a unified inventory, the Great Lakes Commission decided to focus on U.S. federal, state, local, university, and nongovernmental monitoring activities, while the BEC inventory development team focused primarily on Canadian monitoring programs. In order to avoid duplication of effort, it was agreed that all data collected through the Commission and BEC inventory efforts would be mutually exchanged.

Unfortunately, data collected through the BEC inventory did not match the depth and breadth of data collected through the Commission's inventory. As a result, there is considerably more detailed information available for monitoring programs conducted by U.S. agencies and organizations. Expansion of the information fields within the BEC inventory is necessary to capture important elements associated with monitoring efforts, many of which have been captured by the Great Lakes Monitoring Inventory effort. Some of these include funding source, budget, sampling protocol, sampling parameters, sampling station locations, and staff description. The Commission made efforts to fill in additional details for programmatic information collected by the BEC process, but much information on Canadian programs remains lacking.

Upon completion of this report the data collected through the Great Lakes Monitoring Inventory effort was delivered to the BEC monitoring inventory team.

Future enhancement, maintenance and updates will be undertaken following integration with the Great Lakes Observing System (GLOS). GLOS is a developing effort to provide wide community access to real-time and historic data on the hydrology, biology, chemistry, geology and cultural resources of the Great Lakes, its interconnecting waterways and the St. Lawrence River. GLOS is a regional node of the U.S. Integrated Ocean Observing System (IOOS) initiative. The inventory will serve as a foundational component of the GLOS data system. Over time, it will be integrated with live data collection mechanisms to move from a static inventory to a dynamic decision support system. More information about GLOS can be obtained from http://glos.us/.

B. Results

The Great Lakes Monitoring Inventory currently contains information describing more than 600 monitoring programs. The monitoring programs in the Great Lakes Monitoring Inventory range from long-term, basinwide programs run by federal agencies, to local-scale projects run by nongovernmental organizations with limited funding. The monitoring inventory contains extensive descriptive characteristics including, among others, contact information, program description, parameters measured, geographic characteristics, program funding, and data collection procedures. See Appendix A for a condensed list of monitoring programs.

Before results of the Great Lakes Monitoring Inventory are discussed, it is important to note that while considerable effort was made to collect monitoring program information, results relied on voluntary participation from monitoring agencies. Obtaining the participation of monitoring organizations and making contact with the appropriate monitoring program managers or their staff were two key factors influencing results of the inventory. The quality of information in the inventory database was also contingent on the accuracy and specificity of responses to the inventory survey, though efforts were made to clarify responses and fill in missing information through follow-up communication. In addition, in order to avoid duplication of effort, collection of Canadian monitoring program information was left primarily to the BEC monitoring inventory effort. The BEC inventory efforts employed a passive approach to data collection, so relatively little data was available, at the time this report was completed, for the Canadian portion of the Great Lakes basin. The Commission will continue to work – both independently and in cooperation with the BEC monitoring team – to complete the inventory of Canadian monitoring programs.

Results of the Great Lakes Monitoring Inventory indicate that the majority of sampling programs are found at the state/provincial level followed by federal government, local government, university, nongovernmental organizations and private organizations (Figure 1).

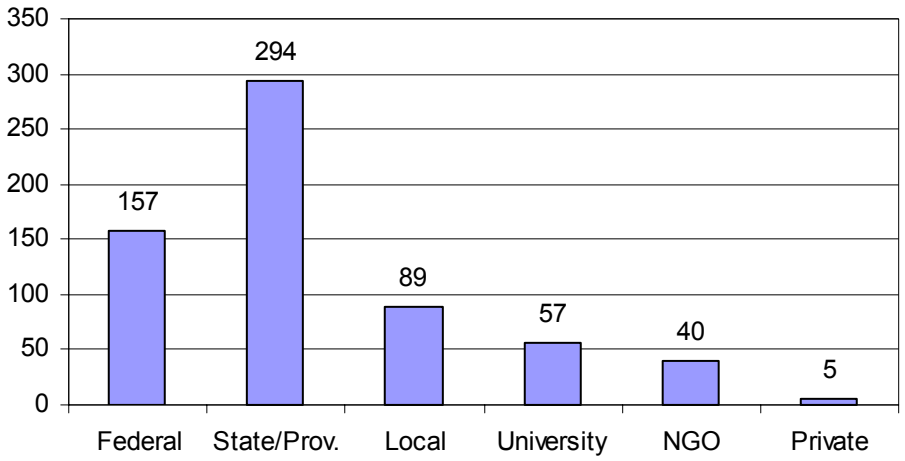

Figure 1. Monitoring programs reported for different agency groups in both U.S. and Canada.

In total, 521 programs were reported for the U.S. portion of the Great Lakes basin, with 123 programs reported for the Canadian portion of the basin. Results indicate that while state agencies manage the largest percentage of reported U.S. monitoring programs, the majority of monitoring by Canadian organizations was reported from the federal sector (Figure 2 and Figure 3).

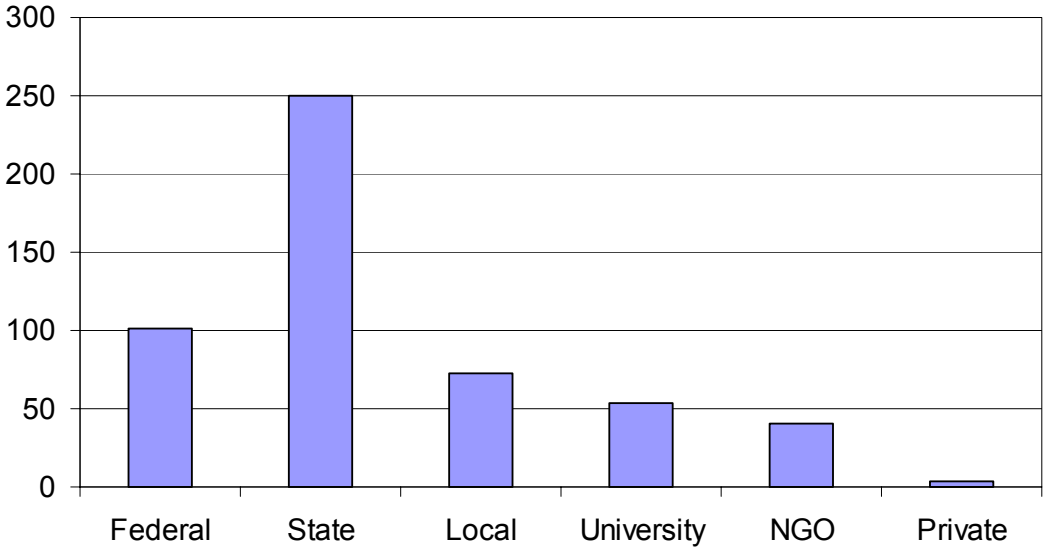

Figure 2. U.S. monitoring programs reported for different organization categories.

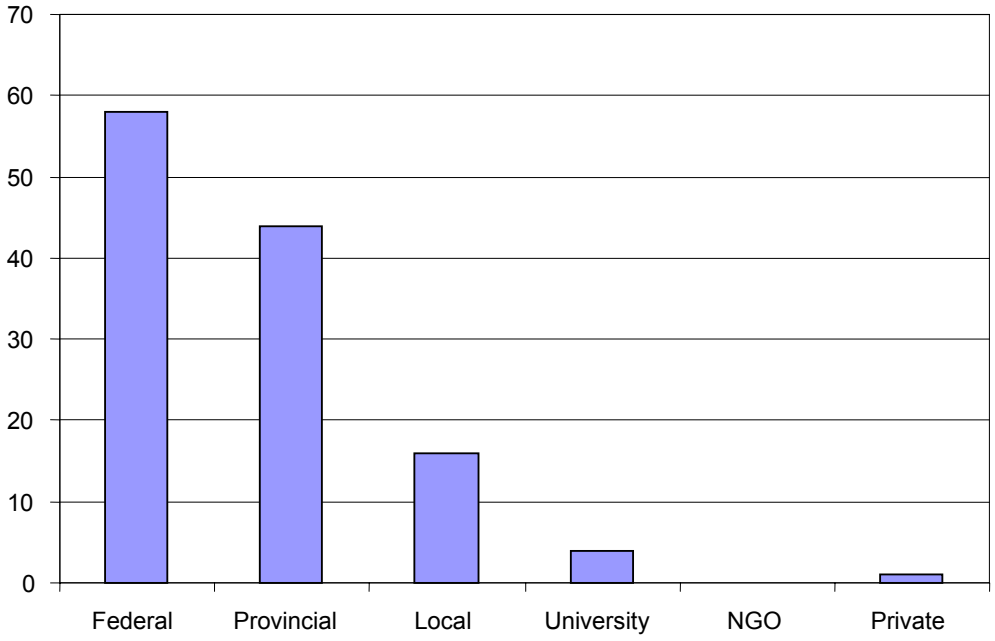

Figure 3. Canadian monitoring programs reported for different organization categories.

The combined U.S. and Canadian monitoring inventory results indicate fairly even geographic distribution of monitoring efforts across the Great Lakes. The greatest number of programs were reported from the Lake Erie basin (341 monitoring programs) followed by Lake Michigan with 299, Lake Superior with 240, Lake Ontario with 198, and Lake Huron with 165 (Figure 4). These numbers include lake basin specific and multi-lake basin monitoring programs.

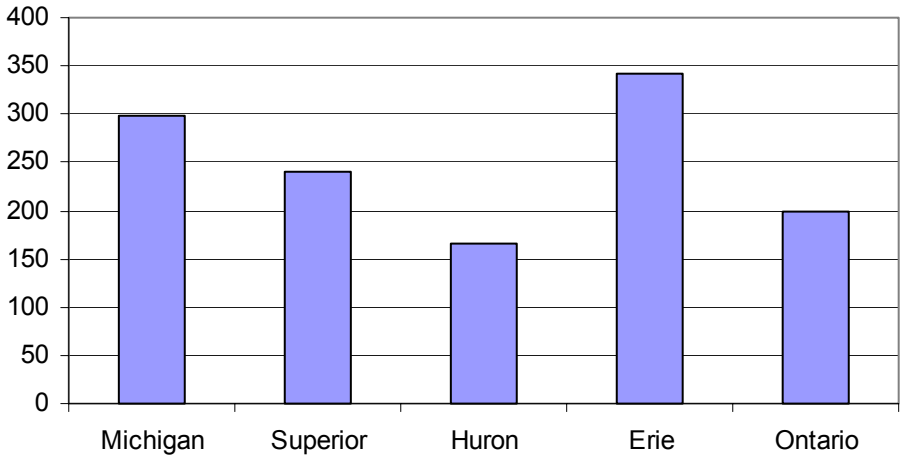

Figure 4. Number of monitoring programs reported for each of the Great Lakes.

Results of the monitoring inventory are available to Great Lakes resource managers and the general public through a web-based, fully searchable database. The web based inventory will include an interactive map of sampling station locations for associated monitoring programs as well as the fully searchable database. The

inventory can be found online at www.glc.org/monitoring/greatlakes/. Results of the Great Lakes Monitoring Inventory, in combination with the needs assessment discussed in the following section, were used to evaluate gap and overlaps in Great Lakes monitoring activities.

Section IV. Needs Assessment

A core set of Great Lakes monitoring needs was established to serve as the foundation for analyzing gaps and overlaps in Great Lakes monitoring programs. Because the value of monitoring programs is tied closely with how well the resulting data address key environmental concerns, there is great utility in aligning and evaluating monitoring programs based on these environmental concerns. Therefore, the SOLEC indicators were used as the foundation for a needs assessment for the Great Lakes basin and a list of key monitoring needs was established.

In 1998, SOLEC developed a set of indicators to serve as a baseline for environmental status and trends in the Great Lakes basin. The SOLEC conference is held every two years and an indicator report is generated in the off years in response to reporting requirements in the Great Lakes Water Quality Agreement (GLWQA). The conferences are hosted by the U.S. Environmental Protection Agency and Environment Canada on behalf of the two countries with the purpose of restoring and maintaining the physical, chemical and biological integrity of the Great Lakes Basin.

Since its inception in 1998, the SOLEC indicator list has been modified to include 84 primary indicators for which experts within the Great Lakes – St. Lawrence River community periodically generate reports. The generation of SOLEC indicator assessment reports relies upon access to supporting data. The 2003 SOLEC Peer Review Report raised a concern regarding the lack of standardization and the subjective nature of the current indicator assessment process.[2] Data identification is often based on informal surveys and best professional judgment. By using the SOLEC indicators as the framework for the Great Lakes needs assessment, the Great Lakes Monitoring Inventory and Gap Analysis project not only identifies monitoring programs that address the SOLEC indicators, it also assesses gaps and overlaps in current monitoring efforts.

Using the SOLEC indicators as the basis, twenty-one monitoring needs were identified for the Great Lakes basin. In order to condense the number of indicators to a more manageable number, the indicators were grouped into four general categories. See Table 1 for a list of the Great Lakes monitoring needs developed for this project and the associated SOLEC indicators.

Table 1. Great Lakes monitoring needs and related SOLEC indicators.

Monitoring Need	SOLEC Indicator (Indicator Number)
Human Health	
Fish Consumption	Contaminants in Sport Fish (#4201)
Drinking Water	Drinking Water Quality (#4175)
Beach Safety	Beach Advisories, Postings and Closures (#4200)
Air	Air Quality (#4202)
Habitat and Biodiversity	
Fish Population Health	Fish Habitat (#6) Salmon and Trout (#8) Walleye (#9) Preyfish Populations and Communities (#17) Lake Trout (#93) Contaminants in Young-of-the-Year Spottail Shiners (#114) Contaminants in Whole Fish (#121) External Anomaly Prevalence Index for Nearshore Fish (#124) Status of Lake Sturgeon in the Great Lakes (#125)
Wildlife Ecology	Contaminants in Colonial Nesting Waterbirds (#115) Contaminants Affecting Productivity of Bald Eagle (#8135)

Monitoring Need	SOLEC Indicator (Indicator Number)
	Nearshore Species Diversity and Stability (#8137) Contaminants Affecting the American Otter (#8147) Breeding Bird Diversity and Abundance (#8150) Threatened Species (#8161)
Non-native Species	Sea Lamprey (#18) Exotic Species (#9002)
Benthic & Invertebrate Ecology	Native Freshwater Mussels (#68) Benthos Diversity and Abundance (#104) Phytoplankton Populations (#109) Zooplankton Populations (#116) Hexagenia (#122) Benthic Amphipod (Diporeia spp.) (#123) Nearshore Species Diversity and Stability (#8137)
Coastal Wetlands	Coastal Wetland Invertebrate Community Health (#4501) Coastal Wetland Fish Community Health (#4502) Coastal Wetland Amphibian Diversity and Abundance (#4504) Contaminants in Snapping Turtle Eggs (#4506) Wetland-Dependent Bird Diversity and Abundance (#4507) Coastal Wetland Area Extent by Type (#4510) Coastal Wetland Restored Area by Type (#4511) Sediment Flowing into Coastal Wetlands (#4516) Phosphorus and Nitrogen Levels (#4860) Effect of Water Level Fluctuations (#4861) Coastal Wetland Plant Community Health (#4862) Land Cover Adjacent to Coastal Wetlands (#4863) Human Impact Measures (#4864)
Plant Ecology	Health of Terrestrial Plant Communities (#8162) Forest Health Criterion #1: Conservation of Biological Diversity (#8500) Forest Health Criterion #2: Maintenance and Productive Capacity of Forest Ecosystems (#8501) Forest Health Criterion #3: Maintenance of Forest Ecosystem Health and Vitality (#8502) Forest Health Criterion #4: Conservation and Maintenance of Soil and Water Resources (#8503)
Habitat and Community	Area, Quality, and Protection of Lakeshore Communities (#8129) Nearshore Species Diversity and Stability (#8137) Protected Nearshore Areas (#8149) Status and Protection of Special Places and Species (#8163)
Land Use and Human Impact	
Atmospheric Deposition	Atmospheric Deposition of Toxic Chemicals (#117) Acid Rain (#9000)
Nutrient Management	Sustainable Agricultural Practices (#7028) Nutrient Management Plan (#7061) Integrated Pest Management (#7062)
Land Use	Land Cover-Land Conversion (#7002) Ground Surface Hardening (#7054) Habitat Fragmentation (#8114) Extent of Hardened Shoreline (#8131) Nearshore Land Use (#8132) Extent and Quality of Nearshore Natural Land Cover (#8136)

Monitoring Need	SOLEC Indicator (Indicator Number)
	Artificial Coastal Structures (#8146)
Erosion	None
Urban Issues	Commercial/Industrial Eco-Efficiency Measures (#3514) Household Stormwater Recycling (#3516) Urban Density (#7000) Brownfield Redevelopment (#7006) Water Withdrawal (#7056) Energy Consumption (#7057) Solid Waste Generation (#7060) Municipal Wastewater Treatment (#7063) Vehicle Use (#7064)
General Monitoring	
Water Quality	Phosphorus Concentrations and Loadings (#111) Toxic Chemical Concentrations in Offshore Waters (#118)
Sediment Quality	Concentration of Contaminants in Sediment Cores (#119) Sediment Available for Coastal Nourishment (#8142)
Soil	None
Groundwater	Natural Groundwater Quality/Human-Induced Changes (#7100) Groundwater and Land: Use and Intensity (#7101) Base Flow Due to Groundwater Discharge (#7102) Groundwater Dependent Animal and Plant Communities (#7103)
Climate/Weather	Climate Change: Ice Duration on the Great Lakes (#4858) Climate Change: Effect of Crop Heat Units (#9003)

These Great Lakes monitoring needs serve as the basis of comparison and analysis within the monitoring gap analysis. There are a number of SOLEC indicators that were not addressed through this process. These include Commercial/Industrial Eco-Efficiency Measures (#3514), Household Stormwater Recycling (#3516), Biologic Markers of Human Exposure to Persistent Chemicals (#4177), Geographic Patterns and Trends in Disease Incidence (#4179), and Economic Prosperity (#7043). In addition, the monitoring inventory did not target economic, epidemiological or social monitoring and, therefore, no relevant information was collected to evaluate these indicators. It is also important to note that a few of the SOLEC indicators fall into more than one need category.

Section V. Gap Analysis

A. Methods

Determining the extent of current monitoring programs and understanding where gaps in monitoring exist is an important first step in achieving broad coordination and collaboration among monitoring organizations. Understanding the scope of monitoring performed and how it relates to Great Lakes basin monitoring needs is also crucial in order to develop of an effective and efficient regional monitoring strategy.

To identify gaps and overlaps in monitoring efforts, the monitoring inventory was evaluated within the structure of the monitoring needs assessment. The 21 monitoring needs categories are closely aligned with the SOLEC indicators established to target regional restoration goals. (See Table 1 in the previous section for links between these key management need areas and SOLEC indicators.) To conduct this analysis, the monitoring programs were first associated with one or more of the indicators by examining the program goals and description. The indicators were then assessed by comparing monitoring program characteristics with the purpose and intent of each indicator as defined through the SOLEC process. Throughout this report any mention of indicators refers to the SOLEC indicators. Commission staff specifically examined each monitoring program or group of programs addressing a given indicator by geographic distribution, sampling frequency (or level of effort), parametric specificity and programmatic sustainability (as determined by the stability and source of funding). Each of the monitoring needs categories presented below reviews current monitoring programs followed by a findings section that addresses potential monitoring gaps and possible areas to focus on to increase efficiency of monitoring programs in the basin.

Following the development of gap analysis findings and results, a set of recommendations was developed by Commission staff. These recommendations are contained in Section VI. A complete draft report was developed to include the monitoring inventory results, gap analysis findings and staff recommendations. This report was circulated broadly for review and comment throughout the monitoring community in the Great Lakes basin. In addition, a set of conference calls was established to coordinate feedback and advice from monitoring experts on specific sections of the report. Experts were recruited from all levels of government and several academic institutions. The reviewers helped to fill information gaps in the inventory, correct errors and inaccuracies, comment on recommendations, and suggest additional areas for analysis and management recommendations. A list of these reviewers by topic area conference call is included in Appendix B.

B. Results

Programs in the monitoring inventory were analyzed in relation to previously-identified monitoring needs for the Great Lakes basin. Related needs are grouped into four sections addressing the broad categories of Human Health; General Monitoring; Habitat and Biodiversity; and Land Use and Human Impact.

The findings presented in this section represent potential monitoring gaps or areas of concern in the Great Lakes basin monitoring efforts as reported to the Great Lakes Monitoring Inventory. As the monitoring inventory evolves and becomes more complete, it may be found that the gaps initially identified are not truly gaps but rather missing information.

1. Human Health

a. Fish Consumption

A major human health concern in the Great Lakes basin is consumption of contaminated fish. Bioaccumulation, the build-up of chemicals from the environment in the aquatic food chain, is the primary reason for the high contaminant concentrations in Great Lakes fish. Through environmental deposition or direct environmental pollution, chemical contaminants are fed into an ecosystem and, in turn, absorbed into tissues of organisms in that ecosystem. The concentration of some chemicals in the tissues of top predators, such as lake trout and large salmon, can be millions of times higher than the concentration in the water. Some of the contaminants of concern are mercury, polychlorinated biphenyl (PCB), and persistent bioaccumulative toxic chemicals[3].

States and provinces have primary responsibility for developing their own fish consumption guidelines to protect the public from health risks associated with eating contaminated fish. The primary contaminants that are generally monitored are mercury, PCBs, chlordane, dioxins, and DDT. Using fish contaminant levels collected from state wide monitoring programs and accepted human levels of contaminated fish consumption, U.S. states typically issue five types of advisories and bans, including no-consumption advisories for the general population, no-consumption advisories for sensitive subpopulations, restricted-consumption advisories for the general population, restricted-consumption advisories for sensitive sub-populations, and commercial fishing ban [4].

The goal of the Contaminants in Sport Fish (#4201) indicator is to assess the levels of mercury, dioxin and PCBs in Great Lakes sport and commercial fish and determine the potential harmful effect of consumption of contaminated fish on human health. Official SOLEC requirements of this indicator are to determine contaminant levels from a 5 fish composite made up of boneless, skin-on fillets of the dorsal muscle. Based on inventory results, the Great Lakes region has 18 monitoring programs that address fish consumption concerns related to human health. Each of the eight Great Lakes states and the province of Ontario has dedicated fish contaminant monitoring programs. These programs will be discussed in more detail below.

Illinois – Illinois Environmental Protection Agency manages the state's *Fish Contaminant Monitoring Program*. The objectives of the Illinois *Fish Contaminant Monitoring Program* are to detect the presence and build-up of toxic and potentially hazardous substances in fish; determine the impact of fish contaminants upon aquatic environments; and provide information to aid in the location of contaminant discharge. In the small portion of Illinois that lies within the Great Lakes basin, there are 17 areas where fish advisory data are collected. Data are collected on mercury, PCB, and a number of other pesticides and contaminants, but there is no specific mention of dioxin. No specific information is available on sampling frequency or funding.

HIGHLIGHT – Fish Consumption

- While the U.S. EPA follows the procedures established by the SOLEC indicator for measuring contaminants in sport fish through boneless, skin-on fillets of the dorsal muscle, the Ontario Sport Fish Contaminant Monitoring Program tests contaminant levels from skin-off dorsal fillets.
- The Ontario program includes both dioxin and dioxin like PCBs contaminant levels for establishing fish consumption restrictions while counterparts in the U.S. rely solely on dioxin like PCB analysis. This discrepancy in analysis methods could limit the usefulness of these data for a Great Lakes basinwide evaluation.

Indiana – Indiana Department of Environmental Management manages the *Fish Tissue Contaminants Monitoring Program*. The goal of this program is to support issuance of fish consumption advisories, monitor for trends, and collect information on effects to wildlife. The primary sampling parameters are percent moisture, percent lipid, metals, organochlorine compounds, PAH, PBDE, semivolatiles, and VOC. This program reported that currently there are more than 40 sampling locations that cover the entire Lake Michigan and Lake Erie watershed within the State of Indiana on a rotating 5 year basis. Sites are selected to cover a large number of locations including sites specifically on the St. Joseph River, Trail Creek, Burns Harbor, the Grand Calumet River/Indiana Harbor Canal, the St. Joseph (Erie), St. Mary's and Maumee

River. It was reported that the state of Indiana provides the funding for this program but no specific information was given regarding which type of funds are used.

Michigan – The objectives of Michigan Department of Environmental Quality's *Fish Contaminant Monitoring Program* are to evaluate the need for sportfish consumption advisories and commercial fishing regulations; identify spatial and temporal trends, and evaluate the effectiveness of existing programs. Twenty six fixed station sampling sites monitor whole fish for mercury, PCBs, and pesticides biennially. Edible portion samples are collected for analysis to support consumption advisory development. The number and location of these sites varies from year to year. Caged fish studies have been conducted to varying degrees in about 40 watersheds. Studies are repeated as needed in problematic watersheds. While monitoring efforts include sampling contaminants in caged fish, edible portion and whole fish, only a subset of the data includes information relevant to the Contaminants in Sport Fish (#4201) indicator, which requires testing of the edible portion of the fish. Primary funding for this project comes from Michigan's general state funds and the Clean Michigan Initiative.

Minnesota – Minnesota Department of Natural Resources manages the state's *Fish Contaminant Monitoring Program*. Approximately every 5 years, this program samples and analyzes for contaminants, including mercury and PCBs, in common fish species. There was no specific mention of dioxin monitoring. Funding for this program comes from the state general fund and also the game and fish fund.

New York – New York State Department of Environmental Conservation manages the state's *Sportfish Contamination* program. This program monitors fish contamination throughout New York waters for PCBs, organochlorides, mercury, and dioxins. No further information is available on sampling frequency or funding.

Ohio – The Ohio Environmental Protection Agency manages *Ohio's Sport Fish Tissue Monitoring Program*. This program collects fish samples and evaluates the tissue contaminant data to issue the appropriate fish consumption advisories. The parameters monitored for this program include chlordane, dieldrin, mirex, PCBs, DDT, mercury and heavy metals. No further information is available regarding sampling frequency or funding.

Pennsylvania – Pennsylvania Department of Environmental Protection's *Fish Consumption Advisory* program provides guidance to individuals or segments of the population at greater risk from exposure to contaminants in fish. Program officials did not provide specific information for this program.

Wisconsin – The objectives of Wisconsin Department of Natural Resource's statewide *Fish Contaminant Program* include protection of fish consumers, resource management, and environmental protection. This program has been in place since the mid-1970s. Fish are collected from approximately 50 to 100 sites each year. Current analyses include about 600 samples analyzed for mercury, 350 for total PCBs, 30 for banned pesticides, 20 for dioxin/furan analysis and 10 for PBDEs. Monitoring consists of different components including baseline, advisory, Great Lakes, and trend monitoring. Baseline Fish Contaminant monitoring focuses on sampling new sites and sites where contaminant data are old or limited, or where existing data shows that concentrations may be high and additional data would be beneficial to determine advisory needs. Advisory Fish Contaminant Monitoring refers to monitoring of fish for contaminants where PCB based fish consumption advice is in place and monitoring is conducted to update consumption advice. This monitoring is generally conducted in major industrial rivers and locations where remediation may be necessary. Great Lakes contaminant monitoring consists of collection of fish for contaminant analysis on a biennial basis. Samples include both game fish and forage fish from Lake Superior and Lake Michigan. The final component of this program is to determine trends and geographic patterns of contamination for general DNR staff use. Funding for this program currently comes from a number of sources. Collection of fish is supported by fisheries staff sampling through other programs. Analysis of samples is supported by

the Wisconsin State Laboratory of Hygiene and EPA Clean Water Act Performance Partnership Grant 106 funds. Other supplies and processing are also supported by Clean Water Act funds. Gaps include limits on the number of sites where fish can be collected each year, the number of fish that can be processed, and the number and types of analytes that can be assayed on each sample.

Ontario – Ontario Ministry of the Environment/Ontario Ministry of Natural Resources manages the *Ontario Sport Fish Contaminant Monitoring Program*. This program samples the skin-off dorsal fillets of fish collected around Ontario are analyzed for a suite of contaminants (e.g. PCBs, mercury, mirex, DDT, dioxins/furans). These contaminant levels are used to produce fish consumption restrictions (advisories) in the Guide to Eating Ontario Sport Fish. The *Sport Fish Contaminant Monitoring Program* monitors persistent toxic contaminants in sport fish in the Great Lakes and selected inland lakes and rivers. The contaminant levels are analyzed and used to develop sport fish consumption advisories (recommended meals per month) based on health protection guidelines from Health Canada. The Program advises the public on safe levels of sport fish consumption through the biennial production of the Guide to Eating Ontario Sport Fish. It should be noted that this program includes both dioxin and dioxin like PCBs contaminant level analysis for establishing fish consumption restrictions while counterparts in the U.S. rely solely on dioxin like PCB analysis.

A number of human health related fish monitoring programs take place at the federal level. U.S. EPA manages the national *Fish Consumption Advisories program*. The Great Lakes National Program Office manages the *Great Lakes Fish Monitoring Program (GLFMP)*. The GLFMP consists of two separate elements, an Open Lakes Trend Monitoring Program for whole fish (Element 1) and a Game Fish Fillet Monitoring Program (Element 2) to assess the risks of persistent and bioaccumulative contaminants on the health of the fishery, and on the fish consuming wildlife. Element 1 of the GLFMP is directed at monitoring contaminant trends in the open water of the Great Lakes, and assisting in evaluating the impacts of contaminants on the fishery. Element 2 of the GLFMP is directed at monitoring potential human exposure to contaminants through consumption of popular sport species, as well as providing temporal trend data for top predator species, which have shorter exposures than the lake trout collected in Element 1. Coho salmon and Chinook salmon are collected from Lakes Michigan, Huron, Ontario, and Superior and rainbow trout are collected from Lake Erie during the fall spawning run. Composites of each species, consisting of five individual fish fillets, are analyzed for organic contaminants to assess potential human exposure and to compare it to the meal advice set forth in the *Protocol for a Uniform Sport Fish Consumption Advisory*. These data complement those from Element 1. Trends are not meant to be concluded from Element 2, as the voluntary nature of the program does not allow for consistent collection of salmon from year to year. For trend analysis, GLNPO is currently using only the fish tissue contaminant data for coho salmon from Lake Michigan that are larger than 500 mm. The GLFMP currently collects samples, for both elements of the program, from a set number of sites per lake. Collections alternate on a yearly basis, with even and odd year collections. Element 2 samples consist of 5 skin-on fillets for a total of 15 fish collected per site. The GLFMP currently utilizes an established chemical parameter list for analysis that includes OC pesticides, PCBs, Mercury, and some emerging contaminants of concern. While EPA does not issue fish consumption advice, Great Lakes States and Tribes include GLFMP data in their data sets as a way to increase robustness.

Another federal program managed by the U.S. Geological Survey is the *National Contaminant Biomonitoring Program Database*. With 16 monitoring locations in the Great Lakes basin, this program seeks to document trends in occurrence of persistent toxic chemicals in fisheries. Parameters included in this program are PCB, dieldrin, mercury, DDT, and other contaminants. U.S. Geological Survey also manages the *National Water Quality Assessment Program* (NAWQA) which includes some fish contaminant sampling. In the Great Lakes basin the NAWQA program focuses on western Lake Michigan drainages and Lake Erie-Lake St. Clair drainages.

Another federal program working on fish contamination issues in the Great Lakes basin is the *Great Lakes Human Health Effects Research Program* (GLHHERP), conducted by the Center for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR). This program is designed to characterize exposure to contaminants via consumption of Great Lakes fish, and investigate the potential for short- and long-term adverse health effects. Rather than focusing on measuring contaminant levels in fish this program focuses on determining the effect of fish consumption on humans. This program provides the human health effects research needed for establishing fish consumption advisories.

For additional information on fish monitoring not directly related to human health please refer to the contaminants discussion in the fish ecology section of this report.

Findings – Fish Consumption

The goal of the Contaminants in Sport Fish (#4201) indicator is to assess the levels of mercury, dioxin and PCBs in Great Lakes sport and commercial fish and determine the potential harmful effect of consumption of contaminated fish on human health. Official requirements of this indicator are to determine contaminant levels from a 5 fish composite made up of boneless, skin-on fillets of the dorsal muscle. Monitoring inventory results indicate that while the U.S. EPA follows the procedures established by the SOLEC indicator for measuring contaminants in sport fish through boneless, skin-on fillets of the dorsal muscle, the *Ontario Sport Fish Contaminant Monitoring Program* tests contaminant levels from skin-off dorsal fillets. This discrepancy in analysis methods could limit the usefulness of these data for a Great Lakes basinwide evaluation.

The primary responsibility for fish contaminant monitoring and development of human health advisories lies at the state and provincial levels. The U.S. state-based fish contaminant monitoring programs appear to be funded primarily at the state level. While there are federal requirements for each state to develop fish consumption advisory guidelines and all states are participating in such projects, there is considerable variability from state-to-state in the scope of monitoring, sampling frequency, and parameters measured. The three contaminants required by the Contaminants in Sport Fish indicator include mercury, PCB, and dioxin. In all of the state-managed fish contaminant monitoring programs for which sampling parameter information was available, fish tissues were sampled for mercury and PCBs, but it appears that Illinois, Indiana, Minnesota, and Ohio do not monitor for dioxin. EPA does not issue fish consumption advice, but Great Lakes States and Tribes include data collected through the U.S. EPA *Great Lakes Fish Monitoring Program* in their data sets as a way to increase robustness.

Ontario Ministry of the Environment/Ontario Ministry of Natural Resources manages the *Ontario Sport Fish Contaminant Monitoring Program*. This program samples the skin-off dorsal fillets of fish collected around Ontario are analyzed for a suite of contaminants (e.g. PCBs, mercury, mirex, DDT, dioxins/furans). These contaminant levels are used to produce fish consumption restrictions (advisories) in the Guide to Eating Ontario Sport Fish. It should be noted that this program includes both dioxin and dioxin like PCBs contaminant levels for establishing fish consumption restrictions while counterparts in the U.S. rely solely on dioxin like PCB analysis.

Human Health
b. Drinking Water

The effort to protect drinking water quality has emerged as a key environmental issue in the Great Lakes basin. The Drinking Water Quality (#4175) indicator assesses the chemical and microbial contaminant levels in drinking water and evaluates the potential for human exposure to drinking water contaminants. This indicator is measured by the number and proportion of drinking water systems that fail to meet water

quality regulations. While federal and state agencies set and enforce drinking water standards, each supplier is responsible for the quality of drinking water produced at that facility. While municipalities and their associated drinking water systems undertake significant drinking water quality monitoring programs, the monitoring inventory did not collect monitoring information from each drinking water facility but rather collected program information at federal, state and local government levels.

The following discussion is broken down into two components: public drinking water monitoring and private well testing.

Public Drinking Water Monitoring

U.S. Environmental Protection Agency's Safe Drinking Water Act (SDWA) requires states to develop and implement Source Water Assessment Programs (SWAP) to analyze existing and potential threats to the quality of the public drinking water. Each of the states in the Great Lakes basin has completed a SWAP which includes delineation of source water protection areas; contaminant source inventory; determining the susceptibility of public water supply to contamination from the inventoried sources; and release of assessment results to the public. Because each SWAP draws data from existing state run programs, each state's SWAP will not be discussed in detail but to the extent possible the inventory will address the drinking water monitoring programs supplying data to the SWAP.

U.S. Environmental Protection Agency maintains the *Safe Drinking Water Information System (SDWIS)*. SDWIS contains information about public water systems and EPA drinking water regulation violations at these facilities. This database has been in operation since 1993. A website developed for this system provides a listing of all water systems required to submit water quality data. Public water utilities are responsible for monitoring the quality of drinking water provided. Owners of private wells are not required to monitor drinking water quality and are therefore excluded from this list.

HIGHLIGHT – Drinking Water

- Most drinking water monitoring is directed at evaluating treated drinking water systems. Due to the high cost of this type of monitoring, few resources are available for monitoring surface water sources. More resources may need to be directed at monitoring drinking water sources to get an accurate understanding of the health of the ecosystem.

- Most states and provinces test well-water when installing wells, but subsequent testing of wells is not generally conducted for single family users. The Great Lakes basin would benefit from development of a targeted program to monitor high-risk private, single-family, well-water systems.

Results of the monitoring inventory show that the following programs collect information in support of SDWIS. The Indiana Department of Environmental Management manages the *Public Water Supply Information* – an online database that provides descriptive information as well as chemical results for public water supplies. Michigan Department of Environmental Quality manages the *Public Drinking Water Chemical Database* which is the state's major source of drinking water data. The *Michigan Source Water Assessment Program* identifies areas that supply public drinking water and inventories contaminants and susceptibility of water to contamination. The Minnesota *Source Water Assessment Program* presents the results of source water assessments online and includes the contribution area for a well or intake; the susceptibility of the source of drinking water to contamination; and contaminants that are of concern to the users of a pubic water supply. Ohio EPA Division of Drinking and Ground Waters manages their *Public Water System Supervision Program* (PWSS). This program was established by the U.S. EPA to ensure that water is safe for human consumption. The Ohio EPA is responsible for scheduling chemical and bacteriological monitoring for Ohio's 5,425 public water systems, reviewing water quality results, determining compliance and enforcement of non-compliant systems. Public water system operators

monitor treated drinking water for approximately 100 contaminants on a monthly, quarterly, annual or triennial basis. The Pennsylvania Department of Environmental Protection manages the state's *Drinking Water Reporting System*. This system is an online database of drinking water facilities and sampling results. Wisconsin Department of Natural Resources manages a number of drinking water monitoring programs. The purpose of the *Groundwater Retrieval Network (GRN)* is to link groundwater data residing in various database systems into one central location for analysis. This system reports data from the Department's Public Water Supply (public drinking water supply wells), Private Water Supply (private drinking water supply wells, non-point source priority watershed projects, and special groundwater studies), the Bureau of Waste's Groundwater and Environmental Monitoring System (GEMS) (landfill wells) and the Bureau of Watershed Management's System for Wastewater Applications and Monitoring Permits (SWAMP). Wisconsin DNR also manages the *Public Water Monitoring Program* which includes monitoring of treated drinking water quality data for groundwater and surface water systems as well as untreated water quality data from groundwater systems. The Wisconsin Department of Agriculture, Trade and Consumer Protection also maintains a *Groundwater Pesticide and Nitrate Database*. Public drinking water monitoring programs found at the local level include Michigan's Oakland County *Drinking Water Supply Program, Well Protection and Education Code* and the New York Cayuga County Health Department *Public Water Supply Monitoring*.

A Canadian program complimentary to U.S. EPA's SDWIS is Ontario Ministry of the Environment's *Drinking Water Surveillance Program (DWSP)*. DWSP is a monitoring program developed to provide reliable information on municipal drinking water. DWSP is not a compliance-driven monitoring program. Rather, participation of water supply systems in DWSP is voluntary. This program monitors the chemical composition of drinking water at approximately 150 water systems. In addition Ontario Ministry of the Environment's *Provincial (Stream) Water Quality Monitoring Network (PWQMN)* collects surface water quality information from rivers and streams at over 350 strategic locations throughout Ontario.

Well-Water and Investigatory Monitoring

It appears as if most states and provinces test well-water during the well installation process but subsequent testing is not required.

The Illinois Environmental Protection Agency manages two programs that evaluate drinking water quality. Illinois' *Groundwater* program provides an overview of the groundwater conditions at community water supply wells in Illinois and provides an overview of groundwater conditions in the major aquifers in Illinois. Among a host of other tasks, the Illinois *Intensive Basin Survey* assesses the success of current procedures to meet drinking water goals. Michigan Department of Environmental Quality's *Drinking Water Contamination Investigation Program* conducts drinking water testing in areas with known or suspected environmental contamination. Minnesota Pollution Control Agency's *Ambient Ground Water Quality Monitoring* consists of a network of 100 to 150 shallow monitoring wells and 100 to 150 deeper drinking water wells. The shallow wells provide an early warning network of initial changes in water quality. The deeper wells provide information about the quality of water that people are drinking. Each well is sampled biennially. Chemical parameters include nitrate, volatile organic compounds, and chloride. The Minnesota Department of Health conducts health risk assessments relating to groundwater once contamination is detected and works with counties to establish water quality databases for private wells. Minnesota currently conducts very limited sampling in the northern areas of the state. More resources may need to be directed at this region. The New York State Department of Health Wellhead *Protection Program* works to protect the ground water sources and wellhead areas that supply public drinking water systems from contamination. In addition, the New York State Department of Environmental Conservation's Division of Water conducts *Ground Water Monitoring* throughout the state. Each year's sampling attempts to monitor selected private and public wells, surficial and bedrock wells, and other geographic areas. For Wisconsin's *Town-based Arsenic Sampling* program homeowners in Outagamie and Winnebago counties sample their

well-water for arsenic. This data set was developed to evaluate the extent of naturally occurring arsenic in private wells in Northeastern Wisconsin. The Central Wisconsin Groundwater Center administers a *Private Well-water Testing Program* which includes a comprehensive database. U.S. Geological Survey *Groundwater Observation Network* includes water levels measured in approximately 120 wells throughout Wisconsin. The network is part of a comprehensive and ongoing effort to maintain a water resource database responsive to the needs of the state and the nation. Approximately 20 wells are measured daily with electronic recorders; the remainder are measured on a weekly, monthly or quarterly basis by staff or observers.

Ontario Ministry of the Environment's *Drinking Water Surveillance Program (DWSP)* is a monitoring program developed to provide reliable information on municipal drinking water but it also monitors raw water from well supplies. In addition the *Provincial Groundwater Monitoring Network (PGMN)* also collects data on groundwater quantity and quality.

Heidelberg College National Center for Water Quality Research conducts the *Cooperative Private Well Testing Program.* This is a voluntary program focusing on analysis of water from private wells, and interpretation of the results in the contexts of shallow groundwater quality and human health risks from contaminants in well-water. More than 50,000 wells have been tested through this program including sites throughout the entire Great Lakes basin with the majority focused in Ohio. The National Center for Water Quality Research also manages a *Tributary Monitoring Program* that collects highly detailed data on concentrations of a wide range of water quality constituents at stations near the mouths of the major rivers in Ohio and the River Raisin in Michigan. This program is unique in the region because it collects data detailed enough to use as baseline data for drinking water quality source investigations.

For additional information on groundwater monitoring see the Groundwater section of this report.

Findings – Drinking Water

Federal and state agencies set and enforce drinking water standards but each supplier is responsible for the quality of drinking water produced at that facility. The monitoring inventory did not collect monitoring information from each drinking water facility but rather collected program information at federal, state and local government levels. The most comprehensive drinking water monitoring resources in the basin are U.S. EPA's *Safe Drinking Water Information System (SDWIS)* and Ontario Ministry of the Environment's *Drinking Water Surveillance Program (DWSP).* SDWIS provides detailed information on public drinking water facility locations and environmental compliance throughout the U.S. portion of the basin and DWSP provides information on municipal drinking water and is voluntary rather than compliance-driven.

Most drinking water quality monitoring is directed at evaluating treated drinking water systems. Relatively few resources are directed at evaluating surface water sources of drinking water. Evaluation of surface water sources requires monitoring for smaller concentrations of contaminants than general water quality monitoring. Currently there is very little funding for this type of drinking water source monitoring. More resources may need to be directed at monitoring drinking water sources to get an accurate understanding of the health of the ecosystem.

It appears that well-water sources are monitored unevenly throughout the states and Ontario. In general, it appears as if most states and provinces test well-water during the well installation process but subsequent testing is not required for single family users. Rather than collecting baseline monitoring data, private well testing appears to be largely issue driven. The basin may benefit from the development of a targeted program to monitor high-risk private, single-family, well-water systems.

A relatively new concept in water monitoring is installation of real-time monitoring devices at water intake systems. Such systems would allow for early detection of source water contamination prior to treatment and consumption. The necessity and utility of employing real-time monitoring systems may depend largely on risk characterization in local areas and current ability of drinking water facilities to detect contaminants in surface water sources.

Human Health
c. Beach Safety

Determining if bathing beaches are safe for recreation is an important shared goal across the Great Lakes basin. This issue is heightened in highly populated and industrialized areas. The primary reason for beach safety warnings and closures is bacterial contamination. The wide use of outdated combined sewer systems and the extensive urbanization of landscapes contribute large amounts of nutrients to surface waters in the region, which encourages bacterial growth. While both U.S. and Canadian federal agencies administer reporting systems, state/provincial, tribal, and local agencies are responsible for monitoring water quality at beaches and posting warnings or closures when pollutant levels in the water are too high.

US EPA is required under Clean Water Act to publish criteria for monitoring and assessment of coastal beaches and for promptly notifying the public of any failure to meet the water quality standards. The Clean Water Act authorized EPA to award grants to states to implement monitoring and notification programs, but only if the programs meet certain requirements. One of these requirements is that the monitoring and notification programs must be consistent with U.S. EPA's National Beach Guidance and Required Performance Criteria. U.S. EPA's recommended *E. coli* standard is 126/100 ml for the geometric mean of five samples over 30 days and 235/100 ml for a single sample.

HIGHLIGHT – Beach Safety

- While standards are defined at the federal level, states have been given a certain degree of autonomy to design their own monitoring programs to meet their specific needs. This has lead to a decentralization of beach monitoring activities resulting in somewhat inconsistent, disjointed monitoring efforts and beach advisory postings. While each program collects *E. coli* data, the number of sampling sites and frequency of monitoring vary considerably among states and local agencies.

While beach monitoring is carried out by county and municipal agencies, these agencies report monitoring results to state agencies that, in most cases, are responsible for posting swimming advisories and beach closures. The Great Lakes Monitoring Inventory attempted to collect information on county and municipal monitoring programs but the scope of the project did not allow for contacting each of the nearly 200 local health departments conducting monitoring across the region. An attempt was made to collect detailed information for each state and provincial beach program to help account for limited local level information. This report and the results of the Great Lakes Monitoring Inventory focus primarily on Great Lakes beaches, not inland lake beaches.

The Beach Advisories, Postings and Closures (#4200) indicator assesses the number of health related swimming advisories, beach closures, and posting days for freshwater recreation areas in the Great Lakes basin. Beach advisories, postings, and closures are based on elevated levels of *E. coli,* or other indicator organisms, as reported by county or municipal health departments in the Great Lakes basin.

The monitoring inventory includes 33 monitoring programs that address beach safety in the Great Lakes region. Each of the Great Lakes states and Ontario reported some level of beach monitoring and each also reported a comprehensive monitoring or reporting system at the state/provincial level. These programs are

described in more detail below. Primary emphasis is on state level beach monitoring and monitoring coordination programs, but county programs are also discussed where information was available. It also should be noted that the Great Lakes Beach Association includes members from Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Pennsylvania, New York, Environment Canada, and states and countries outside of the Great Lakes Region. This group holds meetings annually to discuss regional beach monitoring issues.

Illinois – The Illinois Department of Public Health runs the *Illinois beach monitoring and notification program*, except for Lake Michigan beaches in Cook and Lake Counties. The state run program monitors only inland lake beaches and therefore will not be discussed in more detail in this report. The Lake County Health Department and Community Health Center *Lake Michigan Beach Monitoring Program* conducts daily *E. coli* monitoring from the end of May to Labor Day each year at 11 Lake Michigan beaches and weekly *E. coli* monitoring at 2 Lake Michigan Dog Beaches. This program is funded through county and federal funds. The Chicago Park District *Beach Monitoring* program conducts monitoring at the city's 29 lakefront beaches and one in-land beach. These beaches are monitored for elevated *E. coli* levels five days a week. Funding for monitoring the Lake Michigan beaches in Chicago comes from the City of Chicago.

The responsibility for monitoring Cook counties Lake Michigan beaches lies with the municipalities. Some of these municipalities include Kenilworth, Evanston, and Winnetka. In total approximately 38 beaches are monitored in Cook County. More detailed information regarding sampling frequency and parameters was not available.

Indiana – The Indiana Department of Environmental Management (IDEM) *Beach Monitoring* program, developed in cooperation with the Interagency Taskforce on *E. coli*, is responsible for monitoring Indiana's Lake Michigan beach waters for elevated bacteria levels. Participants in this program monitor *E. coli* levels five to seven days per week from Memorial Day through Labor Day at 34 locations along Indiana's Lake Michigan shoreline. Participants in Indiana's Beach Monitoring program include: the Lake County Parks and Recreation Department, the Hammond Health Department, the East Chicago Department of Public and Environmental Health, the Gary Sanitary District, the Town of Ogden Dunes, the Town of Dune Acres, and the LaPorte County Health Department. Though the Dunes National Lakeshore is not authorized to receive federal funding through the BEACH Act, those beaches are monitored 1 day per week. Through a grant awarded by IDEM, the statuses of all recreational beaches are posted to the "EARTH911" website from both the participating communities and the Dunes National Lakeshore. This website is a valuable tool for use by the public in determining the status of a beach they are interested in visiting.

Parameters such as water and air temperature, wave height, wind speed and direction are recorded at the time of sample collection. If a water sample exceeds the 235 cfu/100 ml federal *E. coli* standard, the local beach managers determine whether to post an advisory or close the beach. In 2004 and 2005, IDEM funded two predictive model development projects with the goal of improving the efficiency of monitoring activities along Indiana's Lake Michigan shoreline in future years by replacing the 18-hour sample testing methods currently employed.

Michigan – Michigan Department of Environmental Quality's *Beach Monitoring* program handles beach monitoring in the state. While Michigan counties monitor the beaches through grants awarded by the state, the Beach Monitoring database is a compilation of all of the county collected beach monitoring information. In total 83 counties and 43 local health departments collect data in support of beach advisory postings. Monitoring occurs primarily once a week during the swimming season. There are 833 lakefront and in-land beaches and 360 of these beaches are in 41 counties located along the Great Lakes. Because of the extensive list, each of these counties and sampling sites will not be listed in this document but this program has a comprehensive website on which detailed beach monitoring, advisory, and closing

information can be searched for each county and beach monitored. The program is funded through the Clean Michigan Initiative, and the U.S. BEACH Act.

Minnesota – The *Lake Superior Beach Monitoring and Notification Program* administered by Minnesota Pollution Control Agency is responsible for beach monitoring in Minnesota's Lake Superior basin which includes Cook, Lake, and St. Louis counties. In Cook County, Paradise Beach, Kadunce Creek, Durfee Creek Area, Old Shore Road, Grand Marais Campground, Grand Marais Downtown, Cutface Creek Wayside Rest, Temperance River State Park, Schroeder Town Park, and Sugarloaf Cove Beaches are monitored. In Lake County, the beaches monitored include Tettegouche State Park, Silver Bay Marina, Split Rock Lighthouse State Park, Split Rock River, Twin Points Public Access, Gooseberry Falls State Park, Stewart River, Flood Bay, Burlington Bay, Agate Bay and Knife River Marina Beaches. In St. Louis County, Stony Point, Bluebird Landing, French River, Brighton Beach, Lester River, 42nd Ave. East, Lakewalk East/16th Ave. East, Leif Erikson Park, Lakewalk, Franklin Park, New Duluth Boat Club, Hearding Island Canal, Lafayette Community Club, Southworth Marsh, Park Point Beach House, Sky Harbor, Clyde Ave. Boat Landing, and Boy Scout Landing Beaches are monitored. This program collects samples from 39 Lake Superior beaches and analyzes those samples for *E. Coli*, fecal coliform, water temperature, wave height, and surface winds. Sampling takes place one to two times weekly from May through October. This project is funded through the U.S. BEACH Act and section 406 of the Clean Water Act.

New York – In total, there are 38 New York beaches along the Great Lakes and all are being monitored. All beaches are monitored for *E. coli* while a number of the beaches are also monitored for fecal coliform and enterococci. The majority of the beaches are monitored on a weekly basis. State and county agencies contributing to beach monitoring along New York's Great Lakes coastline include Chautauqua County Department of Health (Blue Water, Main Street, Point Gratiot, Sheridan Bay, Sunset Bay Beach Club, Town of Hanover, Wright Park East, and Wright Park West Beaches), Erie County Department of Health (Wendt, St. Vincent DePaul, Point Breeze, Pioneer Camp, Lake Erie, Hamburg, Evans Town Park, and Bennett Beaches), Geneva District Office monitored by New York State Department of Health (Sodus Point Bayside, Sodus Point Lakeside, and Pultneyville Mariners Beaches), Monroe County Department of Health (Ontario Beach), Niagara County Department of Health (Krull Park Beach), Oswego County Department of Health (Dowie Dale, Mexico Point, Chedmardo, Brennan's Beach, Rainbow Shores Beaches), and New York State Office of Parks, Recreation and Historic Preservation (Evangola and Woodlawn beaches, Erie County; Fair Haven Beach, Cayuga County; Hamlin Area 3 and 4 Beaches, Monroe County; Lake Erie Beach, Chautauqua County; Sandy Island and Selkirk Shores Beaches, Oswego County; Southwick, Wescott Camp, and Wescott Main Beaches, Jefferson County; Wilson Tuscarora Beach, Niagara County).

Ohio – The Ohio Department of Health's *Bathing Beach Monitoring Program* monitors the waters at selected public bathing beaches along the Ohio/Lake Erie border. Swimming advisory recommendations issued by the Department of Health are based upon the *E. coli* or fecal coliform bacteria content of water samples collected. The standard for *E. coli* follows the U.S. EPA's recommended *E. coli* standard of 126/100 ml for the geometric mean of five samples over 30 days and 235/100 ml for a single sample. The fecal coliform standards indicates that a mean based on not less than five samples within a 30-day period shall not exceed 200 fecal coliform colonies per 100 ml of water; and fecal coliform content shall not exceed 400 fecal coliform colonies per 100 ml of water in more than 10% of all samples taken during any 30-day period. In total, the Department of Health monitors 22 stations 4 times a week for elevated *E. coli* or fecal coliform levels. The beaches monitored by the Department in Lucas County include Maumee Bay (inland), Maumee Bay (Erie), and Crane Creek. In Ottawa County beaches monitored include Camp Perry, Port Clinton, Catawba Island, South Bass Island, East Harbor, and Lakeside. In Erie County, the beach on Kelly's Island is monitored. In Lorain County two beaches, Lakeview and Century are monitored. In Cuyahoga County the beaches at Edgewater, Villa Angela, and Euclid are monitored. The beaches at Geneva, Walnut Beach, Lakeshore Park, and Conneaut Township Park in Ashtabula County are also monitored by the Department of Health. Additionally, the Lake County Health District monitors beaches within its jurisdiction at

Headlands West, Headlands East, and Fairport Harbor. The Cuyahoga County Board of Health monitors 16 beaches within its jurisdiction, and the Erie County Health District monitors 20 beaches within its jurisdiction. Data from all beach monitoring is reported to the Ohio Department of Health for transmission to the U.S. EPA. Most of these programs are funded by the U.S. BEACH Act.

Pennsylvania – In Pennsylvania there are 12 permitted coastal recreational beaches on the southern shore of Lake Erie. All of Pennsylvania's coastal beaches are located in Erie County. Besides the 11 beaches located in Presque Isle State Park there is one more beach in North East Township on Lake Erie. The Erie County Department of Health (ECDH) subcontracts with Pennsylvania Department of Health (DOH) for funding under the U.S. Beach Act. Presque Isle State Park, which is operated by the Pennsylvania Department of Conservation and Natural Resources (DCNR) is funded through an interagency agreement with the Pennsylvania Department of Health. All monitoring follows U.S. EPA recommended *E. coli* standards. A predictive model of recreational beach quality based on weather, known sewage discharges, storm events, and water currents is being formulated. The information will be used to see if a correlation can be established with weather and high bacterial counts. If a predictive model is established it would allow the beach managers to close beaches on a presumptive basis. This could prevent swimming in contaminated waters. ECDH is in the process of developing a website for the public to access information on the water quality on permitted Lake Erie beaches.

Wisconsin – The *Wisconsin Beach Monitoring Program* managed by the Wisconsin Department of Natural Resources (WNDR) is funded by the U.S. BEACH Act. The WDNR serves as a link between the federal government and local health departments. Through the Wisconsin Beach Program, the WDNR gives grants to communities along Lake Michigan and Lake Superior to monitor beach water for elevated bacteria levels.

In total, 127 Wisconsin Great Lakes beaches are monitored for elevated *E. coli* levels using a three tiered monitoring approach depending on priority of each beach. At high priority at least 4 samples are analyzed per week during the swimming season. High priority beaches will post swimming advisory signs following U.S. EPA's recommended *E. coli* standard of 126/100 ml for the geometric mean of five samples over 30 days and 235/100 ml for a single sample. Medium priority beaches are sampled twice a week during the swimming season. Low priority beach sampling will be determined by state and local authorities. For medium and low priority beaches, advisories will be posted if an *E. coli* sample exceeds 235/100 ml. All beaches will post a closure sign whenever the level of *E. coli* in the beach water sample exceeds 1000/100 ml. Counties conducting Great Lakes beach monitoring include Ashland (7 sites), Bayfield (16 sites), Brown (4 sites), Door (29 sites), Douglas (12 sites), Iron (5 sites), Kenosha (4 sites), Kewaunee (2 sites), Manitowoc (10 sites), Milwaukee (12 sites), Ozaukee (6 sites), Racine (7 sites), and Sheboygan (13 sites).

Ontario - The Ontario Beach Management Protocol is the strongest guideline for the presence of *E. coli* in North America. It requires the posting of beaches as unsafe for swimming if the level of *E. coli* exceeds 100/100 ml. The Ontario Beach Management Protocol requires weekly testing of recreational water quality throughout the swimming season. The Ontario Ministry of Health's Beach Management Protocol is in charge of setting this standard.

Ontario Parks, under the Ontario Ministry of Natural Resources, collects beach samples from 161 beaches at 27 parks on the Great Lakes throughout all of Ontario. There are approximately 3,700 samples taken during the bathing season. Ontario Parks has an agreement with the Ministry of Health and Long Term Care to follow the Provincial Beach Management Protocol. Most beaches are sampled weekly. When a problem is found, Ontario Park consults with the Local Health Units for posting advisories.

The Windsor-Essex County Health Unit monitors 9 beaches throughout the Windsor-Essex County area including Sand Point, West Belle River, Hillman, Point Pelee National Park North West, Seacliffe Park, Cedar Island Beach Kingsville, Cedar Beach Kingsville, Colchester Beach Essex, and Holiday Beach Amherstburg.

Beaches are sampled on a weekly basis during the summer for bacteriological levels. The standards used for determining beach advisories include beach warnings when *E. coli* levels are higher than 100/100 ml and beach closures are posted when *E. coli* levels exceed 1000/100 ml.

Monitoring of Toronto beaches is coordinated by a number of city departments. The Works and Emergency Services Department collects daily water samples. Ten beaches are monitored in Toronto including Marie Curtis Park East, Sunnyside, Hanlan's Point, Centre Island, Ward's Island, Cherry/Clarke, Woodbine, Kew Balmy, Bluffer's Park, and Rouge beaches. These samples are analyzed for *E. coli* content by the laboratories of the provincial Ministry of Health. Toronto Public Health interprets the results and decides if a beach is safe or unsafe for swimming. From June to the end of August, daily water samples are taken from beach locations across the city and tested for water quality.

Federal – U.S. EPA is required under Clean Water Act to publish criteria for monitoring and assessment of coastal beaches and for promptly notifying the public of any exceedance of water quality standards. The Clean Water Act authorized U.S. EPA to award grants to states to implement monitoring and notification programs. U.S. EPA's recommended *E. coli* standard is 126/100 ml for the geometric mean of five samples over 30 days and 235/100 ml for a single sample. The U.S. EPA's *BEACON - Beach Advisory and Closing On-line Notification* is a compilation of all beach monitoring, beach advisory and beach closing information available in the U.S. All information is contributed by participating states.

The Earth 911 *Beach Monitoring Data Repository* is a similar online data distribution system. An additional resource for beach monitoring information is the Natural Resources Defense Council's *State Beach Monitoring Practices* website. This website provides summaries for state run monitoring programs including yearly statistics. It should be mentioned that concerns were raised regarding the completeness and accuracy of NRDC's beach monitoring report. U.S. National Lakeshores conduct their own beach monitoring independent of any U.S. EPA regulations. No detailed information was available on National Lakeshore monitoring.

Environment Canada Ontario Region manages the *Seasonal Water Monitoring and Reporting System (SWMRS)*. During the summer, local Health Units are required to sample water quality of public beaches within their jurisdiction. These beaches are tested for *E. coli* and results are made available through the SWMRS.

Findings – Beach Safety

A considerable level of coordination and collaboration is taking place in the area of Great Lakes beach monitoring. The Great Lakes Beach Association includes members from Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Pennsylvania, New York, Environment Canada, and states and countries outside of the Great Lakes Region. This group holds meetings annually to discuss regional beach monitoring issues.

Programs in each of the Great Lakes states and Ontario reported some level of beach monitoring and each state/province reported a comprehensive monitoring and reporting system at the state level. While U.S. EPA administers the Beaches Environmental Assessment, Closure, and Health Program (BEACH Program), state, tribal, and local agencies are responsible for monitoring water quality at beaches and posting warnings or closures when pollutant levels in the water are too high. The U.S. EPA Beach Act provides the majority of funding for beach monitoring programs in the region. A couple of states, including Illinois, Michigan and New York reported contributing state and local funds as well. While standards are defined at the federal level, lack of centralization of beach monitoring activities results in somewhat inconsistent, disjointed monitoring efforts and beach advisory postings. While each program collects *E. coli* data, the number of sampling sites and frequency of monitoring vary considerably among states and local agencies. It should also be noted that the U.S. and Ontario follow different beach advisory and closing standards. The Ontario

Beach Management Protocol is the strongest guideline for the presence of *E .coli* in North America. It requires the posting of beaches as unsafe for swimming if the level of *E. coli* exceeds 100/100 ml. U.S. EPA's recommended *E. coli* standard is 126/100 ml for the geometric mean of five samples over 30 days and 235/100 ml for a single sample.

Human Health
d. Air

Data on air quality and toxic air pollutants is invaluable when trying to understand threats posed to the environment by atmospheric deposition, human health risks associated with poor air quality, and the overall health of an ecosystem. The primary pollutants of concern impacting human health are generally considered to be particulate matter (PM2.5), ozone and air toxics. In the Great Lakes basin, monitoring efforts are focused both on attainment areas, those areas meeting or exceeding national ambient air quality standards, and non-attainment areas, those areas that do not meet national standards.

Air monitoring data are generally collected through ambient air measurements and emissions estimates. Ambient air concentrations of pollutants in outdoor air are measured at monitoring stations owned and operated mainly by state environmental agencies. Measurements of pollutant concentration are forwarded to U.S. EPA, and U.S. EPA computes a yearly summary for each monitoring station. Emissions estimates are defined as the quantity of pollutants released into the air during a year from materials consumed or products produced. Most emissions estimates are provided to U.S. EPA by state environmental agencies.

The goal of SOLEC's Great Lakes Air Quality (#4202) indicator is to measure levels of criteria pollutants (which include such constituents as carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM10 and PM2.5), and sulphur dioxide (SO2)) released into the ambient air and infer the potential impact of air quality on human health in the region.

HIGHLIGHT – Ambient Air

- There are concerns about possible network reductions due to budget cuts to ambient air monitoring programs. Concurrently, there are discussions of implementing new U.S. national standards that may require more stringent monitoring efforts. With current levels of funding it may not be possible to maintain an effective network of ambient air monitoring stations.

Another relevant indicator is Atmospheric Deposition of Toxic Chemicals (#117). This indicator reports estimates of loadings of PCBs, dieldrin, chlordane, DDT, and their metabolites as well as other chemicals based on measured atmospheric concentrations of chemicals in wet and dry deposition. While atmospheric deposition is mentioned in this section, it is discussed in more detail in the Atmospheric Deposition section of this report.

In total, inventory results indicate thirty-two air monitoring programs that measure either ambient air or point source pollutant levels in the Great Lakes basin.

Ambient Air Monitoring

With more than 1,800 monitoring locations, U.S. EPA's *AirData* database represents the largest collection of ambient air monitoring stations in the Great Lakes basin. *AirData* monitoring information is collected primarily by state environmental agencies and forwarded hourly or daily to the U.S. EPA for analysis and storage. Pollutants measured include sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), lead, and particulate matter. Stations are scattered across each state in the Great Lakes basin with the heaviest concentrations in the major urban areas.

AirData presents annual summaries of air pollution data from two U.S. EPA databases: *Air Quality System (AQS)* and *National Emission Inventory (NEI)*. *Air Quality System (AQS)* provides data on air releases throughout the United States. The measurements include both criteria air pollutants and hazardous air pollutants. The U.S. EPA also manages the *National Emissions Inventory (NEI)* that documents air pollutant emission trends. These data are used for air dispersion modeling, regional strategy development, regulation making, air toxics risk assessment, and tracking trends in emissions over time.

Canada reported two broad ambient air monitoring programs. Environment Canada manages the *National Air Pollution Surveillance (NAPS)* Network. NAPS was established in 1969 as a joint program of federal and provincial governments to monitor and assess the quality of ambient air in Canadian cities. Air quality data for sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3) and total suspended particulates (TSP) are measured in cities in the Canadian portion of the Great Lakes basin. Environment Canada also manages the *Canadian Air and Precipitation Monitoring Network (CAPMON)* which is a non-urban air quality monitoring network.

All of the Great Lakes states operate ambient air toxics monitoring networks. When available, details were provided on each of these networks. In general, these monitoring networks collect measurements of trace metals, volatile organic compounds (VOCs) and carbonyl compounds. States may supplement these measurements with additional chemical testing such as polynuclear hydrocarbons. In association with PM2.5 speciation monitoring efforts, a suite of other measurements collected include organic carbon, elemental carbon, trace metals, nitrate, and sulfate. Measurements of black carbon, trace levels or criteria gases, ammonia, and continuous particulate levels are also collected at various locations throughout the region.

Illinois – Illinois Environmental Protection Agency's *Air Monitoring* program collects particulate matter (PM10 and PM2.5), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, lead, heavy metals, nitrates, sulfates, and volatile organic compounds at more than 200 sites throughout the state.

Indiana - The Indiana Department of Environmental Management *Ambient Air Monitoring* program collects ambient air quality data daily at more than 100 sites across the state. Parameters monitored include Carbon Monoxide, Lead, Nitrogen Oxides, Particulates (PM2.5), Smog, Sulfur Oxides, Tropospheric Ozone, and Volatile Organic Compounds.

Michigan - Michigan Department of Environmental Quality's (DEQ) *Ambient Air Monitoring* program collects data for comparison to the National Ambient Air Quality Standards at roughly 35 sites in the state. Michigan DEQ also manages the *Air Toxics Monitoring Network*. Parameters include criteria pollutants, air toxics compounds, speciated fine particulate material (PM2.5), and meteorological measurements. Currently there are areas of Michigan designated as non-attainment areas which do not meet national ambient air quality standards. Michigan DEQ is also working with the University of Michigan to study mercury deposition at several locations throughout the state.

Minnesota - Minnesota Pollution Control Agency's *Air Quality Index for Minnesota* provides a simple, uniform way to report daily air quality conditions. The Minnesota Pollution Control Agency (MPCA) takes hourly measurements of pollutants (ozone, sulfur dioxide, fine particulate matter (PM2.5), and carbon monoxide) at air quality sites located throughout the state.

New York - New York State Department of Environmental Conservation's *Ambient Air Quality Monitoring Network* monitors the levels of ozone, sulfur dioxide, nitrogen oxides, carbon monoxide, lead, and particulate matter (PM2.5) in the ambient air. The objectives of the New York State Department of Environmental Conservation *Atmospheric Deposition Monitoring Sites* program are to provide a consistent, quality-assured, long-term acid deposition database; measure acid deposition in sensitive receptor areas;

measure acid deposition in urban and upwind areas; use these data to perform spatial and temporal analyses of acid deposition; its precursors, and its effects; and track the effectiveness of acid deposition precursor emissions reductions. The state's monitoring network measures acid deposition and related quantities at eight locations throughout the state to assess the effectiveness of sulfur control policy and other strategies aimed at reducing the effects of acid rain. This program measures precipitation, ozone, humidity, temperature, atmospheric pressure, pH, sulfate, nitrate, chloride, fluoride, calcium, magnesium, potassium, sodium, ammonium, and conductivity. In addition the New York State Department of Environmental Conservation manages the PM 2.5 Monitoring program which monitors PM 2.5 levels in the state.

Ohio – Ohio's Air Monitoring Network managed by the Ohio Environmental Protection Agency monitors ambient air quality standard across the state. Data collected includes TSP, Pb, CO, SO2, O3, NO, NO2, PM10, PM2.5, VOCs, Wind Speed, Wind Direction, Arsenic, Beryllium, Cadmium, Chromium, Manganese, Nickel, Zinc, and Mercury.

Pennsylvania - The goals of the Pennsylvania Department of Environmental Protection's (DEP) *Ambient Air Monitoring* program are to evaluate compliance with federal and state air quality standards, provide real-time monitoring of air pollution episodes, develop data for trend analysis, support the development and implementation of air quality regulations, and provide information to the public on daily air quality conditions. DEP monitors air quality in areas having high population density, high levels of expected contaminants, or a combination of both factors. Pennsylvania Department of Environmental Protection also manages the *Monitoring Toxic Pollutants* program. This program monitors toxics at 12 sites throughout the state for a group of 188 toxic pollutants. The *Pennsylvania Atmospheric Deposition Monitoring Network* managed by the Pennsylvania Department of Environmental Protection monitors the amount of acid rain falling at one location in Pennsylvania's Lakes Erie basin. Sampled parameters include pH, sulfate, nitrate, ammonium, chloride, calcium, magnesium, potassium, sodium, specific conductance, and mercury.

Wisconsin – No specific information is available.

Ontario - Ontario Ministry of Environment manages the *Ambient Air Monitoring* program. This program collects data for Ontario's air quality assessment and trend evaluation including data on Carbon Monoxide, Nitrogen Oxides, Particulates, Smog, Carbon Monoxide, Nitrogen Dioxide, Nitrogen Oxides, Ozone, and Sulfur Dioxide levels in the air.

Additional ambient air monitoring programs in the region focus on tracking atmospheric deposition in the basin. A joint U.S. EPA and Environment Canada program, *Integrated Atmospheric Deposition Network (IADN),* was developed in 1990 to monitor atmospheric deposition of toxic chemicals to the Great Lakes. This program measures wet and/or dry atmospheric deposition at 15 locations on shores of the Great Lakes basin. Five of these stations (3 sites in the U.S. and 2 Canadian sites) are master stations where all IADN chemicals are measured in air and precipitation. The program monitors 80 toxic chemicals, including PCBs, dieldrin, chlordane, and DDT. The remaining 10 stations measure a limited number of the IADN chemicals. The U.S. operates 2 satellite stations both located in urban areas. These stations measure concentrations in both air and precipitation. Canada operates 8 satellite stations. One of these stations measures only air concentrations while the other 7 measure only precipitation concentrations.

The U.S. EPA also manages the *Clean Air Status and Trends Network (CASTNET)* focusing on dry deposition monitoring at five locations in the Great Lakes basin. The U.S. EPA also manages the *Photochemical Assessment Monitoring Stations (PAMS) Network* that monitors ozone and its precursors in areas with persistently high ozone levels. Also EPA's *National Air Toxic Trend Sites (NATTS)* monitors specific high risk air toxics such as benzene, formaldehyde, 1,3-butadiene, acrolein, and chromium.

The Great Lakes Research Consortium manages the *Semivolatile Air Monitoring Network* that collects concentration and loading of organics (including dioxin) in air in New York. The *National Atmospheric Deposition Program* (NADP), which is a cooperative research support program of federal, state, and nongovernmental research agencies, measures wet deposition at 31 locations across the Great Lakes basin through the *National Trends Network* program. Other programs managed by NADP are the *Atmospheric Integrated Research Monitoring Network (AIRMON)* and *Mercury Deposition Network (MDN)*. The MDN measures mercury deposition in rainfall at approximately 20 sites within the Great Lakes region. NADP in partnership with Lake Michigan Air Directors Consortium (LADCO) and Central Regional Air Planning Association (CENRAP) operate an ammonia monitoring network at 13 sites across the Midwest and the Plains states. This network has been measuring ammonia/ammonium, nitrate/nitric acid and SO2/sulfate since 2003.

Point Source Monitoring

The U.S. EPA manages the *Toxics Release Inventory* (TRI) which contains information about more than 650 toxic chemicals used, manufactured, treated, transported, or released into the ground, water, or air. Manufacturers of these chemicals are required to report the locations and quantities of chemicals stored on-site to state and local governments. EPA compiles these data in an on-line, publicly accessible national computerized database. TRI tracks approximately 4,500 locations in the Great Lakes basin annually.

The U.S. EPA also manages the *National Emissions Inventory (NEI)* that documents air pollutant emission trends. These data are used for air dispersion modeling, regional strategy development, regulation setting, air toxics risk assessment, and tracking trends in emissions over time. A similar effort to track and predict emission releases is being performed by the Great Lakes Commission through the *Centralized Air Emission Repository On-Line (CAROL)*. This online repository is fully searchable and focused exclusively on the Great Lakes region.

For additional information on atmospheric deposition please refer to the atmospheric deposition section of this report.

Findings - Air

The U.S. EPA's *AirData* program includes data on levels of the key criteria pollutants (CO, NO2, O3, SO2, lead, and particulate matter) called for in SOLEC's Great Lakes Air Quality indicator. AirData presents annual summaries of air pollution data from two U.S. EPA databases: *Air Quality System (AQS)* and *National Emission Inventory (NEI)*. *Air Quality System (AQS) provides* data on air releases throughout the United States. The measurements include both criteria air pollutants and hazardous air pollutants. The U.S. EPA also manages the *National Emissions Inventory (NEI)* that documents air pollutant emission trends. These data are used for air dispersion modeling, regional strategy development, regulation setting, air toxics risk assessment, and tracking trends in emissions over time. Historically, these programs account for more than 9,000 data collection sites in the Great Lakes basin. In Canada, *Environment Canada's National Air Pollution Surveillance (NAPS) Network*, established in 1969, monitors ambient air quality in Canadian cities. Environment Canada also manages the *Canadian Air and Precipitation Monitoring Network (CAPMON)* which is a non-urban air quality monitoring network. Although monitoring sites are found with increased density in urban centers there is strong representation throughout the Great Lakes basin particularly through the U.S. *AirData* program.

While there appears to be a number of federal and state programs collecting information on atmospheric deposition, only *IADN* collects information on the parameters necessary (PCBs, dieldrin, chlordane, and DDT) to evaluate the Atmospheric Deposition of Toxic Chemicals indicator. A potential limitation of *IADN* lies in the distribution of sampling stations and in the corresponding activities at each station. This

network may need to be evaluated to determine if five master stations (one per lake) are sufficient to characterize atmospheric deposition. Monitoring inventory results indicate that U.S. EPA's *Toxic Release Inventory* is the primary collector of point source data in the region. No equivalent program was reported for Canada.

Presently, there are concerns about network reductions due to budget cuts to ambient air monitoring programs. Concurrently, there are discussions of implementing new national ambient air quality standards that may be more stringent than current standards. There are concerns that the ambient air quality standards may not be adequately monitored with current levels of funding. In addition to potential need for increased funding for monitoring activities, there need is also a need to invest resources in development of monitoring technology.

2. General Monitoring
a. Water Quality

Great Lakes monitoring organizations reported 142 water quality monitoring programs. These programs range from small, local volunteer monitoring programs to large, regulatory, multi-parameter, federally funded, basinwide water quality monitoring programs. Results of the inventory show that in the Great Lakes open waters, water quality monitoring is being conducted by twenty one monitoring programs. One hundred twenty monitoring programs in the Great Lakes basin are conducting watershed monitoring, including inland lakes, rivers, and nearshore zones. Major programs in each of these areas will be discussed as will relevant SOLEC indicators.

Open Water Monitoring

In the Great Lakes basin, the greatest number of water quality monitoring programs was reported in the Lake Michigan basin. One reason for this may be that more jurisdictions are responsible for Lake Michigan than any other Great Lake. Open water monitoring showed a relatively even effort across the Great Lakes basin. Open water monitoring results indicate that the greatest number of programs occur in Lake Michigan and Lake Erie, with Lake Huron and Lake Superior reporting the lowest number of monitoring programs (Figure 5).

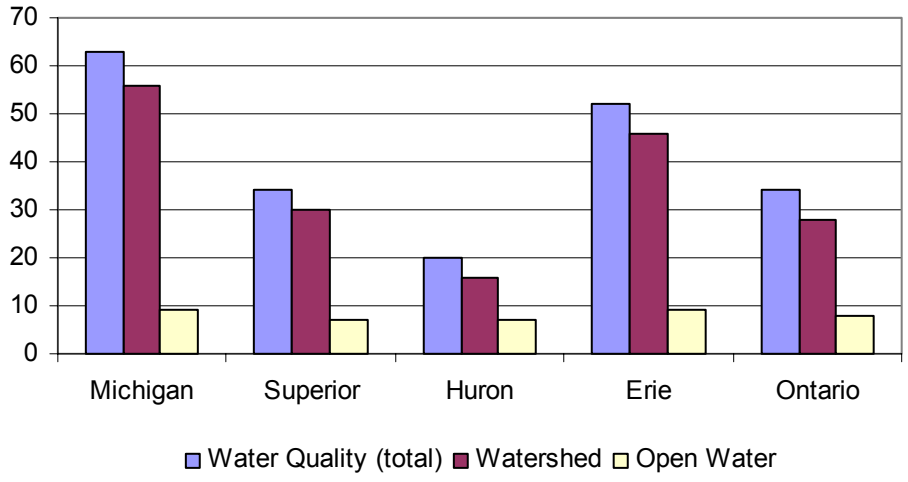

Figure 5. Number of water quality monitoring programs reported to the monitoring inventory by lake for open water, watershed (inland lakes, rivers, nearshore), and combined sampling efforts.

Two SOLEC indicators specifically address water quality in offshore waters. The first is the Toxic Chemical Concentrations in Offshore Waters (#118) indicator that examines the concentration of priority toxic chemicals in offshore waters and infers the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem and progress being made toward elimination of these toxics from the Great Lakes. Chemicals of interest include PCBs, deildrin, chlordane, DDT and metabolites, hexaclorobenzene, toxaphene, and mercury.

The second is the Phosphorus Concentrations and Loadings (#111) indicator with the goal of measuring the total phosphorus levels in springtime open waters and annual total phosphorus loads to each lake. This indicator is used to assess the total phosphorus levels and loadings, and evaluate trophic status and food web dynamics in the Great Lakes.

Open water monitoring is being performed by 21 U.S. and Canadian water quality monitoring programs. Table 2 presents a summary of federal and state/provincial programs grouped by agency, including organization, department and program title. Please see the complete inventory for more detailed information on each program and a more complete listing of reported local government, university, and other nongovernmental programs. In total, 12 open lake water quality monitoring programs were reported by U.S. agencies in the Great Lakes basin and nine were reported by Canadian agencies.

Table 2. Federal and state/provincial water quality monitoring programs in Great Lakes open waters.

Organization	Department	Monitoring Program Title
U.S. Federal Government		
U.S. Environmental Protection Agency	Great Lakes National Program Office	Long-Term Open Lakes Monitoring Program
U.S. Environmental Protection Agency	Great Lakes National Program Office	Lake Erie Dissolved Oxygen Depletion
U.S. Environmental Protection Agency	Great Lakes National Program Office	Limnology Program
U.S. Geological Survey	Tunison	Nearshore Lake Ontario Ecosystem Study Plan
U.S. State Government		
Illinois Environmental Protection Agency	Bureau of Water, Surface Water Section	Lake Michigan Monitoring Program
Michigan Department of Environmental Quality	Water Division	Water Chemistry Monitoring Project
Canadian Federal Government		
Environment Canada	Environmental Conservation, Ecosystem Health	Great Lakes Surveillance Program
Environment Canada	National Water Research Institute	Effects of zebra mussels (sub-project to open lake nutrient assessment)
Environment Canada	Environmental Conservation Branch	Lake Erie exit loadings of chemical parameters
Environment Canada	National Water Research Institute	Open lake trace metal cycling
Canadian Provincial Government		
Ontario Ministry of the Environment	Environmental Monitoring and Reporting Branch	Great Lakes Index Station Network Monitoring

Organization	Department	Monitoring Program Title
Ontario Ministry of the Environment	Environmental Monitoring and Reporting Branch	Great Lakes Water Intake Monitoring
Ontario Ministry of the Environment		Nearshore monitoring and assessment
Ontario Ministry of the Environment		Clean Water Regulation (MISA) Monitoring Data Ontario Point Sources

United States

In total, 12 U.S. monitoring programs sample water quality in the open waters of the Great Lakes basin. The majority of this monitoring appears to be taking place at the federal level through U.S. EPA.

Federal – Four U.S. federal programs monitor water quality in the open waters of the Great Lakes. Of these programs three are conducted by the U.S. EPA and the other is managed by U.S. Geological Survey.

US EPA's *Long-Term Open Lakes Monitoring Program* visits all of the Great Lakes, and consists of spring and summer sampling of a network of fixed stations in the open waters of the lakes. Parameters sampled include total phosphorus, total dissolved phosphorus, nitrate and nitrite, dissolved reactive silica, pH, total alkalinity, specific conductance, and turbidity. Sampling began in 1983 in Lakes Erie, Huron and Michigan, in 1986 in Lake Ontario and in 1992 in Lake Superior.

HIGHLIGHT – Water Quality

- While the cost of monitoring increases each year, the level of governmental funding dedicated to water quality monitoring remains the same. The result is a continuous decrease in monitoring efforts in order to stay within previously set budgets. More effort needs to go toward allotting financial resources based on current monitoring needs, rather than previously set spending limits.
- Michigan's Clean Michigan Initiative bond funding system is a good example of an innovative funding source. Because of this funding system, Michigan has the resources necessary to maintain a comprehensive water quality monitoring program for many years. This type of funding system may serve as a good example for other states and provinces seeking additional financial resources.
- There is limited data on toxic chemical concentrations in offshore waters of the Great Lakes. However, it is important to note that toxic chemical concentrations can be measured in media other than water, such as sediments and fish. More investigation is needed to determine if the benefits of monitoring the toxic chemical concentrations in water is worth the added expense when similar data is being collected in sediments and fish.

US EPA's *Lake Erie Dissolved Oxygen Depletion* program monitors the status of dissolved oxygen in the waters of the Lake Erie basin at a fixed network of stations several times each summer. These data are then used to assess the timing, extent and severity of reduced oxygen conditions. Ten sampling stations are monitored six times each summer to measure dissolved oxygen levels.

US EPA's *Limnology Program* sampling strategy is to collect water and biota samples at specific water depths from a limited number of locations in each lake twice every year to collect information on key environmental factors that influence the food chain and fish of the Great Lakes.

US Geological Survey *Nearshore Lake Ontario Ecosystem Study Plan* monitors water and sediment chemistry using fish and benthic organisms as indicators. Specific details on this program were not available.

While it is not an active monitoring program it should be mentioned that U.S. EPA conducted a Lake Michigan Mass Balance study in 1994 and 1995 sampling seasons. The objectives of this study were to identify chemical loading rates, establish baselines, predict benefits, and improve understanding of ecosystem dynamics. The Lake Michigan Mass Balance Study measured PCBs, mercury, trans-nonachlor, and atrazine in rivers, the atmosphere, sediments, lake water, and the food chain. To characterize Lake Michigan over 200 locations were sampled during the course of the project. The data are currently being analyzed and an ecosystem model is being developed.

Another program that should be mentioned is the joint program between U.S. EPA and Environment Canada to sample contaminants and toxics in each of the Great Lakes except Lake Michigan. This program uses the U.S. EPA's Lake Guardian research vessel to measure contaminant concentrations. Each year the Lake Guardian monitors a different Great Lake. This is not considered an active continuous monitoring program and therefore not included in the Great Lakes Monitoring Inventory because monitoring activities are based on needs identified for each lake at the time of sampling.

State – Two open water water quality monitoring programs were reported by state agencies. Illinois Environmental Protection Agency conducts the *Lake Michigan Monitoring Program* which monitors water quality at 18 locations parallel to the Illinois shoreline up to 5 miles offshore. Sampling includes turbidity, conductivity, pH, ammonia-n (total), kjeldahl-n (total), nitrite and nitrate-n (total), chemical oxygen demand, fecal coliform, chloride, sulfate and phenols. Funding for this project comes through the Federal Clean Water Act.

Michigan Department of Environmental Quality's *Water Chemistry Monitoring Project (WCMP)* assesses temporal and spatial trends in surface water contaminant levels; assesses the current status and condition of individual waters of the state and determines whether Michigan Water Quality standards are being met. In total, 48 sites are monitored throughout the state for an extensive list of chemical and physical properties. Most of these sites are located in inland waters with the exception of seven monitoring locations in Lake Huron's Saginaw Bay and four monitoring sites in Lake Michigan's Grand Traverse Bay. These monitoring sites may be considered a combination of nearshore and open water monitoring efforts. Funding for this program comes through Clean Michigan Initiative bond funding.

Local – Two programs were reported at the county and city level. Michigan's Macomb County Health Department conducts the extensive *Lake St. Clair Water Quality Assessment*. The objectives of this project include establishment of a surface water and sediment quality database; evaluation of impact of climatological variables and sewer overflows on surface water quality; and collection of sediment chemistry data at previously identified locations of concern. The project includes five complementary monitoring activities: nearshore, offshore, watershed, bathing beach, and wet weather. This program samples at 122 locations for chromium, kjeldahl nitrogen, aluminum, copper, salinity, conductivity, water temperature, air temperature, precipitation, and wind speed and wind direction.

In Lake Michigan, the Milwaukee Metropolitan Sewerage District conducts the *WATERBase - Milwaukee Metropolitan Sewerage District Water Quality Monitoring Data* program. The Milwaukee Metropolitan Sewerage District (MMSD) maintains an extensive water quality monitoring program to aid in pollution abatement, facilities planning, and flood control. As a result, a large data set of traditional water quality measurements beginning in 1975 became available. In total, six offshore sites are monitored for an extensive list of chemical and physical properties.

University – Three open lake water quality monitoring programs were reported by three universities in the Great Lakes basin. University of Wisconsin - Milwaukee conducts the *WATERBase - Lake Michigan Monitoring Buoy* and the *WATERBase - Monthly Lake Michigan Monitoring Program*. The *Lake Michigan*

Monitoring Buoy monitors temperature, conductivity, dissolved oxygen, pH, turbidity, and algal fluorescence twice daily at a site approximately sixteen kilometers offshore from the Milwaukee Harbor. The *Monthly Lake Michigan Monitoring Program* monitors eight sites extending from the Milwaukee Harbor to a pelagic station sixteen kilometers offshore, and includes a perch spawning reef and an urban water intake area. The suite of measurements includes temperature, water clarity, water chemistry, phytoplankton and zooplankton abundance, and bacterial and plankton productivity.

Cornell University conducts one monitoring program in the open waters of Lake Ontario. The *Biomonitoring program for Lake Ontario* analyzes water samples at multiple stations for nutrients (TP, Chl-a and N), zooplankton, and possibly phytoplankton from May through end of September. This program includes seven locations in the nearshore and offshore waters of Lake Ontario monitored twice a month.

Nongovernmental Organizations – Grand Traverse Band of Ottawa and Chippewa Indians conducts the *Grand Traverse Band Water Quality Program* to monitor waters within the historic reservation for the purpose of determining the current water quality conditions and detecting long-term trends in water quality. Currently two locations are being monitored including Lake Michigan's Grand Traverse Bay and off of northern Leelanau County, Michigan. Sampling includes an extensive list of chemical and physical properties.

Canada

In total, nine open lake water quality monitoring programs were reported by Canadian agencies in the Great Lakes basin.

Federal – Environment Canada conducts four open water monitoring programs. Environment Canada's *Great Lakes Surveillance Program* monitors water quality as required through the Great Lakes Water Quality Agreement in each of the Great Lakes, except for Lake Michigan, once every two years. Monitoring of water quality is conducted for nutrients, major ions and organic contaminants, as well as selected biological (chlorophyll a) and physical (e.g., temperature, specific conductance) parameters. The main objectives of the program are to ensure compliance with water quality objectives, evaluate water quality trends and identify emerging issues. Sampling typically includes 98 stations on Lake Ontario, 53 stations on Lake Erie, 94 stations on Lake Huron, and 94 stations on Lake Superior. These stations are evenly dispersed throughout each basin. The *Open lake trace metal cycling* program measures trace levels of Cadmium, Chromium, Lead, Manganese, Iron, and Nickel in water. The *Lake Erie exit loadings of chemical parameters* program measures the annual exit loading estimates for nutrients, organic contaminants, in-use pesticides, trace metals in dissolved phase and suspended sediment. The *Effects of zebra mussels (sub-project to open lake nutrient assessment)* program monitors the impact of zebra mussels on water quality particularly the balance of phosphorus and nitrogen.

As mentioned previously, a joint program between U.S. EPA and Environment Canada is in place to sample contaminants and toxics in each of the Great Lakes except Lake Michigan. This program uses the U.S. EPA's Lake Guardian research vessel to measure contaminant concentrations.

Provincial – Ontario Ministry of the Environment conducts four open water monitoring programs that collect water quality information. The *Great Lakes Index Station Network Monitoring* program provides information on where and how water quality conditions are changing over time by periodically monitoring a suite of environmental indicators. A total of 66 core sites have been established throughout the basin. Sampling is undertaken each summer for concentrations of priority toxic contaminants in sediment and suspended particulate material. The primary objective of the *Great Lakes Water Intake Monitoring* is to identify trends in nutrient status using nutrient concentrations and phytoplankton biomass as indicators. This is accomplished by year-round collection of phytoplankton and nutrient samples from intakes at

seventeen water treatment plants that draw water from the Great Lakes. This information is useful when trying to assess the long-term trends of nutrient loads and related nutrient management programs in the Great Lakes. An additional program conducted by Ontario's Ministry of the Environment is the *Clean Water Regulation (MISA) Monitoring Data Ontario Point Sources*. The *Nearshore monitoring and assessment* program samples water, sediment and biota in nearshore zone. Specific details on the last two programs were not available.

University – The University of Windsor Great Lakes Institute for Environmental Research manages the *Western Basin contaminants* program. This program investigates contaminant (OCs, PCBs, and PAHs) levels in water, sediment, birds, fish, benthos, and plankton.

Watershed Monitoring

Watershed monitoring (inland lakes, rivers, nearshore) is being performed by 120 U.S. and Canadian water quality monitoring programs. Table 3 presents a summary of federal and state/provincial programs grouped by agency, including organization, department and program title. Please see the complete inventory for more detailed information on each program and a more complete listing of reported local government, university, and other nongovernmental programs. In total, 106 watershed water quality monitoring programs were reported by U.S. agencies in the Great Lakes basin and 14 were reported by Canadian agencies.

In the U.S., much of the watershed monitoring is taking place in association with requirements placed on states to identify and monitor Total Maximum Daily Loads (TMDL) for attaining water quality standards. Under the U.S. EPA Clean Water Act, the Great Lakes states have adopted provisions into their water quality standards and National Pollutant Discharge Elimination System (NPDES) permit programs that are consistent with U.S. EPA guidance. As a result each state has implemented some type of ambient water quality monitoring system.

Table 3. Great Lakes federal and state/provincial watershed water quality monitoring programs.

Organization	Department	Monitoring Program Title
U.S. Federal Government		
U.S. Geological Survey		National Water Information System (gaging stations)
U.S. Geological Survey	Network Operations Section	Water Quality Sampling in Cooperation with State of Michigan (2001 - present)
U.S. Geological Survey	National Water Quality Assessment Program	National Water-Quality Assessment (NAWQA) Program
U.S. State Government		
Hoosier Riverwatch	IN Department of Natural Resources	Hoosier Riverwatch
Illinois Environmental Protection Agency	Division of Water Pollution Control-Lakes Unit	Illinois Volunteer Lake Monitoring Program
Illinois Environmental Protection Agency	Surface Water Section	Ambient Water Quality Monitoring Network (AWQMN)
Illinois Environmental Protection Agency	Surface Water Section	Intensive Basin Surveys
Illinois Environmental Protection Agency	Surface Water Section	Facility-Related Stream Surveys
Illinois Environmental Protection Agency	Surface Water Section	Ambient Lake Monitoring Program (ALMP)
Illinois Environmental Protection Agency	Surface Water Section	Illinois Clean Lakes Program (ICLP)
Indiana Department of Environmental Management, Office of Water Management	Assessment Branch, Biological Studies Section	No title given

Organization	Department	Monitoring Program Title
Indiana Department of Environmental Management, Office of Water Management	Assessment Branch, Biological Studies Section	No title given
Indiana Department of Natural Resources	Division of Soil Conservation	Lake and River Enhancement Program
Michigan Department of Environmental Quality	Water Division	Water Chemistry Monitoring Project
Michigan Department of Environmental Quality	Water Division	Cooperative Lakes Monitoring Program (CLMP)
Michigan Department of Environmental Quality	Water Division	Lake Quality Assessment Project
Michigan Department of Environmental Quality	Water Division	Water Quality Monitoring
Minnesota Pollution Control Agency	Environmental Outcomes	Biological Monitoring
Minnesota Pollution Control Agency		North Shore Streams Monitoring Project
Minnesota Pollution Control Agency	Environmental Outcomes Division	Lake Assessment Program (LAP)
Minnesota Pollution Control Agency		Citizen Lake Monitoring Program
Minnesota Pollution Control Agency	Environmental Outcomes Division, Rivers and Streams Monitoring Unit	Citizen Stream-Monitoring Program
Minnesota Pollution Control Agency	Regional Environmental Management Division	Total Maximum Daily Load Studies
Minnesota Pollution Control Agency	Environmental Outcomes Division	Minnesota Milestone (Routine Stream) Monitoring
Minnesota Pollution Control Agency	Environmental Outcomes Division	Integrated Stream Monitoring
Minnesota Pollution Control Agency		Stream Toxics Monitoring
Minnesota Pollution Control Agency		Basin Flow and Chemistry Monitoring
Minnesota Pollution Control Agency		Lakes Regional and Trend Monitoring
New York State Department of Environmental Conservation	Division of Water	Rotating Intensive Basin Studies
New York State Department of Environmental Conservation	Division of Water	Finger Lakes Synoptic Water Quality Investigation
New York State Department of Environmental Conservation		Finger Lakes Biomonitoring
New York State Department of Environmental Conservation	Division of Water	Water Quality Study of the Finger Lakes
New York State Department of Environmental Conservation (NYSDEC)	Lake Services Section, Division of Water	Citizens Statewide Lake Assessment Program
Ohio Department of Natural Resources	Division of Natural Areas and Preserves	Ohio Stream Quality Monitoring Project (SQM)
Ohio Environmental Protection Agency	Division of Surface Water	Statewide Biological and Water Quality Monitoring and Assessment
Ohio Lake Management Society		Citizen Lake Awareness and Monitoring (CLAM)
Pennsylvania Department of Environmental Protection		Citizens' Volunteer Monitoring Program (CVMP)
Pennsylvania Department of Environmental Protection	Division of Water Quality Assessment & Standards	Pennsylvania's State-Wide Surface Waters Assessment Program
State University of New York	College of Environmental Science & Forestry	Nutrient Dynamics in Salmon Creek, NY
Wisconsin Department of Natural Resources	Watershed Management	WI Long Term Trend Monitoring

Organization	Department	Monitoring Program Title
Wisconsin Department of Natural Resources	Fisheries Management - Habitat	Citizen Lake Monitoring Network
Canadian Federal Government		
Environment Canada		Pesticides In Aquatic Ecosystems
Environment Canada		Niagara River Upstream/Downstream Monitoring Program
Environment Canada		St. Clair Water Quality Monitoring Program
Environment Canada		Wolfe Island Monitoring Program
Environment Canada	National Water Research Institute	Agricultural non-point sources of pollution
Environment Canada		St. Clair & Detroit River Water Quality Monitoring Program
Canadian Provincial Government		
Ontario Ministry of the Environment		Provincial (Stream) Water Quality Monitoring Network (PWQMN)
Ontario Ministry of the Environment		Clean Water Regulation (MISA) Monitoring Data Ontario Point Sources

United States

In total, 106 U.S. monitoring programs sample water quality in the watersheds of the Great Lakes basin. Because of the large number of programs found in this category, only federal and state programs will be discussed in detail. Details on all programs can be found by examining the full monitoring inventory.

Federal – Three federal monitoring programs have been identified that focus on water quality monitoring in Great Lakes watersheds. These three programs are administered by the U.S. Geological Survey (USGS). It should be noted that there are 3 U.S. EPA programs that include water quality data. These programs are considered databases rather than monitoring programs and will be discussed in the section following the discussion on water quality monitoring in watersheds.

USGS manages three water quality monitoring programs in the Great Lakes basin watershed. In 1991, USGS implemented the *National Water-Quality Assessment (NAWQA) Program*, which has target sampling programs in western Lake Michigan drainages and the Lake Erie-Lake St. Clair basin with a total of 171 sampling locations. Sampling focuses on evaluating data for trends and includes monitoring of general water chemistry, pesticides, contaminants in bed sediments, and contaminants in fish and benthic invertebrates.

National Water Information System (gaging stations), also managed by U.S. Geological Survey (USGS), which collects a combination of water quality and water level data at roughly 75,000 locations in the basin, though the number of active stations is much smaller. The USGS gaging station program monitors surface water flows and quality, and groundwater extensively across the basin. At present, funding for these sampling locations is threatened because a large portion of the operating budget comes from disparate sources outside of USGS, such as state agencies and universities, which can be subject to budget cuts. *Stream Water Quality Data* are also collected in cooperation with the State of Michigan (2001 – present). This program collects mercury, PCB, common constituents, anion, cation, and nutrient data daily. Other reported activities that collect some level of monitoring data in U.S. EPA Region 2 include the Lake Ontario Lower Foodweb Assessment (LOLA), tributary monitoring (no further information was available), sediment studies for Lake Ontario, and an unnamed cooperative monitoring project with Canada. No additional information was submitted for these programs.

State – In total, state governments conduct 38 water quality monitoring programs in the Great Lakes watershed. Each state's programs will be discussed below.

Illinois

Illinois Environmental Protection Agency reported six water quality monitoring programs in its portion of the Great Lakes basin watershed.

The *Ambient Water Quality Monitoring Network (AWQMN)* provides baseline water quality information, to characterize and define trends in the physical, chemical and biological conditions of the state's waters and to identify new or existing water quality problems. In total 213 locations are sampled for air temperature, water temperature, dissolved oxygen, pH, conductivity, turbidity, nutrients, metals, and conventional constituents. This program is funded by the federal Clean Water Act.

One of the primary objectives of the *Ambient Lake Monitoring Program (ALMP)* is to identify areas with significant water quality problems that need further investigations or remediation. Approximately 50 sites are monitored five times a year for phosphorus, chlorophyll, secchi transparency, dissolved oxygen and temperature. Similarly an objective of the *Illinois Clean Lakes Program (ICLP)* is to diagnose current lake water quality problems. This program monitors 3-5 sites twice monthly for air temperature, water temperature, dissolved oxygen, pH, conductivity, alkalinity, turbidity, secchi transparency, and nutrients.

Illinois *Intensive Basin Surveys* program focuses on identifying the chemical, physical and biological quality of selected Illinois streams. Monitoring for this program takes place on a five-year cycle in roughly 100 locations throughout the state. Another stream monitoring program is *Facility-Related Stream Surveys*. This program provides stream quality assessment information for wadeable streams that receive point source discharges.

Finally, the *Illinois Volunteer Lake Monitoring Program* is volunteer-based water quality sampling program that provides historical data to document water quality impacts and support lake management decision-making. The program also serves as an educational program. This program is funded by the federal Clean Water Act. Sites are sampled twice monthly during the summer months for water clarity (secchi disk), water color, aquatic plants, site depth, weather conditions, zebra mussels, ammonia, nitrates, total phosphorus, total suspended solids, volatile suspended solids, and chlorophyll.

Indiana

Four water quality monitoring programs were reported from the Indiana portion of the Great Lakes basin.

Indiana Department of Environmental Management Office of Water Management conducts two water quality monitoring programs. The first program samples a statistically defined number of randomly selected sites to assess and characterize the overall water quality and biological integrity of the state. This program monitors for a large list of chemical contaminants on a five-year rotation. The second program provides basic information to reveal water quality trends and provide data for existing and prospective users of Indiana surface water. No additional information is available for these programs.

Indiana Department of Natural Resources' *Lake and River Enhancement Program* monitors surface water chemistry parameters across the state. No descriptive information was provided for this project.

Hoosier Riverwatch is a statewide volunteer stream monitoring program for schools, citizens, watershed groups, and government agencies that monitors seven locations in the Great Lakes basin. Roughly 700 sampling locations throughout the state sample for BOD, dissolved oxygen, *E. coli*, nitrate, nitrite, pH, phosphate, phosphorus (total), turbidity and water temperature. Funding for this program comes from Indiana Department of Natural Resources Division of Soil Conservation.

Michigan

Michigan Department of Environmental Quality reported four water quality monitoring programs in its portion of the Great Lakes basin watershed.

The purpose of the Michigan Department of Environmental Quality *Water Chemistry Monitoring Project (WCMP)* is to assess temporal and spatial trends in surface water contaminant levels, assess the current status and condition of individual waters of the state, and determine whether Michigan Water Quality standards are being met. In total 48 sites are monitored throughout the basin for an extensive list of chemical and physical properties. Most of these sites are located in inland waters with the exception of seven monitoring locations in Lake Huron's Saginaw Bay and four monitoring sites in Lake Michigan's Grand Traverse Bay. Funding for this program comes through Clean Michigan Initiative bond funding.

A related project, *Water Quality Monitoring*, looks at whether rivers and streams are attaining water quality standards and meeting designated uses. All wadable rivers and streams across the state are sampled on a five-year rotating cycle. This program is funded through the Clean Michigan Initiative and general state funds.

The *Lake Quality Assessment Project* assesses water quality and trophic conditions in randomly selected lakes. Approximately 80 lakes are sampled for transparency, total phosphorus, chlorophyll a, nitrogen, dissolved oxygen and temperature twice a year during a five-year rotating basin cycle. Funding is provided through Clean Michigan Initiative bond funding.

A volunteer monitoring program collecting water quality data in Michigan is the *Cooperative Lakes Monitoring Program (CLMP).* This program is a citizen's volunteer lake monitoring program designed to obtain baseline data on lake productivity indicators for Michigan's inland lakes. Parameters sampled include transparency, total phosphorus, chlorophyll a, and aquatic macrophytes. Funding is provided from Clean Michigan Initiative bond funds, federal funds, and lake association contributions.

Michigan's Clean Michigan Initiative bond funding system is a good example of an innovative funding source. Because of this funding system, Michigan has the resources necessary to maintain a comprehensive water quality monitoring program. This type of funding system may serve as a good example for other states and provinces seeking additional financial resources.

Minnesota

Minnesota Pollution Control Agency reported 11 water quality monitoring programs in its portion of the Great Lakes watershed.

The *Total Maximum Daily Load Studies* program identifies sources and sets load targets to meet water quality standards and beneficial uses for the major and minor watersheds in the state. Federal funds support this project. No further descriptive information is currently available for this project. A related project, *Basin Flow and Chemistry Monitoring*, conducts monitoring to determine the flow and concentration of pollutants coming from each tributary across the state and how these amounts vary at different times of the year, and no additional information is currently available for this project.

Five programs focus on stream water quality monitoring. The *Minnesota Milestone (Routine Stream) Monitoring* program looks at water quality changes over time by continually recording basic chemical measures of stream water quality. Approximately 80 sites are monitored for pH, ammonia, nitrite-nitrate, turbidity, temperature, and dissolved oxygen. Federal funds support this project. The *Integrated Stream Monitoring* project monitors rivers and streams using an integrated approach designed to provide a more holistic picture of river water quality. Basic physical and chemical water quality parameters are monitored

at approximately 100 sites each summer. This project is funded by state funds. The *Biological Monitoring* program monitors the condition of wadeable streams and wetlands. Approximately 200 sampling locations are spread throughout the state. This project is also funded by the state. The *North Shore Streams Monitoring Project* assesses the current water quality conditions at eight sites in the state to provide baseline information on water quality trends. The *Stream Toxics Monitoring* monitors trace metals, including mercury, arsenic, cadmium, chromium, copper, lead, nickel, and zinc in streams in the state's major river basins. No additional information is currently available for this project.

Two programs focus on the water quality of inland lakes. The *Lake Assessment Program (LAP)* samples water quality at 45 sites for total phosphorus, total suspended solids, conductivity, transparency (secchi disk), dissolved oxygen, total Kjeldahl nitrogen, temperature, and chlorophyll-a. State funds support this program. The *Lakes Regional and Trend Monitoring* program samples 30 lakes once to twice a month from June through September. These data are added to the regional database and used for assessing trends. No additional descriptive information is currently available for this project.

Two volunteer monitoring programs conduct water quality monitoring in Minnesota. The *Citizen Lake Monitoring Program* collects transparency, total phosphorus, and chlorophyll data at nearly 1,400 sites. *Citizen Stream-Monitoring Program* collects transparency, appearance, recreational suitability, precipitation, and stream stage at 473 locations in the state. Funding for administration of both of these projects come through the state's general fund.

New York

Six water quality monitoring programs were reported from New York. The New York State Department of Environmental Conservation (NYSDEC) is conducting five of these programs and State University of New York, Syracuse manages one.

NYSDEC's *Rotating Intensive Basin Studies* is a statewide assessment program collecting chemical, toxicity, macroinvertebrate, and sediment data. No additional information is currently available for this project.

The *Citizens Statewide Lake Assessment Program* managed by NYSDEC is a volunteer lake monitoring program. Sampling is conducted statewide for parameters including chloride, conductivity, nitrogen, pH, rainfall, salinity, transparency (secchi disk), suspended and dissolved sediments, water temperature, aquatic vegetation, and chlorophyll.

The Finger Lakes region is the focus area for three of NYSDEC's monitoring programs. *Finger Lakes Synoptic Water Quality Investigation* assesses the conventional water quality and limnologic trends within the Finger Lakes. The *Finger Lakes Biomonitoring* program monitors water chemistry and zooplankton in the region and the *Water Quality Study of the Finger Lakes* program assesses water quality conditions and trends in the Finger Lakes.

The State University of New York's Syracuse *Nutrient Dynamics in Salmon Creek, NY* is a program that studies the processes controlling nutrient delivery from the watershed to the stream. No additional information is currently available for this project.

Other reported activities that collect some level of monitoring data in New York include the Buffalo Remedial Action Plan (RAP) 2005 sediment sampling program, sampling related to sediment remediation work in the St. Lawrence River, RAP coordination in 18 Mile Creek by the Niagara County Conservation District, and Monroe County combined sewer overflow and stormwater abatement monitoring. No additional information was submitted for these programs.

Ohio

In total, three water quality monitoring programs were reported from Ohio.

The Ohio Environmental Protection Agency manages the *Statewide Biological and Water Quality Monitoring and Assessment* program. Each year Ohio EPA conducts biosurveys in 10-15 different study areas with an aggregate total of 300-400 sampling sites to collect biological, chemical, and physical data.

The Ohio Department of Natural Resources conducts the *Ohio Stream Quality Monitoring Project* (SQM), which uses a variety of biological testing techniques to compile information on the quality of the state's rivers and streams. Volunteers are trained to collect and classify aquatic invertebrates. The Ohio SQM Project maintains data on 20 state scenic river segments.

The *Citizen Lake Awareness and Monitoring (CLAM),* managed by Ohio Lake Management Society, is a volunteer lake monitoring program. No additional information was provided for this project.

Pennsylvania
Pennsylvania Department of Environmental Protection reported two water quality monitoring programs within the state.

Pennsylvania's *State-Wide Surface Waters Assessment Program* is a statewide, fixed station water quality sampling system. This program was designed to conduct state-wide stream assessments for all streams, and causes and sources of impairments. Currently there are 120 sampling locations.

The *Citizens' Volunteer Monitoring Program (CVMP)* is a citizen volunteer monitoring network, which collects water quality information as well as performs habitat assessments and water quality ratings based on benthic macroinvertebrate sampling.

Wisconsin
Two water quality monitoring programs were reported from Wisconsin. Both are being conducted by Wisconsin Department of Natural Resources.

The *Wisconsin Long Term Trends* (Tributary) monitoring network consists of 42 surface water monitoring stations throughout the State. Sites are sampled either quarterly or monthly for a variety of parameters including nutrients, suspended solids, dissolved oxygen, and trace metals.

The *Citizen Lake Monitoring Network* is a volunteer monitoring network engaged in sampling water quality conditions at over 850 lakes in Wisconsin. This network is designed to increase public information and involvement in lake management as well as provide water quality data to resource managers.

Wisconsin DNR has also monitored approximately 15 nearshore stations on Lake Michigan (10 meter water depth) the past two years (and plans to continue) for nutrients, suspended solids, dissolved oxygen, conductivity, light penetration, algae nutrient content, and dreissenid mussels as part of a study of nuisance algae.

Local – Local governments also contribute a substantial effort to water quality monitoring in the region. Local governments reported 18 water quality monitoring programs taking place in the Great Lakes watershed. These programs are primarily focused on smaller, regional monitoring efforts and therefore will not be described in detail in this section.

University – In total, universities conduct 24 water quality monitoring programs in the Great Lakes watershed. University of Wisconsin, Heidelberg College, and Cornell University are major contributors to

Great Lakes monitoring. As with local government monitoring programs, these efforts are primarily focused on smaller, regional monitoring efforts and therefore will not be described in detail in this section.

Nongovernmental Organizations – Nongovernmental organizations reported 21 water quality monitoring programs taking place in the Great Lakes watershed. The majority of these programs are local level volunteer water quality monitoring efforts.

Canada

In total, 14 water quality monitoring programs focusing on watersheds were reported by Canadian agencies in the Great Lakes basin. Of these programs, six are conducted at the federal level by Environment Canada, two are conducted by Ontario Ministry of the Environment, and the remaining programs are conducted by regional conservation authorities.

Federal – Environment Canada's watershed water quality monitoring takes place primarily in the interconnecting channels of the Great Lakes basin, including the St. Lawrence, Niagara, St. Clair, and Detroit Rivers. In 1975, the *Niagara River Upstream/Downstream Monitoring Program* was initiated to measure weekly water quality samples for nutrients, major ions, trace metals, pesticides, chlorobenzenes, PCBs, and PAHs. The data from this program are used to determine Lake Erie exit loads, Lake Ontario input loads from the Niagara River, and to monitor the effectiveness of remedial efforts along the Niagara River corridor. The *St. Clair Water Quality Monitoring Program* samples various water quality parameters to track improvements in point and non-point source loadings to the river. The *Wolfe Island Monitoring Program* involves the collection of water and suspended sediment samples at a station located at Banford Point on Wolfe Island. Monthly concentrations of trace organics (pesticides, chlorobenzenes, PCBs, PAHs), trace metals, nutrients and major ions are measured. The data from this station are used to determine exit loads from Lake Ontario, and to provide information on upstream water quality conditions for the St. Lawrence River basin. The *St. Clair & Detroit River Water Quality Monitoring Program* was initiated in 2001 to assess a wide range of organic and inorganic contaminants. The intent of this program is to identify contaminants of concern and detect differences in contaminant concentrations in upstream and downstream locations. A federal program not focused on the connecting channels is Environment Canada's *Pesticides In Aquatic Ecosystems* program. Through this program, surface water is monitored for in-use pesticides in the Great Lakes and in selected watersheds. Surface water environments as well as precipitation are scanned for pesticides commonly used in Ontario. Finally Environment Canada's *Agricultural Non-Point Sources of Pollution* monitors levels of nitrogen, phosphorus, and suspended sediments. No additional information was available for this program.

Provincial – Ontario Ministry of the Environment's *Provincial (Stream) Water Quality Monitoring Network (PWQMN)* collects surface water quality information from rivers and streams at over 350 strategic locations throughout Ontario. Monthly samples are analyzed for a suite of parameters including nutrients, metals, chloride and turbidity. Ontario Ministry of the Environment also manages the *Clean Water Regulation (MISA) Monitoring Data Ontario Point Sources* database. No descriptive information is currently available for this project.

Regional – Four conservation authorities reported their participation in the PWQMN. The St Clair Regional Conservation Authority's *Habitat Stewardship Program* monitors monthly water chemistry, including ammonia, chloride, conductivity, nitrogen, pH, phosphorus, total suspended solids, and water temperature, at twelve sites and benthic macroinvertebrates at 67 sites annually. Funding for this program comes from Environment Canada. In addition, the Upper Thames River Conservation Authority reported the *Benthic Sampling Program*. No descriptive information is currently available for this project.

Water Quality Databases

The U.S. EPA manages three large databases that store water quality data for the Great Lakes basin. Data in these databases is collected by regional, state, and local agencies as well as privately run companies.

US EPA's *STORET* (Storage and Retrieval) database, though not a monitoring program itself, contains raw biological, chemical, and physical surface and ground water data collected by federal, state, and local agencies, Indian tribes, volunteer groups, universities, and others. In addition to water quality data, STORET contains information on why the data were gathered, sampling location, and methods used to sample and analyze the data. STORET has been in operation since 1999 and includes nearly 9,000 sites in the Great Lakes basin. A small percentage of these stations are in open waters of the Great Lakes basin rather than in inland lakes, rivers, or nearshore areas. STORET contains a great deal of historical data going back to the early part of the 20th century. This database is an excellent reference for looking at temporal and spatial trends.

The *Permit Compliance System (PCS)* has been providing information for more than 30 years on companies in the U.S. that have been issued permits to discharge waste water into rivers. This system provides information on when a permit was issued and expires, how much the company is permitted to discharge, and the monitoring data showing what the company has discharged. The PCS database tracks permit compliance and enforcement status to meet the informational needs of the National Pollutant Discharge Elimination System (NPDES). PCS collects data from more than 3,500 locations spread throughout the Great Lakes basin with the highest concentrations in the more heavily urbanized areas.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) is a multi-purpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality based studies. Though it is not a monitoring program, it integrates a geographic information system (GIS), historical watershed and meteorological monitoring data, and state-of-the-art environmental assessment and modeling tools into one convenient package. Among other information included in the database are industrial facilities' discharge sites, water quality stations, bacteria stations, a national sediment inventory, and water quality observation stations.

Findings – Water Quality

Open Waters – U.S. EPA's *Long-Term Open Lakes Monitoring Program* and Environment Canada's *Great Lakes Surveillance Program* are the most extensive open water monitoring programs in the Great Lakes basin. It appears as if federal agencies are primarily responsible for monitoring the open waters of the basin. Nearshore and offshore monitoring conducted by other agencies generally occurred within fifteen kilometers of the shoreline. One exception to this general conclusion is Macomb County, Michigan's *Lake St. Clair Water Quality Assessment* program which monitors at 122 locations throughout the U.S. portions of Lake St. Clair.

Watershed – At the federal level, one of the most comprehensive water quality monitoring programs in the Great Lakes watershed is the USGS *National Water Information System (gaging stations)*, which in the past has collected a combination of water quality and water level data at roughly 75,000 locations in the basin. This is a very valuable resource for the region. Unfortunately, funding for these sampling locations is threatened because a large portion of the operating budget comes from sources outside of USGS, such as state agencies and universities. Three gaging stations in the Great Lakes basin are currently being shut down.

At the state and provincial level, all states and provinces reported dedicated water quality monitoring programs in their sections of the Great Lakes watershed. Ontario Ministry of the Environment reported a

comprehensive stream monitoring program called the *Provincial (Stream) Water Quality Monitoring Network* (PWQMN). Each U.S. state reported specific lake monitoring programs, stream monitoring programs, and large scale volunteer water quality monitoring programs. Funding for these state level programs originates from mixed sources. Some states reported support from federal funds while others reported state or nongovernmental funding. Michigan's Clean Michigan Initiative bond funding system is a good example of an innovative funding source. Because of this funding system, Michigan has the resources necessary to maintain a comprehensive water quality monitoring program. This type of funding system may serve as a good example for other states and provinces seeking additional financial resources.

Nearshore monitoring was identified as a potential monitoring gap. This type of monitoring is generally considered underfunded and therefore not enough monitoring is taking place in the nearshore zones of the Great Lakes basin. This is the area that humans spend most of their time and where the largest anthropogenic effects are seen. More financial resources may need to be directed to nearshore monitoring to address this need.

Indicators – The Toxic Chemical Concentrations in Offshore Waters (#118) indicator calls for the monitoring of PCBs, dieldrin, chlordane, DDT, metabolites, hexaclorobenzene, toxaphene, and mercury. Results of the monitoring inventory show a fair amount of water quality monitoring in the open waters of the Great Lakes basin, but little data are collected on these toxic substances. Three programs specifically mentioned collecting toxic chemical data. These are Environment Canada's *Niagara River Upstream/Downstream Monitoring Program*, Michigan Department of Environmental Quality's *Water Chemistry Monitoring Project*, and University of Wisconsin – Milwaukee/Milwaukee Metropolitan Sewerage District's *WATERBase Monitoring Project*. It appears as if lack of data on toxic chemical concentrations in offshore waters of the Great Lakes may be a monitoring gap in the Great Lakes basin.

It is important to note again that toxic chemical concentrations can be measured in media other than water, including sediments and fish. Typical toxic chemical concentrations in water are much lower than associated concentrations in sediment and fish. Monitoring for these toxic contaminants in water must therefore include tests suitable for detecting extremely low levels of these contaminants. This type of monitoring is very expensive. Currently, toxic chemical investigation in the Great Lakes basin appears to be largely focused on sediments and fish. More investigation is needed to determine if the benefits of monitoring the toxic chemical concentrations in water is worth the added expense when similar data are being collected in sediments and fish.

The Phosphorus Concentrations and Loadings (#111) indicator calls for measuring the total phosphorus levels in the springtime open waters and annual total phosphorus loads to each lake. Most water quality monitoring programs, including those in the open water, inland lakes, rivers, and streams of the Great Lakes basin, reported phosphorus monitoring as part of their sampling protocol. While it appears as if there is a good deal of data available on phosphorus concentrations in waters of the Great Lakes basin, most of these programs, other than Michigan Department of Environmental Quality *Water Chemistry Monitoring Project,* appear not to be focused on determining the sources of contamination and local loading levels. More monitoring may need to be directed at identifying and reducing the impact of the sources of phosphorus contamination.

Water quality monitoring is widespread and diverse in the Great Lakes basin. Programs vary from locally focused to those addressing basinwide issues. In most cases, programs monitor for a wide range of parameters using diverse strategies and methodologies. Additionally, the monitoring programs in the basin address many more water quality issues than the few SOLEC indicators specifically addressing surface water quality. Using the information in this report and the inventory itself, the water quality monitoring community should examine program details against basinwide needs to determine how best to coordinate monitoring. A significant concern was raised about the cost of monitoring increasing each year while the

level of governmental funding dedicated to water quality monitoring remains the same. The result is a continuous decrease in monitoring efforts in order to stay within previously set budgets. More effort needs to go toward allotting financial resources based on current monitoring needs rather than previously set limits.

General Monitoring
b. Sediment Quality

In the Great Lakes basin 43 sites have been designated Great Lakes Areas of Concern (AOC). These areas are located across the Great Lakes basin and designated as AOCs largely due to high degrees of sediment contamination. Sediment contamination is created primarily by industrial and municipal discharges, combined sewer overflows, and urban and agricultural non-point source runoff. Contaminated sediments pose serious human and ecological health concerns. Contaminated sediments also allow for a bioaccumulation effect in aquatic organisms, which in turn leads to human fish consumption advisories.[5]

Sediment monitoring is specifically addressed by two Great Lakes indicators: Concentration of Contaminants in Sediment Cores (#119) and Sediment Available for Coastal Nourishment (#8142). In total, 50 programs were found that monitor sediments in the Great Lakes basin. A number of these programs, as they relate to the Great Lakes indicators, are reviewed below.

Contaminants in Sediment Cores

The Concentration of Contaminants in Sediment Cores (#119) assesses the concentrations of toxic chemicals in sediment by measuring concentrations in sediment cores at selected sites within the Great Lakes basin at ten year intervals. Chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and its metabolites, hexachlorobenzene, toxaphene, and mercury.

HIGHLIGHT – Sediment Quality

- While there is a considerable amount of issue-driven sediment sampling more baseline sediment monitoring may be needed. Currently there is little guidance on baseline sampling for open waters and nearshore areas of the basin. To successfully address SOLEC indicators specific monitoring guidelines may need to be developed.

Federal – USGS conducts two large-scale sediment contaminant monitoring programs. The *National Water-Quality Assessment (NAWQA) Program* has target sampling programs in western Lake Michigan drainages and the Lake Erie-Lake St. Clair basin. Among a host of other sampling media this project targets contaminants in bed sediments. In addition to the NAWQA program, USGS also conducts the *Nearshore Lake Ontario Ecosystem Study Plan* which also samples sediment chemistry in Lake Ontario nearshore regions.

The U.S. Army Corps of Engineers monitors sediment as it is related to navigation and dredging. *The Navigational Dredging Harbors* project is conducted by the Detroit District of the Corps to collect sediment data on commercial and recreational harbors in Michigan and Wisconsin. This program monitors various nutrients and organic indicators on a 5 to 10 year rotating cycle. The *Monitoring Dredged Material* project collects and analyzes sediments from Federal navigation channels to determine proper methods for managing dredged material. This program measures grain size, moisture content, volatile organic content, and total organic carbon on a five year cycle. The *Operations and Maintenance of Federal Navigation Channels* project not only maintains channel depths but also monitors sediment quality in these locations.

US EPA conducts a number of programs that address sediment monitoring. The U.S. EPA *Contaminated Sediment Monitoring* conducts monitoring in nearshore areas of the Great Lakes basin and focuses on biological and chemical sampling in bottom sediments. This sampling is focused in AOCs in the US. The U.S. EPA *National Sediment Inventory (NSI)* is a repository for data on chemical contaminants in river, lake, ocean, and estuary bottoms. U.S. EPA's *STORET (Storage and Retrieval)* is a database that contains state collected contaminated sediment data. STORET includes 8,898 stations in the Great Lakes basin but only a subset of these are sediment monitoring locations.

The U.S. National Oceanic and Atmospheric Administration manages the program *Contaminant fluxes into and out of sediments* that sampled sediment contaminant levels in Lake Erie.

Environment Canada reported on three sediment contamination monitoring projects. The *Great Lakes Sediment Assessment Program* assesses sediment quality in the Great Lakes basin by comparing current sediment contaminant levels to surveys conducted in the late 1960s and early 1970s. This dataset is being developed to determine the spatial and temporal trends in persistent toxics in Great Lakes sediments. Environment Canada conducts the *Lake St. Clair Bottom Sediment Contaminant Characterization* project as part of their *Great Lakes Sediment Assessment Program*. The *Sediment Quality in Canadian Great Lakes Tributaries* is a sediment chemistry survey in the St. Clair River, Lake St. Clair, the Detroit River, Lake Erie, the Niagara River, Lake Ontario, and the St. Lawrence River. The sediment samples are analyzed for organochlorine compounds, polycyclic aromatic hydrocarbons, metals, total organic carbon, dioxins, furans, in-use pesticides, and particle size distribution.

State/Provincial and local – Illinois reported on two sediment contamination monitoring programs. One of the many goals of the Illinois Environmental Protection Agency's *Illinois Clean Lakes Program (ICLP)* is to determine the presence of toxic materials in fish, water, and sediments and the sources of any contaminants. Specific information on parameters, sampling frequency, and funding sources was not reported. The Northeastern Illinois Planning Commission *Lake Water Quality Assessment Program* collects sediment quality data on non-routinely monitored, publicly-owned or publicly-accessed lakes within the northeastern Illinois region. In total 109 lakes are sampled for various nutrients, metals, and organics. This program is funded by the U.S. EPA Lake Water Quality Assessment (Section 314) of the Clean Water Act. No information on specific sediment monitoring parameters was reported for either program.

Michigan reported a number of sediment monitoring programs. The Michigan Department of Environmental Quality (DEQ) *Sediment Contaminant Monitoring in Inland Lakes* measures the spatial and temporal trends in contaminant levels in inland lake sediments. A total of 22 lakes are sampled for nutrients, total organic carbon, PCBs, DDT, Mercury, and trace metals. These lakes are sampled on a ten-year rotating cycle. This program is funded by Clean Michigan Initiative. Michigan DEQ also conducts site specific sediment sampling as part of its *Water Quality Monitoring* program. Through this program sediment samples are tested in selected watersheds on a 5-year rotating cycle. Michigan DEQ does additional targeted sediment sampling as part of regulatory processes (e.g. dam removal). Other programs taking place at the local level are the Wayne County Department of Environment *Rouge River Project*, the Macomb County *Bear Creek Clean Water Initiative*, and the Macomb County *Lake St. Clair Water Quality Assessment*.

Three sediment monitoring programs were reported in New York. New York State Department of Environmental Conservation's *Sediment Sampling* program monitors surficial sediment contamination. In addition, the New York State Department of Environmental Conservation *Finger Lakes Sediment Core Investigation* assesses organic and inorganic chemical trends over time and determines sediment accumulation rates within each of the Finger Lakes. Parameters measured include organic chemicals (DDT, PCBs, etc.) and inorganic chemicals (primarily metals). Cornell University's *Characterize sediment* measures NO3-N, dissolved phosphorus, total phosphorus, alkalinity, sulfate, chloride, and pH at 20 sub-

watersheds of Fall Creek and 10 monitoring wells at Animal Science Teaching and Research Center in Harford, New York. Funding information was not reported for either of these programs.

Ohio reported on three sediment monitoring programs. The Ohio Environmental Protection Agency *Ohio sediment inventory* samples for nutrients, metals and industrial contaminants (primarily PCBs and poly-aromatic hydrocarbons) at 21 locations. Ohio Environmental Protection Agency's *Cuyahoga River Old Channel Assessment* samples 25 sites for contaminated sediments in both core and ponar grab samples. Samples are analyzed for poly-aromatic hydrocarbons, PCBs, chlorinated pesticides, heavy metals, semi-volatile chemicals, total organic carbon and grain size. The Ohio Department of Natural Resources *Sediment cores* program takes core samples from Ohio waters. No more descriptive information is available for this program.

Wisconsin reported two sediment monitoring programs. The Wisconsin Department of Natural Resources *Sediment Core Data* samples sediment cores at 72 lakes. The Green Bay Metropolitan Sewerage District *Ambient Water Quality Monitoring Program* collects water and sediment quality data from the Lower Fox River and Green Bay. Sediment gravity cores are collected every other year for heavy metals and organics analysis.

Ontario Ministry of the Environment manages the *Great Lakes Index Station Network Monitoring.* This program has established a total of 66 core sites within the Great Lakes basin and a minimum of seven sites are visited each year. Each of the Great Lakes, except Lake Michigan, are monitored through this program. This network of stations is designed to provide information on where and how sediment quality conditions are changing over time. Ontario Ministry of the Environment also reported the *Nearshore Monitoring and Assessment* program which monitors sediment, water, and biota in near shore zones of the Great Lakes.

Ontario's Great Lakes Institute for Environmental Research monitors *Western Basin Contaminants* including organochlorine compounds, PCBs, and poly-aromatic hydrocarbons levels in sediment.

Sediment Available for Coastal Nourishment

The purpose of the Sediment Available for Coastal Nourishment (#8142) indicator is to assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and to estimate the amount of sediment available for transport to nourish coastal ecosystems. This indicator is measured through streamflow and suspended sediments at the mouth of major tributaries and connecting channels.

A limited number of programs were found that specifically address suspended sediment monitoring. Results of the inventory did report on at least 48 programs monitoring for turbidity. It is possible that these turbidity data may provide information needed to analyze suspended sediment transport in the region. This section will focus on discussion of the programs specifically addressing suspended sediment monitoring. For information on the programs monitoring turbidity please refer to the complete monitoring inventory database.

Federal – The USGS *National Water Information System (gaging stations)* collects streamflow data from roughly 75,000 locations in the basin. While the majority of the funding for this program comes from USGS, a large portion also comes from state agencies and universities. Environment Canada conducts two suspended sediment monitoring programs. The *Ontario Region Suspended Sediment Program* operates a network of 90 suspended sediment stations around the Great Lakes basin to allow computation of annual sediment loads to the Great Lakes. The suspended sediment network produces annual suspended sediment load calculations for most major tributaries around the Great Lakes. Environment Canada also manages the

St. Clair River, Lake St. Clair & Detroit River Suspended Sediment Characterization program. No descriptive information was reported for this program.

State – Illinois State Water Survey's *Benchmark Sediment Monitoring Program* is a long-term database of suspended sediment transport at 15 locations in Illinois. Michigan Department of Environmental Quality collects total suspended sediments and total dissolved sediments in tributaries throughout the state as part of its *Water Quality Monitoring* program. Heidelberg College manages the *Sediment and Nutrient Concentrations in the River Raisin* Program. The level to which this program measures suspended sediments is unclear.

Findings – Sediment Quality

It appears as if a considerable amount of sediment monitoring is taking place at both the federal and state/provincial levels. Little information was available on specific parameters and sampling frequency at the federal level. A more in-depth examination of parameters and frequency at the federal level would more clearly determine if sampling coverage is adequate.

While a great deal of sediment sampling appears to be taking place in inland lakes and rivers, results of the inventory indicate that there may be a potential gap in sediment sampling in open waters and nearshore areas of the Great Lakes. Results of the monitoring inventory also indicate that while there is a considerable amount of issue driven sediment sampling more baseline sediment monitoring may be needed. Currently there is little guidance on baseline sampling for open waters and nearshore areas of the basin. To successfully address SOLEC indicators monitoring guidelines may need to be developed. Elements of sediment monitoring such as sampling frequency, spatial distribution of sampling site, and chemical parameters should be refined. All states and provinces, with the exception of Indiana, Minnesota and Pennsylvania, reported sediment monitoring programs. Not enough information was reported on funding sources to draw any specific conclusions but concerns were raised about potential reductions to sediment monitoring budgets. Inadequate budgets may affect the effectiveness of baseline sediment contamination monitoring programs and investigatory programs looking at new or historic sources of contaminants.

Only 3 programs reported monitoring suspended sediments or streamflow in Great Lakes basin. At the U.S. federal level, no suspended sediment monitoring programs were reported. Environment Canada conducts two suspended sediment monitoring programs. The *Ontario Region Suspended Sediment Program* operates a network of 90 suspended sediment stations around the Great Lakes basin to allow computation of annual sediment loads to the Great Lakes. Environment Canada also manages the *St. Clair River, Lake St. Clair & Detroit River Suspended Sediment Characterization* program for which descriptive information was available. Suspended sediment monitoring at the state level was lacking in all Great Lakes states except Illinois and Michigan. Results of the inventory indicate that 45 programs monitor turbidity. This may be appropriate for some level of analysis of suspended sediment loads; however more investigation is required to determine if these data are sufficient.

General Monitoring
c. Soil

Because of its fertile soil, the Great Lakes basin accounts for one of the most agriculturally rich areas of the country. These fertile soils also provide a rich template that allows the climatic expression of a diversity of natural habitats ranging from tallgrass prairies in the South to boreal forests in the North. The diverse array of habitats in turn provide for the overall ecological diversity and ecosystem health of the region. Changing land uses can alter soil characteristics and impact environmental processes involving the soil. For example,

soil contamination can lead to ground, surface or drinking water contamination, along with other ecological threats. Although no SOLEC indicator specifically calls for soil monitoring, there are a number of monitoring programs collecting data on soil conditions.

Ten soil monitoring and identification programs were found in the Great Lakes basin. These programs range from local remediation monitoring to basinwide soil identification databases. The most detailed and comprehensive soil mapping program is the *Soil Survey Geographic Database (SSURGO)* managed by U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS). The scale of this mapping effort generally ranges from 1:12,000 to 1:63,360 and is primarily designed for use by landowners, townships, and natural resource planning and management at the county level. This database will cover the entire U.S. when completed and is being developed at the county level. It is scheduled to be complete in 2008. Currently, only portions of the dataset are available in digital form.

Another soil database program, also managed by NRCS, is the *State Soil Geographic Database (STATSGO)*. Through this program soil maps are produced for the entire U.S. The mapping scale for STATSGO is 1:250,000. The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. NRCS also manages the *Soil Climate Analysis Network (SCAN)* that collects near real-time soil moisture and temperature at 4 locations in the Great Lakes basin and is planning to expand the program by adding 1,000 new sampling locations.

The U.S. EPA *Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS)* tracks information on all Superfund sites, both the most hazardous and those where cleanup is easier or less urgent. In total there are over 153 CERCLIS monitoring sites in the Great Lakes basin. Many of these sites collect data on soil contamination. U.S. EPA also manages the *Toxic Release Inventory (TRI)* which collects information on toxic chemicals that are being used, manufactured, treated, transported, or released into the environment, including soil resources.

HIGHLIGHT – Soil

- Currently, no SOLEC indicator specifically calls for soil monitoring. To develop baseline data on soil characteristics and the potential environmental impacts of alternations, SOLEC participants may want to consider adding an indicator to address soil composition and contamination.

- The U.S. Department of Agriculture, National Resources Conservation Service manages the Soil Climate Analysis Network (SCAN). This program is the only basinwide program collecting real-time soil moisture and temperature locations in the Great Lakes basin. A need for additional sampling locations has been identified and consequently SCAN is seeking to expand its network.

Wisconsin reported three distinct soil sampling programs. This includes a registry of closed remediation sites for the state, a nutrient management program that addresses proper soil nutrient management, and the forestry compartment reconnaissance database which considers soil resources as part of an ecosystem management plan. A small scale site restoration project was also reported in New York State.

Other soil sampling programs include local remediation, contaminant monitoring and nutrient management programs.

Findings - Soil

The *Soil Survey Geographic Database (SSURGO)* managed by U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) is the most detailed and comprehensive soil mapping program in the basin. This database is being collected at the county level for the entire U.S. Currently only a portion of U.S. counties have been digitally mapped but the database is scheduled to be complete in 2008. A more

general soil database also managed by NRCS is *State Soil Geographic Database (STATSGO)*. These soil maps are produced for the entire U.S. by generalizing the detailed soil survey data. For most management issues involving soil, however, these data are too coarse to be of much use. NRCS also manages the *Soil Climate Analysis Network (SCAN)* that collects real-time soil moisture and temperature at 4 locations in the Great Lakes basin. A need for additional sampling locations has been identified and consequently *SCAN* is seeking to expand its network to include another 1,000 real-time sampling locations nationwide. SOLEC should consider adding an indicator to address soil composition and contamination. If contamination mapping becomes a need, more effort will be needed to join existing datasets and fill in numerous gaps in the coverage. Remediation and point source contaminant monitoring is funded by the responsible parties, while *SSURGO*, *STATSGO*, and *SCAN* rely on federal support.

General Monitoring
d. Groundwater

Monitoring groundwater contamination has become a key environmental issue as land use intensity across the Great Lakes basin increases. Groundwater is the safest and most reliable source of available freshwater. Ninety percent of the freshwater resources in the United States are stored as groundwater. Groundwater plays an important role in the hydrologic cycle and is an important resource in areas of limited precipitation. Results of the monitoring inventory indicate that 29 groundwater monitoring programs are conducted in the Great Lakes basin. Groundwater health and availability is addressed by four SOLEC indicators. Each of these indicators and relevant monitoring programs as reported to the monitoring inventory are discussed below. See the drinking water section for more information on drinking water monitoring

Groundwater Quality

The Natural Groundwater Quality and Human-Induced Changes (#7100) indicator assesses the quality of groundwater used for drinking water, agriculture, and ecosystem function. Measured parameters include atrazine, nitrate/nitrite, total coliform, E. coli, taste, odor, total organic carbon and other parameters of concern.

HIGHLIGHT – Groundwater

- More resources need to be directed toward monitoring groundwater discharges in the region. No specific groundwater discharge monitoring programs were reported to the inventory.
- The USGS gaging station program monitors surface water, groundwater, and water quality extensively across the basin. Funding for many of these sampling locations comes from sources outside of USGS, such as state agencies and universities. Due to federal, state and non-governmental budget cuts, funding for this important program is consistently threatened.

The U.S. EPA *STORET (Storage and Retrieval)* database contains biological, chemical and physical ground water data collected and uploaded by federal, state and local agencies. STORET currently includes nearly 9,000 stations in the Great Lakes basin, the bulk of which are in Minnesota, Wisconsin, and Michigan. It is important to note that only a subset of these locations monitor chemical contaminants in groundwater. USGS conducts two sampling programs that also sample chemical composition of groundwater in the basin. The *National Water-Quality Assessment (NAWQA) Program* has study area sampling programs in western Lake Michigan drainages and the Lake Erie-Lake St. Clair basin with a total of 171 sampling locations. Among other media this program monitors groundwater contaminants. Study areas are intensively monitored on a rotating basis across the U.S. The *National Water Information System*, also managed by USGS, historically has collected water quality and water level data at roughly 75,000 locations in the basin. Included in these sampling locations are ground water sampling sites collecting water chemistry data.

The Illinois Environmental Protection Agency conducts the *Groundwater* program, which provides an overview of the groundwater conditions in the state by establishing baselines and identifying trends in water quality. Parameters sampled at these sites include pH, conductivity, temperature, specific conductance, oxidation- reduction potential (Eh), pumpage rate, inorganic chemical analysis, volatile organic and aromatic chemical analysis.

Minnesota Pollution Control Agency's *Ambient Ground Water Quality Monitoring* consists of a network of 100 to 150 shallow monitoring wells and 100 to 150 deeper drinking water wells. The shallow wells provide an early warning network of changes in water quality. The deeper wells provide information about the quality of water that people are drinking. Each well is sampled biannually. Chemical parameters include nitrate, volatile organic compounds, chloride, and pesticides.

Ohio Environmental Protection Agency's *Ambient Ground Water Monitoring Program* provides state-wide ground water quality information to enhance water resource planning and protection activities. The sampling network includes 280 wells distributed across the state of Ohio that are sampled for a suite of 32 inorganic water quality parameters every six or eighteen months. Emphasis is placed on sampling aquifers used by public water systems. Funding for this program comes primarily from U.S. EPA Clean Water Act programs.

Wisconsin Department of Natural Resources' *Groundwater & Environmental Monitoring System (GEMS)* monitors groundwater chemistry semiannually at over 640 sites in the state. Wisconsin's *Groundwater Retrieval Network (GRN)* links groundwater data residing in various program-related database systems to one central location for analysis. Included in this database are public drinking water supply wells, private drinking water supply wells, non-point source priority watershed projects, landfill wells, and special groundwater studies.

Groundwater programs found at the local level include the Kellogg Biological Station *Nutrient Monitoring* program and the Superior Environmental Corporation *Roger B. Chaffee Blvd site* and *54th and Clyde Park site*.

Groundwater Use

The Groundwater and Land Use and Intensity (#7101) indicator measures land use and water use intensity within political sub-divisions and supply and demand issues related to ground water. This indictor is used to infer the potential impact of land use practices on the quantity and quality of groundwater resources.

Only one program was found that directly measures groundwater use patterns. The *National Water Use Information* program managed by USGS is a compilation of site-specific data and water-use maps for each state in the U.S. Included in this database are water-use levels for public supply, domestic, irrigation, industrial, livestock, aquaculture, mining, and thermoelectric power. These data are collected and compiled for each state every five years. Additional information needed to evaluate this indicator is well-water permit and construction records. These data are likely available, but were not reported via the monitoring inventory. For more information on land use please refer to the land use section of this report.

Groundwater Discharge

Two SOLEC indicators investigate groundwater discharge in the basin. The Base Flow Due to Groundwater Discharge (#7102) indicator is used to help determine the impacts of surficial alterations on the quantity of groundwater resources. This indicator is a measure of the contribution from groundwater discharge made to surface water base flow. The Groundwater Dependent Animal and Plant Communities (#7103)

indicator is a measure of the numbers and diversity of invertebrates, fish, wildlife, and plant communities dependent on groundwater discharges in tributaries and nearshore areas of the Great Lakes basin. This indicator assess the locations of groundwater inputs, contribution of groundwater to stream and nearshore flows; and trophic status, food web dynamics, and location of groundwater fed habitats and communities.

No information was reported directly on groundwater discharge monitoring programs but a number of monitoring programs may contribute some degree of relevant information. The USGS *National Water-Quality Assessment (NAWQA) Program* may provide some level of detail on groundwater discharge in the western Lake Michigan drainages and the Lake Erie-Lake St. Clair portion of the basin. Two state run surveys, including Illinois Environmental Protection Agency's *Intensive Basin Surveys* and the Ohio Department of Natural Resources *Water Inventory*, may also contribute to the groundwater discharge data available for those states but not enough information is available for these programs to evaluate their relevance. Additional monitoring programs relevant to the Groundwater Dependent Animal and Plant Communities indicator can be found in the wildlife and plant sections of this report.

Findings - Groundwater

Ground water quality monitoring is addressed by three large federal programs, the most comprehensive being the USGS *National Water Information System (gaging station)*. While a number of the Great Lakes states reported groundwater quality monitoring programs, Indiana, Michigan, New York, and Pennsylvania did not report any programs. It is difficult to evaluate shortcomings related to specific parameters because little to no sampling parameter information was provided for each program. The USGS *National Water Use Information* program is the most comprehensive water use inventory for the region. Additional information needed to evaluate the Groundwater and Land Use and Intensity indicator is well-water permit and construction records. These data are likely available but were not investigated through the monitoring inventory effort. It was also found that more investigation is needed on groundwater discharge monitoring in the region. While a few programs in the region may provide some level of groundwater discharge information, no specific groundwater discharge monitoring programs were reported. If this is an accurate assessment of the coverage of groundwater monitoring programs, additional resources will be needed to inform all SOLEC groundwater indicators. Additional monitoring programs relevant to the Groundwater Dependent Animal and Plant Communities indicator can be found in the wildlife and plant sections of this report. It should be noted that the U.S. Geological Survey gaging station program monitors surface water, groundwater, and water quality extensively across the basin. At present, funding for these sampling locations is threatened because a large portion of the operating budget comes from sources outside of USGS, such as state agencies and universities.

General Monitoring
e. Climate/Weather

Concerns regarding changes in climate and weather patterns have attracted a great deal of attention in recent years. Unnatural rates of climate changes have profound implications for natural ecosystems. Increasing temperatures may lead to changes in many aspects of weather, including wind patterns, amount and type of precipitation, and the occurrence of severe weather events. The suite of SOLEC indicators includes two indicators directly addressing climate change. These include Climate Change: Effect of Crop Heat Units (#9003) and Climate Change: Ice Duration on the Great Lakes (#4858).

Crop Heat Units (#9003) are a measure of crop suitability used by farmers when selecting varieties or hybrids of crops suitable for their area. This indicator considers the effect of changes in atmospheric temperature on regional species diversity, spatial variability and crop yields. The primary measure of this

indicator is daily maximum and minimum temperature averages using day and night readings. The second relevant indicator is Ice Duration on the Great Lakes (#4858) which aims to detect the impacts of climate change in the region by tracking ice on each lake over time. To interpret this indicator, data for maximum percentage of ice cover needs to be gathered each year.

Based on inventory results, the Great Lakes region has 18 operational weather and climate monitoring programs. These programs range from local precipitation monitoring programs to multiple parameter, federally funded, regional climate monitoring programs

HIGHLIGHT – Climate/Weather

- Overall monitoring for the climate change indicators appears to be quite complete, but the continuing need for this monitoring should be emphasized to those with budgetary oversight to ensure that monitoring coverage continues.

- A considerable amount of weather related data is collected at land based stations. While 47 marine buoys are present, they are not as widespread as land-based stations. These differences in spatial coverage may lead to accuracy differences between land and marine temperature models.

Land-based temperature averages across the Great Lakes basin are measured primarily by NOAA's *National Climatic Data Center* which measures daily air temperature averages in all Great Lakes states as well as other weather related parameters. Information on the specific number of monitoring locations was not available, but many locations are distributed throughout the basin. The Midwestern Regional Climate Center (MRCC) *Climate Data Sets* measures daily digital climate data for several thousand stations across the region as well. Measurements include high, low, and mean temperatures; hourly precipitation; dew point; pan evaporation; snowfall; modeled soil moisture data; and soil temperature. Numerous widely dispersed or local programs also monitor terrestrial atmospheric temperatures across the region. A few of these programs include southeastern *Michigan's Precipitation Data Network*, *Illinois' Climate Network Data*, and *Minnesota's Climate Monitor*.

NOAA also manages a set of 33 marine buoys monitoring air temperature as well as atmospheric pressure and wind in each of the Great Lakes. Environment Canada maintains fourteen *Marine Buoys* in the Great Lakes basin measuring air temperature and other parameters needed for weather forecasting. Other marine buoys measuring temperature and other weather and climate related data are the *Sterling Meteorological Station* located in southern Lake Ontario; the *Lake Michigan Monitoring Buoy* managed by University of Wisconsin, Milwaukee; and the *Lake St. Clair Weather Buoy* managed by University of Michigan.

NOAA *Great Lakes Ice Cover Climatology and Great Lakes CoastWatch Nodes* collect information on ice cover in the Great Lakes basin. The *Great Lakes Ice Cover Climatology* program collects ice cover information from many federal agencies to develop ice cover climatology reports and provides a benchmark of ice cover and ice cover variation of the Great Lakes since 1960. The *Great Lakes CoastWatch Nodes* collects near real-time information on various physical parameters including ice cover.

Findings – Climate/Weather

The results of the inventory show that data are gathered for both the 'Climate Change: Effect of Crop Heat Units' and the 'Climate Change: Ice Duration on the Great Lakes' indicators. NOAA's Great Lakes Ice Cover Climatology provides the information needed to analyze changes in ice cover over time. Results of the inventory also show that a considerable amount of weather related data are collected at land based stations. While 47 marine buoys are present, they are not as widespread as land-based stations. These differences in spatial coverage may lead to accuracy differences between land and marine temperature models.

While we are unable to collect specific budget information for the weather and climate monitoring programs, the analysis shows that the primary weather and climate monitoring programs are large-scale data collection efforts managed by NOAA. Funding is generally consistent year-to-year, but can be subject to congressional cuts or outright elimination. While monitoring for the climate change indicators appears to be quite complete, the continuing need for this monitoring should be emphasized to those with budgetary oversight to ensure that monitoring coverage continues.

3. Habitat and Biodiversity
a. Fish Population Health

Fish population monitoring is necessary in order to measure the effect of anthropogenic factors, such as exotic species, over-fishing, predator stocking programs, habitat destruction, and habitat contamination on long-term fish population health and integrity. Also, because fish population composition and abundance can be an indicator of water quality, fish monitoring programs help to establish the overall environmental health of an ecosystem.

Based on inventory results, 107 fish monitoring programs are being conducted in the Great Lakes basin. These programs will be discussed in relation to relevant SOLEC indicators. Only those programs that directly address a specific SOLEC indicator will be mentioned. To see a complete listing of programs see the monitoring inventory. The monitoring programs were separated into three groups, based on program goals: fish contamination, species specific monitoring, and habitat and prey monitoring programs.

A U.S. Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state, and provincial organizations, has been developed to address fisheries related issues including instability of fish communities, over harvesting, sea lampreys, lost fishing opportunities, invasions and introductions, inadequate environmental quality, and competition and conflicts among users of the fishery resources. This Joint Strategic Plan has laid a framework necessary for organizations to coordinate and collaborate fisheries related monitoring activities across the Great Lakes basin. Through the Joint Strategic Plan, Lake Committees have been established for each of the five Great Lakes and Technical Committees have been established to advise these Lake Committees. Every five years formal "State of the Lake Reports" are prepared by the Lake Committees.

Fish Contamination

There are a number of SOLEC indicators that address fish contamination. This section focuses on fish contamination monitoring not related directly to human health. A number of monitoring programs collect data to assist in establishing fish consumption advisories for human health. For a discussion of these programs please refer to the Fish Consumption Advisory section of this report.

The SOLEC indicators addressing this monitoring need are Contaminants in Whole Fish (#121), Contaminants in Young-of-the-Year Spottail Shiners (#114), and External Anomaly Prevalence Index for Nearshore Fish (#124). The purpose of the Contaminants in Whole Fish indicator is to measure the concentration of persistent bioaccumulating toxic (PBT) chemicals in Great Lakes whole lake trout and walleye as a general status and trend indicator. The Contaminants in Young-of-the-Year Spottail Shiners indicator monitors the concentration of PBT chemicals in young-of-the-year spottail shiners. This information is used to identify local areas of elevated contaminant levels that may pose a threat to piscivorous wildlife. External Anomaly Prevalence Index for Nearshore Fish is used to reflect external anomaly rates in nearshore fish. Anomalies include raised lesions and barbell abnormalities in brown bullhead catfish.

US EPA reported one fish contaminant monitoring program. The EPA Great Lakes National Program Office (GLNPO) manages the *Great Lakes Fish Monitoring Program* (GLFMP) that has annually monitored the toxic chemicals in Great Lakes fish since 1970. The GLFMP consists of two separate elements, an Open Lakes Trend Monitoring Program for whole fish (Element 1) and a Game Fish Fillet Monitoring Program (Element 2) to assess the risks of persistent and bioaccumulative contaminants on the health of the fishery and on the fish consuming wildlife. Element 1 of the GLFMP is directed at monitoring contaminant trends in the open water of the Great Lakes, and assisting in evaluating the impacts of contaminants on the fishery. The program provides for collection and analysis of whole-fish composites of lake trout in the size range from 600 mm to 700 mm from Lakes Michigan, Huron, Ontario, and Superior, and of walleye in the size range of 400 mm to 500 mm from Lake Erie. Composites of each species, consisting of five whole individual fish, are analyzed for contaminants to assess temporal trends in organic contaminants in the open waters of the Great Lakes, using fish as biomonitors. These data can also be used to assess the risks of such contaminants on the health of this important fishery and on the wildlife that consume them. Element 2 of the GLFMP is directed at monitoring potential human exposure to contaminants through consumption of popular sport species, as well as providing temporal trend data for top predator species, which have shorter exposures than the lake trout collected in Element 1. The GLFMP currently collects samples, for both elements of the program, from a set number of sites per lake. Collections alternate on a yearly basis, with even and odd year collections. Element 1 samples consist of 5 whole fish composites for a total of 50 fish collected per site. The GLFMP currently utilizes an established chemical parameter list for analysis that includes OC pesticides, PCBs, Mercury, and some emerging contaminants of concern. Funding for this program comes through the Clean Water Act sections 104 and 108.

The USGS *National Contaminant Biomonitoring Program* database, with 16 monitoring locations in the Great Lakes basin, seeks to document trends in occurrence of persistent toxic chemicals in fisheries. Parameters included in this program are PCB, dieldrin, mercury, DDT, and others. USGS also manages the *National Water Quality Assessment Program (NAWQA)* which includes some fish contaminant sampling. In the Great Lakes basin, NAWQA focuses study on western Lake Michigan and Lake Erie-Lake St. Clair drainages.

HIGHLIGHT – Fish Population Health

- A Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state and provincial organizations, has been developed to address fisheries related issues. This partnership framework is a strong example of effective coordination and collaboration and may be used as a model for other areas of Great Lakes monitoring.
- The Canadian Dept. of Fisheries and Oceans Great Lakes Fish Contaminants Surveillance Program has been collecting important fish contaminant data since 1977. Funding for this program was cut in the spring of 2005. This has created a large gap in regional fish contaminant monitoring and interrupts one of the few Great Lakes long-term fish contaminant monitoring programs capable of documenting trends and changes in the Great Lakes basin.
- Analysis of inventory results indicate that more fish habitat monitoring is needed in the Great Lakes basin at both the federal and state levels.

Illinois, Michigan, Minnesota, New York, and Wisconsin reported fish contaminant monitoring programs at the state level. Illinois Environmental Protection Agency manages three programs. The *Fish Contaminant Monitoring* program investigates the presence and build-up of toxic and potentially hazardous substances in fish, determines the impact of fish contaminants on aquatic environments, and provides information to aid in the location of contaminant discharge. Data are collected on mercury, PCBs, and a number of additional pesticides and contaminants in 17 locations. No specific information is available on sampling frequency or

funding. The *Ambient Lake Monitoring Program (ALMP)* and the *Illinois Clean Lakes Program (ICLP)* both mention some fish contaminant monitoring, but no specific details were provided.

Another state level contaminant monitoring program is Michigan Department of Environmental Quality's *Fish Contaminant Monitoring Program* that has the objective of evaluating the need for sportfish consumption advisories and commercial fishing regulations, identifying spatial and temporal trends, and evaluating the effectiveness of existing programs. Twenty six fixed station sampling sites monitor whole fish for mercury, PCBs, and pesticides biennially. Edible portion samples are collected for analysis to support consumption advisory development. The number and location of these sites varies from year to year. Caged fish studies have been conducted to varying degrees in about 40 watersheds. Studies are repeated as needed in problematic watersheds. Primary funding for this project comes from Michigan's general state funds and the Clean Michigan Initiative.

The Minnesota Department of Natural Resources manages the state's *Fish Contaminant Monitoring Program*. Approximately every 5 years this program samples and analyzes for contaminants, including mercury and PCBs, in common fish species found in Lake Superior. In addition, this program collects 15 coho salmon and 15 chinook annually at French River on Lake Superior and monitors levels of mercury and PCBs. Funding for this program comes from state general funds and the state's game and fish fund.

The New York State Department of Environmental Conservation manages the *Lake Ontario Contaminant Trend Analysis* program that collects contaminant concentrations of PCBs, organochlorine pesticides, and mercury in salmonids at 11 Lake Ontario sampling locations. New York's *Sportfish Contamination* program monitors contaminant levels, including PCBs, organic carbon, mercury, dioxins and furans in Lake Erie and Lake Ontario fish. Funding for both of these programs is provided via state funds.

The objectives of Wisconsin Department of Natural Resources' Statewide *Fish Contaminant Program* include protection of fish consumers, resource management, and environmental protection. This program has been in place since the mid-1970s. Fish are collected from approximately 50 to 100 sites each year. Current analyses include about 600 samples analyzed for mercury, 350 for total PCBs, 30 for banned pesticides, 20 for dioxin/furan analysis and 10 for PBDEs. Monitoring consists of different components including baseline, advisory, Great Lakes, and trend monitoring. Baseline Fish Contaminant monitoring focuses on sampling new sites and sites where contaminant data are old or limited, or where existing data shows that concentrations may be high and additional data would be beneficial to determine advisory needs. Advisory Fish Contaminant Monitoring refers to monitoring of fish for contaminants where PCB based fish consumption advice is in place and monitoring is conducted to update consumption advice. This monitoring is generally conducted in major industrial rivers and locations where remediation may be necessary. Great Lakes contaminant monitoring consists of collection of fish for contaminant analysis on a biennial basis. Samples include both game fish and forage fish from Lake Superior and Lake Michigan. The final component of this program is to determine trends and geographic patterns of contamination for general DNR staff use. Funding for this program currently comes from a number of sources. Collection of fish is supported by fisheries staff sampling through other programs. Analysis of samples is supported by the Wisconsin State Laboratory of Hygiene and EPA Clean Water Act Performance Partnership Grant 106 funds. Other supplies and processing are also supported by Clean Water Act funds. Gaps include limits on the number of sites where fish can be collected each year, the number of fish that can be processed, and the number and types of analytes that can be assayed on each sample.

Canada reported a number of fish contaminant monitoring programs. The Department of Fisheries and Oceans (DFO) manages the *Great Lakes Fish Contaminants Surveillance Program* that has annually monitored the toxic chemicals in fish and fish communities throughout the Great Lakes since 1977. The program collects information at 10 Great Lakes sites, including 4 stations on Lake Ontario and 2 stations each on Lake Erie, Lake Superior, and Lake Huron. Approximately 450 fish samples are analyzed annually

for routine pesticides, total PCBs and up to nine trace metals. A subset is also analyzed for dioxin and furan isomers, PCB isomers, toxaphene isomers and brominated flame retardant. DFO also manages the *Hamilton Harbor Contaminant Trend Monitoring Study*. The objective of this study is to generate fish community contaminants data to assist in describing the progress of remediation in the Hamilton Harbor ecosystem. The two previously mentioned DFO fish contaminant monitoring programs are facing funding concerns. Due to cuts in funding, these programs ceased operation April 1, 2005. DFO is currently in the process of refocusing its efforts to its core mandate of determining impacts of toxic chemicals on fish. Negotiations are currently underway between DFO and Environment Canada to shift responsibility for this monitoring program to Environment Canada but concerns have been raised that current financial resources could be a limiting factor in continuing this program.

Ontario Ministry of the Environment (OME) collects data through the *Ontario Sport Fish Contaminant Monitoring Program.* No descriptive information is available for this program. The Forage Fish Monitoring Program also run by OME collects forage fish samples around the Great Lakes and selected inland lakes and rivers and analyzes for a suite of contaminants including PCBs, mercury, mirex, DDT, and dioxins/furans. OME's *Tributary Mouth Biomonitoring* uses juvenile young-of-the-year fish to determine Canadian tributaries contributing significant loadings of BHC, chlordane, dieldrin, dioxin, HCB, mirex, OCS, PCBs, DDT, Pb, and Hg. Also Great Lakes Institute for Environmental Research *Western Basin Contaminants* study analyzes levels of contaminants (OCs, PCBs, PAHs) in fish.

While there are many fish contaminant monitoring programs throughout the Great Lakes, little information was collected on the methods employed. Therefore, it was difficult to assess the number of programs that directly address the Contaminants in Whole Fish indicator. *Michigan's Fish Contaminant Monitoring Program* and GLNPO's *Great Lakes Fish Monitoring Program* are the only active monitoring programs that specifically mention whole fish contaminant sampling. The Canadian monitoring program equivalent to GLNPO's *Great Lakes Fish Monitoring Program*, Department of Fisheries and Oceans (DFO) *Great Lakes Fish Contaminants Surveillance Program,* has collected fish contaminant data, including whole fish samples, since 1977. Funding for this program was cut in the spring of 2005.

The only organization that reported specifically conducting young-of-year contaminant sampling was the New York State Department of Environmental Conservation (NYSDEC). Their *Young of year (YOY) fish tissue sampling* program monitors contaminants, including organic carbon, PCB, mercury, and poly-aromatic hydrocarbons (PAH), in young-of-year spottail shiners in Lake Ontario and Lake Erie. Their *Monitoring Persistent Toxic Contaminant Trends in Young Fish in New York State Great Lakes Areas of Concern* program monitors contaminant levels, including mercury, PCB, and organochlorine pesticides, in young-of-year fish in order to assess spatial and temporal changes in contaminants within New York's Great Lakes basin. This program currently monitors eleven sites five times a year. Funding for this program comes through U.S. EPA and the New York State Conservation Fund.

As an estimate of ecosystem health, the External Anomaly Prevalence Index for Nearshore Fish indicator is used to reflect external anomaly rates in nearshore fish. Anomalies include raised lesions and barbell abnormalities in brown bullhead catfish. While there are many general fish monitoring programs that may collect such data, only Pennsylvania Sea Grant reported monitoring anomalies in brown bullhead. The *Fish Tumors in Brown Bullhead Catfish* monitors liver and skin tumor rates in brown bullheads from seven sites in Presque Isle Bay, Lake Erie. Funding for this project comes for U.S. EPA.

Species Specific

The following will be a brief discussion of monitoring programs related to specific fish species of interest in the Great Lakes basin. Many of the monitoring activities in this section are coordinated monitoring efforts by Technical Committees in support of the Joint Strategic Plan for Management of Great Lakes Fisheries.

More than twenty five general fish community assessment programs were reported in the Great Lakes basin. The larger scale general fish community assessment programs include the U.S. Geological Survey *Status and Trends of Prey Fish Populations in Lake Michigan, Fish Community Assessment*, and *Distribution, abundance, and biology of fish populations (Lake Ontario)*; Quebec Ministry of Natural Resources and Wildlife *St. Lawrence River Fish Monitoring Network*; Wisconsin Department of Natural Resources *Lake Michigan recreational fishing statistics*; Illinois Department of Natural Resources *Lakewide Assessment Plan*; Michigan Department of Natural Resources *Lake Michigan fish population*, *Assessment of the Fish Community of Lake St. Clair*, *Saginaw Bay Fish Community Survey*, *Les Cheneaux Islands Fish Community Assessment*, *St. Marys River Fish Community Assessment* and *Status and Trends in Aquatic Resources Michigan*; Ontario Ministry of the Environment Ontario *Young-of-the-year Monitoring Program*; Ohio Department of Natural Resources *Commercial Fishery Monitoring*, *Lake Erie Trawl and Gill Net Surveys*; Ohio Environmental Protection Agency Statewide *Biological and Water Quality Monitoring and Assessment*; and Ontario Ministry of Natural Resources *Monitoring and assessment of fish populations; Lake Superior Commercial Fish Program; Lake Superior Recreational Fish Program; Great Lakes Basin Rare Species Biodiversity Inforamtion for Ontario; Commercial Catch Sampling Program; Nearshore Fish Community Assessment Program; and Offshore Fish Community Index Program*. Because little specific information was presented on which species were being monitored each of these programs is not specifically discussed in this section, but it is important to note that these monitoring programs may contain information relevant to the indicators that address trout, salmon, walleye, and sturgeon monitoring. It is also important to recognize that natural heritage programs found in each state may provide additional information on fish populations in the Great Lakes basin.

Two SOLEC indicators address salmonid populations. The Lake Trout (#93) indicator measures the abundance and self-sustainability through natural reproduction of lake trout in the Great Lakes basin in order to determine status and trends. The Salmon and Trout (#8) indicator assesses population trends of introduced trout and salmon. This indicator is measured by the productivity, yield, or harvest of Pacific salmon, rainbow trout, and brown trout.

Lake Trout - The USGS Great Lakes Science Center conducts three Lake Trout restoration projects. The *Lake Trout Restoration in Eastern Lake Erie* and the *Lake Trout Restoration in Lakes Michigan and Lake Huron* programs look at population dynamics of lake trout to assess potential population rehabilitation. Abundance, age, growth rates, genetic strain, and lamprey wounding rates are monitored at twenty locations in Lake Erie, six locations in Lake Michigan, and six locations in Lake Huron. The program *Evaluate progress and identify impediments toward restoring lake trout populations in Lake Ontario* also managed by the USGS Great Lakes Science Center assesses the abundance of lake trout and investigates population biology of these species. Funding for these projects comes from federal budgets.

Illinois, Michigan, New York, and Wisconsin also conduct specific Lake Trout assessment programs. The Illinois Department of Natural Resources *Fall/Spawning Lake Trout Assessment* program monitors abundance of spawning lake trout at one stocked and two non-stocked sites in Lake Michigan. The Michigan Department of Natural Resources conducts two Lake Trout monitoring programs. *Assessment of Lake Huron Lake Trout* monitors trout growth, maturity, reproduction, abundance, mortalities, movement, diet, and estimated prey consumption at twelve sites in Lake Huron. The *Assessment of Lake Trout Populations in Michigan Waters of Lake Superior* program monitors relative abundance, length and age composition, sex and maturity, sea lamprey wounding, growth, and mortality at 117 sites in Lake Superior. Both of Michigan's trout monitoring programs are federally funded. New York State Department of Environmental Conservation conducts the *Juvenile and adult Lake Trout Assessment* program. No specific information is available for this program. No specific information was reported on Wisconsin's Lake Trout monitoring projects. Ontario Ministry of Natural Resources conducts a number of general fish monitoring programs many of which identify Lake Trout as one of their focus species.

Through the Joint Strategic Plan for Management of Great Lakes Fisheries, a coordinated approach for monitoring the Lake Trout populations on Lake Michigan has been established. Through this coordinated approach, lake trout are sampled lake wide during two assessments which were designed by the Lake Michigan Lake Trout Task Group (Lake Michigan Technical Committee under the Joint Strategic Plan) and their coordinated implementation involves state, federal, and tribal entities. A spring lake trout sampling protocol for Lake Michigan is defined in the *Lake Wide Assessment Plan for Lake Trout* and includes sampling by four states, two federal, and tribal entities. All groups sample within a specific time frame at several locations around Lake Michigan to collect data on abundance, age, growth rates, genetic strain and stocking location, diet, fish health, recruitment of juvenile fish, and lamprey wounds. Mortality and growth indices are also developed from these data in Michigan waters. A fall/spawning assessment of lake trout is conducted by Illinois, Wisconsin and Indiana, U.S. FWS, and USGS. The sampling design of this assessment, an offshoot of the *Lake Wide Assessment Plan for Lake Trout*, specifies sampling at stocking locations and other known historic spawning locations to collect data on abundance, age, growth rates, genetic strain and stocking location, diet, and lamprey wounds. Data from both of these assessments are summarized in the annual report to the Lake Michigan Committee. Summarized data and a database of coded-wire tag recoveries are managed by the U.S. FWS Green Bay Fisheries Resource Office.

Salmon and Trout - Other more general salmon and trout monitoring programs include Illinois Department of Natural Resources *Fall Harbor Salmonid Assessment* that monitors abundance and population parameters of salmonids in four Illinois harbors of Lake Michigan. The Michigan Department of Natural Resources *Assessment of Lake Michigan fish populations* program emphasizes trout and salmon monitoring. This program monitors fish species, length, weight, age, sex, and maturity. Wisconsin Department of Natural Resources manages a number of data collection programs including *Lake Michigan Charter Boat Data*, *Lake Michigan Contest Data*, and *Lake Michigan Moored Boat Data*. Each of these programs collects data on recreational fisheries and salmon and trout harvests. Ontario Ministry of Natural Resources manages a *Coaster Brook Trout PIT Tagging Study* to monitor population health and also the *Rainbow Trout Population Assessment Using Fish Counter Technology* program to quantify the effect of current fishing regulations on rainbow trout numbers. Ontario Ministry of Natural Resources also conducts a number of general fish monitoring programs many of which identify Lake Trout as one of their focus species.

On Lake Michigan all four state management agencies working within the Joint Strategic Plan for Management of Great Lakes Fisheries fund a sport fishing creel survey which monitors recreational harvest of salmon and trout. Although the data collection methods employed differ because of differences in the fisheries, the data are comparable and data summary is coordinated through the Creel Working Group (Lake Michigan Technical Committee under the Joint Strategic Plan). USF&WS Green Bay Fisheries Resource Office houses a database of summarized lakewide catch, harvest, and effort data, which also includes charter boat information collected by the four states.

Wisconsin and Michigan also perform fall salmon and trout assessments at weirs during spawning. Data on species composition, abundance, age, growth rates, fish health, genetic strain, and lamprey wounds are recorded. Data from all salmon and trout (except lake trout) assessments are summarized and coordinated through the Lake Michigan Salmonid Task Group (Lake Michigan Technical Committee under the Joint Strategic Plan). Salmon and trout assessments data considered to be key indicators of population health are summarized in the annual report of the Lake Michigan Salmonid Task Group to the Lake Michigan Committee.

Walleye - The Walleye (#9) indicator seeks to measure the relative abundance, biomass, or annual production of walleye populations in historical, warm-cool water habitats of the Great Lakes basin. Four programs were found that specifically include walleye population monitoring in the Great Lakes basin. The

Michigan Department of Natural Resources conducts walleye monitoring in Lake Huron's Saginaw Bay. Through their *Saginaw Bay Fish Community Survey*, walleye population statistics are collected and through the *Vital Statistics of Walleye in Saginaw Bay* program, walleye are tagged to determine estimates of total annual mortality and survival, exploitation rates, and information on movement. Both of these programs are supported by the Sport Fish Restoration fund (75% Federal, 25% State). The Ohio Department of Natural Resources' *Walleye Tagging* program tags and tracks walleye in Ohio water of Lake Erie to estimate survival, exploitation, mortality rates, sex ratios and movement. Ontario Ministry of Natural Resources' also manages a walleye population monitoring program. The objective of this program, *A Preliminary Investigation of Walleye,* is to begin to assess the status of the walleye stock utilizing Lake Superior's Black Sturgeon River.

Lake Sturgeon - The Status of Lake Sturgeon in the Great Lakes (#125) indicator measures the population numbers of lake sturgeon in the Great Lakes basin as an indicator of ecosystem health. Two programs were found that specifically address lake sturgeon monitoring. The U.S. Fish & Wildlife Service *Lake Sturgeon Monitoring* program coordinates a multi-agency effort to assess the current status of lake sturgeon stocks in Lakes Huron, Erie, and the St. Clair System. This includes a tagging program, a qualitative and quantitative assessment of critical habitat, and an information transfer system that will provide valuable information accessible to interested parties, both inside and outside the Great Lakes basin. The Michigan Department of Natural Resources conducts a *Lake Sturgeon Assessment in Lake St. Clair and St. Clair River* program that monitors populations, spawning locations and movements within the St. Clair System. No specific location, frequency, or funding information was provided for these programs.

Habitat and Prey

The Fish Habitat (#6) indicator assesses the quality, quantity and location of aquatic habitat in the Great Lakes basin. Parameters within this indicator include quality, quantity, and distribution of aquatic habitat, percent of disturbed habitat, and population of fish species residing in each habitat. The Preyfish Populations and Communities (#17) indictor assesses the abundance and diversity of preyfish populations to infer the stability of predator species necessary to maintain the biotic integrity of each lake. Factors that are measured include abundance, diversity, and age and size distribution of preyfish species, including deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives.

The U.S. Fish & Wildlife Service is collecting some level of habitat information through its *Lake Sturgeon Monitoring* program. This program includes a qualitative and quantitative assessment of critical habitat parameters associated with sturgeon populations. The U.S. Geological Survey *National Water-Quality Assessment (NAWQA)* program also collects some degree of habitat information in its study areas, which include a total of 171 sampling locations in western Lake Michigan drainages and the Lake Erie-Lake St. Clair basin.

The Michigan Department of Natural Resources *Status and Trends in Aquatic Resources* program includes some level of habitat monitoring but details on the habitat sampling section of the program are unavailable. Two local-level habitat monitoring programs are also found in Michigan. The *Clinton River Coldwater Conservation Project* is conducted by the Clinton River Watershed Council and Wayne County's *Rouge River Project*. The Wisconsin Department of Natural Resources' *Stream Habitat Evaluations* collects stream habitat and fish data at more than 30 locations throughout the streams of Wisconsin and tributaries of Lake Michigan. This project is funded by the WDNR Watershed Management budget. More information on general habitat monitoring may be found in the coastal wetlands and stewardship sections of this report.

The USGS conducts three programs that collect data on prey fish populations. The *Status and Trends of Prey Fish Populations in Lake Michigan* program annually assesses prey fish populations in Lake Michigan utilizing bottom trawls to sample the prey species. *Status of Pelagic Prey Fish in Lake Michigan* is a

cooperative program between the USGS and the four states that utilizes acoustics to provide a lakewide assessment of the prey population. Both assessments are coordinated through the Planktivore Working Group, a task group under the Lake Michigan Technical Committee and reports are given at the annual Lake Michigan Committee meeting. The USGS *Bottom Trawl Indices* collects data on sculpin populations in southern Lake Ontario. New York State Department of Environmental Conservation conducts the *Binational Prey Fish Hydroacoustic Survey* which monitors the abundance of preyfish at six transects across Lake Ontario. Funding for this program comes from state and federal government budgets.

Findings – Fish Population Health

More than one hundred fish monitoring programs are being conducted in the Great Lakes basin. A Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state, and provincial organizations, has been developed to address fisheries related issues including instability of fish communities, overharvesting, sea lampreys, lost fishing opportunities, invasions and introductions, inadequate environmental quality, and competition and conflicts among users of the fishery resources. This joint strategic plan has laid a framework necessary for organizations to coordinate and collaborate fisheries related monitoring activities across the Great Lakes basin. Through the Joint Strategic Plan, Lake Committees have been established for each of the five Great Lakes and Technical Committees have been established to advise these Lake Committees. Every five years formal "State of the Lake Reports" are prepared by the Lake Committees.

Fish Contaminants – While there are many fish contaminant monitoring programs throughout the Great Lakes, little information was collected on the methods employed. Therefore, it was difficult to assess the number of programs that directly address the Contaminants in Whole Fish indicator. While Illinois, Michigan, Minnesota, New York, and Wisconsin reported fish contaminant monitoring programs at the state level, Michigan's *Fish Contaminant Monitoring Program* and GLNPO's *Great Lakes Fish Monitoring Program* are the only active monitoring programs that specifically mention whole fish contaminant sampling. The Canadian monitoring program equivalent to GLNPO's Great Lakes Fish Monitoring Program, Department of Fisheries and Oceans (DFO) *Great Lakes Fish Contaminants Surveillance Program,* has collected fish contaminant data, including whole fish samples, since 1977. Funding for this program was cut in the spring of 2005. Elimination of this program creates a large gap in regional fish contaminant monitoring and interrupts one of the few long-term fish contaminant monitoring programs capable of documenting trends and changes in the Great Lakes basin. DFO is currently in the process of refocusing its efforts to its core mandate of determining impacts of toxic chemicals on fish. Negotiations are currently underway between DFO and Environment Canada to shift responsibility for this monitoring program but concerns have been raised that current financial resources could be a limiting factor in continuing this program.

The only U.S. agency that reported specifically on young-of-year contaminant sampling was New York State's Department of Environmental Conservation. Their young-of-year sampling programs rely on federal funding and may serve as good example for other U.S. states and federal agencies to follow. Ontario Ministry of the Environment's Tributary Mouth Biomonitoring also uses young-of-the year fish to determine Canadian tributaries contributing significant loadings. It should also be mentioned that the only program found in the basin that collects information relevant to the External Anomaly Presence in Nearshore Fish indicator is Pennsylvania Sea Grant's *Brown Bullhead tumor monitoring* which is also funded by U.S. EPA.

Species Specific – A Joint Strategic Plan for Management of Great Lakes Fisheries, supported by fourteen federal, tribal, state, and provincial organizations, has been developed to address fish community health for a number of species including lake trout. While coordinated activities may be occurring on other lakes, only Lake Michigan reported specific coordinated activities related to Joint Strategic Plan Lake Technical

Committees. Coordinated monitoring approaches were reported for Lake Michigan for both Lake Trout and Salmon/Trout populations. The partnership framework set forth through the Join Strategic Plan for Management of Great Lakes Fisheries is a good example of effective coordination and collaboration in the Great Lakes monitoring community and may be used as an example for other areas of Great Lakes environmental monitoring.

More than twenty five general fish community assessment programs were reported in the Great Lakes basin. Because little specific information was presented on which species were being monitored, each of these programs is not specifically discussed. However, it is important to note that these monitoring programs may contain information relevant to the indicators that address trout, salmon, walleye, and sturgeon monitoring.

Lake Trout population monitoring is performed by USGS Great Lakes Science Center in Lake Michigan, Lake Huron, and Lake Erie. Illinois, Michigan, New York, Wisconsin also conduct specific Lake Trout assessment programs also. Ontario Ministry of Natural Resources conducts a number of general fish monitoring programs many of which identify Lake Trout as one of their focus species. As mentioned above, coordinated monitoring efforts through Joint Strategic Plan Technical Committees were reported for Lake Michigan for Lake Trout.

No specific information was reported on monitoring of introduced trout and salmon, but Illinois, Michigan, Wisconsin, and Ontario all reported general salmon and trout population monitoring which may include data on non-native salmon and trout populations. Coordinated monitoring efforts were reported for Lake Michigan for salmon and trout. No Lake Sturgeon monitoring programs were reported in Lake Michigan, Lake Superior, or Lake Ontario. Ohio, Michigan, and Ontario were the only states/provinces that reported specific walleye monitoring programs.

Habitat and Prey – The monitoring inventory results also indicate that minimal fish habitat monitoring is undertaken in the Great Lakes basin. The only program focused solely on fish habitat monitoring is Wisconsin's *Stream Habitat Evaluations* program. The fish habitat monitoring being conducted by other programs appears to be small in scale or narrowly focused on the habitat of specific target species. Results from the inventory indicate that more fish habitat monitoring is needed in the Great Lakes basin at both the federal and state levels. A limited amount of prey fish data are being collected across the basin. USGS is taking the lead in this effort in Lake Michigan. USGS and the state of New York are collecting prey fish data in Lake Ontario. Prey fish monitoring programs were not reported for Lake Superior, Lake Huron, or Lake Erie.

Habitat and Biodiversity
b. Aquatic Invasive Species

Aquatic Invasive Species (AIS) have threatened the Great Lakes ecosystem since the time of the first settlers. More than 180 non-native aquatic organisms of all types, including plants, fish, algae and mollusks, have become established in the Great Lakes. As human activity and globalization increased in the Great Lakes basin, the rate of introduction of non-native species has increased as well.

There are a few key terms related to this topic that should be defined. The term `invasive species' means a nonindigenous species that when introduced into an ecosystem may cause harm to the economy, environment, human health, recreation, or public welfare.[6] 'Aquatic nuisance species (ANS)' refers to an organism that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquaculture or recreational activities dependent on such waters. The

term 'exotic' or 'nonindigenous' or 'non-native' refers to any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organism transferred from one country to another. [7]

The Great Lakes Panel on Aquatic Nuisance Species (ANS), established in 1991, is a key body in the Great Lakes basin working toward the prevention and control of the occurrence of aquatic nuisance species in the Great Lakes. The Great Lakes Panel on Aquatic Nuisance Species is directed to identify Great Lakes priorities; assist the National Task Force on Aquatic Nuisance Species; coordinate exotic species program activities in the region; advise public and private interests on control efforts; and report to the national task forces prevention, research and control activities in the Great Lakes basin.

Under Section 1204 of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), each state is encouraged to develop an Aquatic Nuisance Species (ANS) State Management Plan. The primary management plan goals focus on prevention efforts to stop ANS introduction and spread and mitigation of associated impacts. The development, implementation and coordination of detection and monitoring efforts are instrumental to achieving these goals. The state ANS management plans, upon approval of the national ANS Task Force, are eligible to receive funding for implementation as stipulated under Section 1204 of NANPCA.

HIGHLIGHT – Aquatic Invasive Species

- The region would benefit from development of a scientifically based early detection monitoring program. This early detection monitoring strategy should be coupled closely with a rapid response program. This type of sound monitoring program, which would be able to effectively and efficiently detect invasions, is important when considering the limited funds currently available.
- The region would benefit from a coordinating body to organize and record AIS monitoring and management activities. A binational AIS monitoring office is needed to serve as a central location for coordinating monitoring activities and serve as a central resource for AIS related monitoring data.

The ANS Early Detection and Monitoring Lake Michigan Pilot Project managed by the Great Lakes Commission has recently been completed. The pilot project was conducted with guidance from the members of the Great Lakes Panel and the Lake Michigan Monitoring Coordination Council. The purpose of this project was to produce a set of guidelines and recommendations for a coordinated system to detect new ANS invasions and track the spread of established ANS populations in the Lake Michigan basin. Project recommendations will be used in efforts to advance the development of a Great Lakes region-wide ANS early detection and monitoring program. The full report on this project is available at http://www.glc.org/ans/initiatives.html. Selected recommendations from the report are listed below.

- Assess capability of current monitoring programs to detect and monitor ANS;
- Develop more programs which incorporate ANS detection and monitoring as a central purpose or goal;
- Financial support of ANS detection and monitoring should become more available for use by existing programs which do not currently collect ANS data;
- ANS reporting must be coordinated through a centralized data repository and information clearinghouse;
- Issues must be addressed that raise barriers and prevent monitoring programs from collecting and recording ANS data while they monitor other parameters;
- Resources for an early detection and monitoring network should be directed toward high risk and high probability areas for ANS invasions; and
- Programs that monitor fish populations or other parameters, such as water quality, should – to the extent possible – incorporate ANS early detection and monitoring protocols.

The Ontario Ministry of Natural Resources (MNR) is working on a similar effort to inventory and analyze monitoring efforts for the entire province of Ontario. MNR is compiling information about aquatic ecosystem monitoring and assessment activities occurring in Ontario waters that may detect aquatic invasive species. The information is being gathered through an on-line questionnaire and a workshop involving representatives from numerous agencies and organizations identified as being directly involved with the management or research of aquatic resources in Ontario even if they are not intended to detect aquatic invasive species (AIS). Monitoring in aquatic systems is critical to preventing, detecting and reducing the spread and impact of AIS which threaten Ontario species biodiversity. The information gathered is helping produce an initial assessment of current activities, needs and opportunities that could contribute to provincial detection and monitoring programs for AIS. It contributes to implementing the Ontario Biodiversity Strategy, the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem and the National Aquatic Invasive Species Action Plan. A report of the outcome of this work may be available by contacting Beth Brownson, Senior Invasive Species Biologist, Ontario Ministry of Natural Resources, at beth.brownson@mnr.gov.on.ca.

Two SOLEC indicators deal specifically with invasive species. The Sea Lamprey (#18) indicator seeks to estimate sea lamprey abundance and assess its overall impact on other fish populations in the Great Lakes basin. This is done by measuring the number of spawning-run adult sea lampreys and wounding rates on large salmonids. The Exotic Species (#9002) indicator will assess the presence, abundance and distribution of exotic invasive species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. This indicator is still under development and no specific species of interest have been identified and no monitoring protocols have been established.

The following discussion will focus on both sea lamprey and general aquatic invasive species monitoring as reported to the Great Lakes Monitoring Inventory. It should be noted that more than 20 general fish community assessment programs (please see Fish Ecology section of this report) and other invertebrate, plant and wildlife community assessment programs were reported in the Great Lakes basin. Each of these programs were not discussed specifically in this section, but many contain information on aquatic invasive species. Additionally, natural heritage programs in each state may provide additional information on aquatic invasive populations in the Great Lakes basin.

Sea Lamprey Monitoring

Results of the inventory indicate that sea lamprey monitoring is well-coordinated between the U.S. and Canada. The Great Lakes Fishery Commission coordinates and conducts a *Sea Lamprey Management Program* in the Great Lakes basin, with a focus on Lake Michigan industrial ports. Field work is conducted for the Great Lakes Fishery Commission by the U.S. Fish and Wildlife Service and Department of Fisheries and Oceans Canada. The purpose of this program is to assess populations of sea lampreys in Great Lakes streams, control population levels, and detect new infestations. Monitoring includes lamprey abundance in larval and adult stages, stream habitat analysis, and water chemistry parameters (pH, alkalinity, temperature, conductivity). The *Fishway* project, employed by the New York State Department of Environmental Conservation, monitors lamprey control effectiveness at a site located on Cayuga Inlet in the state of New York. Central Lake Superior Watershed Partnership's *Monitoring the Waters of Upper Michigan* also assesses sea lamprey populations as part of its baseline data collection focused in the water off Marquette.

A number of programs also reported collecting information on sea lamprey woundings on fish. The U.S. Geological Survey *Bottom Trawl Indices* program collects sea lamprey wounding data from species affected in waters along the southern shore of Lake Ontario. The Illinois Department of Natural Resources monitors sea lamprey woundings as part of their *Fall Harbor Salmonid Assessment*, *Spring Index Assessment*, *Fall/Spawning Lake Trout Assessment*, and *Lakewide Assessment Plan*. In total, the programs in Illinois

collect data at nine locations along the Lake Michigan shoreline. The Indiana Department of Natural Resources, Division of Fish and Wildlife, monitors sea lamprey woundings as part of their Fall/Spawning Lake Trout assessment and Spring Lake-wide assessments. In total, the programs in Indiana collect data annually from 4 to 7 locations along the Lake Michigan shoreline. The Michigan Department of Natural Resources also collects sea lamprey wounding of fish species in Lake Superior and Lake Huron. The *Assessment of Lake Trout Populations in Michigan Waters of Lake Superior* monitors sea lamprey wounding on lake trout at 117 sites in southern Lake Superior. The *Assessment of Lake Huron lake trout* program monitors sea lamprey wounding rates and estimates sea lamprey induced mortality at 12 sites in Lake Huron. Ohio Department of Natural Resources, coordinating with U.S. Fish and Wildlife Service, conducts a sea lamprey survey on the Chagrin River. The Wisconsin Department of Natural Resources also monitors sea lamprey woundings though the *Lake Michigan Charter Boat Data* program. This program collects data on the number of lamprey attached to chinook salmon and lake trout along the Wisconsin shore of Lake Michigan. Two sea lamprey wounding programs taking place at the tribal level include the Grand Traverse Band of Ottawa and Chippewa Indians *Grand Traverse Band - Biological Services Program* and the Chippewa Ottawa Resource Authority *Inter Tribal Fisheries and Assessment Program*. Both of these programs monitor in the Grand Traverse Bay.

General Aquatic Invasive Species Monitoring

Results of the Great Lakes Monitoring Inventory indicate that sixty-seven programs perform some level of AIS monitoring. AIS monitoring was not the focus of the majority of these programs but rather these programs passively collected AIS information as part of a larger effort. No specific AIS information was supplied for these programs and therefore the following discussion will focus only on programs with AIS monitoring as their primary objective. This discussion excludes sea lamprey monitoring which was discussed previously.

The U.S. Fish and Wildlife Service reported comprehensive aquatic invasive species monitoring programs in each of the Great Lakes. The purpose of the U.S. Fish and Wildlife ANS monitoring program is to conduct assessments to detect new ANS populations, and monitor changes in abundance of ANS in each of the Great Lakes. The U.S. Geological Survey Great Lakes Science Center also conducts a number of routine monitoring programs in each of the Great Lakes, many of which collect some level of invasive species monitoring data.

The Indiana Department of Natural Resources Division of Fish and Wildlife conducts AIS monitoring programs under contract with Ball State University, while they conduct Yellow perch assessments at three locations along the Southern Lake Michigan shoreline. Round goby and alewife abundance is measured as non-target species during trawling and gill net activities during the collection and assessment of the yellow perch population. A joint monitoring program to conduct surveillance for snakehead is conducted in conjunction with field collections during the spring and fall as part of the GLNPO, fish consumption advisory program in Trail Creek and Burns waterway.

In Michigan, there were a number of aquatic invasive species monitoring programs reported. Michigan Sea Grant's *Zebra Mussel and Aquatic Nuisance Species Monitoring* collects Zebra Mussel sighting data for Michigan's inland lakes through citizen reports, personnel from various Great Lakes agencies, and Sea Grant staff. Specific details on this program were not available. Michigan Lakes & Streams Association, Inc. conducts three aquatic invasive species monitoring activities including the *Purple Loosestrife Watch, Eurasian Watermilfoil Watch* and *"Drop-a-Brick" (Zebra Mussel Watch)*. These three programs are essentially one similar effort with three parts: document the introduction of these species, map the location and rate of spread, and monitor the success/failure of any local control or eradication programs. Michigan's Clinton River is the focus of the Nature Conservancy's *Interactions Between Freshwater Mussels and Zebra Mussels in the Upper Clinton River*. The goal of this project is to determine if chronic low levels of zebra

mussel infestation on native mussels has a long-term impact on the native freshwater mussel populations. This program samples biannually at two locations in the Clinton River.

Ohio Department of Natural Resources reported a number of aquatic invasive species monitoring programs. Among these programs are the *Statewide Zebra Mussel Surveys*, *Statewide Asian Carp Surveys*, *ANS Plan Species Monitoring and Control*, and the *Lake Erie ANS Trawl Surveys*.

Other aquatic invasive species monitoring programs reported to the inventory include the Pennsylvania Department of Environmental Protection *Pennsylvania Zebra Mussel Monitoring Network* that collects Zebra Mussel presence/absence records for approximately 50 of the state's 67 counties. The objective of this program is to serve as an early warning signal for these areas. The Wisconsin Department of Natural Resources also conducts *Invasive Species Monitoring* to track the spread of invasive species in Wisconsin waters and to document presence/absence of aquatic invasive species in waters of the State. Wisconsin's Marinette County Land and Water Conservation Department conducts a *Purple loosestrife and Eurasian Watermilfoil Monitoring* to track the spread of these species. Specific details on this program were not available. Finally, the Inland Seas Education Association *Invasive Species Monitoring Program* is an educational program collecting data on the introduction or spread of invasive species in Lake Michigan. Sampling takes place at 6 sites in Lake Michigan including Suttons Bay, Lower West Arm of Grand Traverse Bay, Little Bay de Noc, Betsie Bay, Lake Charlevoix, Little Traverse Bay and Snail Shell Harbor.

Findings – Aquatic Invasive Species

Results of the inventory indicate that sea lamprey monitoring is well-coordinated between the U.S. and Canada. The Great Lakes Fishery Commission coordinates and conducts a *Sea Lamprey Management Program* in the Great Lakes basin, with a focus on Lake Michigan industrial ports. Field work is conducted for the Great Lakes Fishery Commission by the U.S. Fish and Wildlife Service and Department of Fisheries and Oceans Canada. In addition, a number of shared concerns and potential gaps in the current Great Lakes AIS monitoring strategy, not related directly to the well coordinated sea lamprey monitoring program, were highlighted through the Great Lakes Monitoring Inventory and Gap Analysis project. A primary gap was seen to be lack of a coordinating body to organize and record AIS monitoring and management activities. A binational AIS monitoring office is needed to serve as a central location for coordinating monitoring activities and serve as a central resource for AIS related monitoring data. Another gap is the lack of a regional monitoring plan. The region needs to develop a scientifically based early detection monitoring program. A suggestion was made that this program should employ a probabilistic sampling approach to more closely look at hot spots for invasion. This early detection monitoring strategy should be coupled closely with a rapid response program. This type of sound monitoring program, which is able to effectively and efficiently detect invasions, is extremely important when considering the limited funds currently available. The set of recommendations developed through the ANS Early Detection and Monitoring Lake Michigan Pilot Project, managed by the Great Lakes Commission, may provide some of the direction needed for the development of an early detection monitoring program. Ontario Ministry of Natural Resources is working on a similar effort to inventory and analyze monitoring efforts for the entire province of Ontario. This project will also provide information for developing an AIS early detection strategy. Other gaps related to funding levels are a lack of nearshore monitoring and also routine monitoring of non-sport fish species.

With over 180 non-native aquatic species in the Great Lakes basin alone, it would be difficult to perform a thoughtful analysis of invasive species monitoring efforts across the basin until the Exotic Species indicator is further defined. Due to the recognized priority of the Great Lakes aquatic invasion problem and the impact on native populations, SOLEC parties and others should focus effort on development of an appropriate indicator and recommended monitoring program. Without such a monitoring program, it will

be difficult to quantify impacts, measure success of control programs and protect against invasions from new species.

Habitat and Biodiversity
c. Coastal Wetlands

Great Lakes coastal wetlands have critically important ecological values and functions. Great Lakes fisheries are dependent on wetlands for spawning, nurseries, and food sources. Coastal wetlands provide essential breeding, nesting, feeding and predator evasion habitats for fish and wildlife throughout the Great Lakes system. Over one-third of plant and animal species listed as threatened or endangered in the United States are dependant on wetland habitats during some portion of their life cycle. The natural water filtering, erosion control and sediment capture capabilities of wetlands contribute to the overall improvement of water quality.[8] Wetlands are also vital to the commercial and recreational sectors of the Great Lakes economy, with commercial sport-fishing and waterfowl hunting being dependent upon the continued productivity of wetlands. The diversity of plant and animal life in wetlands make them a valuable resource for non-consumptive fish- and wildlife-related recreation. Wetlands provide educational and research opportunities, as well as a perspective on historical and cultural values.

HIGHLIGHT – Coastal Wetlands

- Wetland ecosystem health is seen as a high priority in the region but additional resources may be needed to reach short and long-term goals set forth by the Great Lakes Strategy. In addition, implementation of state wetland monitoring plans called for by the U.S. EPA Office of Wetlands, Oceans, and Watersheds may require additional resources.
- A comprehensive inventory of coastal wetlands has been completed, and landscape-level changes can be computed at a coarse scale, but there are currently no programs to regularly update the finer scale wetland inventories.
- There are numerous efforts to restore coastal wetlands, but no programs have reported to be tracking restoration success basinwide.

Despite the significant ecological and economic value imparted by wetlands, there is no U.S. or Canadian national program to set monitoring guidelines for these important resources. However, a regional initiative titled the *Great Lakes Coastal Wetlands Consortium (GLCWC)* has been established to develop and implement a monitoring program for coastal wetlands. Only limited term pilot studies have been conducted by this group to date, but their goal is to develop a program to monitor all SOLEC coastal wetlands indicators. The Great Lakes Environmental Indicators (GLEI) program, funded by a U.S. EPA STAR Grant, is another regional wetlands assessment program. The goal of this assessment program is to develop an integrated set of environmental indicators that can be used to assess the condition of the coastal margins of the U.S. shoreline from Lake Superior to Lake Ontario. The GLEI program includes extensive testing of diagnostic indicators and to date results show that the indicators relate well to watershed-level stressors.

In addition to the coordination activities mentioned above, there is an effort underway by the U.S. EPA Office of Wetlands, Oceans, and Watersheds to develop methodologies for comprehensive state wetlands monitoring and assessment plans. Great Lakes states are currently in the preliminary stage of setting up these monitoring programs. In many cases states are in the process of testing methodology on single watersheds and documenting results before implementing these programs on a larger scale. It should also be noted that the Great Lakes Strategy report identified wetland restoration as a high priority. Reaching the short and longer-term goals set forth by the Great Lakes Strategy report will require the continuation and potentially the expansion of current wetland monitoring efforts.

The analysis below discusses current monitoring efforts reported in the monitoring inventory that are specific to coastal wetlands monitoring. Coastal wetlands monitoring is described by three sets of indictors: landscape indicators, physical and chemical process indicators, and biological indicators.

Landscape Indicators

Several SOLEC indicators cover large-scale ecosystem monitoring. These monitoring efforts are conducted primarily using remote sensing tools such as satellite or airborne imagery and interpretation. One of the most critical indicators for wetland management is the measure of Coastal Wetland Area Extent by Type (#4510). There are several ongoing efforts that map wetland areas. The U.S. Fish and Wildlife Service (US FWS) operates the *National Wetlands Inventory (NWI)* project, which delineates wetland polygons from aerial photographs for all U.S. wetlands, except Wisconsin. U.S. FWS has also been working on a project to develop methodology for monitoring and assessing wetland function as a way of gaining a better understanding of ecosystem health. Wisconsin has developed the *Wisconsin Wetlands Inventory* that uses a somewhat different classification scheme than the NWI. The state of Ohio uses the *Ohio Wetlands Inventory* as a supplement to the NWI maps. The Ontario Ministry of Natural Resources developed the *Ontario Great Lakes Coastal Wetland Atlas* using similar methods, but a different classification scheme from the U.S. inventories. The GLCWC recently compiled all coastal wetlands inventories into a unified *Great Lakes Coastal Wetland Inventory* with a single classification system.

None of the inventory efforts tracks changes in area over time. NOAA's *Coastal Change Analysis Program (C-CAP)* tracks land-use change over time, however, using satellite data. Wetland classification at this coarse scale includes four classes. The program revisits the Great Lakes every five years. Along with coarse scale wetland area, this program also tracks Land Cover Adjacent to Coastal Wetlands (#4863). Fine scale land cover and use maps are also generated by each of the Great Lakes states and provinces, while the USGS maintains the *National Land Cover Dataset* at a coarse scale for the entire U.S. These map products can be used to assess land use change adjacent to wetlands. No current programs were listed in the monitoring inventory database that track Restored Area of coastal wetlands (#4511). However, there are numerous local programs that seek to restore wetland area or function, such as the USGS Great Lakes Science Center's *Metzgar Marsh Wetland Restoration project* and *New York states Buckhorn Island Marsh Habitat Restoration, Tifft Preserve Marsh Habitat Restoration and Hamlin Beach Marsh Erosion Prevention projects* . Human Impact Measures (#4864) are not systematically monitored either.

Physical and Chemical Process Indicators

Several programs monitor local sediment and chemical conditions in wetlands, such as *Nutrient Dynamics in Salmon Creek, NY.* However, nutrient concentrations such as Phosphorus and Nitrogen Levels (#4860) and Sediment Flowing into Coastal Wetlands (#4516) change rapidly over time. No programs were listed that track nutrient or sediment loadings into wetlands. There are programs to monitor water levels in the Great Lakes with tools such as the lake level gauges maintained by NOAA and Canada's Department of Fisheries and Oceans (DFO). The GLCWC has determined that the Effect of Water Level Fluctuations (#4861) can best be measured through the response of biological indicators. The Canadian Wildlife Service administers a program to study Contaminants in Snapping Turtle Eggs (#4506), focusing primarily on Canadian and binational Areas of Concern (AOCs). There is no comparable U.S. program. New York did report having five marsh monitoring program sites within Areas of Concern including Oswego River, Rochester Embayment; Eighteen Mile Creek, Niagara River, and Buffalo River.

Biological Indicators

There are a number of programs that monitor the biological characteristics of coastal wetlands in the basin. Some programs such as the *Durham Region Coastal Wetland Monitoring* and the *Critical Trends Assessment Program* for the state of Illinois are tracking a number of biological indicators for a small group of wetlands. Ohio's *Wetland Bioassessment Program* similarly seeks to develop measures and assess the biological health and integrity of Ohio's wetlands across several biological indicators such as Indices of Biotic Integrity (IBIs) for plant, invertebrate, fish, and amphibian communities. Methods in the Ohio program are similar to those specified in the SOLEC's Coastal Wetland Plant Community Health (#4862), Coastal Wetland Invertebrate Community Health (#4501), Coastal Wetland Fish Community Health (#4502), and Coastal Wetland Amphibian Diversity and Abundance (#4504) indicators. It is unclear whether there will be ongoing funding to support these programs. Wisconsin's *Mapping Wetlands Dominated by Reed Canary Grass* program identifies wetlands dominated by the invasive Reed Canary Grass using satellite data. The methodology could be transferred to other areas of the Great Lakes basin. The Ontario *Wetland Evaluation System (OWES)* is a science-based ranking system that was developed primarily to meet the policy needs of Ontario's Planning Act. The OMNR is responsible for determining which wetlands and wetland complexes (groups of individual wetland units which are functionally related in some important manner) are provincially significant, whether OMNR or other qualified individuals conducts the evaluations. The wetland evaluation system does not produce a detailed biophysical inventory of each wetland. Rather, it assists trained evaluators in ranking the relative importance of different wetlands based on a numerical ranking of wetland values or functions. Bird Studies Canada runs a basin-wide program to track marsh amphibians and Wetland-Dependent Bird Diversity and Abundance (#4507) through its *Marsh Monitoring Program*. Monitoring routes for this program are located more prevalently in Ontario. This seems to be the only basinwide set of biological information for Great Lakes Coastal Wetlands. Several state programs, such as the *Michigan Frog and Toad Survey* and *Wisconsin Frog and Toad Survey* use similar methods for amphibians, as does *Frogwatch USA*. The State of New York runs a number of bird, amphibian, and reptile monitoring programs intended to provide some baseline data distribution and habitat health. Some of these programs include *New York State's Breeding Bird Atlas*, *Bird Conservation Area Program*, *Amphibian and Reptile Atlas Project*, and *Important Bird Area (IBA) program* of Audubon New York.

Findings – Coastal Wetlands

There are a number of programs that reported monitoring in coastal wetlands in the Great Lakes basin, however there is currently no comprehensive program to cover all critical indicators at this broad scale. A comprehensive inventory of coastal wetlands has been completed, and landscape level changes can be computed at a coarse scale, but there are no current programs to regularly update the finer scale wetland inventories. Additionally, while there are numerous efforts to restore coastal wetlands, no programs have reported to be tracking restoration success basinwide. There is an effort underway by the U.S. EPA Office of Wetlands, Oceans, and Watersheds to develop methodologies for comprehensive state monitoring and assessment plans for wetlands. Great Lakes states are currently in the preliminary stage of setting up these monitoring programs but more testing is needed before large scale implementation can occur. While there appear to be several short-term studies examining the effects of nutrients and sediments on wetlands, there is no program to systematically track nutrient or sediment loads to coastal wetlands. Biologically, amphibian abundance and diversity seems to be well tracked, but an examination of program overlap and methodological consistency needs to be conducted. Finally, assessments of most other biological indicators (including those covering plant, invertebrates and fish communities) are not being conducted consistently across the basin, however, the GLCWC is currently developing plans to address this gap. Wetland ecosystem health is seen as a high priority in the region but additional resources may be needed to reach short and long-term goals set forth by the Great Lakes Strategy. In addition, implementation of state wetland monitoring plans called for by the U.S. EPA Office of Wetlands, Oceans, and Watersheds may require additional resources.

Habitat and Biodiversity
d. Wildlife Ecology

The Great Lakes basin's wildlife populations are threatened by disappearing and fragmented habitat area; pressure from invasive species; and contaminant levels in air, food, and water. These pressures are largely due to the region's increasing human population, industry, and intensive agricultural practices. To ensure the future sustainability of the region's wildlife, it is important to develop an understanding of healthy population levels and monitor population trends, contaminant levels, and overall wildlife health.

Throughout the Great Lakes basin there are many data collection activities that monitor various aspects of wildlife populations. A total of 51 programs were found that collect some level of monitoring data on wildlife populations. A number of these programs are discussed in more detail below, including those with broad scopes, large geographic ranges, and those that directly address wildlife-related SOLEC indicators.

General Wildlife Ecology Monitoring

Each Great Lakes' state manages a *Natural Heritage Program*, though in Michigan, this program is called *Michigan Natural Features Inventory (MNFI)*. *Natural Heritage Programs* collect information on biological diversity, including species occurrence in both terrestrial and aquatic ecosystems. The goal of the *Natural Heritage Program* is to build, maintain, and provide accurate and accessible ecological information needed for conservation, planning, and natural resource management and also to provide information for management of threatened and endangered species. The national *NatureServe* program compliments the state run *Natural Heritage Programs* by establishing standards for biological inventories and data management procedures, developing comprehensive species and ecological community databases, and making these data available to the public through online resources.

HIGHLIGHT – Wildlife Ecology

- Results indicate that the state Natural Heritage Inventory Programs and related state biological community surveys may collect data needed to evaluate the nearshore species diversity indicator. Two potential limitations:
  - Datasets are primarily land based and
  - The scope may not be focused enough.

- Wildlife managers in the region and SOLEC decisionmakers should re-evaluate the wildlife monitoring needs of the Great Lakes basin to determine how best to fill in potential monitoring gaps and coordinate individual species monitoring programs.

The U.S. Geological Survey runs the *Gap Analysis Program*. The goal of the program is to keep common species common by identifying those species and plant communities that are not adequately represented in existing conservation lands. This program focuses on common species rather than those considered threatened or endangered, which are managed through other programs such as the ones listed above. By identifying the habitats of common species, and the conservation status of those habitats, the Gap Analysis Program gives land managers, planners, scientists, and policy makers the information they need to make better-informed decisions when identifying priority areas for conservation.

A number of wildlife monitoring programs in the basin have state-wide scopes. These programs are generally managed by each State's Department of Natural Resources. Wisconsin manages the *Wildlife Health Disease Surveillance Database*, *Biotics*, *Wildlife Health Contaminant Database*, *Checklist of Wisconsin Vertebrates*, and *Big Game Hunting Data*. Michigan's Department of Natural Resources manages *Wildlife Surveys*, *Wildlife Contaminant Monitoring*, and *Evaluation of impacts of toxic substances on nontarget wildlife*. Additional state-wide general wildlife monitoring programs include the *Minnesota County Biological Survey* and *Ohio Population Surveys*.

A number of SOLEC indicators address general wildlife monitoring.

The purpose of the Threatened Species (#8161) indicator is to assess the number, extent and viability of threatened species and use this information to infer the integrity of ecological processes and systems in the Great Lakes basin. The state run *Natural Heritage Inventory Programs* collect information on individual species, such as known and observed ranges, habitat preferences and population dynamics. This information may be used to analyze the viability of threatened species in specific areas. Additional state run community surveys conducted in Wisconsin, Michigan, Minnesota, and Ohio may provide data useful for assessing threatened species populations. Results of the inventory also include many individual species monitoring programs. Please refer to the results of the monitoring inventory for a complete list of these programs.

Nearshore Species Diversity and Stability (#8137) measures the type and number of plant and wildlife species within 1 kilometer of the shoreline to better understand the composition and abundance of nearshore plant and wildlife species over time. The state run Natural Heritage Inventory Programs and additional state run biological community surveys collect some of the information needed to evaluate this indicator. Two potential limitations of these datasets are that they are primarily land-based, which may limit the availability of nearshore population data, and the information within the nearshore zone may not be complete enough to offer a full evaluation.

The following is a discussion of targeted mammal and bird monitoring programs that directly address specific SOLEC indicators. Additionally, although no indicators directly address amphibian monitoring outside of the one discussed in the wetlands section, there will be a brief discussion on this topic.

Mammals

The only SOLEC indicator addressing mammal specific species is Contaminants Affecting the American Otter (#8147). The goal of this indicator is to assess the contaminant concentration found in American otter populations and to infer the presence and severity of contaminants in the aquatic food web. No programs reported monitoring of American Otters. Wisconsin Department of Natural Resources Wildlife *Health Contaminant Database* may include American otter monitoring, but details on individual species was not provided for this project. According to the results from the monitoring inventory, there is little to no monitoring taking place to measure the Contaminants Affecting the American Otter indicator.

Birds

The goal of the Breeding Bird Diversity and Abundance (#8150) indicator is to assess the status of breeding bird populations and to infer the health of breeding bird habitat by measuring the diversity and abundance of breeding bird populations and communities in selected habitat types. Results of the inventory show that 24 monitoring programs monitor bird populations in the Great Lakes basin. Of these 24 programs, nine are basinwide or state-wide general wildlife population surveys not focused on individual species. Results of the monitoring inventory indicate that a considerable amount of breeding bird monitoring data are being collected throughout the Great Lakes basin with no obvious gaps present.

The Contaminants in Colonial Nesting Waterbirds (#115) indicator assesses the chemical levels, including DDT, PCBs, Polychlorinated dibenzo-p-dioxin (PCDD), and polychlorinated dibenzofurans (PCDF), mercury and other organic contaminants, in a representative sample of colonial waterbirds. The Michigan Department of Natural Resource *Michigan Wildlife Contaminant Monitoring* measures spatial and temporal trends in bioaccumulative contaminant levels in herring gull eggs. This program measures PCBs, DDT, pesticides, and mercury annually for some nests, less frequently for others. This program is funded

by Clean Michigan Initiative bond funds. Wisconsin Department of Natural Resources Wildlife *Health Contaminant Database* may include waterbird contaminant monitoring, but details on specific species were not given for this project. The Canadian Wildlife Service manages the *Great Lakes Herring Gull Egg Monitoring Program*. No descriptive information is available for this program.

The purpose of the Contaminants Affecting Productivity of Bald Eagle (#8135) indicator is to assess the number of fledged young, developmental deformities, and concentration of organic and heavy metal contamination, including DDT, PCB, PCDD, PCDF, mercury and other organic contaminants, in Bald Eagle eggs, blood, and feathers. The Michigan Department of Natural Resources' *Michigan Wildlife Contaminant Monitoring* measures spatial and temporal trends in bioaccumulative contaminant levels in bald eagles. This programs measures PCBs, DDT, pesticides, and mercury annually for some nests, less frequent for others. This program is funded by Clean Michigan Initiative bond funds. Wisconsin Department of Natural Resources *Wildlife Health Contaminant Database* may include Bald Eagle contaminant monitoring, but details on individual species was not provided for this project. The Canadian Wildlife Service manages the *Southern Ontario Bald Eagle Monitoring Program*. No descriptive information was provided for this program.

Amphibians

The only SOLEC indicator directly addressing monitoring of amphibian populations is Coastal Wetland Amphibian Diversity and Abundance (#4504). Programs relating to this indicator are discussed in the Coastal Wetlands section of this report. Bird Studies Canada runs a basin-wide program to track marsh amphibians through the Marsh Monitoring Program. The National Wildlife Federation manages *Frogwatch USA*. Frogwatch USA is a long-term frog and toad monitoring program managed by the National Wildlife Federation in partnership with the U.S. Geological Survey to collect information about frog and toad populations in the U.S. This program is driven by volunteers who collect frog occurrence information at more than 1,000 locations throughout the Great Lakes basin. Michigan Department of Natural Resources' *Frog and Toad Survey* monitors the long-term abundance and distribution of frog and toad populations. Volunteers monitor frog and toad occurrence at more than 4,800 locations three times a year throughout the state. This project is funded by a State Wildlife Grant. *Wisconsin Frog and Toad Survey* also collects amphibian abundance data.

Findings – Wildlife Ecology

The state run *Natural Heritage Inventory Programs* collect specific species information as well as habitat information that may be used to analyze the viability of threatened species in specific areas. While Wisconsin, Michigan, Minnesota, and Ohio manage additional population surveying programs that may collect information on threatened species, results of the inventory indicate that other Great Lakes states do not have broad wildlife population monitoring programs.

When evaluating Nearshore Species Diversity and Stability (#8137), results indicate that the state run *Natural Heritage Inventory Programs* and additional state run biological community surveys may collect information needed to evaluate this indicator. Two potential limitations of these datasets is that they are primarily land based, which may limit the availability of nearshore population data, and the scope may not be focused enough to evaluate this indicator.

Results of the monitoring inventory indicate that a considerable amount of breeding bird monitoring data are being collected throughout the Great Lakes basin. Inventory results also show that Michigan was the only Great Lakes state that reported monitoring programs specifically addressing contaminants in colonial nesting birds and Bald Eagles. According to results of the monitoring inventory, there is very little to no monitoring taking place to measure the Contaminants Affecting the American Otter indicator. Wildlife

managers in the region and SOLEC leaders should re-evaluate the wildlife monitoring needs of the Great Lakes basin and determine how best to fill in these identified gaps and coordinate individual species monitoring programs.

Habitat and Biodiversity
e. Benthic and Invertebrate Ecology

Benthic and other invertebrate communities are variable and diverse throughout the Great Lakes ecosystem. Invertebrates in the Great Lakes system vary from microscopic organisms suspended in a lake's water column to large mussels attached to substrate along a river-bottom. Invertebrates serve many important functions in a sustainable ecosystem. They serve as a food source for larger species and are vital to the success of fish populations. They consume nutrient inputs and filter pollutants and other chemical constituents. Invertebrates offer a good measure of aquatic health, as they can be found in all habitats. Their composition reflects the physical and chemical structure of a habitat and individual species respond quickly and differently to changes in nutrient and pollutant levels and other pressures.

HIGHLIGHT – Benthic and Invertebrate Ecology

- General monitoring for benthic and macroinvertebrate abundance and diversity may be sufficient (except in the Lake Superior basin), but some native species may be being overlooked.
- Zooplankton and phytoplankton are regularly collected at only eleven sites throughout the basin. Also, monitoring for Diporeia and Hexagenia is limited to only a few programs in single lake basins. These programs may need to be evaluated for expansion if a better understanding of the population dynamics of these species is desired.
- There are a number of programs monitoring mussel populations, but further investigation may be needed to determine if this provides a thorough enough investigation into these sensitive native species whose population viabilities are threatened.

The analysis that follows examines the current monitoring capacity to detect status and trends of benthic and other invertebrate communities in basin habitats across a variety of SOLEC indicators. Zoo- and phytoplankton populations are considered, as well as more complex invertebrates. Monitoring of several important individual native species or families are examined, as well as general measures of diversity and abundance. In all, 32 separate programs were found to be monitoring aspects of benthic or invertebrate ecology. Most of these were federal, state or university programs in the United States, with only one program included from the Canadian side of the basin.

Three programs engage in monitoring of plankton populations in the open Great Lakes or large inland lakes. Zooplankton Population (#116) samples are collected by the *Lake Michigan Biological Station* of the Illinois Natural History Survey in the southern basin of Lake Michigan, the *Open Lake Surveillance* Program of U.S. EPA-GLNPO using their research vessel at eleven sites below 85 m in all Great Lakes, and the *Finger Lakes Biomonitoring* program of New York State Department of Environment and Conservation for the inland Finger Lakes. Only the *Open Lake Surveillance* program also collects Phytoplankton Populations (#109).

The only one program that specifically indicated monitoring the Benthic Amphipod (Diporeia spp.) (#123) is the *Benthic Community Change* program administered by the USGS at a target depth of 130 m near Oswego, Rochester, and Olcott in Lake Ontario. There are a number of programs that monitor Benthos Diversity and Abundance (#104), and some of these programs may also collect Diporeia samples. The *Long-Term Trends in Benthic Populations* of NOAA-GLERL and a program by the Illinois Natural History Survey

monitor benthic community populations in southern Lake Michigan, the NYSDEC at the mouth of the Buffalo River, GLERL's *Assessments of Benthic Macroinvertebrate Communities in the Great Lakes* at 80 sites in Lakes Huron and Ontario, the *Benthic Community Change* at sites in Lake Ontario, GLNPO's *Open Water Surveillance Program* at twenty open-water sites throughout the Great Lakes, and the USGS Great Lakes Science Center's *Benthos for western Lake Erie* every ten years at 60 sites in Lake Erie. This indicates that only Lake Superior is lacking in some form of benthic invertebrate community monitoring.

Specific Hexagenia (#122) or mayfly monitoring is conducted by three programs in the basin. The *Mayfly Recovery in Lake Erie* program run by Pennsylvania Sea Grant tracked the nightly emergence of mayflies at six locations, but this program ended in 1993. The *Hexagenia Populations* program of Heidelberg College studies various characteristics of Hexagenia populations and interactions with the surrounding environment. No information was available about monitoring locations or the program's current status. Finally, NOAA-GLERL studies *Temporal and Spatial Variation in Lipid Content of the Mayfly Hexagenia* in Western Lake Erie, Lake St. Clair, and the Straits of Mackinac. Most of these programs are monitoring in nearshore aquatic habitats so may be able to provide data to assess Nearshore Species Diversity and Stability (#8137).

An important sentinel of stream and nearshore aquatic integrity is the abundance and diversity of Native Freshwater Mussels (#68). Monitoring programs approach this indicator from a variety of directions. The Nature Conservancy runs a program to study the *Interactions between freshwater mussels and zebra mussels in the Upper Clinton River.* This program collects and identifies mussel data biannually from two sites in the Upper Clinton River. Environment Canada administers the *Lake St. Clair/St. Clair Delta Native Freshwater Mussel Study.* Specific locations and parameters were not reported for this program. In its *Assessments of Benthic Macroinvertebrate Communities in the Great Lakes* program, GLERL samples dreissenid mussels (along with other benthic macroinvertebrates) at 80 sites in Lakes Huron and Ontario. The *Benthic Community Change* program of USGS tracks various mussel counts at sites in the Lake Ontario basin. NOAA's National Centers for Coastal Ocean Science runs the U.S. *Mussel Watch Project* that samples bivalves – mostly for contaminants – biennially at 24 sites evenly distributed along the shores of Lakes Michigan, Huron, St. Clair, Erie, and Ontario.

Finally, a large number of programs have been initiated to sample and measure the diversity and abundance of macroinvertebrates in tributary streams and wetlands. Programs in wetlands are covered in the section on Coastal Wetlands. Each of the states of Indiana, New York, Wisconsin, Ohio, and the Oneida Tribe of Wisconsin operate biomonitoring programs to help assess the biotic integrity of the streams in their states. These programs may differ significantly from one state to another. Additionally, USGS's *National Water Quality Assessment (NAWQA)* program collects macroinvertebrates in a set of their sampling locations along Western Lake Michigan and Lake Erie drainages. SOLEC does not include this type of monitoring as an indicator, but it can reasonably be argued to be important enough to justify the addition of such an indicator.

Findings – Benthic and Invertebrate Ecology

While there are a fair number of programs monitoring invertebrates and benthic communities in the Great Lakes basin, there may be some significant gaps to address. Specifically, while general monitoring for benthic and macroinvertebrate abundance and diversity may be sufficient (except in the Lake Superior basin), several important native species may be being overlooked. Zooplankton and phytoplankton are regularly collected at only eleven sites throughout the basin. It needs to be determined if this is enough information to reasonably estimate the status and trends in these populations. Also, monitoring for Diporeia and Hexagenia is limited to only a few programs in single lake basins. These programs may need to be evaluated for expansion if a better understanding of the population dynamics of these species is desired. Finally, while there are a number of programs monitoring mussel populations, further investigation

may be needed to determine if this provides a thorough enough investigation into these sensitive native species that may be in decline.

Habitat and Biodiversity
f. Plant Ecology

The Great Lakes basin has lost much of its original natural landscape to agriculture, urban development and industry. For example, approximately 65 percent of Illinois was originally tallgrass prairie. Today, less than 0.01 percent of the original prairie remains. The Great Lakes region has also lost more than two-thirds of its natural wetlands to agriculture, urban uses, shoreline development, and recreation.[9] In order to maintain the remaining botanical wealth of the region, careful conservation and monitoring efforts are needed.

Terrestrial Plant Communities

There are four Great Lakes basinwide terrestrial plant monitoring programs taking place at the federal level. The U.S. Department of Agriculture's *National Forest Inventory and Analysis Data Base System* is the national forest census database. This program reports on status and trends in forest area and location, species, size, health of trees, total tree growth, mortality, removals by harvest, wood production and utilization rates by various products, and forest-land ownership. The USGS-National Park Service *Vegetation Mapping Program* is a cooperative effort by the USGS and the National Park Service (NPS) to classify, describe, and map vegetation communities in the national parks across the United States. The U.S. Environmental Protection Agency's *Great Lakes Basin Vegetation Change Analysis* relates vegetation change to global climate change by analyzing vegetation changes in the basin over a 20-year period using satellite imagery. Another Great Lakes regional program is the binational *North American Maple Project* which monitors sugar maple health in the Great Lakes basin.

HIGHLIGHT – Plant Ecology

- Forest age-class and forest successional stage data collection appears to be limited.
- Little monitoring data is available regarding insect or disease monitoring in terrestrial plant communities.
- A number of SOLEC indicators need to be further defined in order to assess data availability.

Results of the inventory show a number of forest monitoring programs managed at the state level. The Wisconsin Department of Natural Resources Forestry Department manages the *Champion Trees of Wisconsin* database as well as the *Forestry Compartment Reconnaissance* database. While the champion trees program keeps track of exceptional examples of trees in the state, the Forestry Compartment Reconnaissance program assesses forest resource information at the property level. The Ohio Division of Forestry *Forest Monitoring* project monitors a series of randomly located forest plots to collect data on trees, saplings, seedlings, and herbaceous plants.

In addition to these programs, several others that remotely collect land cover data are described in the land use section of this report.

Four relatively new SOLEC indicators focus specifically on forest health. Of these four indicators, only one has a complete description. The goal of the Forest Health Criterion #1: Conservation of Biological Diversity (#8500) is to describe the extent, composition and structure of the Great Lakes basin forests by measuring the 1) extent of area by forest type relative to total forest area, 2) extent of area by forest type and by age-class or successional stage, and 3) extent of area by forest type in protected area categories. Forest Health Criterion #2: Maintenance and Productive Capacity of Forest Ecosystems (#8501), Forest Health Criterion

#3: Maintenance of Forest Ecosystem Health and Vitality (#8502), and Forest Health Criterion #4: Conservation and Maintenance of Soil and Water Resources (#8503) have yet to be described.

The most comprehensive forest monitoring program in the Great Lakes basin is the U.S. Department of Agriculture's *National Forest Inventory and Analysis Data Base Systems*. This database provides the information needed to evaluate extent of area by forest type, the first measure of the Forest Health Criterion #1, and the extent of area of protected areas, the third measure of the Forest Health Criterion #1. It appears as if no data are currently available to analyze forest type by age-class or successional stage, the second measure of the Forest Health Criterion #1.

The other indicator that addresses terrestrial plant communities is Health of Terrestrial Plant Communities (#8162) which seeks to measure trends in time and space of 1) non-native insect or disease infestation of plants and 2) plant mortality or damage (including deformities) throughout the Great Lakes basin. No information was available in the monitoring inventory regarding insect or disease monitoring in terrestrial plant communities. The North American Maple Project does collect data on health of individual sugar maple trees throughout the basin.

Aquatic Plant Communities

Results of the inventory show four programs dedicated to aquatic plant monitoring projects. The Wisconsin Department of Natural Resources runs the *Wisconsin Lakes - Aquatic Plant Database,* which is a unique program in the basin that collects information on aquatic plants collected in Wisconsin. An estimate of plant density is determined at each point and water depth and substrate information is available for many sampling points.

Other aquatic plant monitoring programs include *Monitoring and Event Response for Harmful Algal Blooms* and the *Aquatic Macrophyte Abundance Diversity* managed by State University of New York (SUNY) and Cornell University, respectively, and focused in New York state waters of the Great Lakes basin. The U.S. Geological Survey manages a program in the Detroit River monitoring *Status and Trends of wild celery tubers*.

For additional information on terrestrial and aquatic plant communities please refer to the wetlands, stewardship, and land-use sections of this report.

Findings – Plant Ecology

The most comprehensive forest monitoring program in the Great Lakes basin is the U.S. Department of Agriculture's *National Forest Inventory and Analysis Data Base System*. This database provides much of the data needed to evaluate forest health. A potential gap has been identified in forest age-class and forest successional stage data collection. These data are needed to complete a full analysis of Forest Health Criterion #1. Also, very little information was available in the monitoring inventory regarding insect or disease monitoring in terrestrial plant communities. This missing information may represent a gap in the monitoring inventory rather than in monitoring efforts in the region. The final three forest health SOLEC indicators must be described before monitoring data availability for these areas can be assessed.

Habitat and Biodiversity
g. Habitat and Community

The natural resources and ecological wealth of the Great Lakes basin require responsible management and protection. The Great Lakes basin's habitats, communities, and, therefore, natural processes are threatened by the region's high population densities, intensive agricultural practices, and ever increasing pressure on its fresh water resources from inside and outside of the basin. Well designed and managed stewardship efforts will help to insure the health of Great Lakes communities and ecosystems for future generations.

In total, 20 programs were found that generally address issues related to habitats and communities. Of these programs, eight belong to state run *Natural Heritage Programs* managed by each of the Great Lakes states. In Michigan, the complimentary program is called *Michigan Natural Features Inventory (MNFI). Natural Heritage Programs* collect information on biological diversity, including significant natural areas and species occurrences in both terrestrial and aquatic ecosystems. The goal of the *Natural Heritage Program* is to build, maintain, and provide accurate and accessible ecological information needed for conservation, urban planning, and natural resource management and also to provide information to the Threatened and Endangered Species Act. The *NatureServe* program works with the *Natural Heritage programs* throughout the country to establish standards for biological inventories and data management procedures, develop comprehensive species and ecological community databases, and make these data available to the public through online resources.

The State of Illinois is a leader in advancing ecological stewardship goals in the region. In addition to the state run *Natural Heritage Program* collecting information on habitat and species occurrence, the Illinois Department of Natural Resources has designed the *Critical Trends Assessment Program* (*CTAP)* to monitor the specific condition of habitats, including forests, wetlands, grasslands, and streams, throughout the state. *Ecowatch*, a complimentary state run volunteer program, collects scientific data on streams, forests, prairies, and urban green spaces to measure the quality and quantity of habitats in the state.

The U.S. Geological Survey runs the *Gap Analysis Program*. The goal of *Gap Analysis Program* is to keep common species common by identifying those species and plant communities that are not adequately represented in existing conservation lands. This program focuses on common species rather than those considered threatened or endangered. By identifying the habitats of common species, the *Gap Analysis Program* gives land managers, planners, scientists, and policy makers the information they need to make better-informed decisions when identifying priority areas for conservation.

Colorado State University has established a unique program called the *Interagency Monitoring of Protected Visual Environments*. This program currently has two sampling locations in the Great Lakes basin, Seney National Wildlife Refuge and Isle Royal National Park. The goal of this program is to identify chemicals and emission sources responsible for existing man-made visibility impairments and to assess progress towards visibility goals.

HIGHLIGHT – Habitat and Community

- A standardized habitat classification map for the entire Great Lakes basin would be highly useful for bringing habitat monitoring together for basinwide assessment and for focusing stewardship efforts.
- The Illinois Department of Natural Resources Critical Trends Assessment Program provides a strong example of using species and habitat occurrence data as a foundation for assessing habitat conditions and ecological health. Expansion of this type of program throughout the entire Great Lakes basin would improve availability of important habitat quality information.

A number of SOLEC indicators address habitats and communities. Those most directly related to habitats and communities will be discussed in this section while others including land use, wetlands and specific animal and plant communities will be discussed in greater detail in other sections of this report.

Area, Quality, and Protection of Lakeshore Communities (#8129) seeks to measure the area, quality, and protection status of designated communities within one kilometer of the shoreline. The purpose of this indicator is to assess changes in area and quality of these communities. The state run *Natural Heritage Inventory Programs* may collect much of the species and habitat information needed to evaluate this indicator. The *Gap Analysis Program* collects additional information on species distribution across the basin and provides information on the protection status of these designated communities. A limitation of both the *Natural Heritage Program* and the *Gap Analysis Program* is that they may not collect data at the appropriate spatial resolution throughout the entire one kilometer coastal zone of the Great Lakes basin. The Illinois *Critical Trends Assessment* program, which analyzes species and habitat information to determine specific conditions of habitats, provides a valuable set of information on habitat quality. Expansion of this type of program throughout the entire Great Lakes basin may be extremely valuable.

Nearshore Species Diversity and Stability (#8137) seeks to measure the number and type of plant and wildlife species within one kilometer of the shoreline to better understand the composition and abundance of nearshore plant and wildlife species over time. The state run *Natural Heritage Inventory Programs* may collect much of the information needed to evaluate this indicator. A limitation of the Natural Heritage database is that it may not include all shoreline areas.

A related indicator, the Protected Nearshore Areas (#8149) indicator assesses the amount of protected shoreline in the Great Lakes basin. Data to evaluate this indicator may be available through various sources including the *Gap Analysis Program*, the U.S. National Parks Service, and state and local planning agencies. Results from this inventory do not include enough detail to provide a thoughtful analysis of this indicator.

Status and Protection of Special Places and Species (#8163) seeks to determine the area, quality, and protected status of landscapes and species with special cultural or spiritual significance to the people of the Great Lakes basin. A first step in evaluating this indicator would be to examine an inventory of such places. No such inventory was reported to the Great Lakes Monitoring Inventory. Once a place and species inventory is completed, this indicator may still be difficult to evaluate because it may not be possible to use remote sensing data or other strictly scientific data collection method to evaluate the quality of special places. The state run *Natural Heritage Inventory Programs* collect individual species and community information that may produce some of the data needed to evaluate the status of the designated special species.

Additional information on various issues related to habitat and community can be found throughout this report. For additional information on land use and land cover patterns please refer to the land use section of this report. Information on specific animals and plants can be found in the wildlife and plant communities sections of this report. Please refer to the wetlands section for more information on coastal wetland issues.

Findings – Habitat and Community

The state run *Natural Heritage Programs* collect extremely valuable information on biological diversity, including significant natural areas and species occurrences in both terrestrial and aquatic ecosystems. This information should provide the basis for analysis of habitats and communities in the Great Lakes basin. The USGS *Gap Analysis Program* takes this information a step further by evaluating the quality of specific habitats across the region and their protection status. A potential limitation of both these datasets is that they may not collect data at a fine enough resolution to satisfy the needs of all related SOLEC indicators. *Illinois' Critical Trends Assessment Program* provides a fine example of using species and habitat occurrence data as a foundation for assessing habitat conditions and ecological health. Expansion of this type of program throughout the entire Great Lakes basin would drastically improve availability of important habitat quality information. Additionally, a standardized habitat classification map for the entire Great

Lakes basin would be highly useful for bringing habitat monitoring together for basinwide assessment and for focusing stewardship efforts.

4. Land Use and Human Impact
a. Atmospheric Deposition

The primary causes of acid rain are elevated levels of sulfur dioxide (SO2) and nitrogen oxides (NOx) in the atmosphere. In the U.S., a large percentage of the SO2 and NOx come from electric power generation that relies on burning coal, which releases contaminants into the air. The effects of acid deposition on the environment include acidification of lakes and streams, nutrient enrichment of coastal waters and large river basins, soil nutrient depletion and decline of sensitive forests, agricultural crop damage, and impacts on ecosystem biodiversity. Acid rain is measured primarily by tracking the acidity in precipitation using the pH scale.

HIGHLIGHT – Atmospheric Deposition

- Integrated Atmospheric Deposition Network (IADN) appears to be the only program collecting information on the parameters necessary to evaluate SOLEC's Atmospheric Deposition of Toxic Chemicals indicator. A potential limitation of IADN lies in the distribution of sampling stations and in the corresponding activities at each station.

- The necessary spatial frequency of atmospheric deposition sampling locations remains unknown. Atmospheric monitoring of dioxin and mercury is particularly costly so more research should be conducted to determine the appropriate spatial distribution of sampling locations.

The SOLEC Acid Rain (#9000) indicator seeks to assess the pH levels in precipitation and loadings of sulfate to the Great Lakes basin. Issues related to this indicator that are still being addressed are target pH levels, monitoring frequency requirements, and spatial patterns of monitoring sites. Identification of methods to effectively reduce of the levels of sulfur and nitrogen acidic compounds in the atmosphere is the long-term goal set by this indicator. Another indicator related to acid rain is Atmospheric Deposition of Toxic Chemicals (#117). This indicator reports loading estimates of PCBs, dieldrin, chlordane, DDT, and metabolites as well as other chemicals based on measured atmospheric concentrations of chemicals and wet and dry deposition rates.

A total of eight programs were reported in the inventory that address acid rain deposition, specifically pH and sulfate, in the Great Lakes basin. Of these programs, two are conducted at the federal level and measure both wet and dry deposition.

A joint U.S. EPA and Environment Canada program, *Integrated Atmospheric Deposition Network (IADN)*, was developed in 1990 to monitor atmospheric deposition of toxic chemicals to the Great Lakes. This program measures wet and/or dry atmospheric deposition at 15 locations on shores of the Great Lakes basin. Five of these stations (3 sites in the U.S. and 2 Canadian sites) are master stations where all IADN chemicals are measured in air and precipitation. The program monitors 80 toxic chemicals, including PCBs, dieldrin, chlordane, and DDT. The remaining 10 stations measure a limited number of the IADN chemicals. The U.S. has 2 of these satellite stations located in urban areas. These stations measure concentrations in both air and precipitation. Canada has 8 satellite stations. One of these stations measures only air concentrations while the other 7 measure only precipitation concentrations.

The U.S. EPA also manages the *Clean Air Status and Trends Network (CASTNET)* focusing on dry deposition monitoring at five locations in the Great Lakes basin. In addition, the Great Lakes Research Consortium manages the *Semivolatile Air Monitoring Network* that collects concentration and loading of

organics (including dioxin) in air. The *National Atmospheric Deposition Program (NADP),* which is a cooperative research support program of federal, state, and nongovernmental research agencies, measures wet deposition at 31 locations across the Great Lakes basin through the *National Trends Network* program. Other programs managed by NADP are *Atmospheric Integrated Research Monitoring Network* (AIRMON) and *Mercury Deposition Network* (MDN). The MDN measures mercury deposition in rainfall at approximately 20 sites within the Great Lakes region. NADP in partnership with Lake Michigan Air Directors Consortium (LADCO) and Central Regional Air Planning Association (CENRAP) operate an ammonia monitoring network at 13 sites across the Midwest and the Plains states. This network has been measuring ammonia/ammonium, nitrate/nitric acid and SO2/sulfate since 2003. Each of these programs collects information needed to evaluate the Acid Rain indicator, but only *IADN* measures the parameters for the Atmospheric Deposition of Toxic Chemicals indicator.

Three additional atmospheric deposition monitoring programs were found at the state level. The Wisconsin Department of Natural Resources manages the *Long Term Lake Monitoring Program,* which measures the surface water chemistry of 13 lakes in Wisconsin and 8 in the Upper Peninsula of Michigan three times a year in order to determine chemical responses of lakes to changes in the deposition of acidic rain. Pennsylvania Department of Environmental Protection has one *Atmospheric Deposition Monitoring Network* station in the Lake Erie basin measuring acid rain and mercury deposition into the atmosphere. New York State Department of Environmental Conservation manages eight *Atmospheric Deposition Monitoring Sites* within the Lake Erie and Lake Ontario basins. These sites measure both wet and dry samples.

For further information on other types of air monitoring programs please refer to the air monitoring section of this report.

Findings – Atmospheric Deposition

Eight programs were found that specifically address atmospheric deposition. While there appears to be a number of federal and state programs collecting information on atmospheric deposition, *Integrated Atmospheric Deposition Network (IADN)* appears to be the only program collecting information on the parameters necessary (PCBs, dieldrin, chlordane, and DDT) to evaluate SOLEC's Atmospheric Deposition of Toxic Chemicals indicator. A potential limitation of *IADN* lies in the distribution of sampling stations and in the corresponding activities at each station. This network may need to be evaluated to determine if five master stations (one per lake) are sufficient to characterize atmospheric deposition. Currently, both wet and dry deposition monitoring sampling locations are sparsely distributed throughout the basin. The necessary spatial frequency of sampling locations remains unknown and because atmospheric monitoring is particularly costly when considering measurements of dioxin and mercury more research needs to be conducted to determine the appropriate spatial distribution of atmospheric deposition sampling locations. The combined distribution of current atmospheric deposition monitoring sites should be evaluated to determine if it is sufficient to provide enough information to assess the atmospheric deposition patterns and loadings in the Great Lakes basin. No specific budget information is available for these programs but if the need arises for an increase in sampling locations additional funding will be needed in this area.

Land Use and Human Impact
b. Nutrient Management

The Great Lakes basin is one of the highest yielding agricultural regions of the U.S. To achieve these yields, large amounts of nutrients (such as nitrogen and phosphorus) are added to the soil in the form of fertilizers. These nutrients flow off the land through surface or ground water and threaten water quality. In order to

limit these environmental impacts, nutrient management plans are being developed to describe how nutrients are to be applied to agricultural land and how runoff from these lands is to be minimized.

The goal of the Nutrient Management Plan (#7061) indicator is to determine the number of nutrient management plans and environmentally friendly practices in place to prevent ground and surface water contamination through agricultural practices, particularly livestock operations. This indicator is measured by the number of nutrient management plans (NMP) in place and the percent of municipalities with nutrient management standards for intensive livestock operations. A slightly less specific but related indicator is Sustainable Agricultural Practices (#7028). The goal of this indicator is to assess the number of environmental and conservation farm plans in place and to examine to what extent environmentally friendly practices, such as integrated pest management, zero tillage and other soil preservation practices, are being used to prevent ground and surface water contamination. Both these indicators are process measures in that they measure processes being put into place rather than outcome measures that directly measure the impact on the environment. The purpose of the Great Lakes Monitoring Inventory is to collect information about programs that primarily monitor environmental outcomes, so it is possible that programs addressing these indicators were missed by the inventory.

HIGHLIGHT – Nutrient Management

- Additional effort should be made to compare results from nutrient and pesticide management programs (i.e. rates of growth in implementation) with direct monitoring of nutrients and pesticides in surface waters.

Three monitoring programs were reported to the Great Lakes Monitoring Inventory that directly address agricultural nutrient management in the Great Lakes basin. The U.S. EPA's *Permit Compliance System (PCS)* tracks permit compliance and enforcement status of dischargers who are required to file National Pollution Discharge Elimination System (NPDES) permits. This set of dischargers includes agricultural operations. The PCS includes more than 3,500 sites in the Great Lakes basin but information was not available on exactly how many of these sites are directly related to agricultural operations or how many permits were directly related to nutrient management. The state of Wisconsin reported on two nutrient management programs. The University Wisconsin Extension's *Nutrient Management Program* addresses proper nutrient management on farm and home soils. This program focuses on Marinette County Wisconsin, and Menominee County Michigan. The Land Conservation district in Racine County, Wisconsin manages the *Land and Water Resource Management Program* working to prevent direct discharge of agricultural waste products from entering surface and groundwater. The purpose of this program is to develop environmental farm planning procedures and implement proper conservation practices.

Another similar SOLEC process-focused indicator is the Integrated Pest Management (#7062) indicator. The purpose of this indicator is to assess the adoption and uptake of Integrated Pest Management practices by farmers and to infer environmentally friendly practices in place to prevent ground and surface water contamination. No organizations in the Great Lakes basin reported on integrated pest management plans.

Findings – Nutrient Management

Nutrient management planning is a relatively new practice in the Great Lakes basin. Only a few counties in Wisconsin and Michigan reported formal nutrient management programs. No specific nutrient management monitoring programs were reported by other states or counties. It is possible that state and local agencies do not see these types of programs as monitoring programs and thus did not submit information on them into the inventory. Further efforts should be made to ensure all nutrient management programs are included in the inventory in the future. While U.S. EPA's *Permit Compliance System (PCS)* tracks nutrient releases of some agricultural operations, little information is available on which agricultural operations have reporting requirements and the extent of these reporting requirements. No information was reported on integrated pest management plans in the Great Lakes basin. An additional effort should be

made to compare results from nutrient and pesticide management programs (i.e. rates of growth in implementation) with direct monitoring of nutrients and pesticides in surface waters. An analysis of water quality monitoring is included in a separate section of this report.

Land Use and Human Impact
c. Land Use

Understanding the relationship between land use and ecosystem health is important to the long-term preservation of the environmental integrity of the Great Lakes basin. Industrial development, population growth, and expanding residential communities, coupled with deteriorating conditions and abandonment in older city cores create environmental pressures that can lead to detrimental effects on water quality, air quality, and overall ecosystem health. By identifying and tracking measurable land use criteria (in combination with environmental condition monitoring), trends and patterns can be analyzed to project impacts on the environment.

HIGHLIGHT – Land Use

- Limitations to the USGS National Land Cover Characterization Project and the NOAA Coastal Change Analysis Program (C-CAP) are the time periods between dataset development, the spatial resolution of the imagery, and the level of detail of the classification system.
- A more detailed analysis, focused on evaluating specific GIS data needs and availability, should be conducted to identify specific gaps or overlaps in land use and land cover data.

Based on inventory results, 32 monitoring programs collect data on land use characteristics. The USGS *National Land Cover Characterization Project* has developed nationally consistent land cover data sets. Datasets are currently available for 1995 and 2001. These land cover datasets are being used for watershed management, environmental inventories, and land management. This information is all available through the USGS *National Map* project, which is a mapping tool available on the Internet. USGS's *Geographic Analysis and Monitoring Program (GAM)* supports geographic assessments to improve the understanding of land surface change in the United States. Another federal project focusing on land use issues is NOAA's *Coastal Change Analysis Program (C-CAP)*. The objective of this program is to complete a national baseline dataset of land cover and land use change for the coastal regions of the U.S., including the Great Lakes coastal zones. Based on Landsat Thematic Mapper imagery, this dataset provides a coarse-scale classification of habitat types.

Inventory results show that each Great Lakes state has a Geographic Information System (GIS) repository. Each of these repositories may contain a host of data relevant to land use analysis. In many cases, state land use/land cover data sets are based on higher resolution airborne imagery which can contribute to a finer scale analysis of land use change. It was beyond the scope of this project to identify each GIS dataset available. Therefore, the description of land use presented in this report may not represent all available data. Also, the U.S. Census Bureau collects demographic data at the county level throughout the Great Lakes basin. Although it may not be considered environmental monitoring data, these demographic data may contribute to a more comprehensive land use analysis. A number of other land use monitoring projects were found to be conducted by local organizations.

A number of SOLEC indicators address issues associated with land use. These indicators and their relation to the results of the monitoring inventory are discussed in more detail below.

The Land Cover-Land Conversion (#7002) indicator is measured as the percent change in land use from agriculture, urban development, forest, marsh and other natural cover. High rates of land conversion from natural covers are generally associated with rapid rates of urban development. The USGS *National Land Cover Characterization Project* provides information on national land cover for 1995 and 2001 by using remotely sensed data and classifying it by land cover type. NOAA's *Coastal Change Analysis Program (C-CAP)* provides even more detailed information on land cover and land use change in the Great Lakes region. One potential limitation of both of these datasets may be the time between dataset development. Another potential limitation is the spatial resolution of the imagery and the level of detail of the classification system. The U.S. Census Bureau's demographic data may also provide additional valuable information on land use, namely urban growth.

Ground Surface Hardening (#7054) is a measure of the percent of land in a watershed that is covered by buildings, roads, parking lots and other hardened surfaces. Results from the inventory do not include any basin wide monitoring programs that provide data detailed enough to assess hardening rates due to specific buildings, roads, and parking lots, but there are regional datasets available for such analysis, including the USGS Digital Ortho Quarter Quads (DOQQ) and Digital Raster Graphics (DRG). A limitation of these data sources is the frequency with which they are updated. Additionally, a large amount of time would be needed to process these datasets to provide the information needed to assess hardening rates.

Habitat Fragmentation (#8114) is a landscape indicator that measures the pattern of natural habitats. This indicator requires an analysis of habitat patch size, percent intact cover, and area to perimeter ratio. The objective of this indicator is to assess the amount and distribution of "core" natural habitat remaining within each Great Lakes ecoregion and determine the effect land use changes are having on fragmenting large natural habitat patches. The USGS *National Land Cover Characterization Project* described above may provide information needed to analyze habitat fragmentation. Perhaps a more relevant data set is *C-CAP,* which provides a more detailed habitat classification scheme and change analysis. The necessary spatial extent of such an analysis and specific habitat types has not been clearly defined for the Great Lakes region.

The purpose of the Extent of Hardened Shoreline (#8131) indicator is to assess the amount of shoreline habitat altered by the construction of shoreline edge hardening devises used for erosion or storm protection. A similar indicator, Artificial Coastal Structures (#8146), measures the density of artificial coastal structures on the Great Lakes shoreline that extend into waters from the shoreline or are placed offshore to dampen the force of waves. Currently, limited data are available on the geographic extent of shoreline hardening devises, both along the coastline and extending into the waters. USGS *Digital Ortho Quarter Quads (DOQQ)* and *Digital Raster Graphics (DRG)* as well as other available satellite imagery, may provide some of the necessary information. Again, limitations of these data sources are their resolution and frequency with which they are updated. States may have more detailed information on hardened shorelines and artificial coastal structures. Results from the inventory show that the Ohio Department of Natural Resources manages a *Shore Structure Inventory* that assesses the presence of man-made shoreline hardening devices. These types of data are very valuable and would be useful for each state in the Great Lakes basin.

Nearshore Land Use (#8132) seeks to evaluate land use types throughout the basin as related to special lakeshore communities identified by SOLEC. Land use types of interest include urban residential, commercial, industrial, non-urban residential, intensive agriculture, extensive agriculture, abandoned agriculture, closed canopy forest, harvested forest, and wetlands and other natural areas. Again, the *National Land Cover Characterization Project* and *C-CAP,* described above may provide the information needed to analyze land use in the nearshore zone. Results from the inventory show that the Ohio Department of Natural Resources manages a *Nearshore Habitat Dynamics* program that tracks substrate changes. These types of data are needed to analyze nearshore landuse patterns and could be expanded into other states.

Extent and Quality of Nearshore Natural Land Cover (#8136) is a measure of the amount of natural land cover that falls within 1 km of the shoreline and seeks to determine the potential impact of artificial coastal structures on the extent and quality of nearshore ecosystems. Again, the *National Land Cover Characterization Project* and *C-CAP,* described above may provide the best data needed to analyze this indicator.

Findings – Land Use

The extent of land use monitoring in the region is difficult to evaluate due to several factors. It was beyond the scope of this project to analyze all GIS data available at the local, state, and federal levels. Therefore, the description of land use presented in this report may not represent all available data. Also there are a few potential limitations to the nationwide dataset collected through USGS's *National Land Cover Characterization Project* and NOAA's *Coastal Change Analysis Program (C-CAP)*. One potential limitation of both of these datasets may be the time scale between dataset development. Other potential limitations are the spatial resolution of the imagery and the level of detail of the classification system. A more detailed analysis, focused on evaluating specific GIS data needs and availability should be conducted to identify specific gaps or overlaps in land use and land cover data.

Land Use and Human Impact
d. Erosion

Erosion is defined as the wearing away of land by the action of natural forces. The primary forces of erosion are waves, currents, and wind. Most of the Great Lakes coast is comprised of erodible, glacially deposited sand, gravel, clay, and clay-like material. Though erosion is a natural process, it can be influenced by a variety of human activities, including coastal navigation, agriculture, and shore protection structures. [10] Although no SOLEC indicator calls for erosion monitoring directly, there are a number of programs that monitor these processes, so it warrants a brief discussion.

HIGHLIGHT – Erosion

- Comprehensive coastal erosion monitoring programs like Pennsylvania's Bluff Recession Monitoring project and Ohio's Lake Erie Coastal Erosion Study are valuable examples of coastal erosion monitoring. It would be useful from a basinwide perspective if other states and provinces in the basin were to implement such monitoring programs.

Two state-run programs monitor coastal erosion along the Great Lakes shoreline. Pennsylvania Coastal Zone Management's *Bluff Recession Monitoring* project physically measures bluff erosion rates at established control points along Pennsylvania's Lake Erie shoreline. The Ohio Department of Natural Resources' *Lake Erie Coastal Erosion Study* computes erosion rates and identifies the factors controlling the temporal and spatial variation in these rates along Ohio's shoreline to improve the predictive models of future shoreline recession. These comprehensive databases provide important data for coastal management decision making.

A number of other programs contribute to erosion monitoring in the Great Lakes basin. The Wisconsin Department of Natural Resources manages a *Sensitive Area Designations* program that identifies areas that provide a high level of erosion control benefits as well as other ecologically desirable characteristics. Wisconsin's Racine County conducts a *Land & Water Resource Management Program* that monitors soil erosion from cropland. Illinois State Water Survey *Benchmark Sediment Monitoring Program* is a long-term database of suspended sediment transport in the rivers and streams of Illinois. Another program monitoring sediment transport is the *Study of sediment sources in streams of the glaciated Allegheny Plateau* conducted

by Cornell University. These data are valuable for predicting erosion rates and identifying areas sensitive to erosion. Ohio Department of Natural Resources' *Shore Structure Inventory* assesses man-made shoreline hardening devises. These data are valuable for identifying alterations and assessing their impact on natural erosion regimes and would be valuable for each Great Lakes state. Erosion control programs such as the Traverse City, Michigan *River Care Program* work toward improving erosion control.

The land use section of this report also offers information relevant to erosion in the Great Lakes basin.

Findings - Erosion

Comprehensive coastal erosion monitoring programs like Pennsylvania's Bluff Recession Monitoring project and Ohio's Lake Erie Coastal Erosion Study are valuable examples of coastal erosion monitoring. It may be valuable for other states in the basin to implement such monitoring programs. Ohio Department of Natural Resources' shore structure inventory is another example of a program that may warrant implementation throughout the basin. One area in need of monitoring resources in the region is agricultural soil erosion monitoring.

Land Use and Human Impact
e. Urban Issues

Issues related to urban development and population growth and expansion place a large environmental strain on the Great Lakes basin. Wastewater treatment, municipal runoff, energy consumption, vehicle use, eco-efficiency measures, and solid waste generation are just a few of the issues that need to be addressed in this area. While the monitoring inventory didn't specifically target urban environmental concerns, the SOLEC indicators focusing on urban issues will be addressed below.

HIGHLIGHT – Urban Issues

- Results indicate that wastewater treatment programs are focused primarily at the local and municipal level. The focus of the Great Lakes Monitoring Inventory did not make it possible to evaluate waste water treatment monitoring efforts because the inventory focused primarily on federal and state programs. Additional effort is needed to fill in these informational gaps in the inventory.

The newly developed Municipal Wastewater Treatment (#7063) indicator does not yet have a written description. A number of Great Lakes organizations reported wastewater pollution and treatment monitoring programs. These programs appear to be taking place primarily at the county or municipal level with a few exceptions. Because no specific information is available on the purpose and measurement methods for the Municipal Wastewater Treatment indicator, the following will be a general discussion of wastewater monitoring programs reported via the monitoring inventory.

The U.S. EPA's *Permit Compliance System (PCS)* tracks the permit, compliance and enforcement status of dischargers required to file a National Pollution Discharge Elimination System (NPDES) permit. This set of dischargers includes municipalities and waste water treatment operations. The PCS includes more than 3,500 sites in the Great Lakes basin but information was not available on exactly how many of these sites are directly related to wastewater treatment operations. The Illinois Environmental Protection Agency *Whole Effluent Biomonitoring Program* objectives are to conduct whole effluent toxicity tests (bioassays) on representative aquatic organisms in a variety of wastewater effluents from municipal and industrial sources; assess the success of wastewater treatment processes to remove toxic components; determine the relative toxicity of these effluents using common end points; and determine the nature of receiving waters upstream

of effluent discharges. The Michigan Department of Environmental Quality *Source Water Assessment Program* identifies the origination point of source water going into municipal water treatment plants in southeast Michigan. The Fisheries and Oceans Canada also manages the *Municipal Drain Classification Project*. No descriptive information was reported for this project.

At the local level, Milwaukee Metropolitan Sewerage District's *WATERBase - Milwaukee Metropolitan Sewerage District Water Quality Monitoring Data* program maintains an extensive water quality monitoring program to aid in pollution abatement, facilities planning, and flood control. The Northeastern Illinois Planning Commission manages the *Evaluation of Urban Storm water Pollutant Loads to Lake Michigan from Lake County, IL* project. No descriptive information is available for this project. Other local waste water monitoring programs were submitted by the North Shore Sanitary District, Illinois; Saint Clair County, Michigan; Oakland County, Michigan; Macomb County, Michigan; and Center Line Township, Michigan. These are likely just a sample of the communities in the region monitoring waste water.

There are another eight SOLEC indicators that address urban issues. These indicators include Urban Density (#7000), Brownfield Redevelopment (#7006), Water Withdrawal (#7056), Energy Consumption (#7057), Solid Waste Generation (#7060), Vehicle Use (#7064), Commercial/Industrial Eco-Efficiency Measures (#3514), and Household Stormwater Recycling (#3516). No monitoring programs were reported that address any of these indicators. It is possible that agencies monitoring for information related to these indicators did not submit surveys to the monitoring inventory since they may not view their programs as monitoring.

Findings – Urban Issues

Because no written description was available for the Municipal Wastewater Treatment indicator, it is difficult to address specific deficiencies in this area. Results do indicate that wastewater treatment programs are focused primarily at the local and municipal level. Very few municipalities and counties reported monitoring in this area. Extra effort should be made to include additional wastewater monitoring programs. No monitoring programs were reported that address Urban Density (#7000), Brownfield Redevelopment (#7006), Water Withdrawal (#7056), Energy Consumption (#7057), Solid Waste Generation (#7060), Vehicle Use (#7064), Commercial/Industrial Eco-Efficiency Measures (#3514), and Household Stormwater Recycling (#3516). Lack of monitoring program information for this section may be the result of a low emphasis on the part of monitoring inventory data collectors rather than actual gaps in regional monitoring efforts in these areas. Additional effort is needed to fill in these informational gaps before assessing them as potential monitoring gaps.

Section VI. Conclusions and Recommendations

The Great Lakes Monitoring Inventory and Gap Analysis is the first comprehensive resource developed to report on monitoring activities in the basin and how these activities meet previously set goals to protect the environmental health of the Great Lakes. Recommendations have been developed based on results from the inventory and the analysis of gaps and overlaps in monitoring efforts. These recommendations are divided into two categories: recommendations for improving the Great Lakes basin monitoring network and recommendations for improving the Great Lakes Monitoring Inventory.

A. Monitoring Community Recommendations

These recommendations, based on the results of the monitoring inventory and gap analysis, are general recommendations directed at improving the monitoring network in the region.

1. Form coordinating bodies to organize monitoring efforts in key issue areas. Formation of such coordinating bodies was suggested as a necessary element for effective management of monitoring efforts. An example of such a partnership is the Joint Strategic Plan for Management of Great Lakes Fisheries, supported by 14 federal, tribal, state and provincial organizations, that has been developed to address fisheries related issues. This partnership framework is a strong example of effective coordination and collaboration and may be used as a model for other areas of Great Lakes monitoring.

2. Encourage regular discussions among individuals managing similar monitoring programs. There is currently limited interaction between program managers directing similar monitoring efforts in different parts of the Great Lakes basin within a number of monitoring areas. Conference calls conducted as part of this project led to a number of sideline discussions among program managers about the discrepancies of individual monitoring protocols across the basin. These types of open discussions will increase coordination and collaboration across monitoring programs, leading to more comparable datasets to evaluate basin wide trends.

3. The monitoring inventory should be used by the SOLEC indicator working groups as a resource for information on monitoring efforts currently taking place in the region. Currently there is no systematic process in place for identifying monitoring efforts that address each SOLEC indicator. The Great Lakes Monitoring Inventory and Gap Analysis provides the foundation for identifying relevant monitoring efforts. During the next review of SOLEC indicators, reviewers should examine the inventory and this report to better document monitoring programs under each indicator.

4. Evaluate monitoring needs, costs, and current regulations prior to establishing funding levels. Funding levels should be based on resources needed to meet previously set monitoring objectives and regulatory requirements. Funding levels also need to account for constantly changing monitoring costs.

5. Monitoring programs need to be assessed for compatibility. Reporting on SOLEC indicators requires an assessment of programs collecting data and a comparison of results across these programs. In many cases, monitoring for a given indicator is accomplished by a number of programs within various organizations, and often for purposes other than reporting on basinwide indicators. Before summarizing data from these disparate datasets, it is critical that a compatibility analysis be conducted to determine if the monitoring methods, data analysis and reporting elements are comparable between programs. If they are not, steps should be taken to better coordinate programs to allow for direct comparison and aggregation of data.

6. Federal and state monitoring mandates should respond more directly to regional basinwide monitoring needs. Many of the programs included in the inventory are national in scope and are designed to meet national objectives. Often, these objectives are not compatible with the informational needs of the Great Lakes or other regions. Regional offices of federal agencies need to encourage program administrators to allow greater discretion and flexibility to address regional needs. Similarly, state and provincial and critical local or nongovernmental programs need to have the flexibility to be altered to address regional information needs. Without this flexibility, data generated by more narrowly defined monitoring programs may not be useable in a regional context, resulting in monitoring inefficiencies or ineffectiveness.

7. Encourage regional and local level participation at planned monitoring coordination meetings. Regional and local agencies perform a great deal of monitoring in the basin, as the monitoring

inventory shows. Their experience and data can be extremely valuable to basinwide monitoring coordination efforts and, if included, could lead to greater monitoring efficiency and effectiveness. Monitoring program managers at state/provincial and key local or nongovernmental organizations should be included in monitoring coordination meetings and conferences so that they can take part in monitoring network design.

8. Short-term, small-scale monitoring programs should be balanced with basinwide monitoring initiatives. Monitoring is needed at a variety of levels to address numerous objectives. Both small-scale and basinwide monitoring programs are taking place widely across the basin. Each of these levels of monitoring can provide a great deal of value, and when analyzed in conjunction with one another to provide a deeper understanding of the Great Lakes ecosystem. The Great Lakes monitoring community needs to engage in a direct assessment of monitoring needs and capacities to determine how best to balance the needs for narrowly targeted monitoring with the needs for broad-based, long-term monitoring. When data are not compatible and cannot be made compatible, the region needs the ability to set priorities between competing needs.

9. State and regional monitoring programs should better utilize citizen-based or volunteer resources. The monitoring inventory includes a number of examples of citizen or volunteer-based monitoring programs. Often these programs are designed to raise the public's awareness of environmental issues, but in many cases, the programs include thorough quality assurance designed to generate credible data. The vast availability of volunteer resources should not be overlooked, as they may provide a cost-effective way to collect broad-scale status and trends data. State/provincial, regional, and federal programs should assess the viability of using volunteer data to enhance the effective monitoring breadth of their programs.

B. Great Lakes Monitoring Inventory Improvements

The value of the Great Lakes Monitoring Inventory is directly tied to its accuracy and completeness. Development of a comprehensive monitoring inventory is a large-scale, regional effort that takes into account many factors, including participation by the full range of monitoring organizations, as well as information accuracy and completeness. The authors of this report made extensive efforts to collect complete information on the full range of monitoring programs in the basin, but, as the first attempt of this scale, it is likely that a number of programs were overlooked. In order to improve the utility and the validity of this tool and the associated recommendations for improving monitoring coverage and coordination, steps need to be taken to ensure that the Great Lakes Monitoring Inventory accurately and completely reflects monitoring activities in the Great Lakes basin.

The following is a list of recommendations for addressing potential gaps in the monitoring inventory data collection efforts.

1. More detailed information is needed on monitoring efforts in the Canadian portion of the Great Lakes basin. At the time of completion of this report, the representation of Canadian programs in the Great Lakes Monitoring Inventory is limited. The Binational Executive Committee (BEC) monitoring inventory development team focused primarily on collecting information on Canadian monitoring programs, while the Great Lakes Monitoring Inventory focused primarily on U.S. monitoring activities. This split was made to avoid duplication of effort. It was agreed that all program information collected by both parties would be mutually exchanged. The lack of Canadian monitoring program information in the Great Lakes Monitoring Inventory may be the result of several factors, including 1) the BEC inventory timeline for data collection did not correspond to the Great Lakes Monitoring Inventory timeline; 2) a more passive data collection effort was employed

by the BEC monitoring inventory; or 3) limited monitoring efforts in the Canadian portion of the basin. It should be noted that the Canadian entries that have been submitted into the inventory lack the depth needed to analyze monitoring efforts in sufficient detail. This makes it difficult to perform a valid comparison across monitoring efforts in both Canada and the United States in many cases.

2. The completeness and accuracy of the monitoring inventory needs to be regularly evaluated by the Great Lakes monitoring community. While every attempt was made to include all current monitoring programs in the monitoring inventory, programs may have been missed or incompletely represented. A thorough review was conducted prior to publication of this report but it will be important to regularly review the inventory throughout its life so that entries remain current and new programs are added.

3. More information on specific monitoring locations is needed. While programs were asked to submit specific sampling station locations, a minority of program managers provided this level of detail. The result is that the geographic analysis included in the gap analysis is based in large part on general geographic descriptions. The analysis would be much improved with a complete set of monitoring locations included for each program in the database. As the inventory is updated, it is important that particular emphasis be placed on obtaining monitoring location information.

4. More information is needed on the funding sources that support monitoring programs. This information is necessary to perform an accurate and complete analysis of current funding patterns, reliability of these funding sources and funding needs to address monitoring gaps. While the authors of this report attempted to analyze the reliability and sustainability of funding for monitoring in each analytical section of the gap analysis, in most cases, the funding information was too incomplete to draw realistic conclusions. As the inventory is updated, it is important that emphasis be placed on documenting funding sources and amounts for each monitoring program.

5. Program descriptive information needs to be expanded. For many monitoring program entries, only a subset of the requested information was submitted or available. Much of the information contained in the database was collected from public resources and this information is incomplete. These information gaps were described in each section of the gap analysis. It is important to complete entries for those programs in the inventory with missing information.

6. Active, ongoing data collection efforts should be continued through the Binational Executive Committee monitoring inventory effort. As noted above, the entire database of monitoring programs collected through this initiative was shared with the BEC monitoring inventory team. As the parties to the BEC have been called upon to complete this inventory and use it for further planning and coordination of monitoring activities, it may be incumbent upon the BEC's representative agencies to continue management of the inventory.

7. The Binational Executive Committee Monitoring Inventory field list should be expanded. Expansion of the field list included in the BEC inventory is necessary to capture important elements associated with monitoring efforts, many of which have been captured by the Great Lakes Monitoring Inventory effort. Some of these include funding source, budget, sampling protocol, sampling parameters, sampling station locations, and staff description. Without this information, it is difficult to use the BEC inventory for assessment or coordination purposes.

C. Conclusions

The Great Lakes Monitoring Inventory includes hundreds of important monitoring programs, each of which contributes to our knowledge of the Great Lakes ecosystem. Each program, in its own way, enhances the effectiveness of resource management in the region. However, few of these programs are designed to yield broad information about the status and trends of Great Lakes resources as a whole. This gap analysis illustrates many, but not all, of the gaps in environmental monitoring at the basinwide level. It is imperative that the monitoring community and the resource managers that they seek ways to coordinate and combine their knowledge so that Great Lakes resources may be effectively managed as an integrated system. In this way, the monitoring community may make the whole system truly greater than the sum of its parts.

Findings from the *Great Lakes Monitoring Inventory and Gap Analysis* are being disseminated to the monitoring community, resource managers, and federal and state legislators. Efforts will also be made to integrate the inventory and gap analysis into larger Great Lakes monitoring coordination initiatives. The Great Lakes Observing System (GLOS) is an integrated observing system being developed to provide critical real-time data to the region. It will serve as a regional node of NOAA's National Integrated Ocean Observing System (IOOS), which supports research on populations, species, communities, and ecosystems. Coordination with initiatives such as GLOS will further enhance data sharing, reporting, and outreach efforts. The Great Lakes Monitoring Inventory is being integrated as a foundational element of the GLOS data system. Integrating with GLOS will move this initial, static inventory effort into a dynamic decision support system that can enhance environmental management in the Great Lakes basin for years to come.

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