1ST TRIENNIAL ASSESSMENT OF PROGRESS REPORT ON GREAT LAKES WATER QUALITY

STAFF TECHNICAL APPENDIX

DRAFT REPORT FOR PURPOSES OF PUBLIC CONSULTATION

Prepared by the Staff of the International Joint Commission to provide additional details, background, references and technical analysis to support the International Joint Commission's (IJC) assessment of progress pursuant to Article 7(1)(k) of the 2012 Great Lakes Water Quality Agreement

JANUARY 31, 2017

The content of this report reflects the views of the staff of the International Joint Commission as informed by the advice of the IJC's Great Lakes Advisory Boards – The Water Quality Board and The Science Advisory Board, as well as the Health Professionals Advisory Board. The Staff Technical Appendix report is also based on literature reviews, contracted reports and board reports which may not necessarily reflect the opinion of the International Joint Commission. This appendix, as well as the Draft Triennial Assessment of Progress Report will be revised to reflect input received during the public consultation period.

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Chapter 1
Introduction

1.0 Purpose and intended audience

1. Purpose of the technical appendix

This draft **Technical Appendix to the Triennial Assessment of Progress Report** provides technical analysis to support the International Joint Commission's (IJC) assessment of progress carried out under the authority of the 2012 Protocol to the Great Lakes Water Quality Agreement (GLWQA). Views of the Commission can be found in the First Triennial Assessment of Progress on Great Lakes Water Quality: Draft Report for the Purposes of Public Consultation. As a staff document, this draft technical appendix provided input to the triennial assessment of progress but does not, in itself carry Commission endorsement. This draft technical appendix is one of two appendices that will accompany the **Triennial Assessment Report**. The other is the **Synthesis of Public Input on the Progress Report of the Parties**. The Synthesis of Public Input will be developed following the collection of public input in 2017.

Article 7.1 (k) of the GLWQA charges the IJC with the responsibility of providing to the Parties, in consultation with the Boards established under Article 8, a triennial "Assessment of Progress Report" that includes:

(i) a review of the Progress Report of the Parties;

(ii) a summary of Public input on the Progress Report of the Parties;

(iii) an assessment of the extent to which programs and other measures are achieving the General and Specific Objectives of this Agreement;

(iv) consideration of the most recent State of the Lakes Report; and

(v) other advice and recommendations, as appropriate

In addition to providing the technical information and scientific basis for the Triennial Assessment of Progress, this appendix includes extensive background information on process and history for the first triennial assessment that can serve as context for subsequent triennial reports.

2. Audience

This draft staff developed technical appendix is written for a technical audience, that is scientists, engineers, and resource managers who may wish to get detailed information on one or more topics presented in the TAP report. The primary audience of the final TAP Report and its technical appendices will be the Parties. The final report and the final Appendix are also intended to be useful for the Great Lakes public including various levels of government, nonprofit environmental organizations, academia, private industry, and all citizens who care about the well-being of the lakes.

Input and feedback from everyone who comments on the draft TAP report and the staff draft Technical Appendix will be considered in the development of the final report and appendix. The TAP report and this appendix both provide information for that input and feedback process.

The IJC has stated that its Assessment of Progress reports are intended to provide information and advice to help guide decisions. The information and advice expected in the final TAP report can provide a basis for informed environmental management decisions affecting the Great Lakes basin, as well as informing and educating the public about this dynamic and fragile ecosystem.

Recognizing that the audience for the past 16 Biennial Reports included a wide range of readers from technical experts to those with general interests, the language and style of the draft TAP report is aimed towards an environmentally-informed public. The 16th Biennial Report (IJC 2013) and several previous reports provided a summary report accompanied by a more technical report to support the findings. The technical reports provided additional detail for a scientific audience. For example, the 16th Biennial Report has one technical chapter for each indicator discussed and contains hundreds of references.

The same approach is used for this staff developed draft technical appendix, in that it contains much more detail and references to support the findings that are presented in the more concise Triennial Assessment Report. Unlike the draft TAP, however, this draft version of the staff developed technical appendix does not carry Commission endorsement.

Finally, as public engagement is an important task assigned to the IJC under the GLWQA, the IJC determined that providing the Synthesis of Public Comments on the Progress Report of the Parties as a separate appendix would enable all aspects of the public hearings to be fully addressed and properly documented without any constraint on the length of the appendix.

The IJC will revise the draft Triennial Assessment Report along with this draft staff developed Technical Appendix based on public review comments. The final TAP report and the Technical Appendix are intended to be Commission products.

1.1 History of Great Lakes Water Quality Agreement

1. Background

The original GLWQA provided a strong framework for binational action towards restoring the physical, chemical and biological integrity of the Great Lakes when it was first signed in 1972. Significant changes were instituted in 1978, 1983 and 1987. However, the agreement had not been updated for 19 years and was outdated by April 2006, when the Parties launched the most recent review that resulted in the 2012 Protocol.

The 2012 GLWQA was born from a long, rigorous and deliberate collaborative process that began in 2001 with open public and expert consultations and agency reports that informed the formal U.S. – Canadian negotiations that followed. A robust public consultation effort was orchestrated by the IJC at the direction of the Parties, resulting in over 4000 comments and input

summarized in a synthesis report. During this period, the IJC published a special report transmitting its advice to the governments on their review of the GLWQA (IJC 2006).

Environmental non-governmental groups were also influential and were strong advocates for a new and effective, action-oriented GLWQA. The governments formed an Agreement Review Committee (ARC) consisting of nine binational, collaborative working groups (including the environmental groups) to review each section of the GLWQA. The committee also organized a Governance and Institutions workshop and synthesized the findings, results and recommendations in their September 2007 report to the Great Lakes Binational Executive Committee: *Review of the Canada – United States Great Lakes Water Quality Agreement* (ARC 2007).

Extensive bilateral negotiations were conducted between representatives of the two governments and the amended agreement was completed and signed on September 7, 2012, and entered into force on February 12, 2013 (https://binational.net/glwqa-aqegl).

The rigorous process leading to the 2012 Protocol Amending the GLWQA resulted in a mechanism for implementing change and was responsive to the advice given to the governments. New annexes covering aquatic invasive species and climate change impacts were welcome additions; elements carried over from the previous agreements were given a new focus for action by including time-bound commitments.

2. IJC reports on the GLWQA

Since the GLWQA was revised in 1978, the IJC was assigned the responsibility to assess and report on progress made toward achieving objectives and the effectiveness of programs and measures used under the agreement. The IJC has issued 16 biennial reports between 1980 and 2013. This requirement continues under the 2012 revised GLWQA, though the reporting period was extended to a triennial assessment.

Biennial Reports have addressed many important issues related to the physical, chemical and biological integrity of the Great Lakes, including persistent toxic substances, aquatic invasive species and many others. The last several Biennial Reports were devoted to: the challenge of accountability (13th report); wastewater treatment and reduction of nutrient loadings from municipal sources (14th); and the 15th discussed issues related to water quality in the nearshore zone (IJC 2006; IJC 2009; IJC 2011). In anticipation of a revised GLWQA, the 16th Biennial Report (IJC 2013), assessed progress under the agreement from 1987 to 2012 and marked the return to undertaking a more comprehensive assessment. This last biennial report used seven indicators of chemical integrity, five indicators of biological integrity, two of physical integrity, and two performance indicators to assess progress over the past 25 years. The 16 indicators used in the report were selected by IJC staff based on relevance to GLWQA objectives and the availability of data.

The 16th Biennial Report had key recommendations, including that the governments select a set of core indicators related to the objectives of the GLWQA, monitor their status and report on trends over time. The Parties adopted this recommendation and restructured its State of the Lakes

reporting into nine indicators, one for each of the General Objectives of the 2012 GLWQA (Great Lakes Public Forum, 2016).

3. IJC advisory boards

The 2012 GLWQA prompted changes for both the governments and the IJC. To meet the challenges of the agreement, the IJC reconstituted its Great Lakes advisory boards – the Water Quality Board (WQB) and the Science Advisory Board (SAB) – to provide for a dynamic, inclusive and diverse membership. The IJC Health Professionals Advisory Board (HPAB) was also relied upon to provide additional support for human health related topics that are more prominently addressed in the new GLWQA. All of the advisory boards were consulted on the objectives and process associated with conducting the triennial assessment of progress. Advisory board advice, reports and projects informed the commission's advice and recommendations to the governments and were key elements in helping the IJC fulfill its responsibilities to assess the government's progress under the GLWQA.

1.2 Approach and methods

1. TAP report preparation

To develop the TAP, a planning workshop was held with IJC advisory board co-chairs and staff to develop a comprehensive report process. Periodic consultations with boards on the staff technical appendix were included, and Commissioners reported on the development of the report with the Great Lakes Executive Committee leadership at each IJC semi-annual meeting. A public consultation plan was developed to ensure that public input on the Progress Report of the Parties and the IJC's draft Triennial Assessment of Progress Report would be documented and considered in the eventual review phase and revision of the report.

Commissioners reviewed the draft technical appendix, IJC advisory board reports and other documents in the preparation of their draft TAP report.

2. Consultation with advisory boards

In September 2014, the IJC Great Lakes Regional Office hosted a full day workshop designed to establish the approach for preparing the IJC's 2017 Triennial Assessment of Progress Report. Participants focused on developing the overall approach, steps and roles that would guide the development process for the Triennial Report and its technical appendix.

Active consultation with the Great Lakes advisory boards on the development of the technical appendix included a planning workshop, review of the scoping documents, discussions at board meetings, webinars, surveys, and commissioner - co-chairs meetings. In addition, a dialog was

established between IJC staff authors and individual members of the IJC's WQB, SAB and HPAB to consult on sections of the technical appendix as they were being developed. All Great Lakes Advisory Boards then had an opportunity to review and comment on the Technical Appendix.

3. Emphasis on General and Specific Objectives

In contrast to the Progress Report of the Parties, which is organized around the Annexes of the GLWQA, the IJC organized its assessment along the nine General Objectives of the agreement. Progress on achieving the General Objectives is affected by activities conducted by more than one Annex. For example, the first three objectives to have drinkable, swimmable and fishable Great Lakes waters are directly or indirectly impacted by all of the work being done under the Annexes. By placing the focus on the General Objectives of the GLWQA and assessing progress based on indicators, this third-party review is able to take a more holistic approach to evaluating the progress of the Parties across all related Annexes.

4. Principles and approaches

The GLWQA provides a list of principles and approaches to guide the governments' actions to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes. In evaluating progress toward the nine objectives, the IJC chose to consider how some of the 16 principles and approaches listed in Article 2 of the GLWQA were being implemented as on aspect of its assessment. The extent to which these principles and approaches are effectively integrated into government actions to achieve the General and Specific Objectives of the Agreement will be addressed, as appropriate, relative to each General Objective in Chapter 3.

5. Programs and measures

The IJC is tasked with assessing programs and measures to achieve the General and Specific Objectives of the GLWQA. These programs and measures are addressed in Article 4, as well as in each Annex. In fact, descriptions of such programs and measures comprise approximately 25 percent of the text in the GLWQA. This presents a wide range of activity to assess.

List of Programs and Other Measures (Article 4 Implementation, GLWQA)
1. The Parties, in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, other local public agencies, and the Public, shall develop and implement programs and other measures:

(a) to fulfill the purpose of this Agreement, in accordance with the Principles and Approaches set forth in Article 2; and

(b) to achieve the General and Specific Objectives set forth in Article 3.

2. These programs and other measures shall include, but are not limited to:

(a) pollution abatement, control, and prevention programs for:

(i) municipal sources, including urban drainage;

(ii) industrial sources;

(iii) agriculture, forestry, and other land use;

(iv) contaminated sediments, and dredging activities;

(v) onshore and offshore facilities, including the prevention of discharge of harmful quantities of oil and hazardous polluting substances;

(vi) sources of radioactive materials; and

(vii) other environmental priorities that may be identified by the Parties;

(b) aquatic invasive species programs and other measures to:

(i) prevent the introduction of aquatic invasive species;

(ii) control or reduce the spread of existing aquatic invasive species; and

(iii) eradicate, when feasible, existing aquatic invasive species;

(c) conservation programs to:

(i) restore and protect habitat; and

(ii) recover and protect species;

(d) enforcement actions and other measures to ensure the effectiveness of the programs described in (a), (b) and (c); and

(e) research and monitoring programs to support the commitments made in this Agreement.

Table 1.1 summarizes key programs and measures listed in each of the ten annexes of the GLWQA.

Key Programs and Measures Described in Annexes to the Agreement
#1- Areas of Concern
Restore Beneficial Uses
Remove BUI Designation When Criteria Met
Develop, Implement, & Communicate Remedial Action Plans
Delist Areas Of Concern (AOCs)/Designate as AOC in Recovery
#2- Lakewide Management
Establish Ecosystem Objectives
Assess Existing Scientific Info for Current and Future Potential Threats
Identify Need for Government and Public Action to Address Threats
Develop Lake Binational Strategies for Substance Objectives
Develop Integrated Nearshore Framework
#3- Chemicals of Mutual Concern
Identify Chemicals of Mutual Concern
Prepare Binational Strategies for Chemicals of Mutual Concern
Develop and Apply Domestic Water Quality Standards in Law
Reduce Anthropogenic Releases of Designated Chemicals
Evaluate Effectiveness of Pollution Prevention Measures
#4- Nutrients
Develop & Implement Regulations to Reduce Phosphorus Loading (Urban, Industrial, Agriculture, Residential)
Evaluate Practices to Manage Phosphorus Input
Develop Lake Erie Action Plan to Meet Substance Objectives
Identify Priority Watersheds for Nutrient Control
#5- Discharges from Vessels
Implement Laws & Regulations for Vessel Discharges
Adopt Programs for Prevention of Oil and Hazardous Substance Discharges
Provide Reception Facilities for Disposal of Vessel Wastes
#6- Aquatic Invasive Species
Undertake Measures to Prevent Ballast Water Release of Aquatic Invasive Species
Conduct Risk Assessments for Pathways for Introduction & Spread of AIS
Develop Regulations & Management Strategies Based on Risk Assessments
Undertake Education & Outreach Efforts
Implement Early Detection & Rapid Response Initiative
#7- Habitat and Species
Conduct Baseline Survey of Existing Habitats
Implement Conservation Strategies/Lakewide Action & Management Plans
Increase Public Awareness of Habitats & Conservation Efforts
#8- Groundwater
Publish Reports on Groundwater Science
Identify Science Priorities & Actions for Groundwater Protection
Coordinate Binational Activities to Assess & Protect Groundwater Quality
#9- Climate Change Impacts
Binational Communication of Science & Actions to Address Climate Change Impacts

#10- Science
Use Adaptive Management Framework for Science-Based Management
Undertake Monitoring to Address Environmental Concerns
Facilitate Information Sharing

For the purpose of this technical appendix, some of these programs and measures were assessed in a narrative form considering the degree of program implementation as observed by IJC staff and as reported by the governments in the Progress Report of the Parties. IJC staff also reviewed government programs and actions that are carried out in support of each General Objective.

6. Public engagement

Another key element in developing the report is public engagement. The IJC has committed to a rigorous schedule of public engagement activities to capture input on the Progress Report of the Parties and the draft IJC Triennial Assessment of Progress Report.

To meet this challenge, the IJC is using more new developments in technology than ever before to conduct an active, open discourse with the public. Citizens throughout the Great Lakes basin were provided an opportunity to participate in a series of online and in-person discussions and meetings to provide their perspectives about progress by the governments of Canada and the United States under the 2012 GLWQA. The Progress Report of the Parties was released in late September, just prior to the 2016 Great Lakes Public Forum and initiated the IJC's public consultation process. Public engagement opportunities included:

- *Great Lakes Public Forum* and *IJC Public Comment Session*, held in Toronto on October 4-6, 2016. The IJC provided a live-stream of the event with the assistance of Detroit Public TV and TVO and the event was viewed via livestream and YouTube. The IJC Public Comment Session, was held as part of the Forum on Wednesday, October 5, 2016.

- *Toronto Public Meeting*, an additional public meeting convened by the IJC for Toronto residents to share their thoughts and experiences on restoring water quality and water uses along the city's waterfront and Lake Ontario held on Wednesday evening, Oct. 5, 2016 at Toronto's City Hall.

- *Milwaukee Public Meeting* held Tuesday, Oct. 18, 2016 at the University of Wisconsin's College of Freshwater Sciences in Milwaukee, Wisconsin.

- Online *Discussions* – ParticipateIJC. Over a period of ten months, the IJC hosted a series of monthly online discussions on its online democracy platform called ParticipateIJC. The sharing platform provided opportunities for citizens throughout the Great Lakes region to contribute comments, videos, photos and stories, and talk with others about progress to restore and protect the lakes. It also provided video from the Great Lakes Public Forum and other meetings held around the basin for those who could not attend in person.

- *IJC Triennial Assessment of Progress Report and Spring 2017 Public Meetings*. Beginning in March 2017, the IJC will host a series of public meetings around the Great Lakes basin to solicit citizens' comments on the draft Triennial Assessment of Progress Report. The draft report and its appendix were posted at IJC.org and on ParticipateIJC to encourage discussion

and comments. The final report, to be released later in 2017, will incorporate all scientific, policy and citizen input.

1.3 Organization

The staff technical appendix of the IJC's Triennial Assessment of Progress report consists of six Chapters, based on the requirements of Article 7 (k) and the nine General Objectives of the GLWQA:

- *Chapter 1* provides background on the GLWQA and the approach to preparing the Triennial Assessment of Progress and this technical appendix.
- *Chapter 2* reviews the Progress Report of the Parties.
- *Chapter 3*, the main chapter of this report, presents a comprehensive review and assessment of programs and measures undertaken in support of the nine General Objectives of the GLWQA, including work on indicators and national and binational programs. There are nine sections in Chapter 3, with one section corresponding to each of the nine general objectives of the Agreement.
- *Chapter 4* discusses the challenge of assessing and reporting on the condition of the Great Lakes using indicators and communicating the findings to the public.
- *Chapter 5* assesses key challenges that are critically important for making progress toward achieving the objectives of the GLWQA but that are not directly addressed in Chapter 4, including issues related to data availability and accessibility and future improvements to Great Lakes indicators.

The Triennial Assessment of Progress Report itself is structured in a similar manner, so that supporting details in this staff developed technical appendix may be easily referenced from the IJC's draft TAP.

1.4 References

ARC, 2007. Agreement Review Committee. GLWQA Review Report – Volume 1, September 2007. Available at http://publications.gc.ca/collections/collection_2012/ec/En164-21-1-2007-eng.pdf

Great Lakes Public Forum, 2016. State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. Available at https://binational.net/engagement-participation/forum/

IJC, 2006. Advice to Governments on their Review of the Great Lakes Water Quality Agreement. Available at http://www.ijc.org/php/publications/pdf/ID1603.pdf

IJC, 2009. 14th Biennial Report on Great Lakes Water Quality. Available at http://www.ijc.org/files/publications/ID1631.pdf

IJC, 2011. 15th Biennial Report on Great Lakes Water Quality. Available at http://www.ijc.org/files/publications/C265.pdf

IJC, 2013. 16th Biennial Report on Great Lakes Water Quality. Assessment of Progress Made Towards Restoring and Maintaining Great Lakes Water Quality Since 198. Available at http://www.ijc.org/files/publications/16thBE_internet%2020130509.pdf

Chapter 2

Review of the Progress Report of the Parties

2.0 Introduction

1. Purpose

The GLWQA Article 7.1(k) assigns the IJC responsibility to provide to the Parties a triennial "Assessment of Progress Report" and specifies that the report should include a review of the Progress Report of the Parties. The production of a triennial Progress Report of the Parties (PROP) is a new commitment by the Parties under the 2012 Agreement. Article 5.2(e) specifies that the report shall document actions taken domestically and binationally in support of the Agreement and that the report shall be prepared in consultation with the Great Lakes Executive Committee. The government production of the PROP and the IJC review of its Triennial Assessment of Progress Report is a key government accountability feature under the 2012 Agreement. The production of the PROP report, in itself, is a major advancement in accountability under the 2012 Agreement.

The purpose of this chapter is to provide a draft review of the Progress Report of the Parties. The chapter will present review criteria and then apply that criteria to the report. The review presented aims to assess how the well the PROP report meets the reporting requirements set out in the Agreement and how well applicable Agreement principles and approaches, for example accountability and public engagement, are implemented. The chapter concludes with a summary of key findings from the review. The assessment of the extent to which programs and other measures presented in the report are achieving the objectives of the Agreement is presented in Chapter 4 relative to each general objective of the Agreement.

2. Accountability under the Great Lakes Water Quality Agreement

Article 2.4 of the Great Lakes Water Quality Agreement sets out the principles and approaches that are to guide the Parties in their implementation of the Agreement. The first principle listed is accountability. Accountability is defined in the Agreement as establishing clear objectives; regular reporting made available to the Public on progress, and transparently evaluating the effectiveness of work undertaken to achieve the objectives of the Agreement.

In its 13th Biennial Report on Great Lakes Water Quality issued in 2006, the IJC looked in depth at accountability under the Great Lakes Water Quality Agreement. Although that report looked specifically at accountability under the 1987 Great Lakes Water Quality Agreement, its approach and many of its findings and recommendations are applicable to the renewed 2012 Agreement. The 13th Biennial Report states that accountability is generally understood as an obligation to render an account for expected or agreed-upon performance. The Auditor General of Canada

defines accountability as a relationship based on obligations to demonstrate, review and take responsibility for performance, both in terms of the results achieved, based on agreed expectations, and of the means used.

The Biennial Report goes on to state that "[s]uccessfully implemented, accountability focuses action on end goals and ensures that promises are kept and commitments are honored. The best accountability frameworks specify measurable results, the actions to be taken, by whom and by when, how reporting back will occur and the consequences of inaction. Accountability encourages improved performance by learning from what works and what does not. Accountability so conceptualized is pivotal to achieving anything that is as complex and important as the goals of the Great Lakes Water Quality Agreement."

The PROP, the IJC review of the PROP in the Triennial Assessment of Progress Report and public input on the PROP, are not the only mechanisms for government accountability under the 2012 Agreement. Article 3.4 directs the Parties to publicly report on progress in achieving the General Objectives, Lake Ecosystem Objectives and Substance Objectives in the State of the Great Lakes Report and Lakewide Action and Management Plans (LAMPs), as well as the PROP. The IJC is directed to consider the most recent State of the Lakes Report in this assessment of progress. Under Annex 1: Lakewide Management the IJC has the opportunity to provide advice and recommendations when a LAMP report is issued. The IJC also has a role under Annex 1 of reviewing proposals to delist Areas of Concern (AOC) or redesignate them as Areas in Recovery. IJC review of LAMPs and AOC delisting reports are discussed in section 3.9.

3. Criteria for review of the Progress Report of the Parties

This review of the PROP aims to assess how well Agreement reporting requirements are satisfied by the PROP and how well applicable Agreement principles and approaches are implemented. Criteria for review of the PROP were designed to meet these aims. Relevant sections of the Agreement, followed by the associated review criteria, are presented in Table 2.1.1. Reporting requirements for the PROP include specific details of what should be in the report, general reporting requirements and points of process. Accountability has been mentioned as the key principle to be implemented through PROP reporting. Other applicable principles and approaches include: adaptive management, coordination and public engagement. As stated above, assessments of the extent to which programs and measures described in the PROP are achieving the objectives of the Agreement are presented in Chapter 4.

Table 2.1: Criteria for Review of the Progress Report of the Parties

Great Lakes Water Quality Agreement			PROP Review Criteria
Article/Annex	**Sub Section**	**Text**	
Article 2: Purpose, Principles and Approaches	4(a)	The Parties shall be guided by the following principles and approaches in order to achieve the purpose of this Agreement: (a) accountability – establishing clear objectives, regular reporting made available to the Public on progress, and transparently evaluating the effectiveness of work undertaken to achieve the objectives of this Agreement;	Does the report show progress relative to stated objectives? Does the report show the evaluation of effectiveness of work undertaken or provide sufficient information for others to do so?
Article 2: Purpose, Principles and Approaches	4(b)	(b) adaptive management - implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood;	Does the report provide a basis for adaptive management (perhaps by showing what has worked and what has not and demonstrating responsiveness in implementation)? If not, does it provide a basis for the others to assess the need for corrective action?
Article 2: Purpose, Principles and Approaches	4(e)	(e) coordination - developing and implementing coordinated planning processes and best management practices by the Parties, as well as among State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies	Does the report show howthe Parties, have worked with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies to develop and implement coordinated planning processes and best management practices?
Article 2: Purpose, Principles and Approaches	4(k)	(k) Public engagement - incorporating Public opinion and advice, as appropriate, and providing information and opportunities for the Public to participate in activities that contribute to the achievement of the objectives of this Agreement;	Does the report present information in a publicly accessible manner?
Article 3: General and Specific Objectives	4. Reporting	The Parties shall publicly report, in the Progress Report of the Parties, State of the Great Lakes Report and Lakewide Action and Management Plans, on the progress in achieving the General Objectives, Lake Ecosystem Objectives and Substance Objectives.	Does the report discuss progress in achieving the general objectives, lake ecosystem objectives and substance objectives?
Article 5: Consultation, Management and Review	2(e)	The Parties hereby establish a Great Lakes Executive Committee to help coordinate, implement, review and report on programs, practices and measures undertaken to achieve the purpose of this Agreement: (e) the Parties shall prepare, in consultation with the Great Lakes Executive Committee, a binational Progress Report of the Parties to document actions relating to this Agreement, taken domestically and binationally. The first such report shall be	Was the report prepared in consultation with the Great Lakes Executive Committee? Does the report document actions taken domestically and binationally? Was the report provided to the public before the Great Lakes Public Forum?

		provided to the Public and the Commission before the second Great Lakes Public Forum, and subsequent reports shall be provided before each subsequent Great Lakes Public Forum.	
Annex 1: Areas of Concern	C. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties, including: 1. a listing of current AOCs; 2. the status of BUIs in each AOC; 3. the actions completed or initiated in each AOC during the reporting period; and 4. the remaining actions required in each AOC for the removal of the designation as an AOC.	Does the report include these details related to AOCs?
Annex 3: Chemicals of Mutual Concern	D. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties. The report shall include: 1. an identification of chemicals of mutual concern; and 2. the status of initiatives to develop binational strategies to address issues involving chemicals of mutual concern and the status of implementing binational strategies for chemicals of mutual concern.	Does the report include these details related to chemicals of mutual concern?
Annex 4: Nutrients	F. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties. This report shall document: 1. Lake Ecosystem Objectives and Substance Objectives; 2. implementation of the binational strategies and domestic action plans; 3. changes in phosphorus loading and concentrations; and 4. progress toward achievement of the Substance Objectives for phosphorus concentrations, loading targets and loading allocations apportioned by country, established under to this Annex.	Does the report include these details related to nutrients?
Annexes 1-10	Reporting	the Parties shall report on progress toward implementation of each Annex every three years through the Progress Report of the Parties.	Does the report set out progress in the implementation of each Annex?

2.1 Review of the Progress Report of the Parties

The PROP reporting requirement includes details of what should be in the report, general reporting requirements and points of process. Most notably, the report is required to document actions relating to the Agreement that have been taken domestically and binationally.

Does the report document actions taken domestically and binationally?

The PROP reports on actions taken domestically and binationally. This is, indeed, the key accomplishment of the PROP. The report presents a clear and readable catalogue of actions related to the articles and annexes of the Agreement.

Does the report show progress relative to stated objectives?

Article 2.4 of the Agreement sets forth the principles and approaches that are to guide the Parties in Agreement implementation, including the preparation of the PROP report. The first principle is accountability, defined in the Agreement as establishing clear objectives, regular reporting made available to the public on progress, and transparently evaluating the effectiveness of work undertaken to achieve the General and Specific Objectives of the Agreement. The PROP clearly reports against commitments made in the 2012 Agreement. This is effective in some cases, particularly where progress is reported relative to specific, time-bound commitments.

For example, the commitment that the Parties shall by 2016, "develop binational substance objectives for phosphorus concentrations, loading targets and loading allocations to Lake Erie" presents a clearer, time-bound objective than the commitment in the Agreement that the Parties will "coordinate binational climate change science activities to quantify, understand and share information that Great Lakes managers need to address climate change impacts…" In these cases, where Agreement commitments are more general, assessment of the appropriateness of the extent, depth and timing of the task(s) undertaken is more difficult and there is less accountability for the degree of progress made.

Moving forward, with each three-year work cycle of the Agreement, there will be fewer specific time-bound commitments in the Agreement to report against. For example, apart from cyclical commitments (such as the requirement for the Parties to issue a LAMP for each Great Lake every five years) there is only one specific time-bound commitment written into the Agreement for years after 2016 (the commitment to develop binational phosphorus reduction strategies and domestic action plans for Lake Erie by 2018). As the existing milestones are met, specific deadlines dwindle and only general Agreement commitments remain other mechanisms for objective setting will be required, if the governments are serious about maintaining accountability for their progress under the Agreement.

Priorities for Science and Action set at the beginning of each three-year work cycle offer additional objectives against which to measure progress. The PROP would benefit from addressing priorities for the 2014-2016 work cycle as directly and clearly as the time-bound commitments in the Agreement. However, the 2014-2016 priorities for science and action were

not mentioned in the PROP at all, except for the fact that the commitment to set the priorities was met.

Reporting against these priorities would help the IJC and the public to evaluate government actions relative to expectations. For example, the PROP's report on the Chemicals of Mutual Concern (CMC) Annex fails to mention that progress falls well short of the Annex's 2014-2016 priorities for action that included the development of binational strategies for the first set of CMCs by summer 2015 (no strategies had been developed at the time of this report). However, these priorities will only be helpful for evaluating progress if, as per this example, the priorities are specific and time bound. Unfortunately, the Parties' proposed 2017-2019 priorities for science and action lack specific milestones for proposed CMC activities, and a number of other annexes

Does the report discuss progress in achieving the general objectives, lake ecosystem objectives and substance objectives?

In the Agreement, the Parties committed to reporting on progress in achieving the general and specific objectives of the Agreement, however, this commitment is spread across three documents, the PROP, the State of the Great Lakes Report (SOGLR) and Lakewide Action and Management Plans (LAMP) reporting. Relative to this commitment, the Parties describe the PROP as "an overview of binational and domestic activities that have contributed to the achievement of GLWQA objectives" (Governments of United States and Canada, 2016 p5). The Parties have indicated that the reporting on progress relative to the General Objectives of the Agreement will be presented in the SOGLR, expected in 2017. Progress is expected to be reported in the SOGLR using indicators related to each of the General objectives. This SOGLR is discussed further in Chapters 4 and 5. This reporting of progress by the Parties is essential information for the IJC's assessment of progress. However, despite publication of the PROP in September 2016, the SOGLR will not be published until sometime in 2017. The PROP on its own provides only a partial basis for the assessment of progress. The lack of a current SOGLR therefore creates a substantial impediment to the IJC conducting a timely assessment of progress following the issuance of the PROP in this triennial cycle. Coordinated release of the PROP and SOGLRs would enable review of the actions presented in the PROP in comparison to the indicator levels associated with each of the Objectives.

Does the report show the evaluation of effectiveness of work undertaken or provide sufficient information for others to do so? and/or Does the report the report provide a basis for adaptive management (perhaps by showing what has worked and what has not and demonstrating responsiveness in implementation)? If not, does it provide a basis for the others to assess the need for corrective action?

The PROP paints a very positive picture of Agreement implementation. Although that picture is oft times justified, transparency would be improved if the report included discussion of where past or current programs have fallen short of bureaucratic or outcome expectations. This discussion would give the governments the opportunity to show how they are implementing an

adaptive management approach by assessing the effectiveness of actions and adjusting those actions to achieve the objectives of the Agreement as outcomes and processes become better understood (if they are indeed implementing such an approach). The evaluation of programs relative to outcomes (by the Parties or by others) would be facilitated by the publication of the indicator data expected in the SOGLR.

Does the report show how the Parties, have worked with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies to develop and implement coordinated planning processes and best management practices?

Reviewing the lists of organizations and government agencies involved in Agreement Annex Committees, the PROP shows significant coordination among federal, state and provincial bodies in the implementation of the Agreement. However, coordination beyond these bodies is less clear. Whereas some Annex committees (notably Annexes 2 and 6) have broad and varied composition, others (for example Annexes 3, 8 and 10) have predominantly, if not exclusively, government membership. The Annex 6 subcommittee is most notable with respect to coordination in that it not only has a reasonably broad membership, but also works in close cooperation with the Great Lakes Panel on Aquatic Nuisance Species that predates the 2012 Agreement and has its own broad membership. The Parties could perhaps demonstrate wider coordination and engagement if, as per Annex 3, details of the extended subcommittee were provided, either in the report or on binational.net.

Review of participants in Annex Committees shows who is best positioned to coordinate with governments on Annex implementation but it does not show the quantity or quality of that coordination. Greater evidence of coordination could be shown in the PROP document through greater inclusion of binational and domestic actions conducted by a larger range of organizations. Actions listed for the Aquatic Invasive Species Annex (Annex 6) provides some good examples of coordination in action.

Was the report prepared in consultation with the Great Lakes Executive Committee?

A draft of the PROP report was shared with the GLEC membership, commissions and observers in late May 2016 for discussion at the June 2016 GLEC meeting. The Parties took comments until mid-June. Therefore, consultation with GLEC was undertaken but the timeline for the submission of comments was limited – just over two weeks. However, many Annexes prepared their sections of the PROP report in consultation with their Annex Committee members, therefore select GLEC members would have been consulted on PROP reporting for areas of agreement implementations where they are directly engaged. It is notable that the majority of the discussion about the PROP report at the June GLEC meeting related to the need for the report to be more engaging for the public, including that the PROP should have more storytelling. The final GLEC report did not significantly include storytelling. Issues of public engagement are discussed below.

Does the report present information in a publicly accessible manner?

The PROP is a clear, readable catalogue of actions and recognizes the challenge of delivering the report on time. However, the report does not include stories or anecdotes, many of the graphics were not particularly clear or compelling and there were few photographs or pictures to engage the reader. One of the more engaging sections was Annex 7, Habitats and Species where text boxes and photos were used to show examples of how biodiversity strategies are being used in each lake.

In future rounds of reporting, the Parties could improve the report in content and delivery as a tool for public engagement, providing relatable case studies, pictures and legible graphics.

Was the report provided to the public before the Great Lakes Public Forum?

The PROP was released to the public on September 28, 2016, six days before the Great Lakes Public Forum, October 4-6. Therefore, the Parties met their commitment to release the PROP before the Forum. However, the PROP was not released sufficiently in advance of the Forum such that people would have ample time to review it prior to the event. It is also notable that the PROP was released with little publicity. It was made available on the binational.net website and announced on the Great Lakes Information Network but there was no press release or other publicity surrounding the report release. At the Great Lakes Public Forum, the report was rarely mentioned and the report was not referred to in the presentations that discussed progress under the Annexes.

To be an effective vehicle for public engagement at the Forum, the PROP should be released a month before the event and receive adequate publicity. Public engagement around the report would have been improved if, as had been expected, the Parties had used it at the Forum as a context for the various presentations. Similarly, the SOGLR could have been released prior to the Forum to have more informed discussions.

SPECIFIC ANNEX REPORTING REQUIREMENTS

The PROP also addresses each of the specific reporting requirements mentioned in the annexes, though some are addressed to only to a limited extent.

Does the report set out progress in the implementation of each Annex?

The PROP sets out programs and actions implemented for Agreement Articles and Annexes. Specific reporting requirements for the Annexes are discussed below.

Does the report include the required details related to AOCs?

The PROP report contains lists of all Canadian and US AOCs (current and delisted), showing the BUIs have been removed (along with the year of removal) and the BUIs still impaired. Lists are also included to show the status of key actions at each AOC and the expected date for the completion of all actions. The report does not specify all actions completed or initiated in each AOC during the reporting period, however, key actions are highlighted. In future reporting periods, the key actions accomplished in the reporting period could be presented.

Does the report include the required details related to chemicals of mutual concern?

The PROP report shows the chemicals that have been designated as Chemicals of Mutual Concern. The PROP states that draft binational strategies are being developed for all of the CMCs designated, with polychlorinated biphenyls (PCBs) and hexabromocyclododecane (HBCD) to be the first chemicals addressed. However, this is a minimal accounting of the status of initiatives to develop binational strategies required by the Agreement.

Does the report include the required details related to nutrients?

The Agreement states that PROP reporting on nutrients shall document:

1. Lake Ecosystem Objectives and Substance Objectives;
2. Implementation of binational strategies and domestic action plans;
3. Changes in phosphorus loading and concentrations; and
4. Progress toward achievement of Substance Objectives for phosphorus concentrations, loading targets and load allocations apportioned by country, established under this Annex.

The PROP report discusses the development of binational substance objectives for phosphorus concentrations, loading targets, and loading allocations for Lake Erie by 2016 and how these objectives will help to address some of the Lake Ecosystem Objectives mentioned in the Agreement. However, there is no reporting of the status of the nearshore or open waters of the various Great Lakes relative to the Lake Ecosystems Objectives and the only reporting relative to substance objectives (either the interim objectives listed in the Agreement or the newly agreed targets is a graph of total phosphorus loads to Lake Erie by source type for 1967-2013.

The PROP states that binational phosphorus reduction strategies and domestic action plans are being developed. Minimal detail is provided regarding strategy and plan development, however, the PROP does include significant information on nutrient reduction activities and nutrient management strategies, policies and legislative actions in each country.

Improved reporting on progress relative to Lake Ecosystem Objectives and Substance Objectives as well as strategy and action plan implementation will be expected in the next round of progress reporting in 2019. The requirements listed in the Agreement should be seen as a minimum level of analysis and reporting.

2.2 Chapter Summary

- The production of the PROP report is a major advancement in accountability under the 2012 Agreement.

- The PROP report presents a clear and readable catalogue of actions taken domestically and binationally related to the articles and annexes of the Agreement.

- The lack of up-to-date SOGLR data presents a significant impediment to conducting a timely assessment of progress following issue of the PROP.

- The report does show progress relative to commitments in the Agreement but analysis of the effectiveness of that progress, and the need for any corrective action, is limited, in part, by the lack of SOGLR information.

- As time bound commitments in the Agreement are overtaken, binational priorities for science and action could work as a new objective setting process under the Agreement. Specific, time-bound priorities are the most useful for accountability.

- The PROP report shows evidence of good coordination between various government agencies. Coordination with non-government agencies could be better demonstrated and consultation with the GLEC better executed.

- The PROP is not an effective tool for public engagement and the timing and mode of its release did not promote engagement.

Chapter 3
Review and Assessment of General Objectives

3.0 Introduction

Purpose

Chapter 3 presents a comprehensive review and assessment of programs and measures undertaken in support of the nine General Objectives of the *Great Lakes Water Quality Agreement* (GLWQA). The assessment is based largely on a review of:

- data and information from the *2016 State of the Lakes* presentation by the Parties (Great Lakes Public Forum , 2016);
- the **Progress Report of the Parties** (Governments of the United States and Canada, 2016);
- observation of GLWQA Annex implementation, where applicable; and
- review of other programs, as necessary.

General Objectives of the GLWQA

Under Article 3 of the GLWQA, the Parties agreed that the waters of the Great Lakes should:

> *(i) be a source of safe, high-quality drinking water;*
> *(ii) allow for swimming and other recreational use, unrestricted by environmental quality concerns;*
> *(iii) allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;*
> *(iv) be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain;*
> *(v) support healthy and productive* ***wetlands****and other habitats to sustain resilient populations of native species;*
> *(vi) be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of* ***algae*** *and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem;*
> *(vii)be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes;*
> *(viii) be free from the harmful impact of contaminated groundwater; and*
> *(ix) be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes.* (GLWQA, 2012)

GLWQA Annexes

The GLWQA also includes a set of 10 annexes that set out programs and measures that the Parties have agreed to undertake in support of one or more of the General Objectives (Table 3.0).

Table 3.0 List of Annexes under the Great Lakes Water Quality Agreement (2012)

Annex 1	Areas of Concern
Annex 2	Lakewide Management
Annex 3	Chemicals of Mutual Concern
Annex 4	Nutrients
Annex 5	Discharges from Vessels
Annex 6	Aquatic Invasive Species
Annex 7	Habitat and Species
Annex 8	Groundwater
Annex 9	Climate Change Impacts
Annex 10	Science

Organization

Each of the following nine sections of Chapter 3 addresses a General Objective. Each section:

- reviews publicly available information on relevant SOGL indicators and, where appropriate, provides a critique of the indicators used;
- reviews information provided in the PROP;
- reviews, where applicable, the implementation of programs and measures undertaken through one or more of the GLWQA Annexes that may be relevant to the achievement of that particular General Objective;
- reviews, where appropriate, supplemental information from other management programs and activities carried out by federal, state and provincial governments, local governmental agencies and non-governmental organizations in Canada and the United States in support of the General Objective;
- provides a summary of key observations with respect to progress toward achieving the General Objective and the need for future improvements towards meeting the objective.

References:

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Cat. No.: En164-53/1-2016E-PDF. ISBN: 978-0-660-06365-2. Available at https://binational.net/2016/09/28/prp-rep/.

Great Lakes Public Forum, 2016.State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. Available at https://binational.net/2016/11/25/glpf-fpgl-2016-presentations-videos/

3.1 Drinking Water

This section reviews and assesses progress toward achieving General Objective 1 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 1 states that the waters of the Great Lakes should "be a source of safe, high-quality drinking water."

While there is no single Annex in the GLWQA dedicated to the achievement of Objective 1, it directly relates to several annexes that drive action to restore and protect the Great Lakes drinking water by removing beneficial use impairments (Annex 1), improving lakewide action and management (Annex 2) and managing nutrient loadings (Annex 4). The assessment also reviews source-water protection programs in Canada and the United States. Protection of source water is related to implementation of the prevention principle set out in Article 3 of the GLWQA.

3.1.1 Background

The Great Lakes and its connecting channels are a source of drinking water to over 40 million Canadians and Americans. However, they are susceptible to contamination from a variety of sources. As a result, the protection of these source waters is important for the provision of safe drinking water, particularly for those few populations who may not have access to treated drinking water. For most people, protecting drinking water requires a comprehensive, multi-barrier approach, including source water protection, appropriate treatment, and distribution system maintenance and monitoring.

Residents of the Great Lakes basin have experienced a number of tragic drinking water contamination incidents, including: the *E. coli*O157:H7 contamination of a source water supply in Walkerton, ON (2000); the 2014 "do not drink" advisories by Toledo, OH and Pelee Island, ON in response to unsafe levels of microcystin in the treated water; and the 2015 crisis in Flint, MI, in which elevated levels of lead leached from distribution pipes as a result of improper water treatment.

Though only the Toledo and Pelee Island incidents were from the waters of the Great Lakes, these incidents serve as a reminder of the importance of safe drinking water. In addition, they may offer lessons that can lead to improvements in the protection and delivery of safe drinking water. For example, the Walkerton incident resulted in the establishment of the *Ontario Safe Drinking Water Act* and the *Ontario Clean Water Act*, which together form a regulatory framework for a comprehensive management approach. The Flint crisis has put increased pressure on the US Environmental Protection Agency (USEPA) to strengthen its Lead and Copper Rule to prevent any future incidents. Since the Toledo incident, the Ohio EPA has updated its "State of Ohio Harmful Algal Bloom (HAB) Response Strategy" and adopted new HAB rules that establish: microcystin action levels for drinking water; monitoring requirements

for drinking water plants; treatment technique requirements; and requirements for public notification of violations (OH EPA, 2016). Additionally, in 2016 the EPA developed three tools to help communities prepare for and reduce risks from cyanotoxins in drinking water. These tools include a template and example plans for cyanotoxin management in drinking water, a cyanotoxin drinking water treatment optimization document, and a cyanotoxin risk communication toolbox.

While it is a positive step that lessons have been learned through these tragic events, a proactive, approach that embodies the prevention principle called for by the GLWQA is required. The GLWQA defines prevention as anticipating and preventing pollution and other threats to the quality of the waters of the Great Lakes to reduce overall risks to the environment and human health.

3.1.2 Assessment of indicators

1. Overall assessment

At the Great Lakes Public Forum (GLFP 2016), the Parties reported their plans for SOGL 2016. The Parties plan to use a "Treated Drinking Water" indicator to assess the overall quality of *treated drinkingwater* in the Great Lakes basin. This assessment is currently reported separately for Canada and the United States. In both Canada (Ontario) and the United States, the Great Lakes have an overall status of "good" with an "unchanging" trend for treated drinking water. The lakes are not individually assessed (GLPF, 2016).

In Ontario, treated drinking water samples meeting the Ontario Drinking Water Quality Standards (DWQS) ranged from 99.8 to 99.9 percent compliant for the years 2007-2014.. The samples included microbial, chemical and radiological parameters. Treated drinking water samples met radiological standards 100 percent of the time, chemical standards at least 99.67 percent of the time and microbial standards at least 99.85 percent of the time. (GLPF, 2016)

In the United States, from 2012-2014, a total population of approximately 26.5 million people lived in the Great Lakes basin. Over 95 percent of the population was served by water treatment systems meeting health-based water quality standards. During this same time period, 6 percent of the water treatment systems incurred health-based system violations. Overall, people living in the Great Lakes basin can safely drink municipally treated drinking water, unless an advisory is in place.

2. Indicator measures: source water and treated water

In 2014, the IJC's Health Professionals Advisory Board (HPAB) released its recommended human health indicators to assess progress under the GLWQA (HPAB, 2014). These human health indicators were transmitted to the Canadian and US governments by the IJC, with the recommendation that they be evaluated for use as potential indicators in the SOGL reporting process, as they can contribute to the governments' efforts to provide the public with a meaningful assessment of the state of the lakes. The 2014 HPAB report included

recommendations specific to General Objective 1, focusing broader attention on the Great Lakes as a source, in addition to treated drinking water. The recommendations included two proposed source water indicators: Chemical Integrity and Biological Hazard Index.

As noted in the HPAB (2014) report, a focus on source water allows for a more direct connection with the first objective of the Agreement that the Lakes are a source of safe high-quality drinking water and addresses risks to human health. The report also notes that focusing exclusively on source water is not adequate to protect human health and suggests that source water monitoring be augmented by monitoring of treated drinking water.

As described below, the HPAB recommends several source water parameters to use in future SOGL reporting. **The costs for some of this sampling may be prohibitive at this time. However, as** technology advances, costs of sampling and analysis may decrease, which may make increased sampling more practical in the future.

Chemical integrity

The HPAB (2014) recommends that the chemical integrity indicator include endocrine disrupting compounds (estrogenicity assay), atrazine and cyanotoxins (microcystin-LR, anatoxin-a andcylindrospermopsin. These measures provide a cross-section of compounds that are widely dispersed and potentially hazardous to human health, and those where emerging science indicate a cause for concern. The HPAB further recommended that these compounds should be monitored at the intakes of drinking water facilities with standardized methodologies on a weekly basis.

Measure

Current regulations in the United States and Canada do not specify levels and reporting of estrogenicity. However, estrogenicity of Great Lakes water can be expressed in estradiol equivalents (EEQ) as a way to monitor multiple estrogenic compounds in real world conditions.

Ontario has a Maximum Acceptable Concentration for microcystin-LR in drinking water, but no current US regulations exist for cyanotoxin levels. However, the US EPA includes the cyanotoxins, microcystin-LR, anatoxin-a, and cylindrospermopsin on its 2009 Candidate Contaminant List 3 as well as its draft 2015 Candidate Contaminant List 4. The Contaminant Candidate List is a list of drinking water contaminants that are known to occur or anticipated to occur in water supply systems, but are not currently regulated. The contaminants listed may require future regulation under the US *Safe Drinking Water Act*.

Biological hazard index

HPAB (2014) also recommends a biological hazard index indicator that includes the monitoring of *E. coli* (with expansion to include *Cryptosporidium parvum* and *Giardia lamblia*), nitrate and turbidity at the intakes of drinking water treatment plants, on a daily basis. *E. coli* is commonly found in the digestive tracts of humans and animals and is used as a proxy for the presence of other pathogenic bacteria in surface waters. Increased turbidity (*i.e.*, suspended particles) in

source waters is associated with waterborne pathogen contamination (Aramini*et al*., 2000; Atherholt*et. al*., 1998; Jagai*et. al*., 2012). Microbiological contamination and increased turbidity can result from processes such as erosion, surface runoff, sewage effluent, combined sewer overflows, and other discharges.The HPAB further recommends that these parameters be measured with a daily frequency.

Measure

Turbidity is monitored and reported in the United States (Interim Enhanced Surface Water Treatment Rule, 1998; Long Term 1 Enhanced Surface Water Treatment Rule, 2002) and Ontario (Drinking Water Systems: Ontario Regulation 170/03, 2006) based on drinking water treatment regulations. Various methods for measuring and reporting *E. coli*, *Cryptosporidium parvum* and *Giardia lamblia* in source and drinking waters in the United States and Canada have been developed. All three microorganisms are monitored and reported for treated drinking water, per requirements outlined in standards in the US (National Primary Drinking Water Regulations) and Ontario (Ontario Drinking Water Quality Standards). Ontario's Provincial Water Quality Monitoring Network monitors *E. coli* in source waters at select sites, with *C. parvum* and *G. lamblia* included during project-specific studies. There is no continuous national program for monitoring these three microorganisms in source waters in the United States. Baseline monitoring for *C. parvum* was established as part of the US EPA's Long Term 2 Enhanced Surface Water Treatment Rule, 2006, but this monitoring was not established as a continuous long-term program. In further developing the biological hazard index indicator, the next phase should be the examination of the status of current data sets and identifying methods for standardization of measurement and reporting.

3. Improvements in indicator reporting

The "Treated Drinking Water" indicator presented at the 2016 GLPF reported on municipally treated drinking water quality only. While it is useful for the public to know it is safe to drink treated water, it does not properly assess progress towards Objective 1 that the waters of the Great Lakes "should be a *source* of safe, high-quality drinking water". In Ontario, through the Ontario DWSP, both untreated (*i.e.*, source water) and treated drinking water samples are collected from drinking water facilities and analyzed for a suite of organic and inorganic contaminants, both regulated and non-regulated.

There is currently no national US database for source water data (*i.e.*, source water used as a public drinking water supply). The lack of US source water data creates a gap in comprehensively assessing progress toward meeting Objective 1 under the GLWQA. A federal repository for source water data could be established (or current repositories augmented, such as the electronic Storage and Retrieval/Water Quality Exchange data systems), to enhance indicator reporting under the SOGL reporting. Additionally, collecting such data over long time periods would allow for assessment of trends and changes in source water quality and informing source water assessments and protection planning.

3.1.3 Assessment of the Progress Report of the Parties

The PROP (Government of United States and Canada, 2016) focuses on reporting progress on the actions taken by Canada and the United States in meeting the commitments under the Articles and Annexes of the GLWQA during the 2013-2016 timeframe. The actions undertaken in each of the Annexes are intended to lead to the protection, restoration, and enhancement of the Great Lakes waters and will therefore subsequently result in the protection, restoration, and enhancement of sources used as a public drinking water supply. However, there is no Annex that specifically supports the achievement of Objective 1. Progress toward achieving this General Objective could benefit from improved organization around the human use of Great Lakes waters used for drinking. The 2012 GLWQA highlights the importance of the connection of the quality of the waters of the Great Lakes to health, particularly the need to restore nearshore waters given that they are a major source of drinking water. The IJC recommended developing goals, targets, and monitoring of the nearshore in its 15th Biennial Report on Great Lakes Water Quality (IJC, 2011) and the Science Priority Committee of the Science Advisory Board identified the nearshore as one of five priority recommendations on which the Parties should focus.

Although several Annexes have relevance to drinking water (e.g. Annex 3 – Chemicals of Mutual Concern, Annex 9 – Climate Change), linkages between the protection and restoration of the nearshore drinking water sources are recognized in the work undertaken in Annex 1-Areas of Concern (AOCs), Annex 2 – Lakewide Action and Management Plans (LAMPs) and Annex 4 – Nutrients.

1. Annex 1 – Drinking water activities in Areas of Concern

The annex on Areas of Concern (AOCs) commits the Parties to restoring beneficial use impairments (BUIs) in AOCs through the development of Remedial Action Plans (RAPs). There are 14 BUIs representing specific environmental impacts, one of which includes “restrictions on drinking water consumption, or taste and odour problems.” Of the 43 AOCs designated by the Parties, ten of those have (or had) a BUI associated with restrictions on drinking water consumption (Table 3.3).

Table 3.1
Status of BUI "*Restrictions on drinking water consumption, or taste and odour*" in Great Lakes AOCs
(Source: PROP, 2016)

	Restrictions on drinking water consumption or taste and odour	
AOC	BUI Removed	BUI Impaired
St. Clair River (MI/ON)		X
Detroit River (MI/ON)	2011	
Bay of Quinte (ON)		X
St. Lawrence River (ON)	1997	
Grand Calumet (IN)	2012	
Muskegon Lake (MI)	2013	
Saginaw River and Bay (MI)	2008	
White Lake (MI)	2014	
Fox River/South Green Bay (WI)		X
Rochester Embayment (NY)	2011	
TOTAL	7	3

The Parties expect to continue to make progress in the three remaining AOCs with the drinking water restriction impairment:

Bay of Quinte (ON)

All priority actions are expected to be completed by 2019 (PROP, 2016). The BUI specific to drinking water restrictions is currently undergoing re-designation as *not impaired*. In 2014, a municipal drinking water taste and odor survey was completed and the majority of residents were satisfied with their drinking water. Additionally, less than 20 percent of source water samples for the past three years have exceeded the odor threshold concentration for taste and odor compounds. There has been no increase in taste and odor complaints since 2004, and for the past five years all health related water quality parameters in drinking water, including *E. coli* and microcystin-LR, have been at concentrations equal to or below the regulated Maximum Acceptable Concentration ("Bay of Quinte Remedial Action Plan", July 2016).

St. Clair River (ON/MI):

Ontario: All RAP actions are expected to be completed by 2020 (PROP, 2016). The Canadian Remedial Action Plan Implementation Committee recently commissioned a discussion paper (Avanti Insight Consulting, 2016) to help assess the next steps in re-designating the BUI for drinking water restriction to *not impaired* status. The paper cites significant improvements to drinking water risk reductions, since the 1987 Stage 1 RAP, due to: the implementation of source water protection plans; improvements in spills modeling; institution of regulatory requirements for spill prevention and contingency plans; improved government oversight for spills prevention; a 100-fold reduction in the number of spills; and fewer water intake closures. This paper will form the basis of a public consultation process, the results of which will be considered in the final review of the BUI for re-designation.

Michigan: All RAP clean-up actions were completed in 2015 (PROP). The PROP indicates that the St. Clair River AOC is undertaking actions to evaluate and assess its BUIs. With regard to the drinking water restrictions BUI, the BUI will be re-designated as not impaired when

monitoring data for two years show that public water supplies meet the current health standards, objectives or guidelines for treated drinking water, and that treatment needed to make source water potable and palatable does not exceed standard methods (MDEQ, 2008).

Fox River/South Green Bay (WI):

RAP actions are not expected to be completed before 2026 (PROP, 2016). The drinking water restriction BUI was originally listed based upon "unknown risks of toxic substances to human health" and the health risks of exposure to the multitude of chemicals suspected to exist in the AOC (WDNR, 2015). However, the BUI's current status is unknown and requires further assessment of several factors, including: densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances (including cyanobacteria and cyanotoxins) in treated drinking water; the presence of taste and odor in treated drinking water; and treatment costs to make source water suitable for drinking (WDNR, 2015). The Wisconsin Department of Natural Resources will be initiating an effort in 2016 to design the assessment process. The assessment is expected to be challenging as the surface waters of the AOC are not currently used as a drinking water supply, with Lake Michigan used as the preferred alternative.

To summarize the progress on BUI of drinking water in AOCs, the removal of the drinking water restrictions on BUI from AOC has improved, with several removed in the last five years. In addition, the remaining BUIs in the Bay of Quinte and St. Clair River are expected to be removed in the next two to three years, at the latest.

2. Annex 2 – LAMPs

The 2012 GLWQA requires the development of an integrated nearshore framework. When implemented, the framework will allow for an overall assessment of the state of the nearshore waters of the Great Lakes. It will identify waters that are or may become stressed, and establish priorities for action. The draft nearshore framework was released in May of 2016 (Lakewide Management Annex Nearshore Framework Task Team, 2016). The framework highlights the importance of restoring and protecting nearshore areas, not only for recreational uses and the ecological link to the open waters, but also as a source of drinking water for communities. As a result, one of the five key guiding principles under the framework is "healthy Great Lakes support healthy people" – a recognition that the lakes provide a source of drinking water to more than 40 million people. The framework's assessment of nearshore waters will take into account the impact of nearshore conditions on human uses, such as drinking water.

Building on the information provided by the assessment, management actions will be identified to protect nearshore areas of high ecological value, protect water quality and restore degraded areas. The extent to which drinking water sources will be taken into account in both the assessment and management actions is yet to be determined. The Parties' 2017-2019 draft Binational Priorities for Science and Action include the piloting of the nearshore framework assessment component in select areas to refine the approach for basin-wide implementation.

3. Annex 4 – Nutrients

In June 2015, the governors of Ohio and Michigan and the premier of Ontario signed the Western Basin of Lake Erie Collaborative Agreement to reduce phosphorus inputs to the western waters of Lake Erie by 40 percent over the next ten years. In February 2016, the governments of Canada and the United States announced the adoption of a binational target to reduce total phosphorus entering Lake Erie by 40 percent. To meet this target, the Parties are committed to developing domestic action plans by February 2018, as outlined in their draft 2017-19 Binational Priorities for Science and Action. The governments further identified eight priority watersheds for phosphorus control to address algal blooms in the nearshore waters. The domestic action plans will identify and prioritize watershed efforts and actions to meet the phosphorus reduction goals. The success of the domestic action plans is critical to restoring Lake Erie's water quality and to protecting the waters for the millions of people that rely on the lake for their drinking water. The Parties' phosphorus reduction strategies and domestic action plans are discussed in more detail in section 3.6.

4. Gaps in Annex Implementation

The 2012 GLWQA highlights the importance of the connection of the quality of the waters of the Great Lakes with human health, particularly the need to restore nearshore waters given that they are a major source of drinking water. However, there is currently no human health-oriented summary of the quality of the waters of the Great Lakes or the Annex activities of the Parties to address human health issues in the PROP. To increase the prominence of the connection of human health to the quality of the waters of the Great Lakes under the Agreement, committees could be organized around the human use of Great Lakes waters, in this case source waters used for drinking water. This committee could support reporting of human health activities under the GLWQA, enhancing the public's understanding of the Parties' efforts to address human health as affected by the waters of the Great Lakes, and examining emerging issues that could impact the quality of water used for drinking. This committee could also act as a link among the various Annexes that impact the source waters for used for drinking (e.g. climate change, chemicals of mutual concern), increasing the importance of, and giving greater consideration to, drinking water impacts. This committee could also provide an additional mechanism to engage the First Nations, Tribal and Metis communities, populations which may often rely on untreated sources of water for drinking, and incorporate traditional knowledge in protecting the waters of the Great Lakes.

3.1.4 Assessment of key government programs

In Canada, drinking water guidelines are developed through the Federal-Provincial-Territorial Committee on Drinking Water and are administered by Health Canada. These are non-enforceable guidelines and the provision of safe drinking water is left to each province and territory. In Ontario, the Ministry of Environment and Climate Change is responsible for regulating drinking water quality. It is the agency responsible for overseeing the implementation of the *Ontario Safe Drinking Water Act* (ON SDWA) (treatment, distribution, and monitoring

requirements) and the *Ontario Clean Water Act* (ON CWA) (source protection requirements). Together they form a regulatory framework for a *source-to-tap* (or "multi-barrier") approach for the provision of safe drinking water. The combination of these two Acts has resulted in Ontario being recognized as having one of the "most ambitious source water protection programs in Canada" with some of the country's "strongest treatment, testing, operator training and public reporting standards" (Ecojustice, 2011).

In the United States, two significant federal statutes contribute to the provision of safe drinking water, the 1974 *US Safe Drinking Water Act* (US SDWA) and the *US Clean Water Act* (US CWA). The protection of public health is the focus of the national drinking water program. Since the institution of the US SDWA, increases in the percentage of population served by water systems meeting all health-based standards has been attributed to the implementation of a multi-barrier approach (USEPA, 1999). Under the US SDWA, the US EPA establishes national enforceable standards for drinking water quality and ensures monitoring for compliance with these national standards. The US SDWA also delegates primary responsibility to the states for program implementation. The US CWA includes a combination of water quality-based and technology-based approaches to regulate the discharges of pollutants into the waters of the United States and to regulate quality standards for contaminants in surface waters. The EPA has implemented pollution control programs under the US CWA that address water quality standards (*e.g.*, total maximum daily loads), point discharges (*e.g.*, National Pollutant Discharge Elimination System) and nonpoint sources.

1. Source water protection in Ontario

Ontario enacted the *Ontario Clean Water Act* as a first step of the multi-barrier approach. The ON CWA supports the implementation of many recommendations resulting from the 2002 Walkerton Inquiry (Part II) Report, which investigated the cause of *E. coli* O157:H7 contaminated drinking water that resulted in several deaths and a multitude of illnesses. The stated purpose of the act is to "protect existing and future sources of drinking water" by requiring the development of watershed-based source water protection plans (SWPP). These plans are required to include:

- the identification of local activities that could potentially pose a risk to drinking water supplies (wells and surface waters);
- an assessment of the level of risk posed; and
- actions to reduce, eliminate and/or manage the identified risks.

A total of 22 SWPPs have been submitted and approved by the Ontario Minister of Environment and Climate Change, which fulfilled Ontario's commitment to have all the plans approved by the end of 2015. The effective dates of these plans range from October 2014 to July 2016 (Conservation Ontario August 2016). The approved plans include legally binding policies to mitigate source water threats, to be implemented by various bodies, including ministries/government agencies, municipalities, and conservation authorities[1]. These mitigation

[1] Local watershed management agencies, mandated to ensure the conservation, restoration and responsible management of Ontario's water, land and natural habitats.

policies can include land-use planning, regulations, and stewardship, such as education and best management practices. Once a SWPP is in place, municipalities or planning authorities cannot undertake any activity that conflicts with that plan.

Together, the 22 plans protect the source waters of more than 450 municipal drinking water systems, with 154 of these systems having intakes in the Great Lakes (Auditor General of Ontario, 2014). If a source protection area contains water that flows into the Great Lakes, then the SWPP is required to consider the GLWQA, the Great Lakes Charter, Canada-Ontario Agreement and any other agreements related to the Great Lakes basin, to which the governments of Ontario or Canada are party.

In addition, SWPPs are one of many tools used by Ontario in its plan to combat algal blooms and cyanotoxins in the Great Lakes (Government of Ontario, July 2016). For example, SWPPs may manage local activities such as storage and handling of manure and maintenance of septic systems, which can contribute nutrients and promote algal blooms, as well as educate residents on actions they can take to reduce nutrient runoff.

Ontario's action on source water protection received an "A" ranking — the highest in Canada — in Ecojustice's Canada's Drinking Water Report Card for implementing "the most ambitious source water protection program in Canada" (Ecojustice, 2011).

2. Source water protection in the United States

Through amendments to the US SDWA, the United States included requirements to first protect groundwater, in 1986, through the development of wellhead protection programs and then ten years later for surface waters. The 1996 amendments included provisions intended to protect the nation's drinking water at all sources in order to reduce water treatment costs and risks to public health. The US SDWA required, by 2003, that each state develop a Source Water Assessment Program (SWAP), for approval by the US EPA, to assess the susceptibility of public drinking water supplies to contamination. An Assessment Protocol for Great Lakes Sources was developed for Great Lakes states, to help ensure a more coordinated approach in assessing intakes using Great Lakes source water. The protocol identified two factors that could affect the sensitivity of the intakes: length of intake pipe and depth of intake. The key steps in the source water assessment process are:

- Identify the sources of all public drinking water supplies (groundwater and surface water).
- Map the land area that could contribute water and pollutants to the water supply.
- Identify existing and potential sources of contaminants within the delineated area.
- Determine the susceptibility of water supplies to contamination.

The resulting assessments are intended to provide information to local stakeholders to help prioritize actions in protecting the drinking water supply. The EPA's Source Water Protection Program is intended to support and encourage partnerships among local, state and regional agencies to better manage and prevent contamination by using a combination of regulatory tools (*e.g.*, land use restrictions) and non-regulatory tools (*e.g.*, public education/awareness). The Source Water Collaborative, which consists of 26 national organizations including the US EPA,

works to support coordinated actions between agencies and organizations to promote the implementation of source water protection and increase its chances of success (Source Water Collaborative, August 2016). However, there is no specific federal mandate for the development or implementation of a source water protection program/plan. Rather, the source water protection program relies on voluntary state and local efforts. Without an overarching federal mandate, this leads to a lack of consistency in the development and implementation of source water protection programs among the states. Additionally, the absence of an EPA mandate has been found to be one of the challenges in implementing effective source protection planning (US EPA Office of the Inspector General, 2005; Canadian Environmental Law Association, 2008; Water Research Foundation, 2012). A key challenge is that voluntary programs tend to receive a lower priority for implementation, given limited government resources and the variety of mandates that states must comply with to ensure not only drinking water quality, but other environmental and non-environmental standards.

In August 2015, the USEPA amended the US SDWA with the *Drinking Water Protection Act*, requiring the USEPA to develop a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water system. The strategic plan was developed in November 2015 and provides steps and timelines for EPA activities to address issues such as, source water protection practices to mitigate adverse public health effects human health effects from exposure to algal toxins; factors likely to cause HABs, and drinking water treatment options for removal of algal toxins (US EPA, 2015).

3 Infrastructure

Agreement Objectives commit the Parties to assuring the waters of the Great Lakes are a source of safe, high-quality drinking water, allow for swimming and consumption of fish and wildlife unrestricted by concerns due to harmful pollutants. Therefore providing and maintaining infrastructure adequate to meet these objectives is one of the governments' most basic – and expensive responsibilities. Both Parties have partnered with provincial, state and municipal governments in supporting essential infrastructure for drinking and waste water treatment systems.

Over the next 20 years the six Great Lakes states (Minnesota, Wisconsin, Illinois, Indiana, Michigan and Ohio) need an estimated $77.5 billion in capital investment for wastewater, stormwater and combined sewer overflow infrastructure (EPA, 2016). To continue the provision of safe drinking water in the Great Lakes states, a 2013 EPA report indicates that over the next 20 years an investment of $102 billion is needed for drinking water infrastructure. For the 2016 fiscal year, Congress appropriated $863 million for the EPA's State Revolving Fund program for drinking water infrastructure and $1.39 billion for wastewater infrastructure (Congressional Research Service, 2016). The drinking water and wastewater infrastructure appropriations have decreased by $43.6 million and $55 million, respectively, since the 2014 and 2015 fiscal year (NEMWI, January 2017).

Major capital needs for drinking water and sewage treatment also exist in Ontario. In September 2016 the Canadian federal government and Ontario provincial government announced a bilateral agreement that will make more than $1.1 billion in combined funding available under the Clean Water and Wastewater Fund (CWWF) (Government of Ontario, January 2017). The federal

government is providing up to 50 per cent of this funding, amounting to almost $570 million, for projects while the provincial government will invest almost $270 million. Municipalities, First Nations and local services boards will cover the remaining costs.

Infrastructure investments will continue to place considerable demands on public budgets, and planning for future needs is essential. Ensuring the adequacy of existing infrastructure to meet the objectives of the Agreement for at least one generation into the future, and assessing anticipated costs required to provide this infrastructure, requires continual attention from governments.

3.1.5 Section Summary

- **Treated drinking water quality in the Great Lakes is generally of a high quality on both the US and Canadian sides of the Great Lakes basin.**

- **The assessment and reporting of this objective, that is focusing on the Great Lakes as a *source* of high quality drinking water, could be improved by extending comparable intake water quality metrics to both nations.**

- **Another potential improvement for enhancing the reporting of progress under this objective is to include monitoring and SOGL reporting on source water parameters that include, estrogenicity (as EEQ), atrazine, cyanotoxins (**microcystin-LR, anatoxin-a and cylindrospermopsin), **turbidity, nitrate, and** *E. coli* (expanding to include *Cryptosporidium parvum* and *Giardia lamblia).* Ideally, these measures would be taken from source water sites in both countries on a weekly basis for the first three parameters and on a daily basis for the latter three. **Costs for such sampling may be prohibitive at this time.** However, as technology advances, costs of sampling and analysis may decrease, which may make increased sampling more practical in the future.

- Continued work on preventing contamination of source water is needed to help ensure that incidents of drinking water contamination do not occur. Prevention is the basic principle behind the implementation of source water protection in a multi-barrier (or *source-to-tap*) approach for the provision of safe drinking water.

- Actions taken through Annexes such as those for Areas of Concern (Annex 1), Lakewide Action and Management Plans (Annex 2) and Nutrients (Annex 4) can ultimately result in the protection, restoration, and enhancement of sources used as a public drinking water supply. For example, progress has been made in restoring the BUI "restrictions on drinking water consumption, or taste and odor problems" in various AOCs. Under Annex 2, the Parties have developed a draft nearshore framework to support the overall assessment of the state of the nearshore waters of the Great Lakes, which recognizes the importance of drinking water sources in the nearshore.

- **Under the GLWQA, t**here is no Annex that specifically supports the achievement of Objective 1. Progress toward achieving this objective could benefit from improved

organization around the *human use* of Great Lakes waters used for drinking, through the development of a committee for the human health-related objectives.

- **A key component in the delivery of safe drinking water is the development and implementation of source water protection plans. The requirement for the development and implementation of source water protection plans varies between Ontario, where it is regulated, and the US states, where it is voluntary. Having a US federally-regulated requirement to develop and implement source water protection planning would create greater consistency across states and provide a higher level of priority for implementation.**

- Infrastructure investments will continue to place considerable demands on public budgets, and planning for future needs is essential. Ensuring the adequacy of existing infrastructure to meet the objectives of the Agreement for at least one generation into the future, and assessing anticipated costs required to provide this infrastructure, requires continual attention from governments.

3.1.6 References

Appropriations Tracking for Key Regional Programs. Accessed January 2017.Retreived from http://www.nemw.org/reports-output/tracking-of-federal-funds/

Aramini, J., McLean, M., Wilson, J., Holt, J., Copes, R., Allen, B., Sears, W., 2000. Drinking water quality and health care utilization for gastrointestinal illness in Greater Vancouver. Can. Commun. Dis. Rep. 26(24), 211-214.

Atherholt, T.B., LeChevallier, M.W., Norton, W.D., Rosen, J.S., 1998. Effect of rainfall on Giardia and Cryptosporidium. J. Am. Water Works Assoc. 90(9), 66-88.

Avanti Insight Consulting Services, May 2016.Discussion paper on the status of the beneficial use impairment restriction on drinking water consumption or taste and odour problems St. Clair River AOC. Prepared for the Canadian Remedial Action Plan Implementation Committee. http://www.friendsofstclair.ca/www/pdf/Donna/Drinking%20Water%20Discussion%20Paper%20Final%20Draft%20May%2020,%202016.pdf

Bay of Quinte Remedial Action Plan. Accessed July 2016. Retrieved from http://www.bqrap.ca/bui/9/

Canada and Ontario Reach Agreement Under the New Clean Water and Wastewater Fund. Accessed. January 2017. Retrieved from https://news.ontario.ca/moi/en/2016/09/canada-and-ontario-reach-agreement-under-the-new-clean-water-and-wastewater-fund.html

Canadian Environmental Law Association, 2008. Great Lakes drinking water source protection: a comparison of Ontario and neighbouring Great Lakes Jurisdictions. Prepared for the Ontario Ministry of Environment. http://www.cela.ca/sites/cela.ca/files/689-SPMOE.pdf

Congressional Research Service. March 2016. Federally Supported Water Supply and Wastewater Treatment Programs.RL30478 .https://fas.org/sgp/crs/misc/RL30478.pdf

Conservation Ontario Drinking Water Source Protection. Accessed July 2016. Retrieved from http://conservationontario.ca/what-we-do/source-water-protection, Accessed

Ecojustice. 2011. Waterproof 3: Canada's drinking water report card. https://www.ecojustice.ca/wp-content/uploads/2014/11/Waterproof_Essentials_web_corrected_Dec_8.pdf

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Cat. No.: En164-53/1-2016E-PDF. ISBN: 978-0-660-06365-2. Available at https://binational.net/2016/09/28/prp-rep/

Government of Ontario, Canada and Ontario Reach Agreement Under the New Clean Water and Wastewater Fund. Accessed January 2017. Retrieved from https://news.ontario.ca/moi/en/2016/09/canada-and-ontario-reach-agreement-under-the-new-clean-water-and-wastewater-fund.html

Government of Ontario Blue-green Algae. Accessed July 2016. Retrieved from https://www.ontario.ca/page/blue-green-algae

Great Lakes Public Forum. 2016. State of the Great Lakes. Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. https://www.youtube.com/watch?v=myZi6_Pe_t4&list=PLwe1DQGIxfLMjKHSoVSQR22fXFff0PEoA&index=1

Health Professionals Advisory Board (HPAB), 2014.Recommended human health indicators for assessment of progress on the Great Lakes Water Quality Agreement. International Joint Commission.http://ijc.org/files/tinymce/uploaded/HPAB/Recommended-Human-Health_Indicators-June2014.pdf

International Joint Commission, 2011.15th Biennial Report on Great Lakes Water Quality.

Jagai, J. S., Griffiths, J.K., Kirshen, P.K., Webb, P., Naumova, E.N., 2012. Seasonal patterns of gastrointestinal illness and streamflow along the Ohio River. Int. J. Env. Res. Pub. Health 9(5), 1771-1790.

Lakewide Management Annex Nearshore Framework Task Team, September 2016. The Great Lakes Nearshore Framework. https://binational.net/wp-content/uploads/2016/09/Nearshore-Framework-EN.pdf

Michigan Department of Environmental Quality, 2008.The Michigan Department of Environmental Quality Biennial Remedial Action Plan Update for the St. Clair River Area of Concern.http://www.michigan.gov/documents/deq/deq-water-ogl-stclairriver-RAP-12052008_342555_7.pdf

Northeast Midwest Institute Appropriations Tracking for Key Regional Programs.Accessed January 2017. Retrieved from http://www.nemw.org/reports-output/tracking-of-federal-funds/

Ohio EPA, March 2016. Public Water System Harmful Algal Blooms Overview of Upcoming Rules.http://epa.ohio.gov/Portals/28/documents/habs/HAB%20rules%20factsheet%20March%202016.pdf

Office of the Auditor General of Ontario, 2014.Annual report 2014. Queen's Printer for Ontario. http://www.auditor.on.ca/en/content/annualreports/arreports/en14/312en14.pdf

Source Water Collaborative, About the Source Water Collaborative. Accessed August 2016. Retrieved from http://sourcewatercollaborative.org/about

United States Environmental Protection Agency, 1999. 25 years of the *Safe Drinking Water Act*: history and trends. Office of Water.https://nepis.epa.gov/Exe/ZyNET.exe/200027R1.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1995+Thru+1999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C95thru99%5CTxt%5C00000015%5C200027R1.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

USEPA, 2005. Source water assessment and protection programs show initial promise, but obstacles remain. Office of the Inspector General.https://www.epa.gov/sites/production/files/2015-12/documents/20050328-2005-p-00013.pdf

USEPA, November 2015. Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water.https://www.epa.gov/sites/production/files/2015-11/documents/algal-risk-assessment-strategic-plan-2015.pdf

USEPA, 2016. Clean Watersheds Needs Survey 2012 Report to Congress. EPA-830-R-15005 https://www.epa.gov/sites/production/files/2015-12/documents/cwns_2012_report_to_congress-508-opt.pdf

US EPA. 2017. Cyanotoxins in Drinking Water. https://www.epa.gov/ground-water-and-drinking-water/cyanotoxins-drinking-water. Updated on January 19, 2017.

Water Research Foundation, 2012.Source water protection vision and roadmap. http://www.waterrf.org/PublicReportLibrary/4176b.pdf

Wisconsin Department of Natural Resources, 2015.Remedial Action Plan update for the Lower Green Bay and Fox River Area of Concern. http://dnr.wi.gov/topic/greatlakes/documents/LGBFRAOCRAP2015.pdf

3.2 Swimming and Recreational Use

This section reviews and assesses progress toward achieving General Objective 2 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 2 states that the waters of the Great Lakes should "allow for swimming and other recreational use, unrestricted by environmental quality concerns."

While there is no single Annex in the GLWQA dedicated to the achievement of General Objective 2, work toward this objective is supported by work on Areas of Concern (Annex 1), and improving lakewide action and management (Annex 2) and science (Annex 10). The discussion of recreational waters is also related to implementation of the adaptive management principle set out in Article 3 of the GLWQA.

3.2.1 Background

The coastal beaches and waters of the Great Lakes provide a source of recreation to the 40 million United States and Canadian citizens that reside in the basin, and to tourists from outside the basin. It is estimated that millions of people each year use beaches on the Great Lakes (Great Lakes Information Network, 2012). Coastal and in-lake recreation in the Great Lakes has many positive benefits. Activities such as swimming, boating, and beach use may also adversely affect human health through exposure to biological hazards (for example, bacteria or viruses) found in the waters. Targeted epidemiological studies have shown a number of adverse health effects (including gastrointestinal and respiratory infections) to be associated with fecally-polluted recreational water (Marion et al, 2010; USEPA, 2015), including those of the Great Lakes (Wade, et al, 2008). These effects can result in a significant burden of disease and economic loss (World Health Organization, 2003).

Humans living in close proximity to or in frequent contact with the Great Lakes live in complex and extremely varied environments. Their health patterns are strongly affected by their own behaviors and influences unrelated to biological hazards in the Great Lakes. The health effect of any particular recreational water hazard depends on how much, over what period of time and by what pathway (via ingestion, dermal exposure, or inhalation) individuals come into contact with that hazard. Routes of exposure to biological hazards in recreational fresh water include "body contacts, immersion and ingestion" during their recreational activities namely, "swimming, bathing, surfing, water skiing, tubing, water play by children, and similar water contact activities"(Gorham and Lee, 2015; USEPA, 2012). In general terms, this combination of proximity to biological hazards and human behavior, moderated by government advisories, serves as a starting point for examining the question of human illness risk from waters.

Human illness risk may vary depending on the types and extent of activities of beach goers. The relative risk of a health effect, such as developing gastrointestinal illness, is higher among beach visitors who bury their body in the sand as compared to those who are simply digging in the sand (Heaney *et al.*, 2009). The survival and potential regrowth of organisms such as *Escherichia coli* (*E. coli*) and enterococci in sand and surficial sediments serves as an important source of microbial pollution (Desmarais*et al*., 2002; Solo-Gabriele *et al*., 2000; Solo-Gabriele, *et al.*, 2015). Another study of human health risk looked at exposure to recreational water contaminated with urban sewage effluents in the Chicago Area Waterways System. Even though there were advisories against human activities (including rowing, canoeing, fishing, boating, and kayaking) in these waters due to sewage contamination, people still used the waters and gastrointestinal illnesses and eye infection risk was found to be elevated following the exposure in comparison to fresh water with less sewage contamination (Dorevitch*et al*., 2012).

In additional to human behaviors, environmental factors such as precipitation impact the risk of gastrointestinal illnesses in combinations of hydrodynamic contexts such as lake temperature, wave height and lake stage. According to Patz *et al*. (2008), the projected probability of extreme weather events will rise by 50 to 120 percent in 100 years. They also projected that the incident rate of gastrointestinal diseases will rise in association with the estimated increase of sewage contamination. McLellan and Hollis (2007) conducted a three-year survey on the source apportionment of bacterial invasion following sewage overflow and used *E. coli* as an indicator organism. They found that sewer overflows due to severe rainstorms caused a significantly higher increase in *E. coli* concentrations in the receiving water (Lake Michigan) as compared to rain precipitation less than five cm (2 inches). According to their analysis, the proportion of human fecal pollution and non-point sources of *E. coli* was equal during combined sewer overflow (CSO) and sanitary sewer overflow (SSO) events.

3.2.2 Assessment of indicators

The reporting by the Parties on recreational waters includes an indicator addressing the number of beach closures in both countries. The Great Lakes have consistently been reported to have the highest percentage of beach water samples in the United States exceeding the recreational water quality criteria of the US Environmental Protection Agency (USEPA) (Dorfmand and Haren, 2014; Allan et al, 2015). Around the Great Lakes, the criteria for beach closures are determined by First Nation/ Tribes, states, provinces and local governments, based on the regulations and programs supporting quantitative monitoring that have been implemented in both countries. However, monitoring and criteria that support beach closing decisions vary across jurisdictions (Nevers and Whitman, 2010), adding to the complexity of interpreting trends in beach closures.

1. Sub-indicators status and trends

The Parties assessed trends in recreational water quality and its relationship to human health using one sub-indicator, Beach Advisories, which assesses the reported health-related swimming advisories or closings days for recreational areas, to determine the number of days that monitored Great Lakes beaches are open and safe for swimming during the summer season. For the current assessment cycle, the Parties reported that the overall status of the Beach Advisories sub-indicator is Fair to Good and the trend is Unchanging since 2011 (GLPF 2016). However,

individual lake assessments show that Lake Erie's condition remains Poor. Among the remaining lakes, Lakes Superior, Michigan, and Huron maintain their status of Good," and Lake Ontario's status remains Fair to Good (Table 3.3.1).Public Great Lakes beaches are open and safe for swimming during 96 percent of the season in The United States and 78 percent of the season in Ontario.

Beaches

Status: GOOD FAIR POOR

SUB-INDICATOR	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Beach Advisories	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging

Table 3.2.1 (Source: GLPF, 2016)

2. Indicators for Human Health

Any attempt to assign indicators of Great Lakes human health must attempt to account for beachgoer activities, environmental factors and other causal factors that might result in an individual's health outcome. Considering these varied causes, only the strongest correlations will be evident for a health outcomes analysis in the Great Lakes. The IJC's Health Professionals Advisory Board (HPAB) identified improvements for human health indicators to assess progress in implementing the GLWQA (HPAB, 2014). The HPAB's work resulted in two recommended indicators for Recreational Water Contact, the first *Risk of illness from Great Lakes beaches*focuses on known health hazards (e.g., microbiological hazards) and the second *Identified risks at Great Lakes beaches* looks at the sources of those hazards and uses a survey of best practices.

Indicator 1. Risk of illness from Great Lakes beaches

The HPAB, supported by the IJC, recommends continuing to measure E. *coli* levels in Great Lakes water, relying on the concept of "indicator organisms" as time- and resource-efficient for estimating the existence of other microbiological hazards in source and recreational waters (HPAB, 2014). This measurement is well understood, has abundant historical reference information and is clearly linked to human health. *E.coli* is the dominant bacterium in the gastrointestinal tract of all warm-blooded animals and humans, anda widely used indicator organism for recreational water. There are 11 recognized pathogenic types of *E.coli* (Hamelin *et al.*, 2006) that can result in illness, though most strains of *E.coli* are not hazardous. Nevertheless, monitoring this organism for general fecal contamination of recreational water has proven historically useful, based on the assumption that it has sensitivity and specificity that is appropriate as an indicator for the presence of bacteria, viruses, and parasitic cysts in water.

The weaknesses and strengths associated with using both *E. coli* and enterococci in current regulations of both countries are openly acknowledged in the 2012 Recreational Water Quality

Criteria (USEPA, 2012) and Guidelines for Canadian Recreational Water Quality. However, Health Canada has concluded that *E. coli* and enterococci are still the best available indicators due to the considerable knowledge and scientific evidence available regarding both the merits and limitations inherent in indicators of microorganisms in source and recreational water (Health Canada, 2012). In addition to culture-based assessment of E. coli and enterococci the 2012 criteria allow for the use of Enterococcus quantitative PCR (qPCR) which is a more rapid molecular measurement that has stronger health relationships to GI-illness than Enterococcus culture. E. coli qPCR methods are also available and can be used for on a site specific basis.

Indicator 2. Identified risks at Great Lakes beaches

The second recommended indicator would include two measures. The first would provide a periodic and uniform assessment of the sources of contamination for Great Lakes beaches. A measure to determine microbial source has been identified as key to improving the current binational monitoring regime (HPAB, 2014). The second measure would show how many beaches are adhering to best practices by using a beach survey tool (HPAB 2014). Microbial presence in recreational water originates from a range of sources, including wildlife, CSOs and SSOs, sediments, algae, inputs from tributary streams and surface and agricultural runoff (Anastasi *et al.*, 2010; Ishii *et al*., 2007; Roll and Fujioka, 1997). CSOs and SSOs are the major source of viruses and pathogenic bacteria likely to have originated from humans (Aslan *et al*., 2011). Other major anthropogenic sources of *E.coli* in the Great Lakes basin are the effluent of municipal sewage, ship discharge of untreated waste and factory effluents (Liu *et al.*, 2006; Rose and Dreelin, 2008).

The IJC recommended the results of the HPAB-led indicator development exercise in a letter to governments in 2014. More recently, the IJC's Research Coordination Committee (RCC) concluded there is an opportunity for the Parties to strengthen their reporting on activities towards recreational water objective of the GLWQA (RCC, 2016). It is recognized that completely integrating datasets across national boundaries and formats for recreational water indicators will require considerable – though not insurmountable – effort.

3.2.3 Assessment of key monitoring programs

Both the US 2012 Recreational Water Quality Criteria and Canada's Criteria Guidelines for Canadian Recreational Water Quality, have provisions to use *E. coli* and enterococci in bacterial quality monitoring of fresh and marine waters (Health Canada, 2012; USEPA, 2012). In the US, current recreational water quality monitoring (USEPA, 2012) includes provisions to protect human health from illnesses through possible primary and secondary exposure to various causes of human illnesses (USEPA, 2012). The *Canadian Guidelines for Canadian Recreational Water Quality Act* was passed in 2012 and in the same year, Health Canada set separate criteria for primary and secondary contact with recreational water.

The *US Beaches Environmental Assessment and Coastal Health Act*was passed in 2000 with a strong emphasis on the bacterial monitoring of recreational waters. It requires all coastal states, including Great Lakes states, to develop programs for effective water quality monitoring and

public notification at coastal recreational beaches. All eight states in Great Lakes basin have signed onto the Act, including Wisconsin for Lake Superior, where previously there was no bacterial monitoring (Sampson *et al.*, 2005). The US EPA also developed a Great Lakes Beach Sanitary Survey to identify sources of contamination at Great Lakes beaches, first in 2004 under the Great Lakes Regional Collaboration, and then updated in 2008 (USEPA, 2008). These programs generally are implemented through state health or natural resources departments. Local and state health departments in the United States have experienced major budget and staff reductions since 2008, which presents challenges to meeting their public health responsibilities. Moreover, sustained funding for the Beach Act historically has required extensive Congressional lobbying to preserve the program and its continued support is by no means certain.

In Ontario, the Safe Water Program requires Boards of Health to conduct surveillance of public beaches and assess factors and emerging trends related to illnesses and injuries (Ontario Ministry of Health and Long-Term Care, 2014a). Ontario Public Health Standards (Ontario Ministry of Health and Long-Term Care, 2008) establish recreational water monitoring protocols based on authority from the Ontario's *Health Protection and Promotion Act* (Government of Ontario, 1990). Environmental surveys are also a key element of beach management, and are required as part of public beach management (Ontario Ministry of Health and Long-Term Care, 2014b). This approach presents challenges for the health units, in that beach monitoring represents one portion of a wide-ranging mandate for public health in a funding restricted environment.

In addition to current monitoring programs, significant advances in recreational water surveillance include models supporting recreational water quality forecasting. Ongoing work by the USEPA (USEPA, 2016) and the United States Geological Survey (USGS) (USGS, 2016a) holds significant promise for predicting real-time water quality conditions and increasing the accuracy of beach closure notifications. These programs are particularly valuable given the current lag time in availability of *E. coli* data can be up to 24 hours (Francy*et al.*, 2013) and the recognition that beach water quality can change quickly (USEPA, 2010).

Advances are being made on the development molecular tools for fecal source tracking markers. Human fecal markers and other fecal source identification marks are new tools that can be used to better understand the risks and sources of fecal contamination (Boehm et al., 2013; Stewart et al., 2013). Efforts are also underway by the US EPA and stakeholders to collect information on model performance across the Great Lakes and to have the information publically available. Microbial source tracking using qPCR and other advanced methods to identify bacterial sources has been studied by both countries. EPA has published methods to apply microbial source tracking for developing bacterial Total Maximum Daily Loads (TMDL) (EPA, 2011). Environment and Climate Change Canada has developed laboratory methods for microbial source tracking which can identify between bovine and human bacteria (Al-Zabat, personal communication).

There are challenges inherent in any effort to expand monitoring efforts in support of Objective 2. Current approaches for beach monitoring and advisories were developed based on the need to inform decision-making at the level of individual jurisdictions. Leveraging additional monitoring activities to support Objective 2 of the GLWQA would require significant investment by the

Parties. Costs due to human illness from recreational water exposure may be significant and could also be considered when weighing projected monitoring costs.

3.2.4 Assessment of Annex activities

The recreational use objective of the GLWQA lacks a specific corresponding Annex that directly supports assessing progress towards achievement. Annexes that support work related to Objective 2 include Annex 1 (Areas of Concern), Annex 2 (Lakewide Management) and Annex 10 (Science). As a result, there are numerous activities that: indirectly monitor and protect recreational water quality; rely on assessment of recreational water quality during decision-making (for example, AOC beneficial use impairments before delisting); and consider recreational water quality when developing management action plans (LAMPs).
The monitoring to support SOGL reporting is supported under Annex 10, which would include human health indicators. The SOGL reporting process provides appreciable insight into the status of the Great Lakes basin ecosystem. However, there is no provision for routinely identifying and reporting emerging issues related to human health general objectives.

Progress towards achieving the recreational use objective would benefit from improved government coordination around beach and recreational water issues. A Swimming and Recreational Use Objective Committee could report on progress and examine emerging issues related to recreational water quality. Such a committee could also provide a forum for identifying synergies of various Annex activities and improvements for recreational water reporting under the GLWQA. For example, the re-emergence of harmful algal blooms (HABs) in the Great Lakes, addressed through Annex 4, could impact human health for beachgoers, anglers and coastal boaters. Recent work specific to the Great Lakes includes NOAA's experimental products in HABs tracking and forecasting (Wynne *et al.*, 2015). The work of the USGS on western Lake Erie (USGS, 2016b*)* also supports HABs modeling capabilities for both monitoring recreational water trends and informing beach closure decision making. Yet the path for recognizing HABs as a recreational water issue and incorporating new HABs monitoring technologies into present recreational water reporting under the GLWQA is unclear.

3.2.5 Assessment of principles and approaches

The GLWQA's principle of Adaptive Management addresses how to evaluate current actions and adjust future actions once outcomes and ecosystem processes in the Great Lakes become better understood. The principle provides a rationale for expanding indicators for assessing progress towards the recreational water objective. Advances in science and local monitoring programs now provide quantitative information for levels of bacteria such as *E. coli*, along with qualitative information on their likely potential source from survey information. This additional information would improve reporting on human health risks.

Applying an adaptive management approach for this objective would be supported by the use of *technology forcing* to motivate development of new indicators, and the data sharing practices and standardized measurement techniques to support reporting and analysis. Technology forcing is a

strategy that mandates that currently unachievable and uneconomic performance standards be met at some future date as part of a regulatory or monitoring framework.

For indicators without data, for example, technology forcing for monitoring could be implemented for inclusion of Human Health Indicators as part of Great Lakes monitoring within a five-to-ten- year time frame, or within two or three reporting cycles of the Triennial Assessment of Progress.

Current technologies used to open and close beaches related to microbial risks are notoriously unreliable, often reflecting past risk better than current and short-term future risk. Meanwhile, most predictions about climate change impacts (increased precipitation and temperature, etc.) favor worsening of bacterial contamination in the Great Lakes basin, so risks cannot be assumed to be stable. Public safety demands better, more accurate near-real-time risk assessment. The same technology advances supporting near real-time analysis also contribute to better characterization of human health risk trends over time, which is the intent of indicators. Thus both consumer protection and lake health monitoring demand similar technology surge.

While new indicators reporting will incur additional costs by the Parties, there are also significant costs associated with illness attributable to swimming and other activities at Great Lakes (and other) beaches (DeFlorio-Barker et al 2016). The costs of improving monitoring, notification, and reporting, may lead to actions which would improve water quality and offset costs of illness. Indicator refinement for this objective would not involve new monitoring, though a significant effort would be needed to standardize and integrate existing *E. coli* and Beach Sanitary Survey or Environmental Health and Safety Survey data streams from states, provinces and Tribes/First Nations into the SOGL process. General recommendations from the HPAB regarding differences between indicators are relevant to GLWQA Objectives 1, 2 and 3, in particular the need for additional dialogue between the HPAB and the SOGL reporting regarding indicator approaches.

3.2.6 Section Summary

- The Parties continue to improve their reporting on recreational water quality and in particular their focus on the human use of the Great Lakes resources through the SOGL report.

- While the SOGL Beach Closures indicator considers recreational water quality decision making and potential for human risk, it lacks a specific measure of human health hazards such as bacteria levels. Other human health-related indicators reported by the Parties have some measures that track changing levels of contaminants.

- There is an opportunity for the Parties to strengthen their reporting on activities towards recreational water objective of the GLWQA. Current SOGL reporting would benefit from focusing on *quantitative measures* of human-related pathogens and *qualitative information* regarding pathogen source based work. The HPAB has identified two key indicators that would support such a shift in focus and IJC supports their use.

- A quantitative indicator (Risk of Illness from Great Lakes beaches) would support a more streamlined process for establishing common methodologies for the measurement, monitoring, and reporting of trends. It also would help the general public use Great Lakes waters for recreation in a safer manner.

- An indicator using qualitative data from existing survey and indicator organism programs (Identified risks at Great Lakes beaches) would provide a wider range of information to assess conditions for recreational water use. Moreover, monitoring the frequency of elevated levels of indicator organisms allows for inferences on the health of the ecosystem not currently possible with existing reporting by the Parties.

- There is currently no human health-oriented summary of the quality of the waters of the Great Lakes or the Annex activities of the Parties to address these human health issues in the Progress Report of the Parties. Committees for human health objectives under the GLWQA could support reporting of human health activities to enhance the public's understanding of the Parties' efforts to address human health as affected by the waters of the overall in the Great Lakes basin, and examine emerging health issues related to Great Lakes water quality.

3.2.7 References:

Allan, J. D., Smith, S. D., McIntyre, P. B., Joseph, C. A., Dickinson, C. E., Marino, A. L., Biel, R. G., Olson, J. C., Doran, P. J., Rutherford, E. S., Adkins, J. E. and Adeyemo, A. O. (2015), Using cultural ecosystem services to inform restoration priorities in the Laurentian Great Lakes. Frontiers in Ecology and the Environment, 13: 418–424. doi:10.1890/140328

Anastasi, E.M., Matthews, B., Gundogdu, A., Vollmerhausen, T.L., Ramos, N.L., Stratton, H., Ahmed, W., Katouli, M., 2010.Prevalence and Persistence of Escherichia coli Strains with Uropathogenic Virulence Characteristics in Sewage Treatment Plants. Appl. Environ. Microbiol. 76, 5882–5886.

Aslan, A., Xagoraraki, I., Simmons, F. j., Rose, J. b., Dorevitch, S., 2011. Occurrence of Adenovirus and Other Enteric Viruses in Limited-contact Freshwater Recreational Areas and Bathing Waters. J. Appl. Microbiol. 111, 1250–1261.

Al-Zabat, 2016.Personal communication.

Boehm, A. B., Van De Werfhorst, L. C., Griffith, J. F., Holden, P. A., Jay, J. A., Shanks, O. C., Wang, D., Weisberg, S. B., 2013. Performance of forty-one microbial source tracking methods: A twenty-seven lab evaluation study. Water Res. 47, 6812-6828.

DeFlorio-Barker S, Wade TJ, Jones RM, Friedman LS, Wing C, Dorevitch S. Estimated Costs of Sporadic Gastrointestinal Illness Associated with Surface Water Recreation: A Combined Analysis of Data from NEEAR and CHEERS Studies. Environ Health Perspect; http://dx.doi.org/10.1289/EHP130

Desmarais, T.R., Solo-Gabriele, H.M., Palmer, C.J., 2002. Influence of Soil on Fecal Indicator Organisms in a Tidally Influenced Subtropical Environment. Appl. Environ. Microbiol. 68, 1165–1172.

Dorevitch, S., Pratap, P., Wroblewski, M., Hryhorczuk, D.O., Li, H., Liu, L.C., Scheff, P.A., 2012. Health risks of limited-contact water recreation. Environ Health Perspect. 120(2):192-7.

Dorfman, M. and Haren, A., 2014.Testing the Waters. National Resources Defense Council.

Francy D.S., Stelzer E.A., Duris J.W., Brady A.M.G. , Harrison J.H., Johnson, H.E., Ware M.W., 2013. Predictive Models for Escherichia coli Concentrations at Inland Lake Beaches and Relationship of Model Variables to Pathogen Detection Appl Environ Microbiol.79(5): 1676–1688.

Great Lakes Information Network, 2012.Beach Health and Water Quality. http://www.greatlakes.net/beachcast/health_quality.html

Great Lakes Public Forum. 2016. State of the Great Lakes. Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada.

Gorham, T.J., Lee, J., 2015. Pathogen Loading From Canada Geese Faeces in Freshwater: Potential Risks to Human Health Through Recreational Water Exposure. Zoonoses Public Health.Zoonoses and Public Health.

Hamelin K., Bruant G., El-Shaarawi A., Hill S., Edge T.A., Bekal S., Fairbrother J.M., Harel J., Maynard C., Masson L., Brousseau R., 2006. A Virulence and Antimicrobial Resistance DNA Microarray Detects a High Frequency of Virulence Genes in Escherichia coli Isolates from Great Lakes Recreational Waters. Appl Environ Microbiol 2006;72: 4200–4206.

Health Canada, 2012.Guidelines for Canadian Recreational Water Quality.

Health Professionals Advisory Board, 2014.Recommended Human Health Indicators for Assessment of Progress on the Great Lakes Water Quality Agreement.http://ijc.org/files/tinymce/uploaded/HPAB/Recommended-Human-Health_Indicators-June2014.pdf

Heaney, C.D., Sams, E., Wing, S., Marshall, S., Brenner, K., Dufour, A.P., Wade, T.J., 2009. Contact With Beach Sand Among Beachgoers and Risk of Illness. Am. J. Epidemiol. 170, 164–172.

Ishii, S., Hansen, D.L., Hicks, R.E., Sadowsky, M.J., 2007. Beach Sand and Sediments are Temporal Sinks and Sources of Escherichia coli in Lake Superior. Environ. Sci. Technol. 41, 2203–2209.

Liu, L., Phanikumar, M.S., Molloy, S.L., Whitman, R.L., Shively, D.A., Nevers, M.B., Schwab, D.J., Rose, J.B., 2006. Modeling the Transport and Inactivation of E. coli and Enterococci in the Near-Shore Region of Lake Michigan. Environ. Sci. Technol. 40, 5022–5028.

Marion, J.W., Lee, J., Lemeshow, S., Buckley, T.J., 2010.Association of gastrointestinal illness and recreational water exposure at an inland US beach.Water Res., Shifting paradigms in the assessment of recreational water quality 44, 4796–4804.

McLellan, S., Hollis, E., 2007.Bacterio Source, Transport and Fate Study - Phase 1, Volume 3.

Nevers, M. and Whitman, R. 2010. Policies and practices of beach monitoring in the Great Lakes, USA: a critical review. J. Environ. Monit., 12, 581-590.

Ontario, Government of, 1990. He*alth Protection and Promotion Act*, R.S.O. 1990.

Ontario Ministry of Health and Long-Term Care.Ontario Public Health Standards. Toronto, ON: Queen's Printer for Ontario; 2008 [revised 2014 May 1].

-- Public Health Division. Recreational Water Protocol. Toronto: Queen's Printer for Ontario; 2014a.

-- Public Health Division. Beach Management Guidance Document, 2014b.

Patz, J.A., Vavrus, S.J., Uejio, C.K., McLellan, S.L., 2008. Climate Change and Waterborne Disease Risk in the Great Lakes Region of the US Am. J. Prev. Med., Theme Issue: Climate Change and the Health of the Public 35, 451–458.

Roll, B.M., Fujioka, R.S., 1997. Sources of faecal indicator bacteria in a brackish, tropical stream and their impact on recreational water quality. Water Sci. Technol., Health-Related Water Microbiology 1996Selected Proceedings of the IAWQ 8th International Symposium on Health-related Water Microbiology 1996 35, 179–186.

Rose, J., Dreelin, E., 2008. Effective Cross-Border Monitoring Systems for Waterborne Microbial Pathogens : A Plan for Action.

Sampson, R. W., Swiatnicki, S.A., McDermott, C., Kleinheinz, G. T., 2005. E. coli at Lake Superior Recreational Beaches. Journal of Great Lakes Research 31(1):116-121

Science Advisory Board, Research Coordination Committee. 2016 .Future improvements to Great Lakes Indicators. Prepared for the International Joint Commission's Science Advisory Board- Research http://ijc.org/files/publications/SAB-RCC_indicators_report.pdf

Stewart, J. R., Boehm, A.B., Dubinsky, E. A., Fong, T-T., Goodwin, K. D., Griffith, J. F., Nobel, R. T., Shanks, O. C., Vijayavel, K., Weisberg, S. B. 2013. Recommendations following a multi-laboratory comparison of microbial source tracking methods. Water Res. 47, 6829-6838.

Solo-Gabriele, H.M., Wolfert, M.A., Desmarais, T.R., Palmer, C.J., 2000. Sources of Escherichia coli in a Coastal Subtropical Environment. Appl. Environ. Microbiol. 66, 230–237.

Solo-Gabriele, H. M.; Harwood, V. J.; Kay, D.; Fujioka, R. S.; Sadowsky, M. J.; Whitman, R. L.; Wither, A.; Caniça, M.; Carvalho da Fonseca, R.; Duarte, A. 2015. Beach sand and the potential for infectious disease transmission: observations and recommendations. Journal of the

Marine Biological Association of the United Kingdom, 96: 1-20.United States Environmental Protection Agency, 2008. Great Lakes Beach Sanitary Survey User Manual. EPA-823-B-06-001.

US EPA 2010.Sampling and Consideration of Variability (Temporal and Spatial) for Monitoring of Recreational Waters.EPA-823-R-10-005.

-- 2011. Using Microbial Source Tracking to Support TMDL Development and Implementation.Region 10 Watersheds Unit. https://www.epa.gov/sites/production/files/2015-07/documents/mst_for_tmdls_guide_04_22_11.pdf

-- 2012. Recreational Water Quality Criteria 2012.Office of Water 820-F-12-058.

-- 2015. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012 [WWW Document]. URL http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6424a4.htm?s_cid=mm6424a4_w (accessed 10.11.15).

-- 2016., Exposure Assessment Models— Virtual Beach.

United States Geological Survey. 2016a. Ohio NowCast.

-- 2016b. Western Lake Erie, River Influence And Harmful Algal Blooms.

Wade, T.J., Calderon, R.L., Brenner, K.P., Sams, E., Beach, M., Haugland, R., Wymer, L., Dufour, A.P., 2008. High Sensitivity of Children to Swimming-Associated Gastrointestinal Illness: Results Using a Rapid Assay of Recreational Water Quality. Epidemiology 19, 375–383.

World Health Organization, 2003. Guidelines for safe recreational water environments: volume 1 coastal and fresh waters. World Health Organization. Geneva, Switzerland.

Wynne, T.T., T.W. Davis, R. Kelty, E.J. Anderson, and S.J. Joshi. (2016 in text) NOAA forecasts and monitors blooms of toxic cyanobacteria in Lake Erie, in: Water Environment Association Inc., *Clear Waters*, Syracuse, NY, pp. 21-23.

3.3 Consumption of Fish and Wildlife

This section reviews and assesses progress toward achieving General Objective 3 of the *Great Lakes Water Quality Agreement* (GLWQA).Objective 3 states that the waters of the Great Lakes should "allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants."

While no single Annex in the GLWQA is dedicated to the achievement of Objective 3, work toward this objective is supported by work on Areas of Concern (Annex 1), improving lakewide action and management (Annex 2) and advances in science (Annex 10). The assessment also discusses the findings of other IJC reports related to fish consumption. The discussion of fish and wildlife consumption is related to implementation of the adaptive management principle set out in Article 3 of the GLWQA.

3.3.1. Background

General information about fish and wildlife consumption in Great Lakes

Fish and wildlife harvesting in the Great Lakes provide a range of commercial and recreational opportunities and sustenance for the region's population. In addition to substantial economic benefits of commercial fisheries in the Canada and the US, Great Lakes recreational fishing results in over $4 billion for US local communities along with 55 million angler days of recreation (Minnesota Sea Grant, 2016), and $2.2 billon to the economy of Ontario. (Government of Ontario, 2016). Bird and turtle populations, especially snapping turtles, also support local recreational and subsistence activities though they do not sustain commercial harvesting.

Many Great Lakes residents support their diets with local fish, gaining an important source of omega fatty acids and protein. Despite the nutritional value and health benefits from consuming Great Lakes fish, the fish accumulate toxic chemicals from their environment that may interfere with any conferred benefit. Potential health impacts are not restricted to anglers, as many species of Great Lakes fish are available for sale in commercial markets, such as lake trout, walleye, and perch. Duck and snapping turtle populations are prone to similar exposure to contaminants.

Research has shown that a primary pathway for exposure to PCBs and mercury is through consuming sport and commercial fish from the lakes. (Turyk et. al., 2012), especially for children and women of childbearing age. Native Americans, First Nations and Metis may also experience distinct cultural, economic, and spiritual impacts resulting from their commercial and subsistence fish production, particularly in Lake Superior (Dellinger et. al., 2012). Legacy toxic substances and emerging contaminants have triggered health advisories recommending limited human consumption of some species in some locations. Fish consumption advisories exist for some fish in each of the Great Lakes. These advisories vary across the region and are most notable for long-lived top predators and fish that have more fat, such as walleye and lake trout. Polychlorinated biphenyls (PCBs) are responsible for the majority of advisories, followed by mercury and dioxins. Health advisories related to Great Lakes fish consumption are of greatest

concern for those who consume large amounts of Great Lakes fish. These groups include indigenous communities, anglers and their families, some Asian communities and those who are most vulnerable to the impact of toxic substances, such as women of child bearing age and children.

Below, is an assessment of the Parties' activities regarding fish monitoring and human health. The Parties do not support national programs that cover similar basin-wide wildlife monitoring, although steps by US states and Ontario to monitor these wildlife for contamination and use that information to advise the public regarding health risks are noted.

3.3.2 Assessment of Indicators

1. Sub-indicators status and trends

Determining ecological health and assessing progress made by remedial actions underpins the scope and reporting for the previously reported indicator Contaminants in Whole Fish (SOLEC, 2014). This indicator was originally developed to report on ecological health in the Great Lakes rather than as a human health indicator, and it measured status and trends of contaminant concentrations (polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), mercury, chlordane, Mirex, dieldrin, toxaphene, polybrominated diphenyl ethers (PBDEs)) in lake trout and walleye. Perfluorinated acids and synthetic musks were reported as contaminants of emerging interest. However, the sampling design and methods employed to use fish to help evaluate the ecological health of the Great Lakes is not optimal for evaluating risks from consuming Great Lakes fish. For instance, while the number and location of sampling sites are appropriate for assessment of ecological health, they are not appropriate for determining human health because they are not representative of the locations where the populations consuming fish or the fact that the majority of non-commercial anglers are catching nearshore, not offshore fish, and concentrations may vary widely between the two (HPAB, 2014).

The potential for valuable ecosystem health data in the current whole fish indicator is recognized. However, a shift in approach to an indicator focused on the edible fish portions would be more representative of human diet and more suited to capturing human health risk and would better respond to the HPAB (2014) recommendation forwarded by the IJC to the Parties. The previous SOLEC Contaminants in Whole Fishindicator reported the contaminant levels in whole fish (including bones and organs). Bones and organs are not typically consumed (Awad, 2006), nor is use of this indicator consistent with food preparation guidelines that advocate removal of skin and fat, the areas containing the highest levels of some contaminants (Zhang, *et. al.*, 2013).

For the 2016 reporting, the Parties plan to shift their approach, and assess trends in fish and wildlife consumption and its relationship to human health using one sub-indicator (GLPF, 2016). The Parties reported PCB levels for edible portions of fish as decreasing though still above the levels of consumption benchmarks. The parties noted that while PCBs drive most of the fish consumption advisories, high levels of mercury, dioxins, mirex and toxaphene have also caused advisories. For the current assessment cycle, the Parties reported that the overall status of this indicator as Fair and the trend is Improving or Unchanging. Individual lake trends show mixed

results, with Lake Erie's condition Deteriorating. Trends for remaining lakes show Unchanging for Lakes Superior and Huron and Improving for Lakes Ontario and Michigan (Table 3.3.1).

Fish Consumption

Status: GOOD FAIR POOR

SUB-INDICATOR	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Contaminants in Edible Fish	Unchanging	Improving	Unchanging	Deteriorating	Improving

Table 3.3.1.(Source: GLPF, 2016)

Contaminant levels for fish species monitored by the Parties decreased since monitoring commenced in the 1970s. Reporting indicates mercury contamination in fish is currently lower than most health advisories levels. Levels of PCBs, responsible for most fish advisories, plateaued in the 1990s and have remained stable in recent years at levels higher than advisory guidelines.(GLPF, 2016). As a result, consumption limits likely will need to remain in place over the long term.Fish contaminant trends in the lower lakes have been significantly impacted by food web alterations and declining fish productivity (SOLEC, 2014), which makes it harder to correlate progress by the Parties on reducing contaminant levels with fish consumption restrictions. In addition, acceptable consumption levels have declined for some contaminants.

2. IJC Indicators for human health

Using information on fish contamination as it is presently collected under SOLG presents challenges for the assessment of fish consumption. The IJC tasked the HPAB with providing a small set of indicators tying the assessment objectives of the GLWQA to the health of residents and resource users of the Great Lakes basin. The HPAB considered the close link between ecological and human health, and identified an indicator associated with human health hazards arising from consuming Great Lakes fish, Contaminant Levels in Great Lakes Edible Fish Species. The IJC included this indicator, in its recommendations on human health to the governments of Canada and the United States based on HPAB (2014). The indicator is designed to provide a foundation for tracking threats to human health. Using the recommended indicator would describe temporal and spatial trends of bioavailable chemicals of concern in the edible portions of five Great Lakes fish: Lake Trout (*Salvelinusnamayacush*), Walleye (*Sander vitreus*), Yellow Perch (*Percaflavescens*), Whitefish (*Coregonusclupeaformus*), and Smallmouth Bass (*Micropterusdolomieu*).

Contaminants measured as part of the recommended indicator would include legacy persistent bioaccumulative toxicants, such as PCBs (with limited congeners), total DDT/DDE, mercury, total chlordanes, toxaphene and mirex. Fish consumption advisories and trend data have been used to select chemicals for monitoring. Not all chemicals would be measured in all five lakes and the chemicals may change over time (for example, mirex levels have decreased and at some future point may be removed from the list). Additional dialogue between the HPAB and SOGL

reporting was recommended regarding standardizing indicator approaches that pertain to human consumption of Great Lakes fish (HPAB 2014). The Parties shifting indicator reporting from whole fish to fish portions is a positive development.

Differences in collection, analysis, and reporting of data pose challenges in developing a Great Lakes basin-wide indicator for fish consumption. For instance, a comparison of the three indicators discussed above can be found in Table 3.3.2. A common set of fish species and chemicals is needed for future data collection and assessment. The Parties reported on a single species, lake trout, using their Contaminants in Edible Fish sub-indicator, though the use of five species as recommended would provide more robust data. These species are some of the most commonly consumed fish species in the Great Lakes region. As well, Tribes/First Nations and Metis, many states and Ontario already collect contaminant data on the concentrations in the edible portions of these fish species. However, considerable work remains to establish environment-human health relationships and monitor potential indicators in similar ways over time. For instance, data gathered by the Ontario Ministry of the Environment and Climate Change's long-term monitoring program are appropriate to use for long-term trend analysis but do not address Lake Michigan. The Chippewa-Ottawa Resource Authority collects contaminant data in the edible portions of fish from Lakes Superior, Michigan, and Huron (Dellinger *et. al*., 2014).

	SOLEC 2014*	IJC 2014**	GLPF, 2016
Indicator	Contaminants in Whole Fish	Contaminant Levels in Great Lakes Edible Fish Species	Contaminants in Edible Fish
Fish Species	Lake Trout , Walleye	Lake Trout, Walleye, Yellow Perch, Whitefish, Smallmouth Bass	Lake Trout
Legacy Contaminants	polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), mercury, chlordane, Mirex, dieldrin, toxaphene, polybrominated diphenyl ethers (PBDEs)	PCBs (with limited congeners), total DDT/DDE, mercury, total chlordanes, toxaphene and mirex.	PCBs
Beneficial components	NA	NA	
Emerging Contaminants	perfluorinated acids, synthetic musks	NA	

Table 3.3.2. * SOLEC, 2014; ** HPAB, 2014; ***GLPF, 2016.

In the United States, all of the eight Great Lake states collect and, analyze fish tissue and issue fish consumption advice. Some states, including Minnesota and Wisconsin, issue joint advice for shared water bodies. Additionally, the Great Lakes Consortium for Fish Consumption Advisories has developed protocols for issuing consistent advice for select contaminants (Andersen, *et al*., 1993; Hornshaw, 2006; McCann *et al*., 2007). This consortium originally formed as a task force under a charge from the Council of Great Lakes Governors to develop and distribute consistent, science-based fish advisories. However, despite the collaboration of the eight Great Lakes States, uniform advice for the shared waters of the Great Lakes has not yet been achieved.

3.3.3 Assessment of Annex activities

As noted previously, the GLWQA does not include a specific Annex that examines whether the Great Lakes Basin ecosystem adequately supports human consumption of fish and wildlife, though these impacts influence assessment of beneficial use impairments for Restrictions on Fish and Wildlife Consumption and Tainting of Fish and Wildlife Flavor used during the AOC delisting process (Annex 1) and criteria for Lakewide Management (Annex 2).For example, declines in concentrations for PCBs (Ridal et al., 2012) and mercury (Neff, et al, 2013) have been noted for the AOCs at Bay of Quinte and Cornwall, respectively. However, the rates of decline are slow; the delisting criteria have not been met for either AOC. The AOC process has resulted in more focused research and monitoring at these Great Lakes locales relative to other sites, and this information could be leveraged for context in future reporting by the Parties. Progress towards achieving this objective could benefit from improved government coordination around fish consumption issues. A Fish Consumption Objective Committee could examine: linkages between the SOGL report and the Annexes on activities impacted by reporting on risks from fish consumption objectives under the GLWQA; and emerging issues related to fish consumption in the Great Lakes.

While Annex 10 provides a nexus for coordination of scientific efforts by the Parties, it is of concern that human health indicators and emerging issues are not recognized separately under the Key Commitments listed by the Parties on the Annex's web page (https://binational.net/annexes/a10/).

3.3.4 Assessment of key programs

Both countries maintain long-running programs to examine levels of chemicals in Great Lakes fish commonly consumed by humans, and there are multiple drivers for monitoring contaminants in fish and wildlife in both countries. Environment and Climate Change Canada (ECCC) implements Canada's Chemical Management Plan which in part provides for monitoring and surveillance activities to inform risk management under the *Canadian Environmental Protection Act* (Government of Canada, 1999). In the United States, the *Toxic Substances Control Act* gives the Environmental Protection Agency (USEPA) authorities to evaluate potential human health risks posed by legacy, current, and new chemical contaminants.

Whole fish monitoring has been conducted in the Great Lakes by the United States and Canada since the early 1970's (Gewurtz*et al*., 2011; McGoldrick and Murphy, 2015) in response to the 1972 GLWQA and is maintained today under the current agreement and its Annex 3 Chemicals of Mutual Concern. ECCC supports the National Fish Contaminants Monitoring and Surveillance Program, coordinating with the USEPA's Great Lakes Fish Monitoring and Surveillance Program to screen for legacy and emerging contaminants across multiple fish species.

Under the 2016 reporting for this indicator (GLPF, 2016), the Parties reported lake trout PCB levels for the Contaminants in Edible Fish sub-indicator, though in previous years they have also reported contaminants in walleye. The number of contaminants trends reported at the Great

Lakes Public Forum decreased relative to previous reporting by the Parties. The use of a top predator species such as lake trout is commendable, though the use of additional species would provide more robust data. PCBs drive many health advisories in the region, though mercury, DDT and other contaminants remain a concern and that reporting for additional chemicals is warranted.

Wildlife consumption is listed as a separate entity within this objective. However, the 2016 SOGL does not connect human health with wildlife consumed in the Great Lakes other than fish species. While fish and fishing includes a large portion of provisioning services for food within the waters of the Great Lakes, human health risks from consuming wildlife from the waters of the Great Lakes such as duck, are not reported under the SOGL. At present, neither country maintains a program comparable to fish monitoring as previously described to report on chemical contaminants in other forms of Great Lakes wildlife consumed by the human population. Some US states have active health advisories for certain game species of waterfowl (New York State Department of Health, 2016; Pennsylvania Game Commission, 2016; Wisconsin Department of Natural Resources, 2016) and snapping turtles (New York State Department of Health, 2016) due to concerns over levels of contamination by mercury and organic chemicals such as PCBs as determined through state monitoring programs.

Although this objective notes that the waters of the Great Lakes should allow for human consumption of wildlife unrestricted by concerns due to harmful pollutants, the PROP does not mention programs related to wildlife consumption. As well, SOGL reporting does not connect human health with wildlife consumed from the waters of the Great Lakes. Information regarding the widespread consumption of Great Lakes wildlife is limited and potentially informative; however the level and spatial distribution of consumption patterns may not justify binational activities.

3.3.5 Assessment of principles and approaches

The GLWQA puts forth principles and approaches to define basic concepts to guide the Parties work towards achieving the GLWQA's Objectives. The principles and approaches also provide a framework for assessing the success of current programs and measures that support the GLWQA.

As a concept in the GLWQA, adaptive management addresses how to evaluate current actions and adjust future actions once outcomes and ecosystem processes in the Great Lakes become better understood. In recommending that the Parties shift to indicators that support human consumption of fish (Objective 3), the IJC assessed that advances in science provide for better monitoring and reporting on human health than are currently implemented. The GLWQA's principle of adaptive management provides rationale for such a shift.

Successful pursuit of an adaptive management approach for this objective could include the use of technology forcing to motivate development of new indicators, and the data sharing practices and standardized measurement techniques to support reporting and analysis. Technology forcing

is a strategy that mandates currently unachievable and uneconomic performance standards should be met at some future point in time as part of a regulatory or monitoring framework. For example, for indicators without data, technology forcing for monitoring could be implemented for inclusion of Human Health Indicators as part of Great Lakes monitoring within a five-to-ten-year time frame, or within two or three reporting cycles of the Triennial Assessment of Progress. As stated previously, indicator refinement for this objective would not involve new monitoring, though a significant effort would be needed to standardize and onboard existing data streams from states, provinces and Tribes/First Nations into the SOGL process.

Beyond specific monitoring and reporting activities, the adaptive management approach allows for consideration of alternative perspectives on foundational concepts connecting human health and the Great Lakes ecosystem. The IJC's HPAB **acknowledges the importance of integrating ecosystem and human health as part of determining overall well-being and reaching the GLWQA Objectives.** The HPAB has suggested that the perspective offered by an ecosystem health, or EcoHealth, approach would allow a closer incorporation of human health considerations into implementing GLWQA activities and achieving its objectives (HPAB, 2015). EcoHealth seeks to understand linkages between human health and healthy ecosystems using a multi-disciplinary approach, and then take action based on that understanding to improve and sustain both human populations and their natural environments (Blockstein, *et al*., 2007; Coutts *et al*., 2014). This approach couples multi-disciplinary information and perspectives from ecology, public health, social science, and natural resources management with motivation for acting on new knowledge.

Aspects of the current 2012 GLWQA implementation dovetail with an EcoHealth approach, given its stated reliance on the ecosystem approach, and that some indicators reported by the Parties are intended to monitor potential impacts to humans resulting from the use of Great Lakes resources. The importance of health outcomes is noted in Annex 3, where the Parties express the intention to work towards indicators of human health outcomes related to exposure to contaminants under this Annex.

However, the inherent motivation for action in the EcoHealth approach is less obvious in the Parties' current indicators framework, Driving Force – Pressure – State – Impact – Response (DPSIR). DPSIR as implemented by the SOLEC 2014 focuses heavily on reporting of status and trends and presents a static picture of the ecosystem that can be compared with other pictures generated in the past. This static approach led to past criticisms of the DPSIR framework, in that the approach enables two-way interactions between its components to be overlooked, and for missing a sense of urgency to stimulate protective actions that benefit the natural environment, and subsequently human health (Corvalan, *et al.,* 2000; Rapport and Singh, 2006; Liu *et al.,* 2002; Hamblinge*t al.,* 2011).

Alternative frameworks that include human health outcomes can include human health as this sense of motivation and focus for action (Rapport and Singh, 2006). An EcoHealth perspective provides for inclusion of potential human exposure and health effects within an indicators monitoring framework Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA) as implemented by the World Health Organization (WHO) (Corvalán*et al.,* 2000). Reporting on human health exposure and effects within the WHO's monitoring framework connects changes

in ecosystem status and trends with a health-based rationale for needed restoration actions. The inclusion of human health objectives in the GLWQA provides an opportunity for the Parties to consider human health as a focus for action for an alternative SOGL indicators framework. There is support for investigating alternative indicator frameworks under the adaptive management approach of the GLWQA.

3.3.6 Assessment of other reports

A recent report by the IJC evaluated the implications of atmospheric mercury deposition as an external source of mercury to fish in the Great Lakes (IJC, 2015). The USEPA notes studies showing that "generally, the declines in mercury concentrations observed up until approximately 1990 have ceased and that mercury concentrations in fish have started to increase… This suggests that concentrations of mercury in top predator fish are atmospherically driven and the recent increases may be a reflection, in part, of increased global mercury emissions US EPA (2014)." EPA's research also indicated that global anthropogenic sources of atmospheric mercury could account for 14 to 18 percent of mercury in the Great Lakes. It is valuable for the Parties to continue international efforts to address atmospheric deposition coming from North America.

Long range transport mercury is of major concern internationally to both human and ecosystem health, and 140 countries including Canada and the United States reached agreement on a treaty in January 2013, the Minimata Convention, intended to reduce anthropogenic emissions and releases of mercury and mercury compounds. While the Minimata Convention has not yet gone into force pending full ratification by 50 countries, the Parties are implementing many measures of the Convention in the interim.

The Minimata Convention is important step towards reducing risks by mercury to human health and the environment. Other contaminants such as pesticides, flame retardants and other chemicals present a continued risk to the Great Lakes and also have significant atmospheric sources.

3.3.7 Section Summary

- The Parties have invested significant time and resources in long term monitoring for contaminants in whole fish in the Great Lakes. These programs are effective at monitoring contamination levels and ecosystem status for fish species, but are less applicable when assessing risk to human health.

- Contaminant levels for fish species monitored by the Parties decreased since monitoring commenced in the 1970s. Reporting indicates mercury contamination in fish is currently lower than most health advisories levels. Levels of PCBs, responsible for most fish advisories, plateaued in the 1990s and have remained stable in recent years at levels higher than advisory guidelines. As a result, consumption limits likely will need to remain in place over the long term.

- Programs designed by First Nations/Tribes, in addition to states and provinces, provide refined indicator specificity to human health by focusing on boneless fish filets, which better represent the part of fish humans consume.

- The Contaminants in Edible Fish sub-indicator presented at the GLPF focused on lake trout and PCBs, suggesting a reduction in the number of species and contaminants to be reported compared to previous reporting on this objective. The use of a top predator species such as lake trout is commendable, though the use of additional species would provide more robust data. While PCBs drive many health advisories in the region, mercury, DDT, and other contaminants remain a concern and reporting for additional chemicals is warranted.

- Health considerations factor into the implementation of various Annexes, but there is no centralized effort to consolidate reporting on the human health aspects of these programs or to identify emerging human health issues in the basin.

- The wildlife consumption provisions of the GLWQA are not included as part of the 2016 PROP, and reporting on wildlife consumption health risks for additional species such as waterfowl and snapping turtles is missing from the planned SOGL reporting. It is useful that some Great Lakes states have issued health advisories based on their own monitoring programs. It is recognized that the level and spatial distribution of consumption patterns may not justify binational activities or SOGL reporting.

The HPAB has recognized that a standardized sampling approach, analytical methods, data interpretation and the issuing of advice for fish consumption indicators would strengthen health assessments and resource management in the Great Lakes. This standardization would allow for the development of a basin-wide human health indicator to characterize risks and benefits from fish consumption. However, achieving such standardization is a tremendous challenge. Nevertheless, the intrinsic connection between the health of the Great Lakes ecosystem and its human population propels the need for long-term, standardized monitoring to support human consumption of fish. The HPAB has made general recommendations regarding these differences that are relevant to the broader report and GLWQA Objectives 1-3, in particular the need for additional dialogue between the HPAB and SOGL reporting regarding indicator approaches.

3.3.8 References:

Awad, E., 2006. The results of the 2003 Guide to Eating Ontario Sport Fish questionnaire. Ontario Ministry of the Environment. Toronto, ON.

Blockstein, D.E. and McManus, K.M., 2007. Integrating Environment and Human Health: A report of the Seventh National Conference on Science, Policy and the Environment; National Council for Science and the Environment: Washington, DC.

Canada, Government of, 1999. Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33, s. 93).

Corvalán C, Briggs D, Zielhuis G., eds. Decision-making in environmental health: from evidence to action. Geneva, World Health Organization, 2000.

Coutts, C., Forkink, A., Weiner, J., 2014. The portrayal of natural environment in the evolution of the ecological public health paradigm. Int. J. Environ. Res. Public Health, 11, 1005–1019.

Dellinger, J.A., Dellinger, M., Yauck, J., 2012. Mercury exposure in vulnerable populations: guidelines for fish consumption, in: Bank, M.S. (Ed.), Mercury in the environment: pattern and process. University of California Press, Berkeley, CA, United States, pp. 289-300.

Dellinger, J.A., Moths, M.D., Dellinger, M.J., Ripley, M.P., 2014. Contaminant trends in freshwater fish from the Laurentian Great Lakes: a 20-year analysis. Hum. Ecol. Risk Assess.: An Int. J. 20(2), 461-478. doi: 10.1080/10807039.2012.759475.

Gewurtz, S.B., Backus, S.M., Bhavsar, S.P., McGoldrick, D.J., de Solla, S.R., Murphy, E.W., 2011. Contaminant biomonitoring programs in the Great Lakes region: review of approaches and critical factors. Environ. Rev. 19, 162-184.

Great Lakes Public Forum, 2016.State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada.

Government of Ontario, 2016.https://www.ontario.ca/page/fisheries-ontario

Hambling, T., Weinstein, P., Slaneye, D., 2011.A review of frameworks for developing environmental health indicators for climate change and health. Int. J. Environ. Res. Public Health 2011, 8, 2854–2875.

Health Professionals Advisory Board, 2014.Recommended Human Health Indicators for Assessment of Progress on the Great Lakes Water Quality Agreement.http://ijc.org/files/tinymce/uploaded/HPAB/Recommended-Human-Health_Indicators-June2014.pdf

Health Professionals Advisory Board, 2015.HPAB Recommendations for the Triennial Assessment of Progress, Response to 28Jan2015 Call for Advice by GLRO Director Morris.

Hornshaw, T., 2006.Discussion Paper for a Chlordane Health Protection Value (HPV).Great Lakes Consortium for Fish Consumption Advisories.

Liu, H.Y., Bartonova, A., Pascal, M., Smolders, R., Skjetne, E., Dusinka, M., 2002. Approaches to integrated monitoring for environmental health impact assessment. Environ. Health, 11, 1–13.

McCann, P. J., Anderson, H.A., Great Lakes Sport Fish Consortium, 2007. A Protocol for Mercury-based Fish Consumption Advice: An addendum to the 1993 Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Great Lakes Sport Fish Advisory Task Force.

McGoldrick, D.J., Murphy, E.W., 2015. Concentration and distribution of contaminants in lake trout and walleye from the Laurentian Great Lakes (2008 - 2012).Environmental Pollution. 217, 85–96.

Minnesota Sea Grant. 2016. http://www.seagrant.umn.edu/fisheries/superior_michigan_fisheries
Neff, M.R., Robinson, J.M., Bhavsar, S.P., 2013. Assessment of fish mercury levels in the upper St. Lawrence River, Canada. Journal of Great Lakes Research, 39(2): 336–343

New York State Department of Health, 2016.Health Advice on Eating Sportfish and Game.

Pennsylvania Game Commission. 2016. Pennsylvania Guide to Migratory Game Bird Seasons and Bag Limits 2015-16.

Rapport, D.J.; Singh, A., 2006.An EcoHealth-based framework for state of the environment reporting. Ecol. Indic. 6, 409–428.

Ridal, J.J., Hickey, M.B.C, Marty, J., and Bhavsar, S.P., 2012.Assessing the fish consumption beneficial use impairment in the Bay of Quinte. Aquatic Ecosystem Health & Management 15:453-463.

SOLEC 2014.Technical Report.State of the Great Lakes 2011.Environment Canada and U.S. Environmental Protection Agency.Toxic Chemical Concentrations.http://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdfAccessed September 30, 2016.

Turyk, M.E., Bhavsar, S.P., Bowerman, W., Boysen, E., Clark, M., Diamond, M., Mergler, D., Pantazopoulos, P., Schantz, S., Carpenter, D.O., 2012. Risks and benefits of consumption of Great Lakes fish. Environ. Health Perspect. 120, 11-18.

Wisconsin Department of Natural Resources, 2016.Wisconsin Migratory Bird Regulations.

United States Environmental Protection Agency, 2014. Open Lakes Trend Monitoring: Mercury.

Zhang, X., Gandhi, N., Bhavsar, S.P., Ho, L.S.W., 2013.Effects of skin removal on contaminant levels in salmon and trout filets. Sci. Total Environ. 443, 218-225.

3.4 Review and Assessment of General Objective 4: Pollutants

3.4.1 Introduction

1. Purpose

This section reviews and assesses progress toward achieving General Objective 4 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 4 states that the waters of the Great Lakes should "be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain."

The section presents an assessment of programs and other measures in support of this objective. This assessment is based largely on the review of:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF 2016)
- the **Progress Report of the Parties** (PROP, 2016); and
- implementation measures undertaken in support of the GLWQA Annex 3: Chemicals of Mutual Concern.

2. Background

The Great Lakes are uniquely vulnerable to chemical contamination, especially by chemicals such as PCBs and DDT that build up (bioaccumulate) in the food web and break down slowly in the environment. The Great Lakes have a large surface area and flush slowly, which means many chemicals collect in fish, wildlife and sediment and decline only gradually once controls are put in place (Fuller et al., 1995).

Historically, intense industrial activity in the Great Lakes region and long-range atmospheric transport and deposition of chemicals from out-of-basin sources have contributed to chemical pollution of the Great Lakes. In addition to harming aquatic life, certain chemicals pose human health risks, largely through consumption of contaminated fish (Fuller et al., 1995).

3.4.2 Assessment of indicators

1. Sub-indicators status and trends

The 2016 State of the Great Lakes Report (SOGLR) will include a Toxic Chemicals indicator that corresponds to General Objective 4 of the GLWQA. The indicator includes the following sub-indicators: toxic chemicals in Great Lakes Herring Gulls; toxic chemical concentrations (open water); atmospheric deposition of toxic chemicals; toxic chemicals in sediment; water quality in tributaries; and toxic chemicals in Great Lakes whole fish. A summary of the status and trends for all of the Toxic Chemicals sub-indicators is presented in Table 3.4.1.

The overall assessment of the toxic chemicals in Great Lakes herring gulls sub-indicator is that the status is good and the trend is improving. The long-term trends of virtually all legacy contaminants such as polychlorinated biphenyls (PCBs), dioxins and furans, and organochlorine pesticides are declining levels. However, it was also found that "non-legacy" compounds (for example, dechlorane plus and hexabromocyclodoecane) have increased. The lake-by-lake assessment for these sub-indicators found that the status levels for Lakes Superior, Michigan and Huron are good and that their trends are improving. For Lakes Erie and Ontario, the status levels are fair and the trends unchanging.

The status for the *toxic chemical concentrations sub-indicator* is good with an unchanging trend overall in the Great Lakes basin. On a lake-by-lake basis the status levels for Lakes Superior, Huron, and Michigan are excellent to good with improving to unchanging trends. Lakes Erie and Ontario were found to each have a fair status for this sub-indicator with the trend unchanged. Key findings identified that while long-term trends for many legacy toxic chemicals such as mercury are declining, there has been little to no changes recently.

Table 3.4.1. Summary of the status and trends of the State of the Great Lakes Toxic Chemicals sub-indicators for the overall Great Lakes basin and each Great Lake

State of the Great Lakes - Toxic Chemicals Sub-Indicators		Overall	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Toxic chemicals in herring gull eggs	Status	Good	Good	Good	Good	Fair	Fair
	Trend	Improving	Improving	Improving	Improving	Unchanging	Unchanging
Toxic Chemical concentrations in water	Status	Good	Good	Good	Excellent	Fair	Fair
	Trend	Unchanging	Improving	Unchanging	Unchanging	Unchanging	Unchanging
Atmospheric deposition of toxic chemicals	Status	Fair	Not specifically categorized				
	Trend	Improving					
Toxic chemicals in sediment	Status	Fair	Good	Fair	Good	Fair	Fair
	Trend	Improving	Unchanging	Unchanging	Unchanging	Improving	Improving
Water quality in tributaries	Status	Fair	Fair	NA	Good	Poor	Fair
	Trend	Undetermined					
Toxic chemicals in whole fish	Status	Fair	Fair	Fair	Fair	Fair	Fair
	Trend	Improving	Unchanging	Improving	Unchanging	Unchanging	Improving

(Source: GLPF, 2016)

The *atmospheric deposition of toxic chemicals sub-indicator* status is fair for the overall assessment of the basin with an improving trend. A lake-by-lake assessment was not completed for this sub-indicator. The assessment found that although levels of toxic chemicals in the air are generally low, the large surface area of the Great Lakes results in significant atmospheric deposition. Monitoring for some chemicals of emerging concern, including PBDEs, is increasing and efforts are being made to identify other chemicals that should be included in Great Lakes monitoring programs.

The basin-wide assessment for the *toxic chemicals in sediment sub-indicator* showed that the status for the Lakes is fair and the trend is improving. Lake Superior and Huron were classified as good in terms of their status with unchanging trends. The trend for Lake Michigan was unchanging and its status is fair. Toxic chemical concentrations in sediments in Lakes Erie and Ontario statuses are fair with improving trends. Some of the key findings are that legacy toxic chemical concentrations continue to decrease and are generally below sediment quality guidelines. Many emerging and new toxic chemicals are showing increased concentrations in sediment and may be potential sources of stressors to the ecosystem now and in the future.

The overall status for the *water quality in tributaries sub-indicator* was found to be fair for Canadian tributaries in the Great Lakes. Lake Superior and Ontario were reported as having fair status, while Lake Huron was good and Lake Erie poor. As data for this sub-indicator were only collected for Canadian tributaries, no status was reported for Lake Michigan. Trends were not determined for this sub-indicator.

The *toxic chemicals in Great Lakes whole fish sub-indicator* status is fair with an improving trend. The status levels for Lakes Superior, Huron and Erie were fair with unchanging trends. Lakes Michigan and Ontario were found to each have fair status and improving trends. While there continue to be guidance exceedances for some substances, contaminant levels in Great Lakes whole fish have decreased. Legacy chemicals will continue to be monitored but efforts are being made to incorporate emerging chemicals into both US and Canadian monitoring and surveillance programs. These emerging chemicals are identified through scientific studies, general screening, risk assessments and the identification of chemicals of mutual concern as part of the Parties Annex 3 process under the GLWQA.

2. Toxic chemicals sub-indicators reports

Chemicals of Emerging Concern

A common element of the majority of the sub-indicator results presented at GLPF (2016) is that while legacy chemical levels are generally decreasing or remaining unchanged, emerging chemicals levels are increasing. Most of the sub-indicator presentations indicate that monitoring and surveillance programs are taking this change into consideration and are attempting to incorporate new and emerging chemicals into their routine work. However, there does not appear to be a consistent approach to addressing new and emerging chemicals as the level of effort to identify and incorporate new and emerging toxic chemicals varies across programs.

The Parties have made good efforts to report on the increased levels of new and emerging toxic chemicals as part of their monitoring and surveillance programs. However, there is a need to develop a more consistent strategy for this process.

Chemicals of Mutual Concern – Annex 3

The toxic chemicals in Great Lakes whole fish report states that US and Canadian monitoring and surveillance programs are identifying chemicals of interest through a variety of methods, including the Annex 3 process for identifying chemicals of mutual concern (CMCs) that will be discussed in further detail in section 4.4.5 of this report. This is the only Toxic Chemicals sub-indicator report that mentions the inclusions of CMCs in monitoring and surveillance programs specifically. It is unclear as to whether the programs associated with the other Toxic Chemicals sub-indicators are making similar efforts or are considering CMCs in a similar manner.

3.4.3 Assessment of Progress Report of the Parties

The Chemicals of Mutual Concern (CMCs) chapter in the PROP serves to highlight the binational actions taken by the Parties in relation to *Key Commitments* under Annex 3 since the GLWQA came into force in 2013. The chapter is a high-level summary of successes achieved to date related to select commitments for Annex 3 and emphasizes related domestic actions taken in both Canada and the United States.

GLWQA commitments for the identification of CMCs have been met. While progress has been made in addressing commitments related to targeting CMCs for action and the coordination of science priorities, it is clear that more work is needed in terms of implementing related programs and measures (as discussed below).

3.4.4 Assessment of Annex implementation

1. Overview

Annex 3 commits the Parties to contributing to the General and Specific Objectives of the GLWQA by protecting human health and the environment though cooperative and coordinated measures to reduce the anthropogenic release of chemicals of mutual concern into the waters of the Great Lakes.

Under the *Programs and Other Measures* section of Annex 3, the Parties have committed to two areas of focus: the identification of chemicals of mutual concern; and targeting those chemicals for action.

To ensure that the Parties are able to realize those commitments, a CMCs Sub-Committee has been established. The mandate, principles, roles and responsibilities, organizational structure and membership of the Sub-Committee have been established in a *Terms of Reference (TOR)* dated March 7, 2014 (United States and Canada, 2014).

According to the TOR, the mandate of the Chemicals of Mutual Concern Sub-Committee (referred to as the "C3") focuses primarily on the two areas identified in Annex 3 -- the identification of chemicals of mutual concern and targeting those chemicals for action, as well as supporting the Great Lakes Executive Committee (GLEC) as required. The TOR also identifies the *Principles* that the C3 shall adhere to, including: no impairment to the waters of the Great Lakes; accountable, adaptive and science-based management actions; virtual elimination and

zero discharge of CMCs to be implemented as appropriate, life-cycle management as well as others.

The responsibility of the C3, according to the TOR, is to develop, maintain and deliver three-year work plans designed to ensure that the Parties meet the commitments of the GLWQA. Membership of the C3 consists of government representatives from relevant federal, state, provincial, First Nation, Métis and Tribal agencies in Canada and the United States that are responsible for protection of the ecosystem health within the Great Lakes basin. The C3 is co-chaired by individuals designated by the GLEC Co-Chairs. Decisions of the C3 are made by consensus based on a quorum of nine members including the co-chairs and with a minimum of four participants from each country.

As shown in Figure 3.4.1, the C3 reports directly to the GLEC and has established an Extended Sub-Committee (EC3) as well as Task Teams to address the tasks set forth in the current work plan on an as-needed basis.

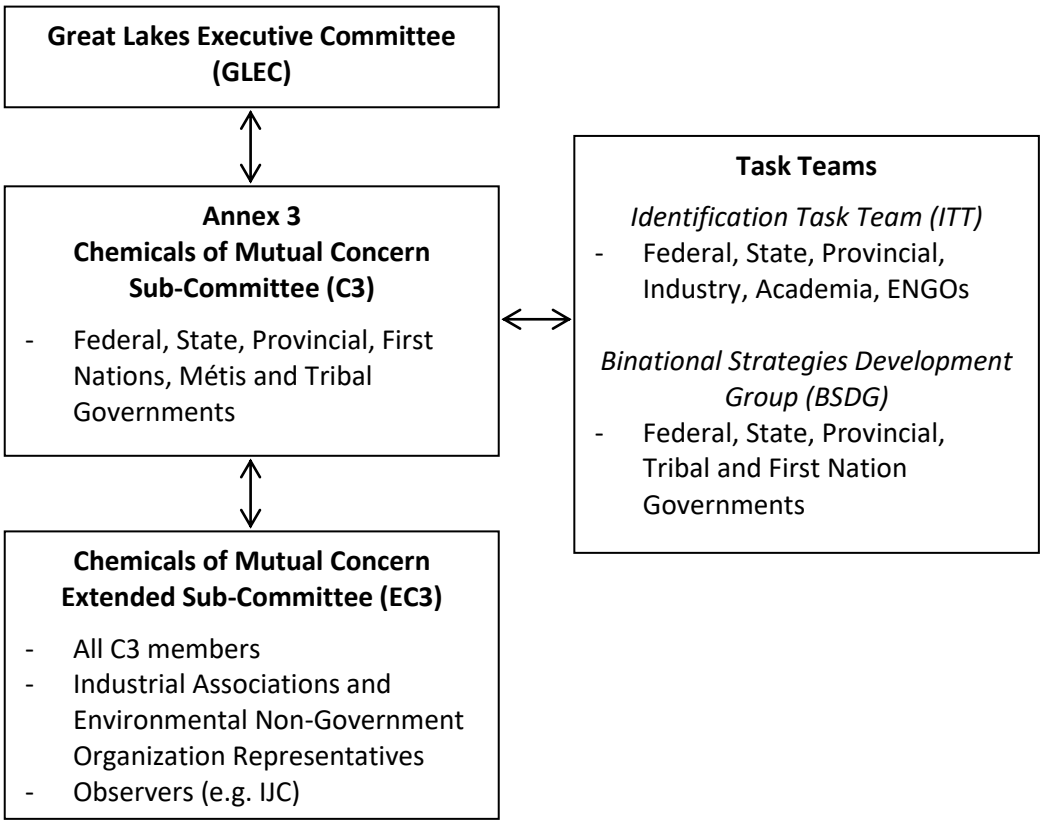

Figure 3.4.1 Annex 3 – Chemicals of Mutual Concern Implementation Organizational Model

The role of the EC3 is to provide input and feedback to the C3 on the development and implementation of the Annex 3 – CMCs work plan. Its membership includes all C3 members as well as selected representatives from industrial associations and environmental non-government organizations.

Observers may also be appointed to the EC3 following a "formal request" with C3 co-chairs reserving the right to deny any application to observe due to venue capacity, meeting balance or other relevant considerations. The IJC has requested and been granted Observer status to the EC3.

The C3 may also form Task Teams on an as-required basis to assist in the delivery of the Annex 3 work plan for a fixed duration of time. Members of the Task Teams are selected by the C3 with input from the EC3 and are required to possess relevant expertise.

To meet its responsibilities, the C3 developed a work plan that focuses on the development and implementation of approaches and processes associated with the identification of CMCs, the development of binational strategies for those CMCs and the development of new or revised domestic water quality standards, and objectives, criteria and guidelines for CMCs during the 2013-2016 timeframe. Specifically, the current work plan committed the C3 to identifying and designating two separate sets of CMC and developing Binational Strategies for the CMCs identified along with beginning work on the implementation of those strategies where applicable (United States and Canada, 2013a).

The C3 also stated that Year 1 of the work plan "is a pilot year to establish, test and refine our process and associated governance" (United States and Canada, 2013b).

Further to the C3's work plan, the Parties agreed to the following *Priorities for Action* for 2014 through 2016 (United States and Canada, 2014a) to guide their work under Annex 3:

- develop a binational process and considerations to identify and designate Chemicals of Mutual Concern on an ongoing basis;
- identify the first set of candidate Chemicals of Mutual Concern in spring 2014;
- apply the binational process and considerations to the first set of candidate chemicals and recommend resulting Chemicals of Mutual Concern for consideration by the GLEC in fall 2014;
- designate the first set of Chemicals of Mutual Concern by the Parties in fall 2014;
- identify and evaluate existing water quality standards, objectives, criteria and guidelines, or, when warranted, develop new water quality standards, objectives, criteria and guidelines for the first set of Chemicals of Mutual Concern in Spring 2015 (to be available on-line);
- complete the development of binational strategies for the first set of Chemicals of Mutual Concern by summer 2015; and
- identify the second set of candidate Chemicals of Mutual Concern in spring 2015.

2. Identifying CMCs

The GLWQA requires the Parties to identify and designate, on an ongoing basis, CMCs that originate from anthropogenic sources and that are agreed to by both Parties as being potentially harmful to the Great Lakes environment and human health.

For the first set of candidate CMCs, the governments of Canada and the United States proposed a list of seven chemicals or classes of chemicals and charged the C3 with identifying those that should be recommended as CMCs. Those chemicals included: PCBs; nonylphenol and its

ethoxylates; mercury; chlorinated paraffins (short, medium and long chain); perfluorinated chemicals (perfluorooctane sulfonate [PFOS]), perfluorooctanoic acid [PFOA] and long-chain perfluorocarboxylic acids [PFCAs]); bisphenol A (BPA); and brominated flame retardants (polybrominated biphenyl ethers [PBDEs] and HBCD).

To accomplish this task, the C3 established an Identification Task Team (ITT). Membership of the ITT included eight representatives from federal, state and provincial governments, four from industry, three from academia and two from environmental non-government organizations. The ITT was tasked with reviewing and critically evaluating relevant existing data and information for the seven chemicals of mutual concern in accordance with the Binational Considerations for Identifying Candidate Chemicals of Mutual Concern in the Great Lakes Basin that was developed by the C3 (see Figure 3.4.2).

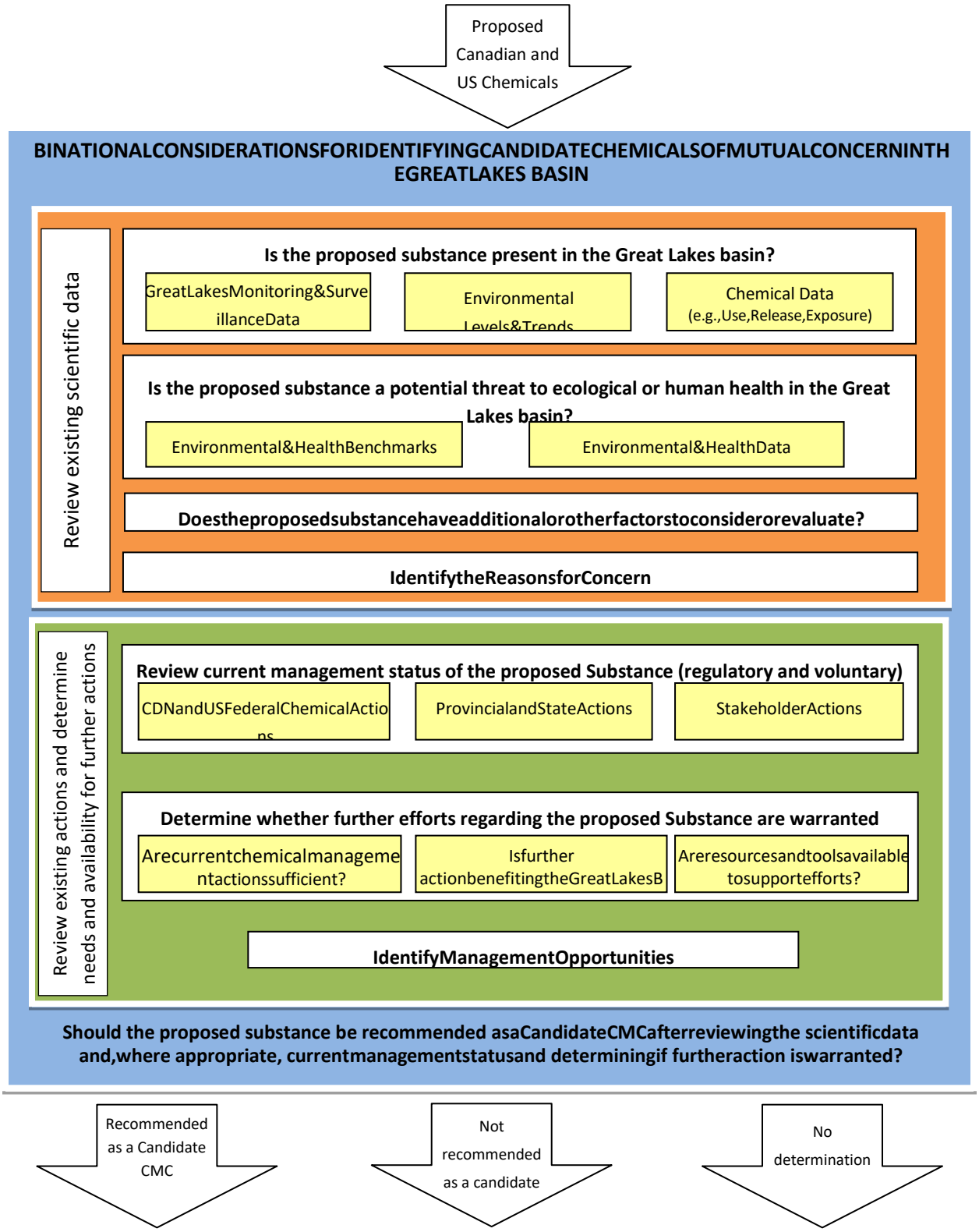

Figure 3.4.2. Binational considerations for identifying Chemicals of Mutual Concern (CMCs) in the Great Lakes Basin(Source: developed by the GLWQA Annex 3 Sub-Committee)

Based on that evaluation, the ITT produced a Binational Summary Report for each candidate CMC. Each report provided a summary of the findings and supporting rationale as to whether that particular chemical or class of chemicals should be:

- recommended as a chemical of mutual concern;
- not recommended as a chemical of mutual concern;
- no determination - no recommendation made due to insufficient data

The ITT recommended to the C3 that the four following chemical groups be designated as CMCs: PCBs; mercury; perfluorinated chemicals; and PBDEs (brominated flame retardant class). Nonylphenol and its ethoxylates, chlorinated paraffins, bisphenol A and HBCD (brominated flame retardant class) received a “No determination” classification.

The ITT recommendations were submitted to the C3 and released for public comment in May 2015. Members of the EC3, and the GLEC were also invited to comment on the Binational Summary Reports. All stakeholder comments were summarized and provided to the C3 for consideration while they decided which chemicals should be recommended for designation to the GLEC. While considering its recommendations the C3 reviewed the principles under the Agreement, it’s Terms of Reference (2013) and further considered the meaning of designation under the Agreement (United States and Canada, 2015d). As a result, the C3 agreed to emphasize certain areas for each chemical to guide its deliberations including:

- evidence the chemical is persistent, bioaccumulative and inherently toxic (PBiT);
- evidence of long range transport;
- inclusion of the chemical under international and/or multilateral environmental agreements; and
- knowledge that additional data from the Great Lakes will be available in the near future to complement current data sets.

Following its deliberations the C3 recommended that PCBs, mercury, perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), long-chain perfluorocarboxylic acids (PFCAs), PBDEs and HBCD (brominated flame retardant class), and short-chain chlorinated paraffins (SCCPs) be designated as CMCs. The C3 decided that there was insufficient information available for medium and long chain chlorinated paraffins (MCCPs and LCCPs), nonylenol and its ethoxylates (NP/NPE), and bisphenol A (BPA) on which to base a determination at that time and did not recommend them for designation.

The C3 presented the first set of recommended CMCs, as mentioned above, to the GLEC at its June 2015 meeting. The GLEC was then responsible for forwarding the recommendations to the Parties for a decision on official designation as CMCs. A summary of this process is represented in Figure 3.4.3.

When presenting its findings and recommendations to the GLEC in June 2015, the C3 also discussed next steps which included an evaluation of ways in which to improve the ITT process. It also considered establishing a mechanism to collect, review and summarize new data that

becomes available for chemicals and that received an “insufficient information” classification and how those chemicals could be re-considered for designation as a CMC by the Parties.

On May 31, 2016 Canada and the United States announced the following chemical or classes of chemicals as the first set of CMCs under the Agreement:

- Hexabromocyclododecane (HBCD);
- Long-Chain Perfluorinated carboxylic acids (LC-PFCAs);
- Mercury(Hg);
- Perfluorooctanoic acid (PFOA);
- Perfluorooctane sulfonate (PFOS);
- Polybrominated Diphenyl Ethers (PBDEs);
- Polychlorinated Biphenyls (PCBs); and
- Short-Chain Chlorinated Paraffins (SCCPs).

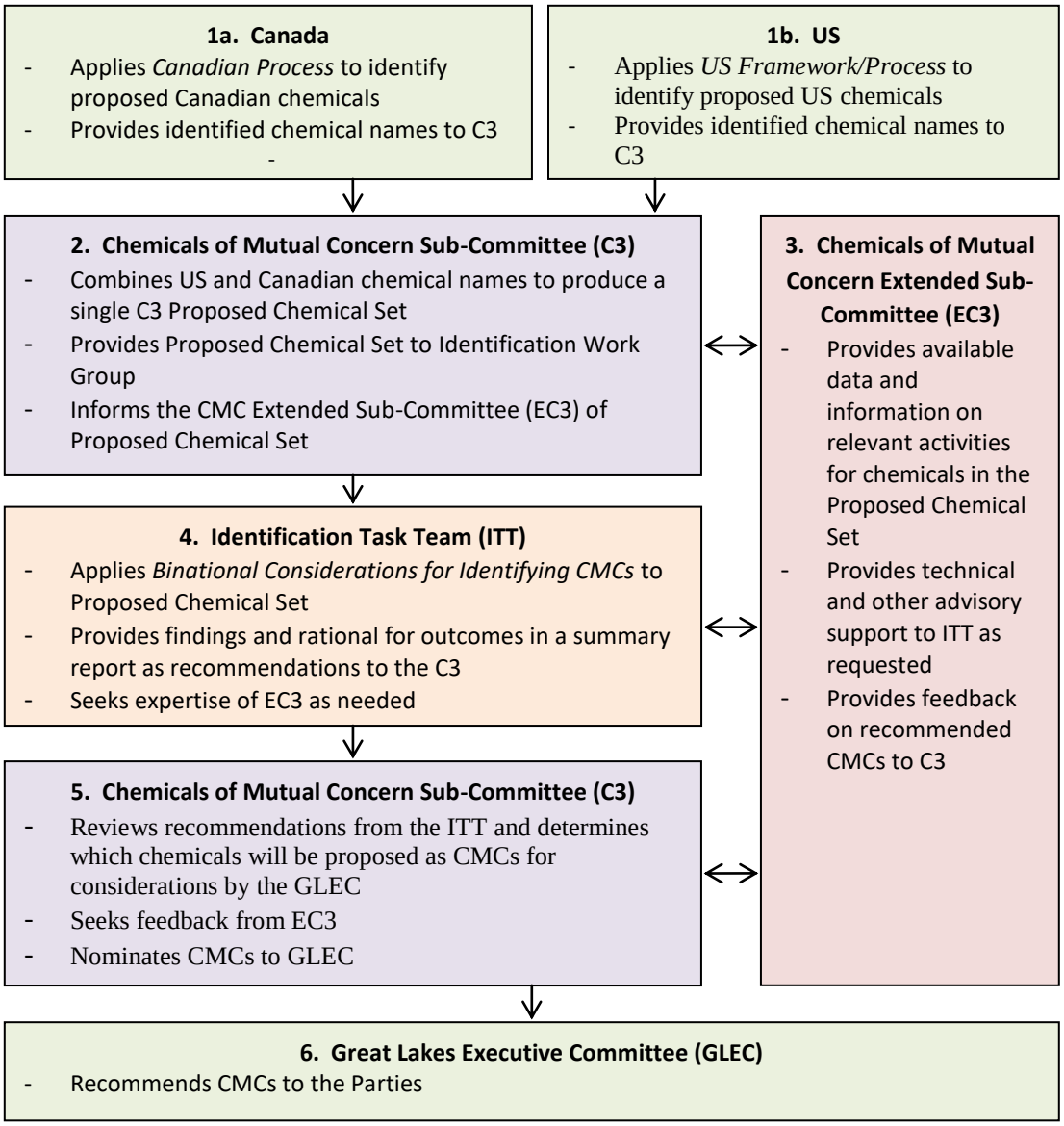

Figure 3.4.3. Summary of Annex 3's Process for Recommending Chemicals of Mutual Concern to the Parties

As noted, the C3 and GLEC Co-Chairs have indicated that this first work plan should be considered as a "pilot" and is an opportunity to develop and refine the processes and governance associated with their Annex 3 commitments. An example of the C3 working to refine the processes associated with Annex 3 is the creation of a process through which stakeholders can propose specific chemicals for consideration as candidate CMCs. During the past three years, the Parties have heard from various stakeholders who expressed an interest in becoming more involved in Annex 3 activities. In response, the GLEC and C3 have developed a process that enables stakeholders from Canada and the United States to formally propose specific substances for consideration as candidate CMCs. The process applies to environmental and human health non-governmental organizations, industry, academia and members of the general public.

The efforts of the Parties to enhance stakeholder engagement activities are encouraging. The Parties could continue to identify areas and opportunities for the public in the Great Lakes region to become more involved in Annex 3 activities.

Another example is the evaluation of the first ITT process the Parties conducted following submission of the Binational Summary reports for the candidate chemicals. As part of the ITT Statement of Work developed by the C3, there was a commitment to conduct an evaluation of the process to attempt to identify what went well and challenges that were encountered. This evaluation provided members of the ITT with an opportunity to identify issues and provide feedback and suggestions regarding the process for consideration by the C3.

This incorporation of an adaptive management mechanism in this process by the Parties is commendable. Nevertheless, several challenges remain in this area.

As noted, a work plan for Annex 3 was developed that specifically committed the C3 to identify and designate two separate sets of CMCs and to develop Binational Strategies for the CMCs identified along with starting work on the implementation of those strategies where applicable (United States and Canada, 2013). These commitments are also reflected and reinforced in the *2014-2016 Priorities for Science and Action* for Annex 3 that the Parties officially agreed to and released to the public in 2014. The Parties only recently, in May 2016, designated the first set of CMCs under the Agreement and work has begun on the development of Binational Strategies for two of the identified CMCs as a pilot to be applied to the remaining substances.

This slow implementation of the Annex 3 work plan and the *2014-2016 Priorities for Science and Action* (2014) can likely be attributed to a number of factors including some beyond the control of the C3 and GLEC. The work plan was also viewed as a "pilot" since it was the first developed for Annex 3 under the revised Agreement and governments may have overestimated what could reasonably have been accomplished in the 2013-2016 timeframe. There may have been an underestimation of the resources needed to accomplish the identified tasks in a timely manner. This is reflected not only in the slow implementation of the work plan but also in documented comments from various members of the EC3 and ITT and others to both the C3 and GLEC Co-Chairs (CGLI 2015a, CGLI 2015b, ENGO 2015a, United States and Canada 2015a). An expedited process is necessary to fulfil all GLWQA Objective 4 commitments.

The current process is resource-intensive and requires considerable effort and time on the part of the members of the ITT. This is not the most efficient use of their experience and expertise, which should be focused instead on reviewing materials and providing input and feedback to the various parts of the review process.

Inadequate resources may have also resulted in a lack of clarity related to many of the guidance documents developed for the ITT process. Members of the EC3 and ITT have noted that documents such as the ITT's *Statement of Work* and the *Binational Considerations When Evaluating Candidate Chemicals of Mutual Concern* lack sufficient detail in certain areas, which resulted in confusion regarding the role and expectations of members as well as a certain level of ambiguity related to the interpretation of the CMC designations described earlier. Additional work by support staff at the beginning of the process to develop clear and consistent guidance documents as well as during the development of the Binational Summary reports could have prevented some of the issues that developed and may have allowed members to spend less time

on more routine resource-intensive tasks such as compiling data and information. As well, utilizing experts from the Parties' national programs and processes with the appropriate experience and backgrounds to assist the ITT would enable the completion of assigned tasks in a more efficient and timely manner.

The ITT also identified a need to conduct more meetings in-person. If resources had been available for face-to-face meetings, members believed that they would have provided a valuable opportunity for deliberation and have assisted the ITT in completing the Binational Summary Reports in a more efficient manner.

As part of the draft Lake Superior Lakewide Action and Management Plan (LAMP), nine toxic substances (mercury, PCBs, dioxin, hexachlorobenzene, octachlorostyrene and four pesticides [dieldrin, chlordane, DDT, and toxaphene]) have been identified as part of a Lakewide Objective to achieve zero release as part of the Lake Superior Zero Discharge Demonstration Program (reference to be added). Of the nine substances, only two have been recommended for designation as CMCs. The Lake Superior LAMP also addresses "substances of concern" or chemicals of emerging concern such as personal care products and pharmaceuticals. At this point, it is not clear the extent to which these substances and the lessons learned from this and similar programs will be considered in relation to the Annex 3 CMC identification process.

2. Targeting CMCs for action

Under the GLWQA, the Parties in cooperation with their government partners and the public commit to targeting CMCs for action under a number of provisions. These include:

- preparing binational strategies for chemicals of mutual concern;
- coordinating the development and application of water quality standards, objectives, criteria, and guidelines;
- reducing the anthropogenic release of CMCs and products containing CMCs throughout their entire lifecycles;
- promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the use and release of CMCs;
- continuing progress toward the sound management of CMCs using approaches that are accountable, adaptive, and science-based;
- monitoring and evaluating the progress and effectiveness of pollution prevention and control measures for CMCs, and adapting management approaches as necessary; and
- exchanging information on monitoring, surveillance, research, technology and measures for managing CMCs.

One of the key commitments listed above is the preparation of Binational Strategies for substances that have been designated as CMCs by the Parties. At present, the C3 is in the process of developing draft strategies for two of the designated CMCs, PCBs and HHBCD. These two draft strategies will serve as examples for the development of the Binational Strategies for the remaining CMCs, taking into account lessons-learned from the initial processes.

As specified in Annex 3, strategies may include research, monitoring, surveillance and pollution prevention, and control provisions to be used to address gaps in data and information as well as

reducing the anthropogenic release of CMCs into the waters of the Great Lakes (United States and Canada, 2016). According to the draft *Roles and Responsibilities for Developing Binational Strategies* guidance document (United States and Canada, 2015c) developed by the C3, the strategies may also include actions associated with the development and application of new and modified domestic water quality standards, objectives, criteria and guidelines by the Parties and other government entities. The continuation of current actions that will result in human health and environmental benefits or enhanced understanding of the sources, fate or effects of CMCs may also be included. Actions specified may be voluntary or mandatory in nature and may be implemented by different levels of government or non-government stakeholders.

To assist in the preparation of the strategies the C3 has established a Binational Strategy Development Group (BSDG). The BSDG is comprised of 19 members including representatives from Canadian and US federal agencies, the province of Ontario, the states of Illinois, Michigan, Minnesota, Ohio, and Wisconsin, and Tribal/First Nations governments.

A statement of work for the BSDG has been completed and the C3 has initiated the development of draft Binational Strategies for PCBs and HBCD. It is expected that the draft Strategies will be completed for review and public input during winter 2017. As part of that process, the BSDG will be seeking input from external stakeholders.

As outlined in Annex 3, the Parties recognize "the need to manage chemicals of mutual concern including, as appropriate, by implementing measures to achieve virtual elimination and zero discharge of these chemicals." Virtual elimination and zero discharge are identified as part of the guiding principles and approaches to the Agreement. Consequently, it is assumed that these concepts will be taken into consideration and addressed as part of each identified CMC's binational strategy. These concepts are not new and have been addressed under earlier versions of the GLWQA through various programs such as Lakewide Management Plans and the Great Lakes Binational Toxics Strategy. Some of those programs, such as the Lake Superior Zero Discharge Demonstration Program, have been successful and "lessons learned" from them could be incorporated into the binational strategies and used as the basis for discussion on the path toward achieving the purpose of the Annex.

One of the Principles identified in the Agreement under Article 2, section 4(a) is Accountability and transparency - specifically "…transparently evaluating the effectiveness of work undertaken to achieve the objectives…" – is an important part of that approach. Concerns have been raised regarding the transparency of the identification and ITT process under Annex 3.

Members of the EC3 and ITT have expressed concern at various times that not enough information is being provided regarding the decision making procedures for various parts of the CMC identification process. For instance, concerns have been raised regarding the fact that interested stakeholders such as members of the EC3, ITT or even the public are not permitted to attend or even observe the meetings of the C3. Materials and summaries of those meetings, including records of decisions and their rationale, are also not generally made available publically. These factors make it difficult for the public to stay informed regarding the work being done and decisions being made by the C3.

Another example is the initial identification of candidate CMCs for consideration and the lack of information on how those substances will be selected. The 2016 PROP outlines numerous

domestic actions being undertaken by both Canada and the United States with regard to various chemicals and substances. However, it is not clear how that work will feed into the Annex 3 process. It is also unclear how the newly adopted "Public Nomination Process" previously mentioned will be included. The *Annual Process for Recommending Chemicals of Mutual Concern in the Great Lakes Basin* developed by the C3 (outlined in Figure 4.4.3) only refers to the Parties applying their own "process" or "framework/process" to identify proposed chemicals and does not specify what that process entails.

It is also uncertain how previous work of the Parties will be used as part of that process. Implementation activities from past versions of the GLWQA, such as the *Binational Toxics Strategy*, produced excellent products and information. It is not clear whether or how those previous efforts are being considered as part of the identification process.

Finally, while the Parties did designate the first set of CMCs under the GLWQA it is not clear how the decision was made to include eight candidate chemicals. As mentioned previously, the ITT recommended that four of the seven candidate chemicals or chemical classes be designated as CMCs under the Agreement. However, after further deliberations and consideration of public and other input on the Binational Summary Reports the C3 recommended that eight chemicals be designated as CMC without a public explanation of how or why the decision was made. The C3 did present its findings and recommendations to the GLEC in June of 2015 with a general overview of the process but without additional details, it appears the work of ITT as a part of the designation process is not an efficient use of limited resources, including the time of the volunteer ITT members.

Additional information would also help avoid confusion on things such as how seven chemicals or classes of chemical were originally nominated to be CMCs but eight chemicals/classes ended up being approved by the Parties for designation in May 2016. A more consistent approach to identifying candidate chemicals (classes of chemical versus individual chemicals) would help in understanding the process.

In June 2015, the C3 committed to improving the ITT process including the establishment of a mechanism to re-consider candidate CMCs for which it was decided that insufficient information was available to make a decision on whether or not they should be recommended for designation (United States and Canada, 2015d). However, no additional information regarding these improvements has been made available publicly since that time. It is unclear what, if anything, the Parties are planning on doing to meet this commitment.

The development of the draft Binational Strategies for PCBs and HBCD also raises some concerns related to the Principle of transparency under the Agreement.

The BSDG, which is responsible for the development of the draft Binational Strategies, is composed of representatives from government agencies only. No representatives from other Great Lakes groups, organizations or stakeholder are included, and while the C3 has indicated that external stakeholders will be consulted as part of the Binational Strategy process they have not provided any information on how those consultations will be carried out.

To avoid some of the issues that developed as part of the ITT process, the Parties could make further efforts to ensure that the Binational Strategies development process is transparent to the public and engages interested external stakeholders on a consistent and timely basis.

2. Public engagement

Public Engagement is also one of the principles and approaches identified under Article 2 of the GLWQA. The Parties have taken some steps, such as the creation of a public nomination process for candidate CMCs, to follow this principle as they work to achieve the objectives of Annex 3; though some organizations have suggested that more could be done (ENGO 2015a, US and Canada 2015a).

Members of the EC3 and ITT have expressed concern about the lack of information that is publicly available regarding the work being undertaken for this Annex. The Parties' website (binational.net) provides a good general overview of key commitments under Annex 3 and how implementation will be carried out, but not much else. Specific information regarding the C3, EC3, task teams and the work that is being done is not readily available. Making available all Annex documents, such as the ITT Statement of Work, and posting regular updates of progress on binational.net would help in keeping the public better informed.

In addition, it is unclear whether Annex 3 has a public outreach strategy. The creation of a public nomination process for CMCs was done in response to interest expressed by stakeholders to be engaged in Annex 3 activities and does not appear to be a part of a strategic approach. Some of the Annex issues may have been avoided if a clear and consistent strategy had been developed and made available publicly thus managing the public's expectations on what to expect during all stages of the implementation process. Engaging the public often and early would enable the C3 to address any issues or potential issues in a timely manner. As well, the C3 also could consider additional methods for engaging the public through social media.

3.4.6 Assessment of other reports

1. Polybrominated Diphenyl Ethers (PBDEs)

PBDEs have been widely used as flame retardants since the 1970s and have been deliberately added to a wide range of commercial and consumer products, such as electronic devices, plastics, mattresses and carpets. Numerous studies have demonstrated adverse impacts on the environment and wildlife from exposure to PBDEs, which have been identified as persistent, toxic, and bioaccumulative. PBDEs were designated as a CMC under the GLWQA by the Parties, who are now committed to developing a Binational Strategy for the substance. The IJC recently released a report on PBDEs (IJC, 2016) that provides suggestions for consideration by the Parties in developing a strategy to address PBDEs in the Great Lakes.

Recommendations in the report specifically address the following, as specified in Annex 3:

- reducing the anthropogenic release of CMCs and products containing CMCs throughout their entire lifecycles;
- continuing progress toward the sound management of CMCs using approaches that are accountable, adaptive, and science-based;

- promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the use and release of CMCs;
- monitoring and evaluating the progress and effectiveness of pollution prevention and control measures for CMCs, and adapting management approaches as necessary; and
- exchanging information on monitoring, surveillance, research, technology and measures for managing CMCs.

The key theme of the IJC's PBDE report is that governments should no longer consider only control of pollutants after they are generated but rather the full product life cycle, from initial design to final disposal. PBDEs illustrate the problems that are created when the environmental fate of a chemical product is either not anticipated or externalized to society at large. In the future, manufacturers should be encouraged or mandated to consider the full life cycle in the design of new products, using environmentally benign materials instead of hazardous chemicals, or to reduce the need for chemical additives. The producers of PBDE-containing products need to have a more substantial role in ensuring that recycling and disposal problems are avoided. The Organization of Economic Cooperation and Development (OECD) defines Extended Producer Responsibility (EPR) as *"*… an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle." (OECD, 2001).

In the report, the IJC advised that this approach be embedded in the binational strategies for control or elimination of CMCs developed by the US and Canadian governments. The IJC urges the Parties to consider the substitution of nonhazardous substances in the implementation of strategies for other flame retardants.

PBDEs are just one example of a wide array of toxic substances in products broadly available around the basin. The Parties should use what is learned through the PBDE experience to deal with other substances in products and how to avoid the creation of these problems in the first place. The IJC concluded that the recommended strategy components presented in its 2016 report, while specific to PBDEs, can be adapted for other substances.

2. Atmospheric deposition of mercury to the Great Lakes basin

Mercury is also one of the substances included in the first set of CMCs designated under the GLWQA. One of the major pathways for mercury entry in the Great Lakes basin that should be accounted for during the development of a binational strategy is atmospheric deposition.

In November 2015, the IJC published a report, *Atmospheric Deposition of Mercury in the Great Lakes Basin*. The report notes that after several decades of effective action by Canada and the United States to address sources of mercury within the Great Lakes basin, the need to address atmospheric deposition of this toxic substance from out-of-basin regional and global sources is increasingly evident.

The USEPA has noted studies showing that decreases in mercury concentrations have ceased and that mercury concentrations in some fish species have started to increase. EPA data analysis suggests that concentrations of mercury in top predator fish are atmospherically-driven and

recent increases in mercury in some Great Lakes fish may be in part a result of increased global mercury emissions (EPA, 2016).

Continued strong efforts by Canada and the United States are needed to coordinate action at the international level, supported by sustained monitoring efforts within the Great Lakes basin to determine the effectiveness of such action. Monitoring mercury pollution is a critical need in light of persistent mercury contamination of Great Lakes fish.

Finally, in the report, the IJC recommended that the Canadian and US governments increase and provide sustainable funding for an optimized binational monitoring network to track atmospheric deposition of mercury in the Great Lakes Basin as well as funding for modeling to allow for source attribution. The IJC also commended the governments for their positive action with respect to pursuing global mercury reduction policies, including support for the mercury-focused Minamata Convention.

3.4.7 Section Summary

- The Parties' SOGL Toxic Chemicals Indicator indicates that the status of the Great Lake basin overall ranges from *Good* to *Fair* with *Improving* to *Unchanging* trends.

- While levels of legacy toxic chemicals such as PCBs and dioxins are generally declining or remaining unchanged across the Great Lakes, levels of several new and emerging toxic chemicals, such as dechlorane plus and hexabromocyclodoecane, appear to be increasing. These pollutants could represent future stressors to the Great Lakes ecosystem.

- By developing a binational process and designating the first set of CMCs under the Agreement, the Parties have met their commitments under Annex 3 for identifying CMCs. They have also have made some progress on meeting commitments related to targeting CMCs for action and coordination on science priorities.

- There are concerns with some of the procedures and processes used to identify CMCs and with some of the initial efforts related to targeting those CMCs for action through the Binational Strategy development process. Concerns include the need for greater transparency in decision making and more effective engagement of stakeholders and the public. In addition, lessons learned from previous efforts and initiatives need to be considered and incorporated into current and future efforts.

3.4.8 References

Abbasi, G, Diamond, M., Soehl, A., Murray, M., 2014. Great Lakes PBDE reduction project summary paper No. 1: PBDE product inventory. Great Lakes Commission.

CGLI, 2014a.August 11, 2014 Letter from Council of Great Lakes Industries to Annex 3 Sub-Committee Co-Chairs. Accessed at: http://cgli.org/wp-content/uploads/2013/11/CGLI-Letter-to-EC3-Co-chairs-8-11-2014.pdf

CGLI, 2014b.August 19, 2014 Letter from the Council of Great Lakes Industries to the Great Lakes Executive Committee Co-Chairs. Accessed at: http://cgli.org/wp-

content/uploads/2013/11/CGLI-Letter-to-GLEC-co-chairs-regarding-Annex-3-process_081914-signed.pdf

CGLI, 2015. August, 27, 2015 Letter from the Council of Great Lakes Industries to the GLWQA Annex 3 Sub-Committee Co-Chairs. Accessed at: http://cgli.org/wp-content/uploads/2013/09/August-28-2015-CGLI-CMC-Process-Letter-to-Annex-3-Co-leads-and-GLEC_082715_final.pdf

Duncan Bury Consulting, 2015. Polybrominated Diphenyl Ethers in the Great Lakes Basin.Final Report.Submitted to the International Joint Commission – Great Lakes Water Quality Board. October 30, 2015. 118pp.

ENGO, 2015a. June 3, 2015 Letter from Environmental Non-Government Organizations to the GLWQA Annex 3 Co-Chairs. Accessed at: http://www.cela.ca/sites/cela.ca/files/June%203%202015%20%20NGO%20comments%20to%20Binational%20Summaries%20with%20NGO%20support%20Final.pdf

ENGO, 2015b.June 20, 2015 Letter from Environmental Non-Government Organizations to the Great Lakes Executive Committee Co-Chairs. Accessed at: http://www.cela.ca/sites/cela.ca/files/NGOletterGLECAnnex3recommendations.pdf

EPA2016.Open Lakes Trend Monitoring: Mercury, http://www3.epa.gov/greatlakes/monitoring/fish/mercury.html, last updated February 22, 2016.

Fuller, K., Shear, H., Wittig, J., 1995. The Great Lakes: An Environmental Atlas and Resource Book. Environment Canada and the U.S. Environmental Protection Agency.pp. 46.

Great Lakes Public Forum, 2016.State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. Available at https://binational.net/2016/11/25/glpf-fpgl-2016-presentations-videos/

International Joint Commission, 2014.Great Lakes Ecosystem Indicators Project Report. June 2014. pp. 63.

International Joint Commission, 2015a.Backgrounder on Polybrominated Diphenyl Ethers.Final Report. August 10, 2015.

International Joint Commission, 2015b.Atmospheric Deposition of Mercury in the Great Lakes Basin. Pp. XX.

International Joint Commission, 2016.Polybrominated Diphenyl Ethers (PBDEs) in the Great Lakes Basin: Reducing Risks to Human Health and the Environment. A Report of the International Joint Commission. September 2016. http://www.ijc.org/files/publications/Polybrominated_Diphenyl_Ethers_Great_Lakes_EN.PDF

Letcher, R.J. and Chu, S., 2010. High-Sensitivity Method for Determination of tetrabromobisphenol-S and Tetrabromobisphenol-A Derivative Flame Retardants in Great Lakes Herring Gull Eggs by Liquid Chromatography-Atmospheric Pressure Photoionization-Tandem Mass Spectrometry. Environmental Science & Technology. 44(22), 8615-8621.

OECD, 2001.Extended User Responsibility: A Guidance Manual for Governments.pp. 9.

Research Coordination Committee (RCC).Identifying future improvements to Great Lakes ecosystem and human health indicators.http://www.ijc.org/files/publications/SAB-RCC_indicators_report.pdf

US and Canada, 2012.Great Lakes Water Quality Agreement. Protocol Amending the Agreement Between the United States of America and Canada on Great Lakes Water Quality, 1978, as Amended on October 16, 1983 and on November 18,1987. Signed September 7, 2012.

US and Canada 2013a.Canada-US Great Lakes Water Quality Agreement. Annex 3 Chemicals of Mutual Concern Sub-Committee. Proposed Work Plan for 2013/2016. September 19, 2013.

US and Canada, 2013b.Proposed Binational Process for Recommending Chemicals of Mutual Concern (CMCs) Presentation. Presented at the 1st Meeting of the Annex 3 Extended Sub-Committee on November 6, 2013.

US and Canada 2014.Great Lakes Water Quality Agreement, Annex 3 Chemicals of Mutual Concern (CMCs) Sub-Committee to the Great Lakes Executive Committee (GLEC).Terms of Reference. March 7, 2014 (Revised June 2nd, 2014). Accessed at: https://binational.net//wp-content/uploads/2014/01/Annex-3-Chemicals-of-Mutual-Concern-Subcommittee-TOR-revised-2014-06-02-doc.pdf

US and Canada, 2014a.2014-2016 Great Lakes Binational Priorities for Science and Action. March 10, 2014. Accessed at: https://binational.net/2014/03/20/psa-pasa-2014/

US and Canada, 2015a.EC/EPA Evaluation of the 1st Identification Task Team (ITT) Process. Annex 3 Extended Sub-Committee Meeting, November 19, 2015.

US and Canada, 2015b.Analysis of the Key Results of the Identification Task Team Evaluations. Annex 3 Extended Sub-Committee Meeting, November 19, 2015.

US and Canada, 2015c.Roles and Responsibilities for Developing Binational Strategies. Annex 3 Extended Sub-Committee Meeting, November 19, 2015.

US and Canada, 2015d. Annex 3 Subcommittee Recommendations On the Designation of Chemicals of Mutual Concern (CMC). Presented to the GLEC on June 24, 2015.

US and Canada, 2016.Progress Report of the Parties.

3.5 Wetlands and Other Habitats

This section reviews and assesses progress toward achieving General Objective 5 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 5 states that the waters of the Great Lakes should "support healthy and productive wetlands and other habitats to sustain resilient populations of native species."

The assessment also reviews supplemental information from the other management programs and activities carried out by governments, local governmental agencies and non-governmental organizations in Canada and the United States.

3.5.1 Background

The GLWQA charges the governments of Canada and the United States with achieving progress toward supporting healthy and productive wetlands and other habitats to sustain resilient populations of native species in the Great Lakes. Since 2013, the Canadian and US governments have been implementing measures that are specifically stated in the GLWQA Habitat and Species Annex (Annex 7) through "conserving, protecting, maintaining and enhancing the resilience of native species and their habitat, as well as by supporting essential ecosystem services" (GLWQA 2012).

The Great Lakes consist of more than 121,406 hectares (300,000 acres) of coastal wetlands, 22,925 km^3 (5,500 $mile^3$) water volume, 246,049 km^2 (95,000 $mile^2$) water surface area, and 16,431 km (10,210 mile) of shoreline. These features provide critically important habitats for native insects, reptiles, amphibians, fish, waterfowl, water birds, mammals and plants. Coastal wetlands play an essential role in maintaining the health of the Great Lakes aquatic ecosystem in improving water quality by filtering pollutants and sediment, and storing and cycling nutrients and organic material from land into the aquatic food web. Although healthy wetlands have always provided essential functions to support thriving plant and animal communities, their value has not always been appreciated. Other habitats (e.g., non-wetland shoreline ecosystems, and coastal tributaries) and habitat features (e.g., connectivity to Great Lakes tributaries, coastal shoreline characteristics, lake substrates composition, water current movement and energy, and water quality and quantity) are also critically important to aquatic lives, ecosystem function and human uses of the Great Lakes.

In addition, the Great Lakes are home to numerous native fish species. Some of these species, such as lake trout, white fish, walleye, yellow perch, largemouth bass, muskellunge, northern pike and sturgeon, are socially and/or economically important. Other smaller native fish species (e.g. minnows, darters) contribute to the biodiversity of the system and some of these serve as prey for their predators, and hence are important in maintaining ecosystem function and process. In turn, those small fish are supported by invertebrates such as benthos, zooplankton and ultimately by phytoplankton. Thus, the flow of energy from sunlight and minerals to primary producers (phytoplankton and other algae), to herbivores, and then to secondary consumers (invertebrates and fish) ultimately supports the predatory species that are often valued for fishing.

The biological food web formed by the interactions among plankton and benthos, preyfish, and top predators and supported by a variety of habitats have been dramatically altered by natural and man-made processes, such as food web alteration by invasive species and fish migration barriers from dams. Other human activities in the watersheds and the lakes have led to chemical pollution and excessive nutrient input, which have also impacted native species. Recognizing the importance of native species and human disturbance to the system, it is necessary not only to know whether the wetlands and other habitats are improving but also to know whether the populations of native species supported by them are improving.

3.5.2 Assessment of indicators

For assessing progress toward achieving Objective 5 and the Habitat and Species Annex objective of the GLWQA in SOGL 2016, the Parties used seven sub-indicators (Table 3.5) to measure coastal wetland and other habitat and nine sub-indicators (Table 3.6) to measure food web status and trends. Each sub-indicator was assessed and reported collaboratively by multiple authors using data from multiple sources. The SOGL assessment of this objective took over one-year and involved more than 30 Great Lakes regional experts from government agencies and non-government organizations.

1. Assessment of coastal wetland indicators

The trends in health of coastal wetlands and other habitats can be assessed using two indicators, one on coastal wetlands and another on the food web. For the current assessment triennial cycle, the governments of Canada and the US (the Parties) used seven sub-indicators to assess status and trends for coastal wetlands by using sub-indicators for amphibians, birds, fish, invertebrates, plants, extent and composition of wetlands and aquatic habitat connectivity within coastal wetlands (GLPF, 2016).

The Parties concluded that the overall health of coastal wetlands is improving, though no individual lake assessments have been conducted for three sub-indicators and aquatic habitat connectivity is the only sub-indicator showing improvement for all five lakes (Table 3.5).

2. Assessment of food web indicators

The health trends of the food web can be measured using nine sub-indicators to assess the biological composition, function and process of the ecosystem. Those nine sub-indicators are phytoplankton, zooplankton, benthos, *Diporeia*, preyfish, lake trout, walleye, lake sturgeon and fish-eating and colonial-nesting waterbirds (GLPF, 2016).

The Parties concluded that the overall trend of aquatic native species is unchanging although the lower food-web component sub-indicators (phytoplankton and *Diporeia*) show a deteriorating trend. Lake sturgeon populations are improving in all five lakes (Tables 3.5.1 and 3.5.2).

Table 3.5.1 Summary of trends for the seven coastal wetlands and connectivity indicators by the Parties

Habitat and Species

Status: GOOD | FAIR | POOR

SUB-INDICATORS	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Coastal Wetland Fish	No lake was assessed separately Overall Great Lakes basin assessment is **Fair** and **Improving**				
Coastal Wetlands: Extent an Composition	No lake was assessed separately Overall Great Lakes basin assessment is **Undetermined**				
Coastal Wetland Invertebrates	No lake was assessed separately Overall Great Lakes basin assessment is **Fair** and **Deteriorating**				
Coastal Wetland Amphibians	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Coastal Wetland Birds	Unchanging	Unchanging	Unchanging	Deteriorating	Improving
Coastal Wetland Plants	Undetermined	Undetermined	Deteriorating	Deteriorating	Unchanging
Aquatic Habitat Connectivity	Improving	Improving	Improving	Improving	Improving

(Source: GLPF 2016)

Table 3.5.2
Summary of trends for the nine food web sub-indicators

Habitat and Species

Status: GOOD | FAIR | POOR

SUB-INDICATORS	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Zooplankton	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Benthos	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging
Diporeia	Unchanging	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Lake Trout	Unchanging	Improving	Improving	Improving	Improving
Phytoplankton	Unchanging	Deteriorating	Deteriorating	Deteriorating	Unchanging
Preyfish	Unchanging	Deteriorating	Undetermined	Improving	Deteriorating
Walleye	Unchanging	Unchanging	Unchanging	Improving	Unchanging
Lake Sturgeon	Improving	Improving	Improving	Improving	Improving
Fish Eating and Colonial Nesting Birds	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging

(Source: GLPF, 2016)

3. Strengthening future assessments

The Parties' PROP report is comprehensive and reflective of available data, and it extends its appreciation to those who have contributed to this effort. The IJC, with the support of its Science Advisory Board, also recognizes that the following areas can be improved in the assessment of wetlands and other habitats and populations of native species.

Data collection strategy

For coastal wetland indicators, data for assessing wetland amphibians, birds, fish, invertebrates, and wetland plants are mainly from one sampling program that has been funded by the Great Lakes Restoration Initiative (GLRI). The first five-year data collection effort (2011-2015) sampled almost all coastal wetlands that are ≥4 hectares (9.88 acres) with a surface water connection to the Great Lakes (Uzarski et al., 2016) and cost $10 million. The second five-year data collection effort (2016-2020) with another $10 million is underway. It will enable the majority of the wetlands to be resampled. The SOGL also used data that are not collected by established monitoring programs, such as data collected by University of Minnesota Duluth's Great Lakes Environmental Indicator project funded by GLRI and wetland bird data from Canadian's Great Lakes Marsh Monitoring Program.

As a result, there is no individual lake status assessment for three of the sub-indicators and no trend assessment for one sub-indicator, because most of the wetlands were sampled systematically only once and the data from other sources include only some of the wetland sub-indicators or only limited temporal scales. The data available for coastal wetland extent and composition assessment are the data generated in 2004 by the Great Lakes Coastal Wetlands Consortium. Since then the data have not been updated completely. Hence, the "current areal extent and composition of coastal wetlands across the entire Great Lakes basin cannot be reported" GLPF, 2016). Therefore, an improved wetland data collection strategy is needed to ensure the detection of trends of this sub-indicator.

For the benthic and planktonic food web sub-indicators, data for phytoplankton, zooplankton, benthos, and *Diporeia*are mainly from the Great Lakes Open Water Monitoring Program and the Cooperative Science and Monitoring Initiative. Since those are long-term programs, the present monitoring programs for open water are adequate to detect trends of those sub-indicators. However, it would be helpful if assessment of those sub-indicators could be extended into nearshore areas. This effort would require a systematic data collection by EPA's Office of Waters National Coastal Condition Assessment and the Cooperative Science and Monitoring Initiative programs in those areas. The IJC has discussed the importance of protecting the nearshore in its 15th Biennial Report of Great Lakes Water Quality (IJC, 2011) and the Science Advisory Board, Research Coordination Committee (RCC) recently identified this recommendation as one of five priority areas (RCC, 2016).

For the fish food web indicators, data for the assessment of preyfish, walleye, lake trout, and sturgeon sub-indicators are derived from the federal and state/provincial fish stock assessment programs and records of recreational and commercial harvests. These data are from long-term sampling for the Great Lakes fisheries management, which are adequate for detecting trends of

those indicators. However, the assessment of those indicators is largely qualitative due to the limited spatial coverage of data. For example, the trend of walleye sub-indicator for Lake Michigan is assessed only using angler harvest data from Green Bay, which largely reflects anglers' use of the fishery and is influenced by various factors that may not be necessarily related to fish population abundance and recruitment status. Hence, it would be helpful to use standardized lake-wide models to calculate adult population abundance and abundance at age and derive estimates of recruitment from the fish stock assessment program data for walleye and lake trout sub-indicators as recommended in the IJC's Great Lakes Ecosystem Indicator Report (IJC, 2014a).

Data management and sharing

In previous State of the Great Lakes reports (e.g., SOL 2011), each sub-indicator has been assessed and reported by one or several co-authors using data from multiple sources. Although this is the best (and possibly the only) practical way to handle the assessment with such a large magnitude of spatial coverage and time constraints, a couple aspects of data collection, management and sharing could be improved (RCC 2016).

First, there is a need to standardize how each sub-indicator is assessed and what data are used. Currently, the author(s) of each sub-indicator makes this decision with the approval of the Parties' task team for each assessment cycle. In the past, some of the sub-indicator authors have changed among assessment years due to retirement or job changes, resulting in a change in assessment standard and data used. These changes can create inconsistency in assessing long-term trends, which may obscure the accuracy of lake health status assessment.

Second, there is a need to synthesize the data that have been used for the past assessments and to maintain the summarized data for each sub-indicator in a centralized, publicly accessible location. Presently, only the sub-indicator authors know where the data come from and how they are synthesized, and have access to such summarized data. Due to the change of some of the sub-indicator authors, the continuity of detecting consistent trends may be jeopardized. Additionally, maintaining the summarized data for each sub-indicator in a centralized publicly accessible location will increase the assessment creditability and transparency, as many of sub-indicator assessments in the SOGL do not have details on the data sources and how the data have been synthesized and used.

Indicator reporting

The 16 sub-indicators used for the assessment of this General Objective and the Habitat and Species Annex are outstanding. For the six wetland sub-indicators, a single wetland indicator may be more informative and more easily communicated than six individual sub-indicators. It is also critically important to update the data needed for assessing the extent and composition of coastal wetlands. With the development of satellite and LiDAR technology and data availability, it is feasible to develop an improved baseline of wetland extent and composition that can be repeated consistently through time. Additionally, since *Diporeia* a rice-size amphipod and keystone species that forms the base of the food have almost vanished, another key food web measure could be added as an additional sub-indicator. *Mysis* could be added using data that

have been collected and summarized by the Great Lakes Open Water Monitoring Program since 2002. The current SOGL report does not include nutrient and food web sub-indicators in the nearshore. It would be a great improvement if those sub-indicators are monitored and reported since the conditions of those sub-indicators are very different between nearshore and offshore for much of the lakes (RCC 2016).

3.5.3 Assessment of Annex implementation

The GLWQA Habitat and Species Annex mandates the Parties to undertake the following initiatives:

- conduct a baseline survey of the existing habitat against which to establish a Great Lakes Basin Ecosystem target of net habitat gain and measure future progress;
- complete the development and begin implementation of lake-wide habitat and species protection and restoration conservation strategies that use adaptive management approaches, identify conservation mechanisms, and address the most significant stressors to native species and habitat;
- assess gaps in current binational and domestic programs and initiatives to conserve, protect, maintain, restore and enhance native species and habitat as a first step toward the development of a binational framework for prioritizing activities;
- facilitate binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat;
- renew and strengthen binational collaborative actions to conserve, protect, maintain, restore and enhance native species and habitat by identifying protected areas, conservation easements and other conservation mechanisms to recover populations of species at risk and to achieve the target of net habitat gain; and
- increase awareness of native species and habitat and the methods to protect, conserve, maintain, restore and enhance their resilience.

Since 2013, the Parties have established the Habitat and Species Annex Subcommittee and Task Teams to address the above tasks. The most significant achievements during the past three years are the development and implementation of lake-wide habitat and species protection and restoration conservation strategies (Strategies) in each lake and establishment of a consistent basin-wide approach to survey Great Lakes habitat and measure net habitat gain (Assessment) (PROP, 2016).

The Strategies, which have been developed for all five lakes as of 2015, assess the status and threats to lake-wide biodiversity and recommend conservation priority for native species and their habitat. Each strategy serves as a tool to foster and guide a shared implementation of priority conservation actions among federal, state, provincial, tribal, academic, municipal and watershed management agencies (PROP, 2016). Numerous government and non-government efforts are in the process of planning, applying and implementing the Strategies at local or sub-basin scales, and therefore have met the mandate of the GLWQA during this period.

The Assessment was developed by the Annex Task Team with support from experts and partners through a series of workshops, meetings and webinars (BATT, 2016). The Assessment proposed to quantify the quantity and condition of existing Great Lakes habitat to allow for future determination of habitat change. The Assessment clearly defines that habitat gain can be measured by: a spatial increase in "priority habitats"for communities of native fish and wildlife species; improvement in habitat condition and functionality of habitat types from severely degraded and not functional to degraded but functional and then to high quality and highly functional; and maintaining the condition of high quality habitat.

Three phases are proposed by the Assessment. Phase 1, to delineate the Great Lakes and connecting rivers into units defined by ecosystem type, based on physical factors that form the basis of habitat structure and change at a relatively slow rate (e.g., depth, fetch, currents). Phase 2, to assess the condition of each unit using habitat factors that are influenced by disturbance, and thus change more rapidly (e.g., substrate, water quality). Finally, phase 3, will use biological information to confirm the condition status of the units. This can only be accomplished in areas where biological data are available.

The Assessment provides a scientifically sound and operational definition to measure habitat gain and identifies the specific processes for its implementation. However, the Assessment is relatively weak on three key elements that are critical for the successful implementation. The Assessment needs standardized and consistent methods and criteria for spatial unit delineation and classification. Although the rationale for using physical factors to delineate and classify spatial units is clear, the methods for delineating the hierarchical spatial units and developing the classification have not yet been identified.

In addition, the Assessment needs to emphasize the importance of standardized and consistent data collection through time in order to ensure that future measurements can be compared to the baseline data. Data consistency used for establishing the baseline and for measuring the future changes will ensure the accuracy of habitat gain reporting. The programs proposed to supply the needed data include the USEPA-led National Coastal Condition Assessment (NCCA) of US coastal areas of the Great Lakes (water quality data), Long-Term Monitoring (LTM) of water quality on Canadian Great Lakes coastal water by the Ontario Ministry of the Environment and Climate Change, the binational Cooperative Science and Monitoring Initiative and the Great Lakes Fisheries Commission lower trophic lake monitoring programs in open water areas. To meet the need of implementing the approach, coordination and sampling method harmonization between NCCA and LTM are needed because they are clearly domestic focused programs.

The Assessment needs an effective data management system and coordination mechanism. The Assessment recognizes that the baseline survey will use information from many sources and will require a mechanism for data coordination; data sharing amongst partners will be facilitated by the "open data" initiatives by Great Lakes partner agencies, organizations and communities. However, no effective data management system and coordination mechanism are proposed to specifically meet the needs of the approach. There is a clear need to store the data and information used to develop baseline conditions, along with all subsequent data, in a strategic, consistent, and accessible manner and system that accommodates future assessment cycles

through time. This system should be managed by a reliable and unbiased entity supported by stable funding.

3.5.4 Assessment of binational programs

Achieving the GLWQA objectives requires binational collaborative partnerships and programs among federal, state and provincial, tribal, First Nation, municipal, watershed management agencies and non-government organizations. Given the large geographic scale of the Great Lakes and their social and ecological importance, numerous collaborative partnerships and program are ongoing, many of which directly support Objective 5. Table 3.5.3 provides examples of some bi-national and domestic basin-wide partnerships that have played key roles in providing resources, coordinating management actions and developing cohesive strategies and policies for addressing this objective.

Those basin-wide binational collaborative partnerships and programs have provided essential resources, technical support, and synergy to the implementation actions of local partnerships. Sections below, using examples, illustrate the contributions of such programs to Objective 5.

Table 3.5.3
Examples of basin-wide government and non-government programs and partnerships that have contributed to the protection, enhancement and restoration of Great Lakes habitats

Partnerships	Year Established	Countries
Action Plan for Clean Water (http://www.tbs-sct.gc.ca/hidb-bdih/initiative-eng.aspx?Org=0&Hi=30)	2007	Canada
Council of Great Lakes Governors (http://www.cglslgp.org/)	1997	Canada and US
Great Lake Action Plan (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=DF30B51A-1)	1989	Canada
Great Lakes Basin Fish Habitat Partnership (http://greatlakes.fishhabitat.org/about)	2001	US
Great Lakes Marsh Monitoring Program http://www.birdscanada.org/volunteer/glmmp/	1995	Canada
Great Lakes Nutrient Initiative (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=4FF37866-1)	2012	Canada
Great Lakes Restoration Initiative (https://www.glri.us/)	2010	US
Great Lakes State Wildlife Action Plans (http://teaming.com/state-wildlife-action-plans-swaps)	2005	US
National Wetland Conservation Fund (https://www.ec.gc.ca/financement-funding/default.asp?lang=En&n=923047A0-1#_09)	2014	Canada
North American Waterbird Conservation Plan (http://www.waterbirdconservation.org/nawcp.html)	2002	US
North American Waterfowl Management Plan (https://www.fws.gov/birds/management/bird-management-plans/north-american-waterfowl-management-plan.php)	1986	Canada and US
Ontario's Great Lakes Strategy 2016 (**https://www.ontario.ca/page/ontarios-great-lakes-strategy-2016-progress-report#section-5**)	2016	Canada

Partners in Flight North American Landbird Conservation Plan (**http://www.partnersinflight.org/cont_plan/default.htm**)	2004	Canada and US
Sustain Our Great Lakes (http://www.sustainourgreatlakes.org/)	2004	Canada and US
US Shorebird Conservation Plan (http://www.shorebirdplan.org/)	2000	US

1. US Great Lakes Restoration Initiative

A large domestic program for the Great Lakes in United States is the Great Lakes Restoration Initiative (USEPA, 2015). This program has provided near $300 million annually to focus on the areas of toxic substances and Areas of Concern, invasive species, nearshore health and nonpoint source pollution, habitat and wildlife protection and restoration, accountability, education, monitoring, evaluation, communication and partnerships each year from 2010-2014 (Table 3.5.4). This program has funded 191 projects in the US watersheds and the five lakes themselves, conducted by 46 different agencies and organizations throughout the Great Lakes (Figure 3.5.1). This program has contributed significantly to the progress made toward achieving Objective 5.

Table 3.5.4
Great Lakes Restoration Initiative Fiscal Year 2010-2014 focus area allocations (as of October 2014)
(Source: Great Lakes Restoration Initiative Report to Congress and the President Fiscal Years 2015)

Focus Area	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Toxic Substances and Areas of Concern	$146,946,000	$100,400,000	$107,500,000	$111,000,000	$106,000,000
Invasive Species	$60,265,000	$57,500,000	$56,900,000	$45,000,000	$57,000,000
Nearshore Health and Nonpoint Source Pollution	$97,331,000	$49,250,000	$54,300,000	$45,000,000	$56,000,000
Habitat and Wildlife Protection and Restoration	$105,262,000	$63,000,000	$57,200,000	$65,500,00	$60,500,000
Accountability, Education, Monitoring, Evaluation, Communication and Partnerships	$65,196,000	$29,250,000	$23,600,000	$17,000,000	$20,500,000
TOTAL	$475,000,000	$299,400,000	$299,500,000[1]	$283,500,000[2]	$300,000,000

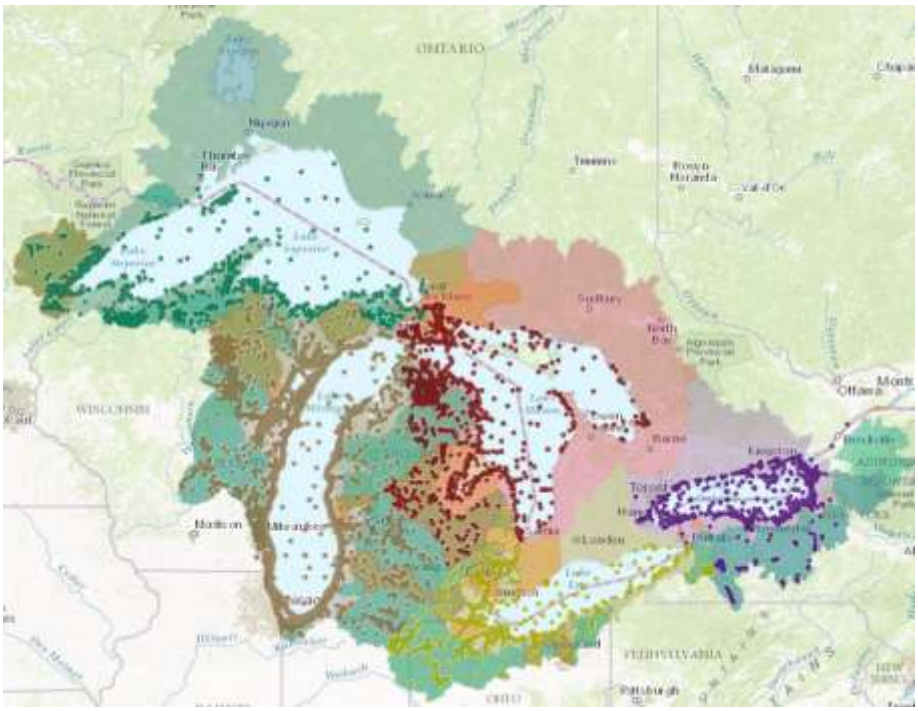

Figure 3.5.1
The 191 Great Lakes Restoration Initiative funded projects that represent 46 different agencies and organizations throughout the Great Lakes

(Source: http://www.glri.us/)

2. Local partnerships

In addition to basin-wide or lake-wide programs, localized partnership programs are effectively making progress to achieve the objective. These programs have received funding from federal, state, provincial and non-government sources, and have proven effective at leveraging existing resources. There are many such location-based partnership programs that provide long-term targeted regional protection and restoration plans and actions. Examples include the Saginaw Bay Coastal Initiative (SBCI) and the St. Clair-Detroit River System Initiative.

The SBCI, established in 2006, brought together groups of interested people, businesses and local governments collaborating with state and federal agencies to improve Saginaw Bay. Collaborating with the federal and state governments' Areas of Concern programs, Saginaw Bay Watershed Initiative Network, Adaptive Integrated Framework and other partnerships, SBCI and its partners have protected 60 percent of the targeted coastal wetlands through public ownership and permanent conservation easements and removed the "loss of fish and wildlife habitat beneficial use impairment" for the Saginaw River/Bay Areas of Concern (Ducks Unlimited, 2013, MOGL, 2014) (Figure 3.5.2). As a result, the fish population in Saginaw Bay has improved significantly.

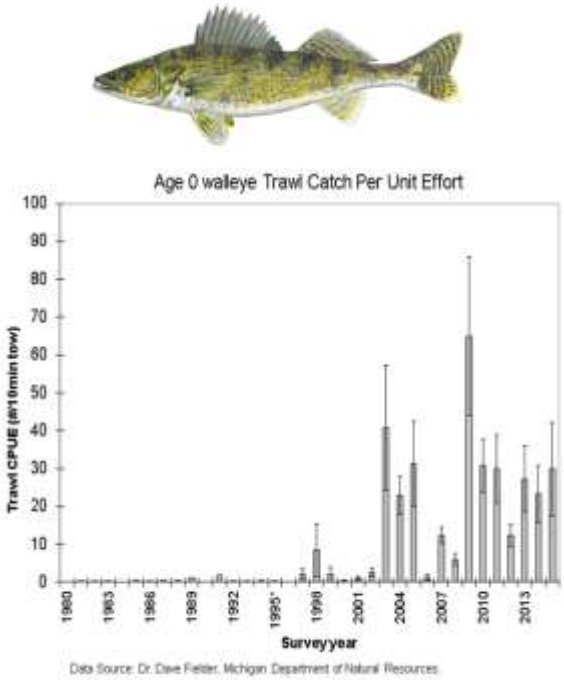

Figure 3.5.2
Map of Currently Protected Coastal Wetlands in the Saginaw Bay (left) area and walleye recruitment improvement at Saginaw Bay (right)

(Source, left: Refining and Updating the Wetland Protection Status in the Saginaw Bay Coastal Plain, Ducks Unlimited, 2013); (Source, right: Fielder, D. G., and M. V. Thomas, 2014. Status and Trends of the Fish Community of Saginaw Bay, Lake Huron 2005–2011. Michigan Department of Natural Resources (MDNR), Fisheries Report 03, and MDNR unpublished data).

The St. Clair-Detroit River System Initiative is an example of a binational local collaborative partnership with more than 30 organizations, including US and Canadian natural resource-related agencies, Tribes/First Nations, units of local government, industry and university partners, non-profit organizations and interested citizens. The partners share a common vision of restoring portions of southern Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River and western Lake Erie to a thriving ecosystem with science-based management and broad social support that provides environmental services for the region and the Great Lakes basin. Working with other partnerships, the St. Clair-Detroit River System Initiative has conducted fish spawning habitat restoration and developed a strategic restoration plan to be carried out into the future years (Figure 3.5.3).

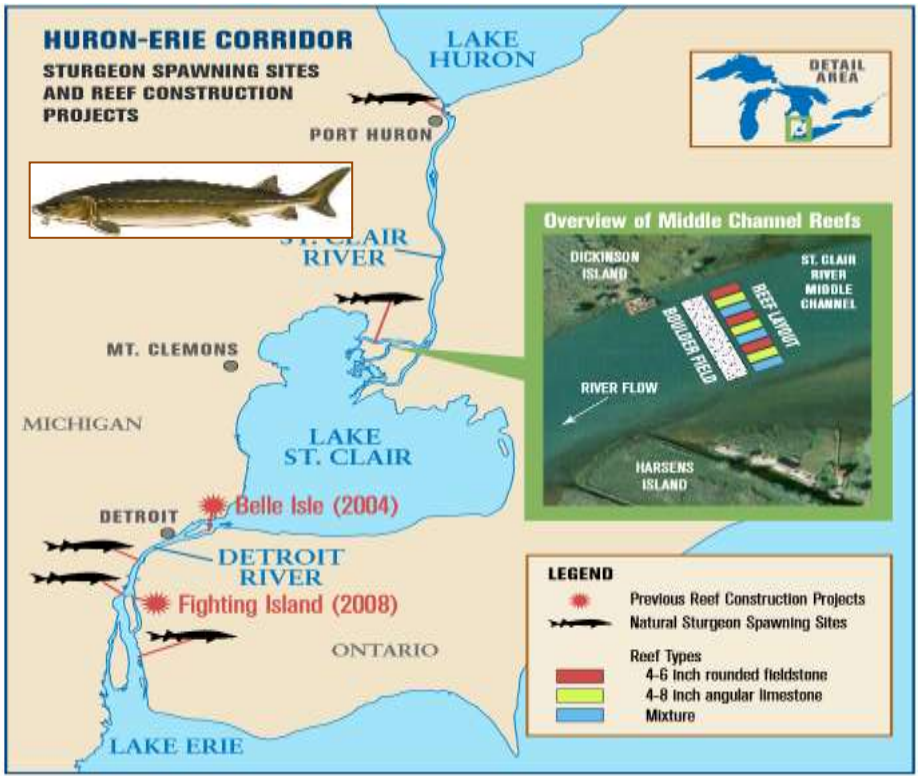

Figure 3.5.3
Huron-Erie Corridor Sturgeon spawning sites and Reef Construction projects
(Source: http://www.habitat.noaa.gov/pdf/restoring_fish_habitat_in_the_stclair_river.pdf)

The international waters that connect Lake Huron to Lake Erie provide habitat for more than 65 species of fish. The region, which includes the Ottawa National Wildlife Refuge and the Detroit International Wildlife Refuge, is part of the central Great Lakes flyway for millions of migratory waterfowl. It contains some of the largest and most diverse wetlands remaining in the region. The partners have implemented a plan to increase over eight ha (20 acres) of fish spawning habitat. The pre- and post-construction monitoring demonstrated an immediate response by more than 14 native fish species, including spawning by the commercially important lake whitefish and the Michigan and Ontario listed threatened species lake sturgeon (Manny et al., 2015).

3. The Lake Ontario-St. Lawrence River Plan 2014

Water level change has a strong influence on Great Lakes coastal wetlands and other habitats. It is difficult, if not impossible, to protect and restore Great Lakes wetlands and other habitat without restoring water levels to their near-natural regime.

The patterns of water-level change of the Lake Ontario-St. Lawrence River system are the driving force that determines the overall diversity and condition of wetland plant communities and the habitats they provide for a multitude of invertebrates, amphibians, reptiles, fish, birds and mammals, imparting a direct linkage to the social and economic wellbeing in the region. After 14 years of

scientific study and public engagement, the IJC recommended the Lake Ontario-St. Lawrence River Plan 2014 (Plan) to the governments of Canada and US in 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows (IJC, 2014b) (Figure 3.5.4).

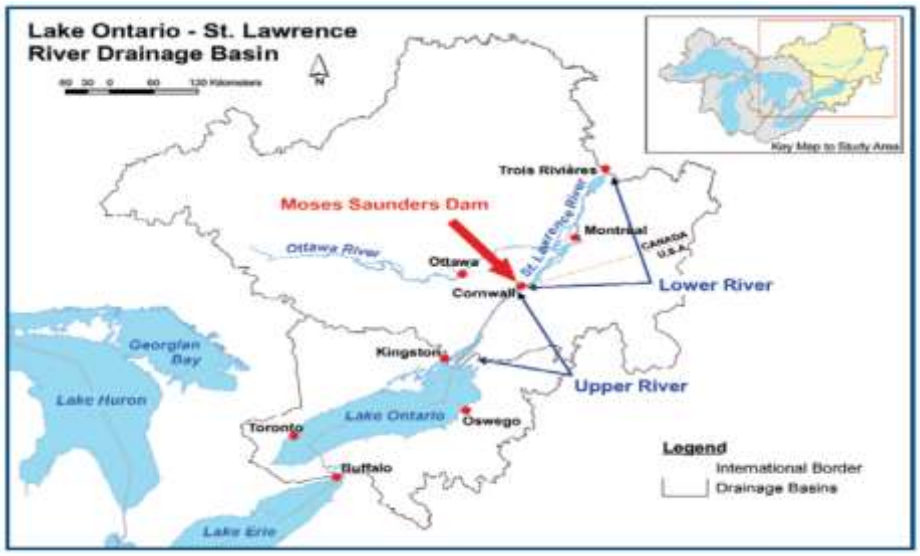

Figure 3.5.4
Lake Ontario-St. Lawrence river drainage basin to show the impacted area of the Plan

(Source: IJC, 2014)

The plan is a result of extensive scientific studies and public engagement supported by more than $20 million provided by the Governments of Canada and the United States. It is expected that the Plan will significantly improve the health of Lake Ontario and the upper St. Lawrence River system by improving the diversity and function of the coastal wetlands that cover 26,000 hectares (64,247 acres), filter runoff, reduce erosion and provide habitat for hundreds of fish and wildlife species. The plan was developed based not only on the analysis of environmental factors, but also on how water level regulation may affect basin interests of coastal property, recreational boating, commercial shipping, hydropower and other social-economic factors. The plan was based on: the analyses of 32 environmental performance indicators that are sensitive to water levels and representative of ecosystem health; evaluation of potential effects to property using a parcel database of buildings and shore protection structures, building elevations, 40 years of hourly wave height and direction data and historical erosion rates; and estimation of potential effects to recreational boating using an inventory of all marinas and launch ramps, as well as surveys of boaters and charter and tour boat operators.

The plan is designed to provide more natural variations of water levels of Lake Ontario and the St. Lawrence River that are needed to restore ecosystem health. It will continue to moderate extreme high and low levels, better maintain system-wide levels for navigation, frequently extend the recreational boating season and slightly increase hydropower production. More year-to-year variation in water levels improves coastal wetland habitats to support highly valued recreational opportunities, filter polluted run-off and provide nurseries for fisheries and wildlife.

The Parties informed the IJC in December of 2016 that they concurred with Plan 2014. The IJC implemented the plan in January of 2017 and looks forward to it contributing significantly to the achievement of Objective 5.

4. Great Lakes Ecological Reserve System

As the Parties continue to facilitate collaborative partnerships, there are also opportunities for facilitating new binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat. This is in line with commitments in the Habitat and Species Annex of the GLWQA and the eventual achievement of the objective of supporting "healthy and productive wetlands and other habitats to sustain resilient populations and native species."

A potential further binational collaborative action would be to support the Great Lakes Ecological Reserve System (GLERS), which was proposed by the United States–Canada Great Lakes Islands Project to span international, state and provincial boundaries and to serve as a basin-wide system of ecological reserves to protect and restore Great Lakes habitat and biodiversity (Vigmostad, 2016).

GLERS focuses on the islands and coastal wetlands that are significant holders of species and habitats to maximize opportunities for biodiversity conservation. The GLERS is a way of connecting areas representing vital habitats to protect endangered, rare and threatened species. GLERS would enable the Parties to ensure a vibrant, biologically diverse, Great Lakes ecosystem over the long run.

GLERS would begin by linking managers of existing protected areas of biological diversity to address their specific species and habitat challenges. GLERS would be built manager-to-manager to address on-the-ground challenges shared by US and Canadian federal parks, conservation areas, refuges, sanctuaries, forests, recreation areas and other entities. An initial pilot project could link several Canadian and US federal managers, expanding over time to include the holdings of federal, state, provincial managers and non-governmental organizations.

Forexample,aconcerninLakeSuperioristheprotectionoflaketroutvariantsfoundamong IsleRoyale's450islands. Scientists couldinvestigatewhethersimilaroradditional laketrout variantsoccuramong the1,000 islandsintheLakeSuperiorNationalMarineConservationArea anddevelopajointmonitoringandmanagementplan.Themanagersmightdeterminethey neednewscientificstudies,additionalinventories,literaturereviewsor helpfromother expertstoidentifyandmanagelaketroutvariants.

The GLERS would ultimately create a virtual basin-wide ecological reserve network spanning national and agency boundaries, authorities and cultures. This will eventually lead to the protection of a percentage of the Great Lakes ecosystem that sustains the ecosystem function and biodiversity. GLERS could also inspire future Canadian National Marine Conservation Areas and US Great Lakes National Marine Sanctuaries to consider and plan for the conservation of habitat and species in addition to their other goals and authorities.

Governments are already taking actions to expand the range of protected Great Lakes freshwater and related terrestrial habitats. In Canada, the Lake Superior National Marine Conservation Area will

soon be recognized as one of the largest protected areas of fresh water in the world. Additional such designations in both US and Canadian waters could help in the achievement of this objective.

The use by GLERS of existing staff and budget resources and the creation of an information-sharing network are consistent with current government resource realities.

3.5.5 Section Summary

- Addressing the water quality objectives for such a complex and spatially extensive system as the Great Lakes presents serious challenges. Important progress has been made by the Parties on addressing Objective 5 and the Habitat and Species Annex objective identified by the GLWQA. Building on many years of experience, the Parties have made considerable effort to assess the status and trends of the health of the Great Lakes related to this objective and prepare useful SOGL information.

- The SOGL data that were presented at the GLPF (2016) show that the overall health of coastal wetlands is relatively stable. No individual lake assessments have been conducted for three sub-indicators and aquatic habitat connectivity is the only sub-indicator showing improvement for all five lakes. In addition, the overall trend of the food web is relatively stable with some sub-indicators improving and some deteriorating. The bottom food-web component sub-indicators (phytoplankton and Diporeia) show a deteriorating trend; lake sturgeon populations are improving in all five lakes.

- Data collection and management is a key challenge to strengthening future assessments of progress towards Objective 5 of the GLWQA. Weaknesses in the current approach relate to: a reliance on short-term monitoring programs, which are vulnerable to being discontinued; a lack of standardized assessment methods among authors; a lack of continuity and transparency in data collection; and a lack of coordination among various individuals and agencies responsible for data collection, analysis and reporting.

- Lake-wide habitat and species protection and restoration conservation strategiesestablished and implemented by the Parties have been an important achievement in support of Objective 5. In addition, the Parties have developed a consistent basin-wide approach to survey Great Lakes habitat and measure net habitat gain during the last three years. These achievements meet the mandate of Objective 5 and the Habitat and Species Annex objective of the GLWQA.

- The recent concurrence of the Parties with the IJC's Plan 2014 for the regulation of flows and levels in Lake Ontario and the St. Lawrence River has the potential to contribute significantly to the achievement of this objective.

- The Parties have facilitated a range of binational collaborative partnerships and programs in support of the GLWQA objectives and the Habitat and Species Annex along with domestic and local collaborative programs. These partnerships have engaged federal, state and provincial, tribal, First Nation, municipal, watershed management agencies and non-government organizations. New opportunities are emerging to promote and support new binational collaborative actions to reduce the loss of native species and habitat, recover populations of native

species at risk, and restore degraded habitat. One such initiative with great potential is the proposal to establish a basin-wide system of ecological reserves to protect and restore Great Lakes habitat and biodiversity.

3.5.6 References

BATT (Baseline Assessment Task Team), 2016.Conducting a Baseline Survey of Great Lakes Habitat.Assessing and Measuring Progress toward a Great Lakes Ecosystem Target of Net Habitat Gain Task Team Report.

Ducks Unlimited, 2013.Refining and Updating the Wetland Protection Status in the Saginaw Bay Coastal Plain. Final report submitted to NOAA Restoration Center.

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Available at https://binational.net/2016/09/28/prp-rep/

Great Lakes Public Forum. 2016. State of the Great Lakes. Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada.

GLWQA (Great Lakes Water Quality Agreement), 2012. Great Lakes Water Quality Agreement, protocol amending the agreement between Canada and the United States of America on Great Lakes Water quality , 1978, as amended on October 16, 1983, and on November 18, 1987, signed September 7, 2012, entered into force February 12, 2013.

IJC (International Joint Commission), 2011.Fifteenth Biennial Report on Great lakes Water Quality, International Joint Commissioner, Canada and the United States. Prepared pursuant to the Great Lakes Water Quality Agreement of 1978 for submission to the Governments of the United states and Canada and the State and Provincial Governments of the Great Lakes Basin.

IJC (International Joint Commission), 2014a.Great Lakes Ecosystem Indicator Report.*A report of the IJC priority assessment of progress towards restoring the Great Lakes, International Joint Commission* Canada and the United States.

IJC (International Joint Commission), 2014b. Lake Ontario-St. Lawrence River Plan 2014: Protecting Against Extreme Water Level, Restoring Wetlands and Preparing for Climate Change.

Manny, B.A., Roseman, E. F., Kennedy, G., Boase, J.C., Craig, J.M., Bennion, D.H., Read, J., Vaccaro, L., Chiotti, J., Drouin, R., Ellison, R., 2015. A scientific basis for restoring fish spawning habitat in the St. Clair and Detroit Rivers of the Laurentian Great Lakes.Restoration Ecology.23 (2), 149–156

MOGL (Michigan Office of the Great Lakes), 2014.Removal Recommendation Loss of Fish and Wildlife Habitat Beneficial Use Impairment Saginaw River/Bay Area of Concern. Document

submitted to USEPA to recommend the removal of BUI from the list of impairments in the Saginaw River/Bay AOC.

RCC (Research Coordination Committee), 2016.Future improvements to Great Lakes Indicators. Prepared for the International Joint Commission's Science Advisory Board- Research Coordination Committee http://ijc.org/files/publications/SAB-RCC_indicators_report.pdf

SOLEC 2014.Technical Report.State of the Great Lakes 2011.Environment Canada and U.S. Environmental Protection Agency.Toxic Chemical Concentrations.http://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdfAccessed September 30, 2016.

USEPA (United States Environmental Protection Agency), 2015.Great Lakes Restoration Initiative Report to Congress and the President, Fiscal Years 2010–2014.https://www.epa.gov/sites/production/files/2015-09/documents/21050720-report_to_congress-2.pdf

Uzarski, D.G., Brady, V.J., Cooper, M.J., 2016. GLIC: Implementing Great Lakes Coastal Wetland Monitoring Semiannual Progress Report, October 1, 2015 – March 31, 2016, prepared for: U.S. EPA GLNPO (G-17J) 77 W. Jackson Blvd. Chicago, IL 60604-3590, Contract/WA/Grant No./Project Identifier: GL-00E00612-0

Vigmostad, K. E., 2016. Letter to the Honorable Lana Pollack and Gordon Walker, May 23, 2016. IJC Archives.Washington, DC and Ottawa, ON.

3.6 Review and Assessment of General Objective 6: Nutrients

3.6.1 Introduction

1. Purpose

This section reviews and assesses progress toward achieving General Objective 6 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 6 states that the waters of the Great Lakes should "be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem." The section presents an assessment of programs and other measures in support of this objective.

This assessment is based largely on the review of:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF, 2016);
- the **Progress Report of the Parties** (Governments of the United States and Canada, 2016); and
- implementation measures undertaken in support of the GLWQA Annex 4: *Nutrients*.

2. Background

Nutrient management was a success story under the 1972 and 1978 iterations of the GLWQA. Total phosphorus loads and the occurrence of algal blooms waned, particularly in Lake Erie, and target loads were reached by the mid-1980s. However, phosphorous concentrations began increasing in the mid-1990s and nuisance and harmful algal blooms (HABs) have proliferated.

Nuisance algal blooms, particularly of a type of algae called *Cladophora*, currently foul some beaches in four of the five Great Lakes. These blooms interfere with recreational beach and water uses and impair aesthetic values (ECCC and USEPA, 2016). Some species of algae can be harmful to human and ecosystem health. HABs often are composed of microorganisms known as cyanobacteria, some of which produce toxins that can cause adverse health effects in humans and animals through the contamination of waterways used for recreational purposes and as drinking water supplies. Cyanobacteria possess characteristics of algae, chlorophyll-a and oxygenic photosynthesis (USEPA, 2016). The primary toxins of concern associated with cyanobacteria in the Great Lakes are microcystin (more than 80 congeners,) saxatoxin, anatoxin a, and cylindrospermopsin (USEPA, 2016). HABs have surged in the western basin of Lake Erie and are occurring in embayments in lakes Michigan, Huron and Ontario (ECCC and USEPA, 2016).

Excessive algal growth can result in hypoxia, or low oxygen content in the bottom layer of some highly productive regions of the Great Lakes, including the central basin of Lake Erie and in Green Bay in Lake Michigan (ECCC and USEPA, 2016). During the summer, excessive nutrient loadings and warm temperatures lead to excessive growth of algae; as organic matter such as algae decomposes, bacteria consume the algae, and as the bacteria flourish from the extra food source, their increased metabolism and respiration reduce oxygen levels in the water column, potentially leading to

oxygen depletion. When levels are below 2.0 mg/l they are considered hypoxic and when all the oxygen is depleted, it is called anoxia. Hypoxic conditions also lead to the release of phosphorus from sediments, known as "internal loading," which also may contribute to the development of algal blooms (Matisoff et al 2016). Human-induced nutrient enrichment has increased the duration and areal extent of hypoxia and anoxia, which can cause fish kills, shifts in fish species distribution, with potential long-term effects on the aquatic food web, along with taste and odor problems for municipal water treatment plants (ECCC and USEPA, 2016).

The effects of excessive nutrient enrichment, or eutrophication, have continued to cause the most significant damage to and most profound changes in the water quality of Lake Erie, Green Bay and Saginaw Bay. In Lake Erie, the worsening condition has manifested in three ways: a recurrence of cyanobacteria blooms primarily in the western basin; significant hypoxic conditions in the central basin hypolimnion; and the recurrence of major *Cladophora* nuisance blooms along the northern nearshore of the lake's eastern basin.

Of the Great Lakes, Lake Erie is showing the greatest frequency and severity of symptoms associated with eutrophication. The increase in frequency and coverage of Lake Erie algae blooms has occurred despite stable total phosphorus loadings over the last 15 years (USEPA, 2015). However, the dissolved phosphorus fraction/component of the loadings has been increasing. Dissolved phosphorus is of concern because it is highly bioavailable to algae, fueling rapid algal growth. About 95 percent of dissolved phosphorus is bioavailable to algae, while only about 30 percent of the particulate phosphorus attached to eroded sediment is bioavailable (Heidelberg University, 2016).

Climate change favors increased lake temperatures and the timing and duration of vertical stratification, which are two integral physical factors affecting eutrophication (Paerl and Huisman, 2009). Climate change will likely also increase the intensity of storms in the Great Lakes basin, leading to greater nutrient runoff and delivery of nutrients beyond the spring freshet (Scavia *et al*., 2014). Consequently, climate change could increase the magnitude, duration, and frequency of algal blooms in the Great Lakes and thus increase hypoxia.

The proliferation of invasive zebra and quagga mussels has indirectly reduced the availability of phosphorus to the fish community. As filter feeders, the mussels filter algae from the water and the phosphorus in algal tissues is then excreted in a form that nuisance aquatic plants and algae close to shore can use (Ozersky, 2010) a phenomenon referred to as a nearshore shunt (Hecky*et al.*, 2004). Phosphorus taken up in these nearshore areas and in deeper mussel beds is essentially trapped at the expense of the open water food chain. Low phosphorus levels caused by the mussels, limit the growth of algae in the open waters, undermining plankton and fish communities of the pelagic food web.

3.6.2 Assessment of Annex Implementation

Annex 4 *Nutrients* of the GLWQA addresses the General Objective of managing nutrients in the waters of the Great Lakes. Annex 4 calls for coordinated binational action to manage phosphorus (and other nutrients if warranted) with respect to concentrations in and loadings to the waters of the Great Lakes through coordinated binational action. The Parties established an Annex 4 subcommittee, chaired by the US Environmental Protection Agency (USEPA) and Environment and Climate Change Canada (ECCC), to carry out commitments in the Annex.

Created by the Parties in September 2013, the Annex 4 Objectives and Targets Task Team of the Nutrients Annex Subcommittee has been active in fulfilling commitments under the GLWQA. The task team convened a sub-team of modeling experts to compare and contrast the results from a suite of existing Lake Erie models to quantify phosphorus load and eutrophication response relationships for the Lake Erie ecosystem. Using nine validated models the team evaluated the impact of a combination of load reduction strategies on western basin cyanobacteria blooms, central basin hypoxia, and eastern basin *Cladophora* (Binational.net, 2016).

The Annex 4 Task Team also considered the role of factors other than phosphorus loads and associated in-lake concentrations in governing eutrophication indicators. These other factors included nitrogen loads and concentrations, *Dreissenid* densities and impacts, and variations in annual precipitation and tributary discharges. Additional considerations included the setting of in-lake phosphorus concentration objectives for nearshore areas and the role that phosphorus bioavailability plays in governing the response of eutrophication indicators to phosphorus loads. Its report established loading targets for total and dissolved phosphorus to address HABs in the Western Basin and hypoxia in the Central Basin. The team continues to work on targets to address nuisance algal blooms in the Eastern Basin. They also identified 14 priority tributaries for nutrient reduction. Nutrient runoff from agriculture is the primary cause of the problems, but efforts to address this concern would need to deal with both agriculture and urban sources (Binational.net, 2016).

In addition to developing domestic action plans for Lake Erie, the subcommittee is working to establish phosphorus reduction targets to control nuisance algae in the eastern basin of Lake Erie, and will be addressing loading and concentration targets for Lake Ontario (Binational.net, 2016).

Intensive work has been undertaken by the Annex subcommittee and task teams.

3.6.3 Assessment of indicators

Nutrient indicators include HABs, nutrients in lakes and nuisance algal blooms (NABs).

Table 3.6.1 Summary Conditions of the Great Lakes, by Nutrient Indicators
(Source: GLPF, 2016)

Great Lakes	Indicators of Progress		
	Harmful Algal Blooms	**Nutrients in Lakes**	***Cladophora***
Lake Superior	The status is **good** and the trend is **unchanged or undetermined**.	The status is **good** and the trend is **unchanging**. Targets have consistently been met	The status is **good** and the trend is **unchanging**. There is no historic occurrence of Cladophora on Lake Superior shorelines
Lake Michigan	The status is **fair** and the trend is **unchanging or undetermined**. There are eutrophic embayments such as Green Bay, Muskegon Bay and drowned river mouths along the western shore.	The status is **fair** and below target, the trend appears to be **deteriorating** further below targets.	The status is **poor** and the trend is **undetermined**. Cladophora remains to be an issue on beaches and is high in many parts of the lake.

Lake Huron	The status is **fair** and the trend is **unchanging off shore while deteriorating in some near shore regions**. The lake is generally oligotrophic but nearshore areas experience nuisance and HAB outbreaks, namely Saginaw Bay and Sturgeon Bay (Georgian Bay).	The status is **fair** and below target, the trend appears to be **deteriorating** further below targets. Offshore TP concentrations continue to decrease to values that may be too low to support a healthy level of lake productivity.	The status is **fair** and the trend is **undetermined**. Cladophora biomass approaches nuisance thresholds in localized areas over the Canadian shoreline. Over broader areas of the nearshore zone
Lake St Clair	The status is **poor** and the trend is **unchanging off shore while deteriorating in some near shore regions**.	No progress reporting provided	No progress reporting provided
Lake Erie	The status is **poor** and the trend appears to be **unchanging to deteriorating**. Toxic cyanobacteria blooms continue to occur throughout the western basin. Blooms in 2013, 2014 and 2015 were ranked as severe in a number of categories. The blooms in 2014 caused closure of the city of Toledo water supply and the 2015 bloom was the worst ever.	The status is **poor** and above target and the trend is **deteriorating**. TP and dissolved phosphorus targets continue to be exceeded and trends indicate possibly increasing concentrations. HABs have plagued the western basin and parts of the central basin	The status is **poor** and the trend is **undetermined**. Broadly distributed along much of the north shore and eastern basin Cladophora biomass is variable from year to year but continues at or above nuisance conditions at most sites sampled.
Lake Ontario	The status is **fair** and the trend appears to be **unchanging offshore to deteriorating/unchanging nearshore**. Offshore waters remain good; however, nearshore waters continue to experience NABs. Beach closures and toxic HABs have been reported in several embayments on the New York (Sodus Bay and Port Bay) and Canadian side (Hamilton Harbour, Bay of Quinte).	The status is **fair** below targets and the trend appears to be **deteriorating** further below target. Offshore TP concentrations continue to decrease to values that may be too low to support a healthy level of offshore lake productivity. Possibly fueled by locally high phosphorus discharges or in-lake nutrient cycling certain nearshore areas are experiencing recurrent nuisance algae.	The status is **poor** and the trend is **undetermined**. Biomass routinely exceeds nuisance conditions in the western end of the lake. Cladophora is widely distributed in Lake Ontario with recent surveys indicating nuisance conditions in both the vicinity of point source inputs and regions remote to known sources. Lack of consistent monitoring and inter-annual variability being comparable to that of Lake Erie and Michigan, assessment of trends is hindered.

3.6.4 Assessment of Lake Erie phosphorus objectives and targets

Annex 4 of the GLWQA includes six Lake Ecosystem objectives adopted by the Parties in support of the purpose of the Annex:

1. minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie;
2. maintain the levels of algal biomass below the level constituting a nuisance condition;
3. maintain algal species consistent with healthy aquatic ecosystems in the nearshore Waters of the Great Lakes;
4. maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes;
5. maintain an oligotrophic state, relative algal biomass, and algal species consistent with healthy aquatic ecosystems, in the open waters of Lakes Superior, Michigan, Huron and Ontario; and
6. maintain mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions in the eastern basin of Lake Erie (GLWQA, 2012).

In Annex 4, the Parties established interim Substance Objectives to achieve the Lake Ecosystem Objectives for phosphorus concentrations for the open waters and nearshore areas of each Great Lake. The Annex 4 subcommittee was then charged with developing final substance objectives and loading targets. The subcommittee chose not to recommend final substance objectives for Lake Erie in part because phosphorus concentrations in the nearshore and open waters vary considerably over space and time, making them very difficult to track in a meaningful way (Annex 4 Objectives and Targets Task Team, 2015).

Canada and the United States in February 2016 did adopt the following phosphorus load reduction targets (compared to a 2008 baseline) for Lake Erie (EPA and ECCC, 2016):

- *To minimize the extent of hypoxic zones in the waters of the central basin of Lake Erie:* a 40 percent reduction in total phosphorus entering the western and central basins of Lake Erie—from the United States and from Canada—to achieve an annual load of 6,000 metric tonnes (6,600 tons) to the central basin. This amounts to a reduction from the United States and Canada of 3,316 metric tonnes and 212 metric tonnes (3,648 tons and 233 tons) respectively.

- *To maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the western and central basins of Lake Erie:* a 40 percent reduction in spring total and soluble reactive phosphorus loads from the following watersheds where algae is a localized problem: in Canada, the Thames River and Leamington tributaries; and in the United States, the Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River and Huron River (Ohio).

- *To maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the western basin of Lake Erie*: a 40 percent reduction in spring total and soluble reactive phosphorus loads from the Maumee River in the United States.

Canada and the United States are working to develop domestic action plans that will outline strategies for meeting the new targets. The GLWQA calls for completion of the plans by February 2018.The Annex 4 subcommittee is workingto establish targets to minimize impacts from nuisance algae in the eastern basin of Lake Erie. The targets are expected to be set in 2017.

3.6.5 Assessment of Progress Report of the Parties

The PROP observes that the Parties have met, or are on track to meeting all Annex 4 commitments under the GLWQA. These commitments are:

- By2016, develop binational substance objectives for phosphorus concentrations, loading targets, and loading allocations for Lake Erie.
- By 2018, develop binational phosphorus reduction strategies and domestic action plans to meet the objectives for phosphorus concentrations and loading targets in Lake Erie.
- Assess, develop, and implement programs to reduce phosphorus loadings from urban, rural, industrial and agricultural sources. This will include proven best management practices, along with new approaches and technologies.
- Identify priority watersheds that contribute significantly to local algae development, and develop and implement management plans to achieve phosphorus load reduction targets and controls.
- Undertake and share research, monitoring and modeling necessary to establish, report on and assess the management of phosphorus and other nutrients and improve the understanding of relevant issues associated with nutrients and excessive algal blooms.

Substance objectives and loading targets

The Parties have met the commitment to develop substance objectives for phosphorus concentrations, loading targets and loading allocations for Lake Erie. These objectives were formally established in February 2016 on the schedule called for by the GLWQA. As part of the process, the Parties undertook a robust public engagement process to explain and justify the proposed targets.

Binational phosphorus reduction strategies and domestic action plans

Although the GLWQA deadline to develop binational phosphorus reduction strategies and domestic action plans to meet the objectives for phosphorus concentrations and loading targets in Lake Erie is not until February 2018, there are concerns about two developments in the process to date.

First, the Annex 4 subcommittee has, to date, not considered the possibility of recommendations for new regulatory authorities in domestic action plans. Incentive-based programs supporting agricultural best management practices have achieved some success; as the Parties note, on the US side of the Great Lakes watershed, an estimated 72.57 metric tonnes (80 tons) of phosphorus will be prevented from entering the Great Lakes annually as a result of projects in targeted watersheds including the Western Lake Erie basin (ECCC and USEPA, 2016). This, however, is only a small fraction of the needed reductions. Tax dollars will likely prove insufficient to support government payments for full implementation of all agricultural practices needed to achieve loading reduction targets. Further, Annex 4 envisions a regulatory component to phosphorus reduction strategies. Section D (3) commits

the Parties to "assess and, where necessary, develop and implement regulatory and non-regulatory programs to reduce phosphorus loading from agricultural and rural non-farm point and non-point sources."

New authorities – or at least the option of new authorities – could be critical to domestic action plans. The general reliance on voluntary initiatives to reduce polluted (nonpoint) runoff from agricultural lands has over the past decade proven insufficient to control eutrophication of western Lake Erie in particular.

In 2015, the State of Ohio enacted an important new statutory requirement for the management of animal waste and chemical fertilizer in agriculture (Ohio Legislature 131st General Assembly, 2015). The new law bans, with some exceptions, the application of manure and chemical fertilizer on agricultural lands that are frozen, snow-covered, or saturated, or when significant rains are predicted. The statute is designed to prevent immediate runoff of phosphorus-rich animal waste in particular. Ontario's Nutrient Management Act, 2002, also prevents application of nutrients to agricultural land when the soil is snow-covered or frozen. The remaining states in the Lake Erie watershed could enact similar laws.

Second, the Annex 4 subcommittee has discussed endorsing plans developed by Ohio, Michigan and Ontario pursuant to their Western Basin of Lake Erie Collaborative Agreement as the state/provincial component of domestic action plans (State of Michigan, 2015). The idea that these plans, in all cases, are sufficient to achieve the 40 percent phosphorus load reductions envisioned in the three-party agreement and the Parties' targets (ECCC and USEPA, 2016), is not persuasive.

Phosphorus management programs

The Parties state that they are evaluating existing programs in Canada and the United States identifying opportunities to maximize phosphorus reduction, and may propose new programs or approaches to manage phosphorus loadings. The possibility of new programs is encouraging.

Careful analysis of agricultural programs, including promotion of voluntary adoption of best management practices, is critical. The agricultural sector is fundamental to food supply, and any new statutory protections for the environment affecting agriculture must be carefully tailored to minimize adverse impact on the industry. However, it is clear that the current reliance on voluntary efforts has not adequately improved western Lake Erie water quality, nor that of Green Bay and Saginaw Bay.

A significant proportion of corn grown in both the United States and Canada, and in the watershed of western Lake Erie, supplies a feedstock to meet renewable fuel mandates. The mandates, in turn, increase financial return to individual agricultural operators for planting the maximum feasible amount of corn, including the use of marginal cropland from which runoff may be excessive (USEPA, 2011). The IJC is currently reviewing the indirect effects of renewable fuel mandates on Lake Erie water quality in a special study.

Research, monitoring and modeling

The Parties have made a positive commitment to "Undertake and share research, monitoring and modeling necessary to establish, report on and assess the management of phosphorus and other nutrients and improve the understanding of relevant issues associated with nutrients and excessive algal blooms" (ECCC and USEPA, 2016). However, there is a lack of specificity in implementing the

commitment. For example, the issue of characterizing and quantifying the influence of the Detroit River on HABs in the western Lake Erie basin remains of critical concern. So, too, is the issue of whether there is adequate monitoring and modeling to develop and evaluate conservation practices and best management practices to control non-point source nutrient pollution. A study conducted by the Northeast-Midwest Institute and the US Geological Survey found that monitoring was inadequate to evaluate the water quality impacts of agricultural best management practices and benefits for Lake Erie (Betanzo*et al.*, 2015). The formation of the new Work Groups within the Annex 4 Task Team is promising and encourages the parties to develop strategies for long term support of the monitoring, modeling, and research needed to address the problems and prevent them from returning in the future.

Other issues

Nutrient inputs to the western Lake Erie basin and Green Bay from concentrated animal feeding operations (CAFOs) and smaller animal feeding operations are not well documented but are a major concern. CAFOs house livestock in a confined space, resulting in the concentration of manure in a small area. By one estimate, 146 CAFOs are located in the western Lake Erie basin, housing almost 12 million dairy, hog and poultry animals. Their estimated waste output is over 2,385 million liters (630 million gallons) annually (Sierra Club, 2016). In the SPARROW modelling conducted by Robertson and Saad (2011) the highest yields (mass/area/time) of phosphorus and total nitrogen were found in areas having intense agriculture and large point sources of nutrients, such as CAFOs.

State regulatory agencies and not-for-profit environmental organizations disagree on the effectiveness of permitting and enforcement efforts by the agencies. For example, the Ohio Department of Agriculture, speaking of its livestock permitting program, observes that "Most farmers and agribusinesses hold themselves to the highest environmental standards. The State of Ohio now ensures the state's largest operations follow science-based guidelines that protect the environment while allowing the facility to be productive" (Ohio Department of Agriculture, 2016). By contrast, the Ohio Environmental Council, a nongovernmental organization, contends that livestock operations avoid regulation by housing a number of animals just under the threshold where a permit would be required. "This means very big livestock operations are raising thousands of animals in Ohio with little oversight and few rules to follow" (Ohio Environmental Council, 2015). Given the significance of CAFOs as a nutrient loading source, the adequacy of the regulatory programs is not clear and merits further investigation. At a minimum, better measures are needed to ensure that the high volume of manure produced by CAFOs is not spread on cropland in excess of crop requirements.

The importance of wetlands in capturing and filtering pollutants is well-established. In northwestern Ohio, only 5 percent of Lake Erie's original 124,238 hectares (307,000 acres) of wetlands remain, and similar patterns exist throughout the rest of the western basin of the lake (IJC, 2016). The draining of coastal wetlands and most of the 297,849 hectare (736,000 acre) Great Black swamp in the tributary watershed "eliminated most of the capacity to prevent pollutants and sediments generated in the upland portions of the watershed from entering the lake." The associated drainage systems and farmland that replaced the wetlands led to increased erosion potential and deliveryof sediment and attached pollutants to Lake Erie (Ohio Department of Natural Resources, 2007).

Accelerated wetland restoration is an important issue for the Parties and state and provincial partners to consider in domestic action plans (IJC, 2016). Research suggests that a constructed wetland whose surface area is 4 percent of its catchment can retain about half of the catchment's agricultural dissolved reactive phosphorus (DRP) load (Boles, 2016). This suggests that constructing and

restoring wetlands as an agricultural best management practice can have significant water quality benefits.

Buffer strips are a technique for reducing agricultural runoff and have proven effective in many applications. Recently, as noted in the PROP, the State of Minnesota has legislated that landowners along public waters maintain a mandatory a 15.2-metre (50-foot) average width, 9.1-metre (30-foot) minimum width, continuous buffer of perennially rooted vegetation or comply with state shoreline standards and criteria promulgated by the State Commissioner of Natural Resources (2015 Minnesota Statutes). Buffers "slow runoff from fields, trapping and filtering sediment, nutrients, pesticides and other potential pollutants before they reach surface water" (Minnesota Department of Agriculture, 2016).

Another legally enforceable protection for western Lake Erie would be the establishment of a Total Maximum Daily Load (TMDL) under the US *Clean Water Act*. As noted in the IJC's 2014 report, *A Balanced Diet for Lake Erie*, the TMDL process entails calculation of the maximum amount of loading of pollutant(s) of concern that an impaired waterbody can receive and still meet water quality standards for that particular pollutant. The TMDL allocates the load to both point and non-point sources. Following development of a TMDL, implementation should proceed in a way that meets water quality standards and restores impaired waterbodies. States are required to develop TMDLs and may use available regulatory authorities in their implementation. The TMDL provides timetables and accountability for implementing phosphorus reduction measures.

The PROP provides little detail on phosphorus reduction activities undertaken pursuant to the Canada-Ontario Agreement (COA) on Great Lakes Water Quality and Ecosystem Health, the federal-provincial agreement that supports the restoration and protection of the Great Lakes basin ecosystem, last updated in 2014. The report could provide additional description of COA-related actions to address nutrient pollution in the four Great Lakes under Ontario jurisdiction.

3.6.6 Assessment of Lake Erie Watershed Management Plans

The Legacy Issues Work Group of the Great Lakes Water Quality Board (WQB), the principal advisor to the IJC as set forth in the GLWQA, undertook a review of watershed management plans within the Lake Erie basin and other jurisdictions that could be used as best practice examples to achieve nutrient load reduction targets and aid in the restoration of Lake Erie (WQB 2016). The WQB recommended:

- The CanadianandUSgovernmentsaswell astheprovincial andstate governments,should ensurethatlake-widebasin, sub-basin, watershed andsub-watershedmanagementplans (including plans tomanage bays, islands andthe nearshore)aredeveloped fornutrientmanagementin Lake Erie.

- There areseveral keysuccess factors thattheCanadianand USgovernments,aswell as theprovincial andstategovernments, shouldensureareincluded inthelake-widebasin, sub-basin, watershed, and sub-watershedmanagement plans for nutrientmanagement. These include science-based watershed characterization, clear goals and an adaptive management approach.

- The Canadian and US governments, as well as the provincial and state governments around Lake Erie, should ensure that funding is available to support planning activities and implementation of watershed management plans for nutrients.

3.6.7 Section Summary

- With the exception of Lake Superior, all Great Lakes are experiencing significant nutrient issues.
    - Open lake nutrients concentrations are below target and likely deteriorating in lakes Michigan, Huron and Ontario, likely due to changes in the food web caused by non-native species. This is undermining desirable fish populations.
    - Nutrient concentrations are above target in western and central basins of Lake Erie, and at target levels in the eastern basin.
- Although record algal blooms in western Lake Erie have captured the most public attention, excess nutrients also fuel harmful algal growth in localized areas such as Green Bay and Saginaw Bay and help to foster harmful algae, while nuisance algae affect nearshore areas of Lakes Erie and Ontario.
- The Parties have met the commitment to develop substance objectives for phosphorus concentrations, loading targets and loading allocations for Lake Erie. In doing so, the Parties undertook a robust public engagement process to explain and justify the proposed targets.
- Over the past ten to 15 years, governments at all levels have focused on incentive-based and voluntary programs to reduce nutrient loadings in the western basin of Lake Erie. These voluntary programs include funding and support for implementation of agricultural best management practices. But open lake concentrations, annual loadings and frequent HAB events in the last ten years show that the voluntary programs are not working or are not sufficient in achieving target loadings set by the Parties in 2016.
- The use of regulatory tools is needed to supplement voluntary initiatives to reduce phosphorus loadings in the western basin of Lake Erie.

3.6.8 References

2015 Minnesota Statutes.Section 103F.48. Riparian Protection and Water Quality Practices. Retrieved from https://www.revisor.mn.gov/statutes/?id=103F.48, October 5, 2016,

Annex 4 Objectives and Targets Task Team, 2015. Recommended Phosphorus Loading Targets for Lake Erie: Annex 4 Objectives and Targets Task Team Final Report to the Nutrients Annex Subcommittee. May 11, 2015.

Betanzo, E.A.,Choquette,A.F.,Reckhow, K.H.,Hayes, L.,Hagen, E.R.,Argue, D.M.,and Cangelosi, A.A., 2015. Water data toanswer urgent water policy questions:Monitoringdesign, availabledata and filling data gaps for determining the effectiveness ofagricultural management practices forreducing tributary nutrient loads toLake Erie, Northeast-Midwest InstituteReport, 169 p., http://www.nemw.orgDOI: 10.13140/RG.2.1.1102.5684

Binational.net. 2016.*Canada –United States Collaboration for Great Lake Water Quality.Nutrients (Annex4) Key Commitments, Implementation.* Retrieved from Binational.net website: http://binational.net/annexes/a4/

Boles, C. 2016.Wetlands as a Strategic BMP in the Maumee River Watershed.Presentation at Great Lakes Tributary Modeling Program 2016 Great Lakes Sedimentation Workshop. June 23, 2016. http://greatlakestributarymodeling.net/files/GLSW-June-2016-Boles.pdf

Department of Agriculture et al. (2013) *Ohio Lake Erie Phosphorus Task Force II Final Report*. Retrieved from: **https://www.motherjones.com/files/task_force_report_october_2013.pdf**

Environment and Climate Change Canada and United States Environmental Protection Agency. (2016) *Annex 4: Nutrients Progress report of the Parties 2016*.

Great Lakes and St Lawrence Cities Initiative.(2016) *Nutrient and Algal Blooms*. Retrieved from: http://glslcities.org/initiatives/nutrients/

Great Lakes Commission.(2016) *Lake Erie Nutrient Targets Workgroup*. Retrieved from: http://glc.org/projects/water-quality/lent/

GLPF. 2016. Great Lakes Public Forum (2016). State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada.

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Available at https://binational.net/2016/09/28/prp-rep/

Great Lake Water Quality Agreement. (2012)

Hecky, R.E.; R.E.H. Smith, D.R. Barton, S.J. Guildford, W.D. Taylor, M.N. Charlton, and T. Howell. (2004). The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences. 61: 1285-1293.

Heidelberg University, (2016).Tributary Loading Program. Retrieved from: http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data

International Joint Commission (2014).*A Balanced Diet for Lake Erie: Reducing Phosphorus Loadings and Harmful Algal Blooms*. Report of the Lake Erie Ecosystem Priority

International Joint Commission. (2016) *Canada, US Set Lake Erie Algae Reduction Targets: What Happens* Next? Retrieved from: www.ijc.org/en_/blog/2016/03/15/canada_us_set_lake_erie_algae_reduction_targets/

International Joint Commission. (2016) *The Coastal Wetlands of Western Lake Erie: Have We Lost our Swiss Army Knife?* Retrieved from: http://www.ijc.org/en_/blog/2014/10/28/coastal_wetlands_lake_erie_tnc/

Matisoff, G., Kaltenberg, E. M., Steely, R. L., Hummel, S. K., Seo, J., Gibbons, K. J., ... & Johnson, L. T. (2016). Internal loading of phosphorus in western Lake Erie.*Journal of Great Lakes Research*, *42*(4), 775-788.

Michigan Department of Environmental Quality Water Resources Division. (January 2016) *Michigan's Implementation Plan Western Lake Erie Basin Collaborative.*Retrieved from:*https://www.michigan.gov/documents/deq/wrd-western-lake-erie_503547_7.pdf*

Minnesota Department of Agriculture (2016). Conservation Practices, Minnesota Conservation Funding Guide, Grass Filter Strip. Retrieved from http://www.mda.state.mn.us/protecting/conservation/practices/buffergrass.aspx, October 5, 2016.

Ohio Department of Agriculture (2016).Livestock Environmental Permitting. Retrieved from http://www.agri.ohio.gov/divs/DLEP/dlep.aspx

Ohio Department of Natural Resources (2007).Ohio Coastal Atlas. Retrieved from https://coastal.ohiodnr.gov/portals/coastal/pdfs/atlas/CH3_watershed.pdf

Ohio Environmental Council (2015).*The Dirty Truth Behind Ohio's Toxic Algae Plague, and How We Can Stop It.*http://www.theoec.org/one-ohio/dirty-truth-behind-ohio%E2%80%99s-toxic-algae-plague-and-how-we-can-stop-it, retrieved August 25, 2016.

Ontario Auditor General (2014). Source Water Protection: Ministry of the Environment and Climate Change. http://www.auditor.on.ca/en/content/annualreports/arreports/en14/312en14.pdf, retrieved September 13, 2016.

Ozersky, Ted (2010) *Dreissenid Mussels and Large Lakes: Effects on Littoral Ecology*. Retrieved from: https://uwspace.uwaterloo.ca/bitstream/handle/10012/5612/Ozersky_Tedy.pdf?sequence=1

Pearl, H.W., Huisman, J. (2009) *Climate Change: A Catalyst for Global Expansion of Harmful Cyanobacteria Blooms*. Environ. Microbiol., 1 (2009), pp. 27–37 Retrieved from: http://www.ncbi.nlm.nih.gov/pubmed/23765717

Robertson, D.M., Saad, D.A., 2011. Nutrient inputs to the Laurentian Great Lakes by source and watershed estimated using sparrow watershed models. Journal of the America Water Resources Association, 47(5): 1011-1033.

Scavia, D., Allan, D.J., Arend, K.K.(2014) *Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia*. Journal of Great Lakes Research., 40 (2) 2014, pp.226-246 Retrieved from:http://www.sciencedirect.com/science/article/pii/S0380133014000252

Sierra Club. (2016). *Follow the Manure: Factory Farms and the Lake Erie Algal Crisis*. Retrieved from http://www.sierraclub.org/michigan/follow-manure-factory-farms-and-lake-erie-algal-crisis, August 6, 2016.

State of Michigan 2015.*Western Basin of Lake Erie Collaborative Agreement.*Retrieved from https://www.michigan.gov/documents/snyder/Western_Basin_of_Lake_Erie_Collaborative_Agreement--Lieutenant_Governor_491709_7.pdf, October 5, 2016.

The Ohio Legislature 131st General Assembly (2015). Senate Bill 1:*Agricultural Pollution Abatement Program-transfer to Department of Agriculture/applicators of fertilizer or manure-regulate/algae management and response.* Retrieved from:https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA131-SB-1

United States Environmental Protection\ Agency. (2011). *Biofuels and the Environment: the First Triennial Report to Congress (2011 Final Report).* Retrieved from the United States Environmental Protection Agency, Washington, DC, EPA/600/R-10/183F, 2011:https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=235881

United States Environmental Protection Agency (2015, September). Recommended Binational Phosphorus Targets to Combat Lake Erie Algal Bloom**.** Retrieved from the US Environmental Protection Agency, Washington, D.C., https://www.epa.gov/glwqa/recommended-binational-phosphorus-targets#why-increasing
United States Environmental Protection Agency. (2016, May 12).Cyanobacteria/Cyanotoxins: Retrieved From: https://www.epa.gov/nutrient-policy-data/cyanobacteriacyanotoxins

Great Lakes Water Quality Board Legacy Issues Work Group, Evaluating Watershed Management Plans – Nutrient Management Approaches In The Lake Erie Basin And Key Locations Outside Of The Lake Erie Basin, August 5, 2016
http://ijc.org/files/tinymce/uploaded/WQB/WQB_LakeErieReport_Aug2016.pdf

3.7 Invasive Species

This section reviews and assesses progress toward achieving general objective 7 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 7 states that the waters of the Great Lakes should "be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes."

This assessment includes a consideration of implementation measures undertaken in support of the GLWQA Annex 5: *Discharges from Vessels* and Annex 6: *Aquatic Invasive Species*. The assessment also reviews supplemental information from the other management programs and activities carried out by governments, local governmental agencies and non-governmental organizations in Canada and the United States.

3.7.1 Background

Non-native species are organisms that enter an ecosystem beyond their native spatial range. More than 180 non-native species, also called nonindigenous species have become established in the Great Lakes due to human activities over the past 175 years.

Invasive species are non-native species to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. (USDA, 2016). Aquatic invasive species (AIS) present one of the toughest challenges facing the Great Lakes basin.

Estimates of the frequency at which introduced species become invasive vary widely from about 1% to over 50% for fresh water species. Williamson and Fritter (1996) estimated that about 10% of introduced species become established and about 10% of those (or about 1/100) become invasive). For freshwater fish, mammals and birds, Jeschke and Strayer (2005) found high rates of establishment (50%) and invasiveness (50%), implying about 25% of introduced vertebrate species are invasive (IJC BR 2013). E García-Berthou et.al. (2011) found high rates of establishment of 123 aquatic species introduced into six contrasting European countries, where the average percentage established is 63%. A study conducted for the Great Lakes Mississippi River Interbasin Study (GLMRIS), *Non-Native Species of Concern and Dispersal Risk for the Great Lakes and Mississippi River Interbasin Study*, concluded that the more alien species that are introduced to the Great Lakes or Mississippi River basins, the higher the probability that some of them will become invasive (USACE, 2011). Accordingly, the literature suggests that roughly one quarter of the established non-native plants, animals and microscopic organisms in fresh water are considered invasive. Conversely, roughly three quarters of non-native species are not considered invasive and some may even be considered desirable. Rainbow Trout, Chinook and Coho Salmon are examples of non-native species that are not considered invasive in the Great Lakes.

AIS not only crowd out native species, but also have negative impacts on the spread of chemical contaminants and nutrients in the Great Lakes ecosystem (Governments of the United States and Canada. 2016). The Great Lakes have suffered ecological damage and economic costs from a number

of aquatic invasive species (AIS) that have successfully invaded this region (Mills et al., 1994). Rothlisberger et.al. (2012) estimated the median estimate of cost to the Great Lakes from invasive species that originate in the ballast water of ocean-going vessels at $138 million annually and possibly more than $800 million (Rothlisberger et al., 2012).

The rate of discovery of new non-native aquatic species in the Great Lakes has plummeted from an average of one new species discovered every 8 months, with over 70% attributed to ballast water discharges, to no new discoveries attributed to ballast water discharges since 2006. With the possible exception of a zooplankton species *Thermocyclopscrassus*, no additional introductions from other pathways have resulted in establishment of a non-native species since 2006. [2]

The IJC has been reporting on the topic and providing a forum for binational collaboration on AIS issues for over 28 years, witnessing the basin-wide impacts of Sea Lamprey (*Petromyzon marinus*), Zebra and Quagga Mussels (*Dreissenapolymorpha* and *Dreissenarostriformisbugensis*) and other high-impact AIS (USACE, 2011) including the Common reed (*Phragmites australisaustralis*) a terrestrial high impact invasive species. These are considered high-impact based on the history of wide-spread and costly impact they have inflicted upon ecosystems they have invaded. Sea Lamprey and Zebra Mussels alone have resulted in basin-wide harmful impacts to the Great Lakes and costs in the billions of dollars. IJC has emphasized preventive action as the "first line of defense" in safeguarding the Great Lakes basin from the adverse ecological and economic impacts of an AIS infestation. IJC has also recognized the need for a "back-up plan" - a rapid response mechanism to quickly and decisively address AIS once an infestation has been reported (IJC, 2011), (IJC, Special Publication 2009-04).

Objective 7 is directly linked to programs and measures undertaken in support of two of the Annexes established under the GLWQA:

- Annex 5 addresses the threat of aquatic invasive species (AIS) introduction and spread through vessels by means of biofouling and ballast water discharge.
- Annex 6 of the commits the Parties to establishing binational strategy to prevent the introduction of AIS, to control or reduce the spread of existing AIS, and to eradicate, where feasible, existing AIS within the Great Lakes basin ecosystem.

Objective 7 indirectly relates to a number of other GLWQA Annexes, including those relating to nutrients, habitat and species, climate change impacts and science. This relationship is clearly demonstrated by the far-reaching impacts that dreissenid mussels have had on the Great Lakes ecosystem, where scientists have documented significant changes to the food web, the distribution of nutrients and toxic chemicals (Hecky*et al.*, 2004), as well as the habitat and substrate available to other organisms. For the purposes of this assessment, only those programs and measures related to Annexes 5 (Discharges from Vessels) and Annex 6 (Aquatic Invasive Species) are addressed in this section.

[2] On November 1, 2016 the U.S. Environmental Protection Agency's Great Lakes National Program Office confirmed the presence of a previously unreported non-native invertebrate zooplankton species *Thermocyclopscrassus* in the western basin of Lake Erie. The NOAA GLANSIS database has recently been updated to reflect this discovery. The species may have been present for some time but was only recently detected in 2014 samples. *Themocyclopscrassus*has been found elsewhere in North America and is not considered an invasive because it does not appear to cause harm to the ecosystem, the economy, or human health.

3.7.2 Assessment of indicator

The SOGL invasive species indicator has four sub-indicators that relate to General Objective 7 (Great Lakes Public Forum, 2016):

- *Aquatic Non-Native Species* – total number and timing of new introductions of aquatic non-native species and the spread of previously established species. (Poor – and Deteriorating)
- *Sea Lamprey* – Abundance and Distribution (Fair/Improving)
- *Dreissenid Mussels* - Abundance and Distribution (Fair/Deteriorating)
- *Terrestrial Invasive Species* - Abundance and Distribution – (Poor/Deteriorating);
  A sub-indicator based on five species of interest – Asian longhorned beetle *Anoplophoraglabripennis*, Emerald ash-borer *Agrilusplanipennis*, Common reed *Phragmites*, Purple loosestrife *Lythrumsalicaria* and Garlic mustard *Alliariapetiolata*.

At the time of publication of the Progress Report of the Parties, the SOGL sub-indicators reported by the governments showed that no new non-native species had been detected in the Great Lakes since 2006. On November 1, 2016 the U.S. Environmental Protection Agency's Great Lakes National Program Office confirmed the presence of a previously unreported non-native invertebrate zooplankton species *Thermocyclopscrassus* in the western basin of Lake Erie. The Great Lakes Aquatic Nonindigenous Species Information System maintained by NOAA was updated in November, 2016 to reflect this discovery. The species was collected in 2014 and may have been present for some time. *Themocyclopscrassus* has been found elsewhere in North America and is not considered to be invasive because it does not appear to cause harm to the ecosystem, the economy, or human health. Despite this recent discovery, the trend of new non-native species detected in the Great Lakes has dropped significantly over the past ten years.

Despite successful prevention activities that have greatly slowed detection of new non-native species, the sub-indicators show a deteriorating trend in the spread and impact of previously established invasive species. This supports a need for resources to develop new methods and control technology to control spread at all stages of research and development - scientific investigation, applied science, and proof of concept.

The IJC SAB (2016) identified sea lamprey abundance as one of eight sub-indicators that should be used for communicating with the public about the condition of the Great Lakes. The testing of a framework for assessing the effectiveness of programs and other measures under the Great Lakes Water Quality Agreement (Johns et al, 2016) showed increasing concern about the spread of previously established aquatic and terrestrial invasive species in the Great Lakes basin, supporting the draft 2016 SOGL findings reported at the GLPF in October 2016. Both studies also supported the notion of providing additional information regarding high-impact AIS such as Asian carps, Sea Lamprey and Dreissenid Mussels.

The three sub-indicators of high-impact species strongly support the overall AIS indicator and it is useful to keep track of the total number of non-natives in the Great Lakes (the fourth sub-indicator). The Parties have selected sub-indicators which, when taken into account with the narrative, effectively communicate progress on Objective 7 of the GLWQA.

3.7.3 Assessment of the Progress Report of the Parties

The AIS PROP discussion clearly reflects a strong emphasis on prevention, monitoring, response planning and risk assessment, with significant research and development undertaken for control and eradication tools. All of the AIS science priorities assigned under Annex 6 in 2013 for this triennial reporting period have been addressed and significant progress has been made. As previously noted, progress in these areas has been accompanied by setbacks with the spread of several aquatic and terrestrial invasive species (Great Lakes Public Forum, 2016)

The Parties have taken the approach of making prevention of new AIS introductions the highest priority and emphasizing the need for risk assessment, sustained comprehensive monitoring for new invasive species and public outreach and education. The efforts of the Parties to establish the first basin-wide AIS early detection network are particularly noteworthy, as are new techniques that enable scientists to detect the genetic material from organisms though water samples.

The PROP demonstrates the positive impact of program funding towards AIS. Executed in 2010, the U.S. Great Lakes Restoration Initiative (GLRI) designated invasive species as one of five major focus areas in its Action Plan, provided much needed funding to implement Great Lakes AIS programs and measures and enabled significant progress. This program is administered by the U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO), which coordinates awards distributed and managed by numerous federal and state agencies, non-governmental and academic institutions. GLRI funding has supplemented base program funding throughout the reporting period and, because it is channeled through a single agency, GLRI funding data can be easily summarized from the GLRI geo-spatial database. For the first five years of the GLRI, total expenditures for AIS were $276.7 million for over 1,775 projects. This represents approximately 18 percent of GLRI funds channeled through the USEPA to federal partner agencies and grantees. GLRI-funded studies have been completed to assess the risk of introduction and establishment of AIS on the Great Lakes, the risk of AIS spread facilitated by domestic shipping and the potential impacts on Great Lakes food webs and fisheries.

During this reporting period, Canada has also made significant investments in AIS initiatives with departmental funding from Fisheries and Oceans Canada (DFO), Canada's Natural Science and Engineering Research Council, Environment and Climate Change Canada (ECCC), the Ontario Ministry of the Environment and Climate Change, the Ontario Ministry of Natural Resources and Forestry (OMNRF), the non-profit Invasive Species Centre and numerous other sources. Details of program expenditures for both US and Canadian AIS initiatives are described in the sections below.

The PROP provides much detail on the commitment of resources and results coming from efforts to prevent the introduction and to control the spread of Asian Carps through the Chicago area waterways and other physical connections to the Great Lakes. The term Asian Carp is very broad and includes the naturalized and abundant common carp, grass carp, black carp and the bighead & silver carps. For the purposes of the PROP and in this triennial assessment report, the term Asian Carp is used to describe a smaller group that includes Bighead carp (*Hypophthalmichthysnobilis*), Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodonidella)* and Black carp (*Mylopharyngodonpiceus)* (USGS, 2016). The government's efforts directed at these species are highly effective and worthwhile.

The Asian Carp Regional Coordinating Committee, representing 28 Federal, State/Provincial, Municipal, non-profit and binational organizations from the United States and Canada is a model of multi-jurisdictional collaboration. Asian Carp management activities have transitioned to a more sustainable funding model, with more than 73 percent of 2015 funding coming from Agency base expenditures in the United States and 27 percent provided by grants from the GLRI (Table 3.7.1). Canadian agencies have made significant contributions to this effort, sharing the results of research and initiatives directed at risk assessments, monitoring, early detection and rapid response efforts.

2015 Annual Report to Congress

Table 1. Total FY 2015 Expenditures for Asian Carp Activities.*

Agency	Total Agency GLRI Expenditures[1]	Total Agency Base Expenditures	Total Reported Expenditures[2]	Total UMRB/ORB (w/o CAWS) Expenditures[3]
USEPA	--	--	--	--
USACE	$2,797,233	$25,745,752	$28,542,985	$192,000
USDA (Forest Service)	--	$27,000	$27,000	$27,000
USGS	$3,044,673	$5,193,799	$8,238,472	$405,249
NOAA	--	$44,220	$44,220	--
USFWS	$2,321,033	$2,352,500	$4,673,533	$1,570,000
USCG (9th District)	--	$46,648	$46,648	$46,648
NPS	--	$40,000	$40,000	$40,000
Indiana	$287,401	--	$421,001	$421,001
Iowa	NA	$146,378	$146,378	$146,378
Kentucky	NA	$60,000	$130,000	$130,000
Illinois[3]	$4,124,000	$58,000	$4,357,000	--
Minnesota	--	$85,000	$1,910,011	$1,910,011
Mississippi	NA	--	--	--
Missouri	NA	$119,929	$119,929	$119,929
New York	--	--	--	--
North Carolina	NA	--	--	--
Ohio	$1,012,651	$28,387	$1,041,038	$519,068
Pennsylvania	--	$40,000	$40,000	$40,000
Tennessee	NA	$54,000	$78,000	$78,000
West Virginia	NA	--	--	--
Wisconsin	--	--	--	--
Total	**$13,586,991**	**$33,877,464**	**$49,856,215**	**$5,650,284**

* Agency expenditures under $10,000 were not reported or included for the purposes of this report except where it is specifically known that no money was spent.

1 GLRI funds are used exclusively for work within the Great Lakes Basin or to conduct mitigative actions within hydrologic connections between the Great Lakes and the UMRB and the ORB. GLRI activities expenditures are included in this Report to provide a complete picture of Asian carp activities conducted within the UMRB, yet are also identified in the ACRCC's annual Control Strategy Framework Strategy (http://asiancarp.us/documents/2015Framework.pdf).

2 Total Report Expenditures includes any other outside funding sources reported. (e.g. Minnesota expenditures include funding from the Minnesota Environment and Natural Resource Trust Fund and the Minnesota Outdoor Heritage Fund).

3 Total UMRB and ORB (without CAWS) Expenditures was used for the work that is highlighted in this Report. This work was conducted to directly protect the UMBR and ORB and tributaries from Asian carp.

Table 3.7.1 Total FY 2015 Expenditures for Asian Carp Activities
Source: USFWS, 2015 Report to Congress

The Asian carp program is a mature, well developed effort, supported by domestic regulations, that has influenced the development of strategic and tactical AIS response plans throughout the region by demonstrating the effectiveness of unified incident response management. The 2016 Asian Carp Monitoring and Response Plan; and Upper Illinois River Asian Carp Contingency Response Plan serve as excellent examples. An extensive amount of information has been made available through a robust public outreach and education effort with both US and Canadian sites at www.asiancarp.us and www.asiancarp.ca.

As discussed in the PROP (Governments of the United States and Canada. 2016), the historical rate of discoveries of new non-native species increased to one new discovery every eight months up until about 2004 (Great Lakes Public Forum, 2016). The highest rate is observed to coincide with the period between the opening of the St. Lawrence Seaway and implementation of strict, mandatory ballast water management regulations. It is significant that, with increased vigilance, greater understanding of the impacts of AIS and improved monitoring, the number of non-native species in the Great Lakes has held steady at approximately 185 for the past decade. The proactive approach of the Parties to conduct AIS risk assessments and establish watch lists will improve understanding of the potential impacts of AIS that have not yet been discovered and help guide response actions if and when they are discovered. The success of ballast water management efforts shows that sustained success in controlling AIS should be reflected in the rate of discovery and demonstrates the value of regulating pathways of introduction of AIS.

The PROP documents considerable progress made in regulating the discharge of ballast water in the Great Lakes. The International Maritime Organization's (IMO) 2004 Ballast Water Management (BWM) Convention, met the requirements for entry into force on September 8, 2016, when Finland ratified the convention. The convention stipulates that it will enter into force 12 months after ratification by a minimum of 30 States, representing 35 percent of world merchant shipping tonnage. Finland's accession brought the combined tonnage of contracting States to the treaty to 35.1441 percent, with 52 contracting Parties. As a result, the BWM Convention will enter into force on September 8, 2017.

The BWM Convention was adopted in 2004 by the IMO, the United Nations specialized agency with responsibility for developing global standards for ship safety and security and for the protection of the marine environment and the atmosphere from any harmful impacts of shipping. The convention reflects the input of science to reduce risk and is influenced by the Great Lakes region. Canada chairs the IMO ballast water review group (IMO, 2016).

Canada provided a position paper to the IMO 68th session of the Marine Environment Protection Committee (MEPC) in March 2015 addressing details of implementation and will move forward with implementing the provisions in its domestic legislation. Unlike Canada, which acceded to the convention on April 8, 2010, the United States has not signed on to the IMO convention. However, in March 2012 the U.S. Coast Guard (USCG) adopted the same discharge standard in its regulations.

The need for effective multi-organizational coordination cannot be overstated since a 2012 study commissioned by the IJC showed that in just a small portion of the Great Lakes basin, there were 100 Canadian and US public and non-governmental organizations somehow involved with AIS response (Donahue et. al. 2013). Close cooperation with the Great Lakes Panel on Aquatic Nuisance Species (Governments of the United States and Canada. 2016) was a key element in harmonizing national and

binational efforts through a network developed over the past 25 years by the ANS Panel[3]. Effort and funding by the Parties has resulted in an impressive list of accomplishments over the past several years (Governments of the United States and Canada. 2016).

3.7.4 Assessment of Annex implementation

1. Annex 6 – Aquatic Invasive Species

Review of 2013 science priorities

The 2013 Science Priorities for Annex 6 – Aquatic Invasive Species include:

- undertake ecological assessments of AIS prevention programs;
- develop and evaluate early AIS detection technologies and methods;
- research and develop technologies and methods for control and eradication of AIS;
- determine the effects of habitat and climate change on risks of AIS establishment; and
- implement and evaluate risk assessments of species, pathways, and vectors of AIS.

The process for conducting ecological assessments of AIS prevention programs has been initiated by the Parties by establishing performance measures and strategic outcomes for key programs. These metrics may be compared with the conditions reported in the State of the Great Lakes report to assess progress. For example, the Fisheries and Oceans Canada Report on Plans and Priorities for 2016-2017(2016) shows that performance measures have been established relative to communicating AIS related science, Sea Lamprey abundance, monitoring and early detection of Asian carps. Similar program metrics have been established by US agencies, for example, the Great Lakes Restoration Initiative Action Plan has established metrics including the number of: GLRI-funded projects that help block pathways through which aquatic invasive species can be introduced to the Great Lakes ecosystem, number of tributary miles protected, early detection monitoring activities conducted, Great Lakes rapid responses or exercises conducted, new technology field tested and information-sharing collaboratives developed. If both countries establish comparable program measures, the Parties could enable program assessment by comparing programmatic trends with indicator trends reported in the SOGL report. By providing for sustained monitoring and reporting of these measures over successive triennial cycles, the Parties may demonstrate a commitment to the guiding principles of accountability, adaptive management, science-based management and sustainability as specified in Article 2 of the GLWQA.

AIS detection, monitoring, eradication and control for numerous species have benefitted from the emphasis placed on Asian carp during this triennial reporting period. Monitoring efforts for many different species have benefitted from the investments made in developing techniques for detecting genetic markers for Asian Carp. New control technology includes seismic pressure “waterguns” and

[3] The Great Lakes Aquatic Nuisance Species (ANS) Panel was created as a regional advisory panel for the U.S. ANS Task Force by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. The Great Lakes ANS Panel has binational representation, with members representing U.S. and Canadian federal agencies, the eight Great Lakes states and the provinces of Ontario and Québec, non-governmental organizations, local communities, tribal authorities, commercial interests, and the academic community.

carbon dioxide that have been tested as a means to both block and herd Asian carp and other fish. New nets and methods for deploying nets that have proven successful in China have been tested. These methods to direct and concentrate fish may be used in tandem with other technologies to improve gear efficiency. The level of effort and funds spent on Asian carp control are well-justified given the potential impacts these carp can cause and by the extent to which the response procedures and control technology developed for Asian carps may be applied to the eradication and control of many other species.

In addition to developing early detection technologies and methods, the need to effectively report detections and share that information among all the agencies conducting AIS monitoring is critically important to informed management decisions. Significant progress has been made in this aspect as demonstrated in the response to detections of Grass Carp in the Great Lakes during this reporting period.

Information sharing has been greatly enhanced through the use of geo-spatial databases and the US Geological Survey (USGS) maintains a Nonindigenous Aquatic Species (NAS) database, which includes records of diploid and triploid Grass Carp (in addition to hundreds of other species). The data are accessible at: http://nas.er.usgs.gov/. The advanced version of the site allows users to access either collection information or generate a map, which can be examined from fine to coarse scale. The database information relies on voluntary submissions, and would be incomplete if agencies did not cooperate in regularly providing data. These include the Aquatic Nuisance Species (ANS) task force and several Great Lakes ANS Panel agencies, including USGS, OMNRF, DFO and several state agencies. The NAS database has become the primary database for depositing their collection data and scientists from these key agencies appear to be equally committed to ensuring this database is up-to-date. This results in a database with only minor gaps. For example, the Grass Carp data are largely complete, and as of August 2016 the only missing data were about several fish captured in the Hudson River. An example map of Grass Carp observations is provided in Figure 3.7.1.

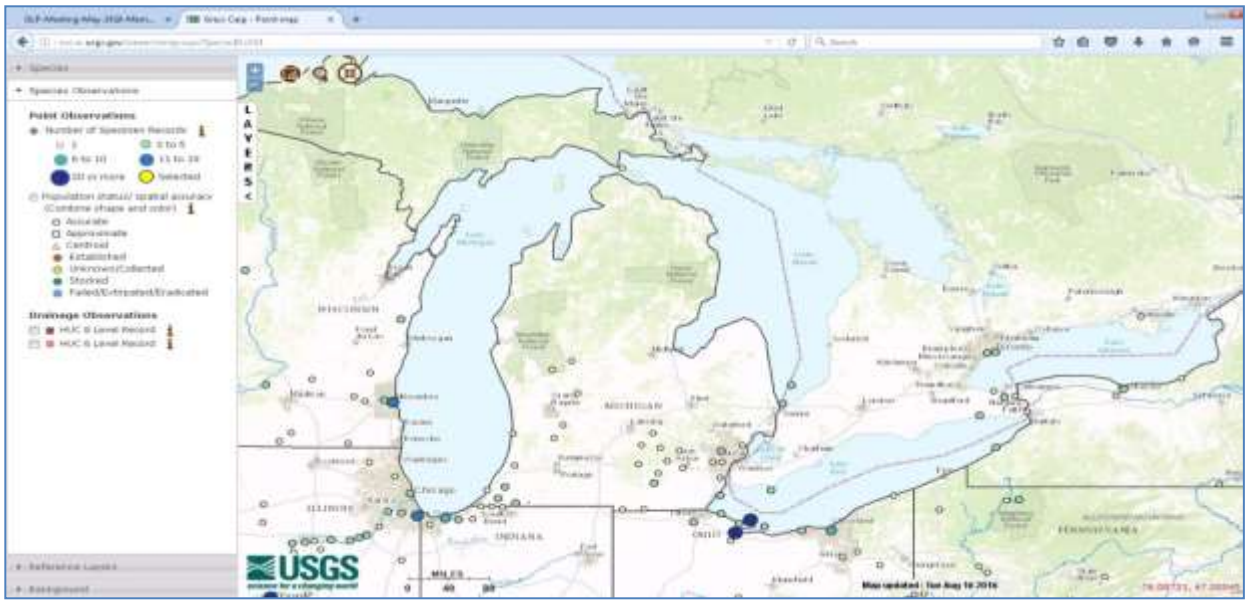

Figure 3.7.1
Map of Grass Carp Observations from NAS Database

Another excellent example of information sharing as well as the potential that exists in "citizen science" is a geographic information system that employs volunteered information that has proven instrumental in mapping terrestrial invasive species in the Great Lakes region. EDDMapS is supported by the National Park Service, US Forest Service, the Ontario Federation of Anglers and Hunters and a number of other organizations. Although there are some limitations, efforts are instituted to provide a measure of quality assurance and efforts such as this need to be further developed and improved to provide a greater understanding of the extent of terrestrial invasive species. The potential of this approach was also highlighted during public comments at the 2016 Great Lakes Public Forum. Such tools will be key in understanding how climate change and other factors affect the spread of terrestrial invasive species. More information about this initiative is provided at the following link: https://www.eddmaps.org/ontario/.

Other significant advances have been made in applied AIS research related to control and eradication. These include the synthesis and testing of Sea Lamprey pheromones for the purpose of increasing efficiency, the use of highly targeted compound from a dead soil bacterium that kills Zebra and Quagga mussels while sparing native mussels and other organisms, methods to deliver piscicides and molluscicides in a highly targeted manner, and "gene silencing" technology which has the potential to control the spread of invasive Phragmites (USEPA, 2015). Field testing and proving all these new technologies has been assigned a higher priority by the Parties, which is appropriate, given the great potential benefits (Governments of the United States and Canada, 2016).

However some obstacles remain. Specifically, the approvals and permits to use chemical control agents vary greatly between the United States and Canada. Given that the challenge of AIS cuts across geographical boundaries, it is important to institute effective and consistent control strategies throughout the Great Lakes. Effective and consistent control strategies could include finding common ground on the safe and environmentally responsible use of all types of control measures, harmonizing permitting, removing administrative barriers and adopting an integrated approach to AIS management.

Significant progress has been made on risk assessments, which also incorporate to some extent the over-arching issues of habitat and climate change. The US Fish and Wildlife Service (USFWS) has made 63 screening risk assessments of high-risk fish, crustaceans and mollusks available at: https://www.fws.gov/fisheries/ans/species_erss_reports.html, in addition to assessments of organisms considered low or uncertain risk. As well, the Centre of Expertise for Aquatic Risk Assessment (CEARA) provides easy access to more than 70 AIS risk assessments for plants and animals and provides an extensive list of references on methods.

Review of time-bound commitments

The GLWQA included time-bound commitments in the AIS Annex which have been met by the United States and Canada.Progress the Parties have made in large part resulted from leveraging the existing, extensive network of federal, state, provincial, and local government agencies and non-government organizations with a depth of AIS related experience. More details of these existing programs are provided in part 3.7.5. These commitments are:

Within two years of entry into force of the GLWQA, develop and implement an early detection and rapid response initiative that:

- develops species watch lists;
- identifies priority locations for surveillance;
- develops monitoring protocols for surveillance;
- establishes protocols for sharing information;
- identifies new AIS; and
- coordinates effective and timely domestic and, when necessary, binational response actions to prevent the establishment of newly detected AIS.

Significant progress was reported by the two Parties related to these time-bound commitments and documented in the December 2015 List of EDRR Achievements and Activities presented to the Great Lakes Executive Committee. The following accomplishments were reported by the Parties:

- Priority locations in the United States to undertake surveillance for the potential introduction of species on the watch list have been identified, and sampling locations were developed in partnership with states and Tribes.
- Hotspots of historical invasions resulting from ballast water discharge based on ecological niche modeling and using sampling techniques developed for a study in Lake Superior by (Grigorovich *et al.*, 2003).
- Connections with the Mississippi River system (http://glmris.anl.gov/).
- Locations near major cities, where live bait, live food, aquaculture, aquarium pet, water garden, biological supply, and water-related recreation are concentrated.

These priority surveillance locations have been identified based on history of invasions in the Great Lakes, risk assessments that describe potential points of invasion into the Great Lakes, and cities where human-mediated invasional pathways are most concentrated. Those pathways include the live bait, live food, aquaculture, aquarium pet, water garden, biological supply, and water-related recreation. Locations sampled for Asian carps were developed based on associations with projected spawning habitats.

In the United States, monitoring and surveillance protocols were developed in partnership with states and tribes. Schloesser and Quinlan (2015) provide a detailed summary of eDNA methods and results related to US sampling and are available at http://www.fws. gov/midwest/fisheries/eDNA.html.

The US Fish and Wildlife Service is monitoring the fish community to detect any new non-native fish.in several locations in Lake Superior including the St. Louis River, Upper St. Marys River, Thunder Bay, and Chequamegon Bay (US Fish and Wildlife Service, 2014).

In the United States, protocols for sharing information were developed, which includes information being shared among the Fish and Wildlife Service and each state, and also under the aegis of the Great Lakes Fishery Commission's Lake and Technical Committees.
With the possible exception of the previously unreported non-native invertebrate zooplankton species Thermocyclopscrassus in the western basin of Lake Erie, described above, no new non-native species have become established in the Great Lakes since 2006, well before the start of the 2012 GLWQA. Some specimens of Grass carp have been collected in the Lake Erie system and are reproducing but

fishery scientists do not consider the population to be proven as established and self-sustaining (Embke et al. 2016).

Canada and the United States continue to undertake activities such as the coordination of plans and preparations for any response actions necessary to prevent the establishment of newly detected AIS and to be prepared in the event of the identification of newly detected AIS in the Great Lakes. All of the activities listed below are enhancing the ability of agencies to respond to newly detected AIS in the Great Lakes:

- *Cooperative State and Ontario/Canada Asian Carp Response Plans* are in place in Ohio and Michigan. All eight Great Lakes states have AIS Management plans in place(http://www.anstaskforce.gov/stateplans.php), and all of those plans include AIS response plans that can be implemented for Asian carps and other AIS.

- *Governors' and Premiers' Mutual Aid Agreement* (MAA); http://www.cglslgp.org/media/1564/ais-mutual-ai d-agreement- 3-26-15.pdf) is in place to prevent the introduction and spread of AIS in the Great Lakes, foster mutual aid among the Great Lakes states and provinces to respond to serious threats to the Great Lakes Basin from AIS; and encourage further cooperative actions by the parties to combat AIS. One of the projects recently initiated under the MAA is an innovative pilot program by Michigan, Ohio and Ontario to harmonize approaches to address AIS risk, and further cooperation among those three jurisdictions (http://www.cglslgp.org/medi a/1591/ais-harmonization- resolution-6-13-15.odf).

- *Incident Command System training* has been delivered in various venues, including the "Table-top" exercise convened by the AIS Annex Subcommittee and its partners. Table-top response exercises for Asian carp and other species have been conducted within and among jurisdictions to enhance preparedness for a possible detection of additional AIS in the Great Lakes. Those exercises evaluate plans and procedures, clarify roles and responsibilities, develop effective agency relationships, assess resources and capabilities, and identify needs and solutions. One such exercise was convened under a partnership of the AIS Annex Subcommittee, Michigan, Ohio, Ontario, the IJC, and others. The exercise's After Action Report will summarize the exercise and lessons learned. Another such exercise was convened under the newly created Great Lakes Interstate Management Plan. Individual states continue to conduct exercises that include cross-agency relationships, assessing resources and capabilities, and identifying needs and solutions.

Under the Council of Great Lakes Governors and Premiers MAA:

- Illinois and Indiana convened a *Ruffe Detection Exercise* in 2015. Other Great Lakes states were invited to participate.
- Michigan and Ohio convened a *Grass Carp Detection exercise* in Lake Erie. That exercise was convened as the result of Grass Carp detections in the Lake Erie system.
- DFO and OMNRF coordinated a *Grass Carp response* along with partners, executing a full Incident Command Response to complete intensive surveys. A laboratory analysis was undertaken on the samples to determine fertility, origin, and age testing. The work was coordinated with USGS experts and indicated that all Grass Carps found were large adults originating from ponds, two were found to be sterile (triploid) and six were fertile (diploid).

The U.S. Fish and Wildlife Service (USFWS) and Ontario Ministry of Natural Resources and Forestry (OMNRF) undertook a number of detection and response initiatives to prevent the spread of AIS throughout the reporting period. For example, 2015 reports to the Great Lakes Executive Committee include:

- USFWS eDNA sampling for Bighead carps conducted in 2015 - From the 5,028 water samples collected, none were eDNA positive.
- OMNRF eDNA sampling in 2015 - From the 848 water samples collected, two positive samples were found however no fish were found. eDNA sampling from Bay of Quinte and Toronto area were added after discoveries of Grass carp (see bullet below).
- U.S. Fish and Wildlife Service 2015 sampling included:
    - 348 invertebrate samples in Lakes Superior, Michigan, and Erie
    - 248 samples of newly hatched fishes in Lakes Superior in 2015. From the 35 Early Detection locations sampled across Lakes Huron, Erie, Superior and Ontario (800 field sampling sites) Grass Carp was discovered in Lake Ontario and Lake Erie during July to September, 2015.

2. Annex 5 Discharges from Vessels

The two governments have long standing regulatory programs and measures, supported by domestic legislation, to address discharges from vessels. International shipping conventions are enforced by both governments, and legislation such as the Federal Water Pollution Control Act, the Comprehensive Environmental Response Compensation, and Liability Act, the Clean Water Act, National Aquatic Invasive Species Control Act, and the Canada Shipping Act provide a solid foundation for regulatory programs. As reported in bi-annual reports by the USCG, USEPA, Transport Canada (TC) and DFO between 1988 and 2012, both countries have greatly reduced ship-source pollution. This has been accomplished through internationally consistent regulation of all aspects of the commercial shipping industry including the ship's design, operating requirements, inspection and certification as well as licensing of crew members. Key commitments in Annex 5 relating to the AIS general objective relate to ballast water discharges.

Joint ballast water management efforts conducted by the United States and Canada are described in the annual summary of the Great Lakes Seaway Ballast Water Working Group. The group is composed of representatives from the St. Lawrence Seaway Development Corporation, St. Lawrence Seaway Management Corporation, TC – Marine Safety and Security and the USCG. Consistent with previous years, the 2015 report shows that 100 percent of ships entering the Great Lakes received ballast management exams on each Seaway transit. In total, all 8,361 ballast tanks were assessed during the 455 vessel transits. Regulations require all ships entering the Great Lakes St. Lawrence Seaway from outside the Exclusive Economic Zone (a zone extending out up to 200 nautical miles from the territorial sea) to conduct ballast water exchange or flushing. Both governments have coordinated enforcement programs to achieve nearly 100 percent compliance. Ships that did not exchange their ballast water or flush their ballast tanks at sea were required to either retain the ballast water and residuals on board, treat the ballast water in an environmentally-sound and approved manner, or return to sea to conduct a ballast water exchange. Ships that were unable to exchange their ballast water/residuals were required to retain them onboard. Verification exams conducted on outbound voyages of ships exiting the Seaway and 100 percent screening of ballast water reporting

forms indicated that there was no non-compliant ballast water discharged in the Great Lakes Seaway system in 2015. Continued high vessel compliance rates for the 2016 navigation season are anticipated.

The spread of AIS already in the lakes may be exacerbated by ships that pick up ballast water at one port in the Great Lakes and travel to another port and then discharge ballast water. To address the spread of AIS by this pathway, the regulation of ballast water discharges from "Lakers", ships that remain within the Great Lakes, is being considered by Transport Canada as well as several States, although Lakers are currently exempt from U.S. Coast Guard requirements. The two governments have agreed to seek consistency and compatibility between U.S. and Canadian ballast water requirements in the 2017-2019 priorities for science and action, and this should provide a path towards compromise and harmonious joint implementation for both Lakers and seagoing vessels.

In 2010, Canada allocated $4 million per year to DFO for the implementation of the Invasive Alien Species Strategy for Canada. The strategy was developed in 2004 by the federal/provincial/territorial Canadian Council of Fisheries and Aquaculture Ministers. A Canadian Action Plan to Address the Threat of Aquatic Invasive Species developed under the strategy, calls for the prevention of unwanted introduction, early detection of potential invaders, rapid response to prevent the establishment of aquatic invasive species, and management to contain those species that have already become established. Some of this funding has been directed at ballast water management (IAS Strategy, 2004).

US GLRI funding and agency program funds have also provided for developing and refining new procedures for testing the efficacy of ballast water treatment systems in the Great Lakes. Several promising ballast water management systems were performance tested, with many tests conducted at the Great Lakes ballast water testing facility in Superior, WI operated by the Great Ships Initiative. Under US regulations the manufacturer of a Ballast Water Management System (BWMS) approved by a foreign administration can request a USGS determination that its system complies with US ballast water management regulations as an Alternate Management System (AMS) and as of August 2016, the USCG has accepted 65 ballast water treatment systems as AMS. As of July 2016, 38 letters of intent were received by the USCG for systems being submitted for USCG type approval. As of January 2017, the USCG has approved two ballast water treatment systems, marking significant progress in the process of identifying practicable systems for salt water vessels entering the Great Lakes.

The regulatory playing field in the United States is complicated by the fact that the U.S.EPA also regulates ballast water discharges under the Clean Water Act with its Vessel General Permit (VGP) program, which is implemented in partnership with the states. The current VGP program has also adopted the IMO discharge standard, with the additional requirement for vessels entering the St. Lawrence Seaway to continue mandatory ballast water exchange/tank flushing. Transport Canada has also recommended continuation of the practice, although it is not required by federal regulations once the IMO ballast water treatment requirements become instituted by domestic legislation. Mandatory exchange and flushing of ballast water tanks would also no longer be required under the current USCG rules once approved treatment systems are installed. As the "gate keepers" for entry into the Great Lakes, the seaway authorities have made ballast water exchange and flushing a mandatory requirement for entry into the Saint Lawrence Seaway; and have the authority to keep this requirement in place.

The patchwork of requirements and implementation dates has created much uncertainty for ship owners. Both countries have stated that they will cooperate in enforcement of BWM regulations and the details of implementation will eventually be worked out over the coming years. However the complexity and uncertainty that exists during the transitional period before the IMO Ballast Water convention comes into force has caused some vessel owners to delay installation of ballast water treatment systems. Other vessel owners, such as FedNav, have already begun installing ballast water treatment systems on newly constructed saltwater vessels under the assumption that the treatment systems will eventually be granted type approval by the USCG.

Harmonizing BWM requirements between the United States and Canada is a stated priority of the Parties for action in the upcoming triennial reporting cycle under the GLWQA. Accordingly, swift action by the two governments to act on this priority and provide clear direction to all segments of the marine industry will facilitate uniform compliance and protect the Great Lakes. In the meantime, current requirements for 100 percent ballast water exchange and salt water flushing of empty ballast tanks continue to be in effect. These requirements have been effective, as is evidenced by the fact that, with the possible exception of the previously unreported non-native invertebrate zooplankton species Thermocyclopscrassus in the western basin of Lake Erie described above, no new non-native species has been discovered in the Great Lakes that can be attributed to ballast water discharges since 2006. These requirements are considered the strictest BWM requirements in the world and provide a "safety net" protecting the Great Lakes from ship-mediated AIS introductions.

The Ballast Water Working Group concluded that:

"*For any regulatory regime to be effective, the Great Lakes and the St. Lawrence Seaway must be treated as a single system. The only way to ensure consistent ballast discharge regulations across the Great Lakes Seaway system is to have strong federally mandated standards managed by unified federal agency coordination between Canada and the United States in partnership and consultation with the States and Provinces."* (BWWG, 2016)

A strict enforcement regime of mandatory ballast water exchange and flushing could provide an effective backstop to the new treatment requirements.

3.7.5 Assessment of key programs and measures

Numerous programs and measures have been established at all levels of government which support the general objective of preventing the introduction and spread of AIS. For the most part, existing programs have been sustained and new measures implemented in support of the GLWQA. Key programs and measures related to the programs and measures listed in Annex 6 are highlighted below.

1. Great Lakes Panel on Aquatic Nuisance Species

This panel and several others around the country were established by the United States in 1991 by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-646). Its purpose is to facilitate collaboration between the national ANS Task Force and state and local government partners on ANS prevention and control programs. The legislation was reauthorized in 1996 as the

National Invasive Species Act (NISA, Public Law 104-332). Its mission is to "coordinate the development of education, research and policy to prevent new aquatic invasive species from entering the Great Lakes basin and to control and mitigate those AIS populations already established." The panel is staffed by the Great Lakes Commission and draws its membership from US and Canadian federal agencies, Great Lakes states, the provinces of Ontario and Québec, regional agencies, user groups, local communities, tribal authorities, commercial interests, and the university/research community. Details about the panel may be found on its website.

Over the past 25 years, the panel has become a mainstay for binational, regional collaboration on policy, research and operational protocols to stop the establishment and spread of AIS. The panel has identified Great Lakes priorities, assisted with the national ANS Task Force, coordinated AIS program activities in the region and advised public and private interests on control efforts. With the growing concerns regarding AIS as reflected in the 2012 Protocol to the GLWQA, the panel has taken on an important role, promoting actions to support the goals set in the Annex 6. The panel continues to make a vital contribution with collaboration on US – Canadian AIS risk-assessments, species-based binational collaborative groups such as the Grass Carp Ad Hoc committee, information sharing, priority species list, and research recommendations.

Organizational relationships and professional contacts established over the many years have a direct, positive impact on the speed and effectiveness of AIS early detection and rapid response. Unfortunately, funding for the panel has declined in real terms. Its funding has never been adjusted for inflation and decreased from $50,000 per year to $40,000 per year in 2012 by sequestration. With the added workload associated with implementation of the 2012 GLWQA, the Great Lakes Panel clearly requires increased funding to sustain its operations. Although direct funding for the Great Lakes ANS Panel has come from the United States, given the benefits of binational cooperation facilitated by the Panel both governments should consider contributing funding. This issue has been brought to the attention of the ANS Task Force by multiple regions and the need is well documented, for further information see: http://glc.org/files/projects/ais/GLP-ltr-regional-panel-funding-10312014.pdf and http://projects.glc.org/ans/documents/ANS%20Panels%20Letter%20to%20ANSTF%20March%203%202009.pdf.

2. Great Lakes Fishery Commission (GLFC)

The GLFC was established by the 1955 Convention on Great Lakes Fisheries to: formulate a coordinated fishery research program between the United States and Canada; make recommendations to governments; formulate and implement a program to control the invasive, noxious Sea Lamprey in the Great Lakes; and establish working arrangements among the fishery management agencies, including provincial, state, tribal and federal authorities.

The GLFC is made up of eight Commissioners (four from each country). Its work is supported by an institutional structure that includes the Board of Technical Experts and the Sea Lamprey Research Board to advise on science, the Sea Lamprey Control Board and committees of citizen advisors. To maintain working arrangements, the GLFC facilitates the implementation of "A Joint Strategic Plan for Management of Great Lakes Fisheries," a multijurisdictional agreement among the basin's fishery management agencies. Through the Joint Strategic Plan, the members work together to develop and

implement shared fishery objectives and to harmonize their policies. The process occurs through several Joint Strategic Plan committees including a lake committee for each lake, technical committees, a basin-wide Council of Lake Committees, the Law Enforcement Committee, and the Great Lakes Fish Health Committee.

On June 9, 2016, the Government of Canada announced increases in funding for Sea Lamprey Control. At the Annual Meeting of the Great Lakes Fishery Commission, officials announced that the Government of Canada is making an investment of an additional $8 million over two years to the Great Lakes Fishery Commission for Sea Lamprey control. This new infrastructure funding will be used to improve physical barriers to prevent Sea Lamprey from gaining access to suitable spawning and nursery habitats in tributaries of the Great Lakes and in new infrastructure to help prevent the spread of invasive Sea Lamprey in the Great Lakes and their tributaries. The investment will be directed towards the maintenance and improvement of low-head physical barriers, as well as the rehabilitation of dams built for other purposes that also serve an important role in Sea Lamprey control.

Sea Lampreys are a highly destructive invasive species. Since entering Lake Ontario over 200 years ago, Sea Lampreys have inflicted significant economic damage and harm to the fishery and ecosystem. Canada's Sea Lamprey Control Program (SLCP) uses several techniques to target Sea Lampreys during different stages of the life cycle including lampricides, physical barriers and trapping. The SLCP has been effective in controlling this aggressive and resilient invasive species, and remains critical in restoring balance to the Great Lakes ecosystem.

3. Canadian Aquatic Invasive Species Network (CAISN)

The CAISN, funded by the Canadian Natural Science and Engineering Research Council (NSERC), focused on early detection, rapid response, AIS as part of multiple stressors and reducing uncertainty in prediction and management. CAISN received $400,000 in NSERC funding from 2013 through 2015 and contributed to efforts in several areas including assisting industries affected by AIS, developing government policy and advancing early detection methods and control technology, but this program has not been continued.

4. Great Lakes Phragmites Collaborative (GLPC)

The GLPC is a partnership established to improve communication and collaboration and lead to more coordinated, efficient and strategic approaches to management of the Common Reed *Phragmites*, restoration of native habitat and research across the Great Lakes basin in both the United States and Canada. The GLPC serves as an effective communication conduit via an interactive website, a webinar series and social media outlets to facilitate access to information and resources, and encourages technology transfer and network building among habitat managers, governmental agencies, and private landowners. This initiative is led by a core team supported by staff from USGS – Great Lakes Science Center and the Great Lakes Commission with oversight and input from a regional Advisory Committee which includes representatives from the public and private sector in the United States and Canada. This effort is part of a broader USGS project funded through the Great

Lakes Restoration Initiative and has become a model for effective collaboration across multiple jurisdictions.

5. Invasive Mussel Collaborative

The collaborative was established by USGS, NOAA, GLFC and GLC to advance scientifically sound technology for invasive mussel control. It provides a species-specific framework for communication and coordination. This collaborative has enhanced communications related to response actions and lessons learned, helping responders to new infestations more effectively implement effective control actions.

6. Asian Carp Regional Coordinating Committee

The committee has overseen comprehensive monitoring, risk assessment, control and eradication efforts. These efforts have not only added to the knowledge base regarding Asian carp, but have significantly increased the capacity to detect and control other AIS, such as snake head, Sea Lamprey, Eurasian Ruffe, and Zebra Mussels.

7. Invasive Species Centre

The Invasive Species Centre is a Canadian non-profit organization that builds partnerships and supports collaborative projects in natural and applied science, policy research, outreach and education to protect Canada's forests, fields, gardens, waterways and cities from the damaging effects of invasive species. Founded in Ontario, the Invasive Species Centre has a global reach to address invasive species issues across Canada. Its main source of revenue is from the OMNRF. The Centre provides a well-organized communications platform for other "nested" Canadian programs including: Asian Carp Canada, Forest Invasives Canada and the Early Detection & Rapid Response (EDRR) Network Ontario project.

8. Centre of Expertise for Aquatic Risk Assessment (CEARA)

The objectives of CEARA were to develop a national standard for conducting biological risk assessments of AIS; educate practitioners on the risk assessment process; develop a process for prioritizing risk assessment needs; provide advice to headquarters on national priorities for risk assessments; coordinate and track progress of national risk assessments and ensure that deliverables are met. As discussed above, CEARA contributed significantly to the development of AIS risk assessments supporting Annex 6 goals; however the program was not continued.

9. Ontario detailed-level risk assessment guidelines

The OMNRF finalized this guidance in 2011. The regulation classifies 16 species identified on the Conference of Great Lakes and St. Lawrence Governors and Premiers "Least Wanted Aquatic

Invasive Species List" and all species in the family Channidae (Snakeheads) as prohibited under the *Invasive Species Act, 2015*. (Fish: Bighead Carp, Silver Carp, Grass Carp, Black Carp (these four species of carp are commonly known as Asian carp), Snakehead, Stone Moroko, Zander and Wels Catfish. Aquatic Invertebrates: Killer Shrimp, Yabby (crayfish), Golden Mussel. Aquatic Plants: Hydrilla, Brazillian Elodea, Water Soldier, European Water Chestnut, Parrot Feather).
This proposal follows the 2013 commitment to block these species from entering the Great Lakes basin; and, classifies Phragmites, Dog Strangling Vine and Japanese Knotweed as restricted species under the *Invasive Species Act, 2015*.

10. Great Lakes Aquatic Nonindigenous Species Information System

This is a web-based database consisting of three lists: species nonindigenous to the Great Lakes basin (not native to any part of the basin); range expansion species (native only to a portion of the basin); and a watch list (species not currently found in the Great Lakes but considered to be of high risk). These lists provide an up-to-date accounting of nonindigenous species and have been enhanced during the reporting period link with the USGS NAS system described above. This linkage provides an effective portal for detailed information about the species as well as its distribution and impact.

11. Internet trafficking in AIS

The Great Lakes Commission, with funding from the GLRI and USEPA, developed the Great Lakes Detector of Invasive Aquatics in Trade in 2016. This tool enables users to better understand the risk of AIS being traded on internet in the Great Lakes region. It also facilitates outreach to internet-based sellers, with information about relevant regulations and potential risks or impacts associated with AIS. The July 2015 phase 1 report is available at the following links: Report, Appendices.

12. Great Lakes Mississippi River Interbasin Study (GLMRIS)

GLMRIS is a US Army Corps of Engineers study that presents a range of options and technologies to prevent ANS movement between the Great Lakes and Mississippi River basins through canals. The study examined 18 other potential connections in addition to the Chicago Area Waterways (CAWS). This extensive study released several reports during the GLWQA triennial reporting period and added significant information to the understanding of Great Lakes aquatic connections. The final report was released in January 2014 and presents options for addressing/mitigating the impact of the hydraulic connection between the two basins. These options range from a complete physical separation of the Mississippi and Great Lakes basins to options that would maintain a physical connection while creating an ecological separation. Ecological separation is defined as no inter-basin transfer of aquatic organisms via the Chicago Area Waterway System at any time, and the prohibition of movement or inter-basin transfer of aquatic organisms between the two basins. Since the Chicago Area Waterway System serves as a conduit for treated wastewater, provides flood control and an important transportation link there are many factors to consider. The eight alternatives reported in the GLMRIS included a wide range of options for structural and non-structural controls, new technologies, buffer zones and hydrologic separation schemes as well as rough estimates of cost which ranged from $68 M dollars to more than $18 B dollars.

U.S. Army Corps of Engineers costs for the GLMRIS study and the related studies for Eagle Marsh and the Brandon Road Lock and Dam started in FY 2013 and projected through FY 2019 amount to over $19 M dollars. The combinations of approaches and technology proposed for testing at the Brandon Road Lock and Dam project over the next three years may serve to identify a viable way forward in preventing migration of AIS through the CAWS.

13. Chicago Area Waterway System Advisory Committee

This advisory committee provides significant support for implementing measures identified by the 2010 CAWS study and GLMRIS follow-on work. This includes testing new AIS control technology to create a barrier at the Brandon Road Lock and Dam located downstream of the junction between the Des Plaines River and the Chicago Sanitary and Ship Canal. Further details of the Brandon Road project are available at: Brandon Road Lock Project website.

14. Ontario Conservation Authorities

Ontario has 36 Conservation Authorities - resource management agencies that operate on the basis of local watersheds. Conservation Authorities provide science-based advice and services within their watersheds, undertake biological and fish monitoring and are instrumental in AIS monitoring, removal, and restoration activities, especially for the lower-Great Lakes. They are funded primarily through municipalities (48%) and self-generated revenues (40%). Additional sources of funding for Conservation Authorities are provided by the Province (10%) and Federal government (2%) (2014). In 2012, they engaged 495 landowners and provided $5.9 million in grants to carry out rehabilitation/restoration projects with wetlands, habitats, shorelines and stream & fish habitat. 127 projects were aimed at invasive species.

15. Ontario's Invading Species Awareness Program

The Ontario Federation of Anglers and Hunters (OFAH), runs a joint program with the Ontario Ministry of Natural Resources and Forestry (OMNRF) called "Ontario's Invading Species Awareness Program" (www.invadingspecies.com). Established in 1992, the program has worked cooperatively to prevent the introduction of invasive species through multiple pathways, including recreational watercraft, use of live bait, and the aquarium, water garden, live food fish, and horticulture industries. The program includes invasive species outreach, monitoring, and stewardship activities. It promotes early detection of new species in the through citizen reports to the Invading Species Hotline and the Early Detection and Distribution Mapping System (EDDMapS) within North America, the Great Lakes, and Ontario's inland waters.

Potential gaps - The October 26, 2016, the Environmental Commissioner of Ontario (ECO) 2015/2016 Environmental Protection Report, Volume 2, chapter 2 addressed invasive species management in Ontario. It recommended the Ministry of Natural Resources and Forestry take actions to restrict known pathways of invasive species spread; tackle invasive species in provincial parks; establish advisory panels with scientific expertise and local and Aboriginal knowledge to propose species for regulation; and to report publicly on progress to manage invasive species regulated under

the Invasive Species Act, 2015. The report also called for an increased program funding and less reliance on grants. Another potential gap noted on the Canadian side, is that there do not appear to be invasive species policies or procedures in place for dealing with invasive algae. The OMNRF addresses aquatic plants and animals, but not algae. The Ontario Ministry of Environment and Climate Change (MOECC) handles algal bloom issues, but does not have any management strategy for non-native algae such as Starry Stonewort (*Nitellopsisobtusa*), which has been increasing in abundance in the lower Great Lakes.

3.7.6 Section Summary

- The United States and Canada have fully developed mature AIS prevention programs in place that are institutionalized in domestic legislation and regulations. Every Great Lakes State and Province has instituted and exercised rapid response plans and Governors and Premiers have established a mutual aid compact. Significant progress has been made in the areas of monitoring, prevention and risk assessment during the reporting period.

- Over the past 25 years, the Great Lakes Regional Panel on ANS has become a mainstay for binational coordination and regional collaboration on policy, research and operational protocols to stop the establishment and spread of AIS. It provides an important forum for activities related to Annex 6 of the GLWQA.

- The United States and Canada have consistent ballast water management programs in place that take into account the international ballast water discharge standard issued by the IMO. The joint efforts of the two governments strictly enforce ballast water exchange and flushing requirements for vessels entering the Great Lakes through the St. Lawrence Seaway.

- A strictly enforced regime of mandatory ballast water exchange and flushing currently in place has proven effective and research sponsored by the Canadian government indicates that treatment to the IMO discharge standard in addition to ballast water exchange and flushing will further reduce the risk of introduction.

- Given that the challenge of AIS cuts across geographical boundaries, it is important to institute effective and consistent control strategies throughout the Great Lakes. The Parties could find effective and consistent control strategies on the safe and environmentally responsible use of all types of control measures, harmonize permitting, remove administrative barriers and adopt an integrated approach to AIS management.

- Significant progress has been made by the Parties on all 2013-2016 priorities for science and action on AIS. The Great Lakes Panel has placed emphasis on collaboration, coordination and information sharing.

- The Parties have selected AIS sub-indicators for the AIS indicator that effectively communicate progress on General Objective 7 of the GLWQA in the 2016 SOGL.

- Efforts by the Parties to control the spread of Asian Carps and prevent their introduction to the Great Lakes are commendable. The Asian Carp Regional Coordinating Committee, representing

28 federal, state/provincial, municipal, non-profit and binational organizations from the United States and Canada is a model of multi-jurisdictional collaboration. The level of effort and funds spent on Asian carp control are well-justified by the program results and by the extent to which the response procedures and control technology developed for Asian carps may be applied to the eradication and control of many other species.

- The spread of existing AIS within the basin was highlighted in presentation of the draft SOGLR during the Great Lakes public forum as a serious concern resulting in an overall *poor – deteriorating* status.

- The process for conducting ecological assessments of AIS prevention programs has been initiated by the Parties by establishing performance measures and strategic outcomes for key programs.

- Significant progress has been made in sharing key information to support of management decisions among all the agencies conducting AIS monitoring, as demonstrated in the response to detections of Grass Carp in the Great Lakes during this reporting period.

- The regulation of ballast water discharges from "Lakers", ships that remain within the Great Lakes, is being considered by Transport Canada as well as several States as a means to address the spread of AIS, from one port to another within the lakes. The two governments have agreed to seek consistency and compatibility between US and Canadian ballast water requirements and this could provide a path towards harmonious joint implementation for both Lakers and seagoing vessels.

- The GLMRIS, Chicago Area Waterways and Brandon Road Lock studies have identified options for effectively separating the Mississippi River and Great Lakes basins.

3.7.7 References:

BWWG, 2016. 2015 Summary of Great Lakes Seaway Ballast Water Working Group February 2016. Available at: www.greatlakes-seaway.com/en/pdf/2015_BW_Rpt_EN.pdf

Donahue et. al. 2013.Donahue, Burrows, Taylor, Christie, IJC Work Group on Binational AIS Rapid Response. Binational AIS Rapid Response Planning for the Great Lakes-St. Lawrence River Basin -Analysis of Jurisdictional Roles and Capabilities. Funded by the 2010 Great Lakes Restoration Initiative.As revised August 19, 2013. Available at http://ijc.org/files/publications/2013-AIS-RResponse-JurisdictionalAnalysis-FinalReport-GLRI.pdf

E García-Berthou, et al, 2011. Introduction pathways and establishment rates of invasive aquatic species in Europe. Canadian Journal of Fisheries and Aquatic Sciences, 2005, 62(2): 453-463, 10.1139/f05-017. Published on the web 12 April 2011.

Executive Order 13112 of February 3, 1999 - Invasive Species.FederalRegister.gov. Federal Register: Feb 8, 1999 (Volume 64, Number 25); Amended by Executive Order -- Safeguarding the Nation from the Impacts of Invasive Species (Dec 5, 2016).

Embke et al, 2016. Journal of Great Lakes Research, Vol 42, Issue 4, August 2016, Pages 899–903. Available at http://www.sciencedirect.com/science/article/pii/S0380133016300612

Fisheries and Oceans Canada. 2016. Report on Plans and Priorities: Program 2.2 Fisheries Protection. http://www.dfo-mpo.gc.ca/rpp/2016-17/so-rs-2.2-eng.html

Governments of the United States and Canada. 2016. Progress Report of the Parties. Available at https://binational.net

Governments of the United States and Canada. 2016. 2017-2019 Binational Priorities for Science and Action. Available at https://binational.net/2016/10/03/psa-pasa-2017/

Great Lakes Public Forum, 2016.State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. Available at https://binational.net/2016/11/25/glpf-fpgl-2016-presentations-videos/

Grigorovich, I. A., et al, 2003. Lake Superior: an invasion coldspot? Hydrobiologia 499:191-210.

Hecky, RE. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences. Vol 61: 1285–1293 (2004), doi: 10.1139/F04-065

Hill, JP, D Eichinger. 2016. A Framework for Assessing the Effectiveness of Programs and Other Measures Developed to Address the Objectives of the Great Lakes Water Quality Agreement. Submitted to the International Joint Commission by James. P. Hill and Daniel Eichinger, Central Michigan University, March 8, 2013. Available at: http://ijc.org/en_/Assessing_the_Effectiveness_of_Programs_under_the_GLWQA

IAS Strategy, 2004. Federal, Provincial, Territorial Canadian Council of Fisheries and Aquaculture Ministers.Invasive Alien Species Strategy for Canada 2004. Available at http://publications.gc.ca/site/eng/462217/publication.html

IMO, 2016.International Maritime Organization.(2016). Global treaty to halt invasive aquatic species to enter into force in 2017. Accessed (8/9/2016) (http://www.imo.org/en/MediaCentre/PressBriefings/Pages/22-BWM-.aspx).

Jeschke and Strayer. 2005. Invasion success of vertebrates in Europe and North America. Proceedings of the National Academy of Sciences 102:7198-7202.

IJC, Special Publication 2009-04. Work Group Report on Binational Aquatic Invasive Species. Rapid-Response Policy Framework Work Group Report. 2009. Available at http://www.ijc.org/files/publications/C223.pdf

IJC, 2011.15th Biennial Report on Great Lakes Water Quality. Available at http://www.ijc.org/files/publications/C265.pdf

IJC, 2013.16th Biennial Report on Great Lakes Water Quality. Assessment of Progress Made Towards Restoring and Maintaining Great Lakes Water Quality Since 198. Available at http://www.ijc.org/files/publications/16thBE_internet%2020130509.pdf

IJC SAB, 2016. An assessment of the communicability of the International Joint Commission ecosystem indicators and metrics.Great Lakes Science Priority Committee. Available at http://www.ijc.org/files/publications/ScienceAdvisoryBoard_CommunicationIndicatorsReport_en.pdf

Johns, C., VanNijnatten, D., Thorn A., 2015.Testing a framework for assessing the effectiveness of programs and other measures under the Great Lakes Water Quality Agreement. Available at http://ijc.org/files/tinymce/uploaded/documents/IJC_GLEEM_Report_January_2016.pdf

Mills, EL; Leach, JH; Carlton, JT; et al. (1994) Exotic species and the integrity of the Great Lakes: lessons from the past. BiolSci 44(10):666–676.

Rothlisberger JD, Finnoff DC, Cooke RM, Lodge DM. 2012. Ship-borne Nonindigenous Species Diminish Great Lakes Ecosystem Services. Ecosystems (2012) 15: 462–476.

USACE, 2011.GLMRIS Natural Resources Team. Non-Native Species of Concern and Dispersal Risk for the Great Lakes and Mississippi River Interbasin Study; Available at: http://glmris.anl.gov/documents/docs/Non-Native_Species.pdf

USDA. 2016. National Invasive Species Information Center. What is an Invasive Species.https://www.invasivespeciesinfo.gov/whatis.shtml

USEPA, 2015.Great Lakes Restoration Initiative Report to Congress and the President. Accessed (7/20/2015). Available at https://www.glri.us/pdfs/21050720-report_to_congress.pdf

USGS, 2016.U.S. Geological Survey.(2016). Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed (12/16/2016) (https://nas.er.usgs.gov/queries/SpeciesList.aspx?Group=Fishes).

Williamson and Fitter, 1996.The varying success of invaders.Ecology, 77(6), 1996, pp. 1661-1666 © 1996 by the Ecological Society of America. Available at www.reabic.net/publ/Williamson_Fitter_1996.pdf

3.8 Contaminated Groundwater

This section reviews and assesses progress toward achieving General Objective 8 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 8 states that the waters of the Great Lakes should "be free from the harmful impact of contaminated groundwater."

This assessment includes a consideration of implementation measures undertaken in support of the GLWQA Annex 8: *Groundwater* and other key programs related to groundwater.

3.8.1 Background

Groundwater in the Great Lakes basin is a critical part of the region's water resources. Groundwater and surface waters are inextricably linked in terms of both quality and quantity (Figure 3.9). Reductions in groundwater quantity, due to over-pumping for example, can reduce base flow to streams negatively impacting surface waters and degrading groundwater dependent habitats and ecosystems. If groundwater contaminant levels are higher in surface waters than groundwater, then groundwater ultimately discharged to receiving waters can deteriorate surface water quality. For instance, surface waters of the Great Lakes can be affected by leaking underground storage tanks or other sources of groundwater contamination. Sometimes, groundwater transported to surface waters can be of higher quality than the receiving waters, resulting in improved surface water quality.

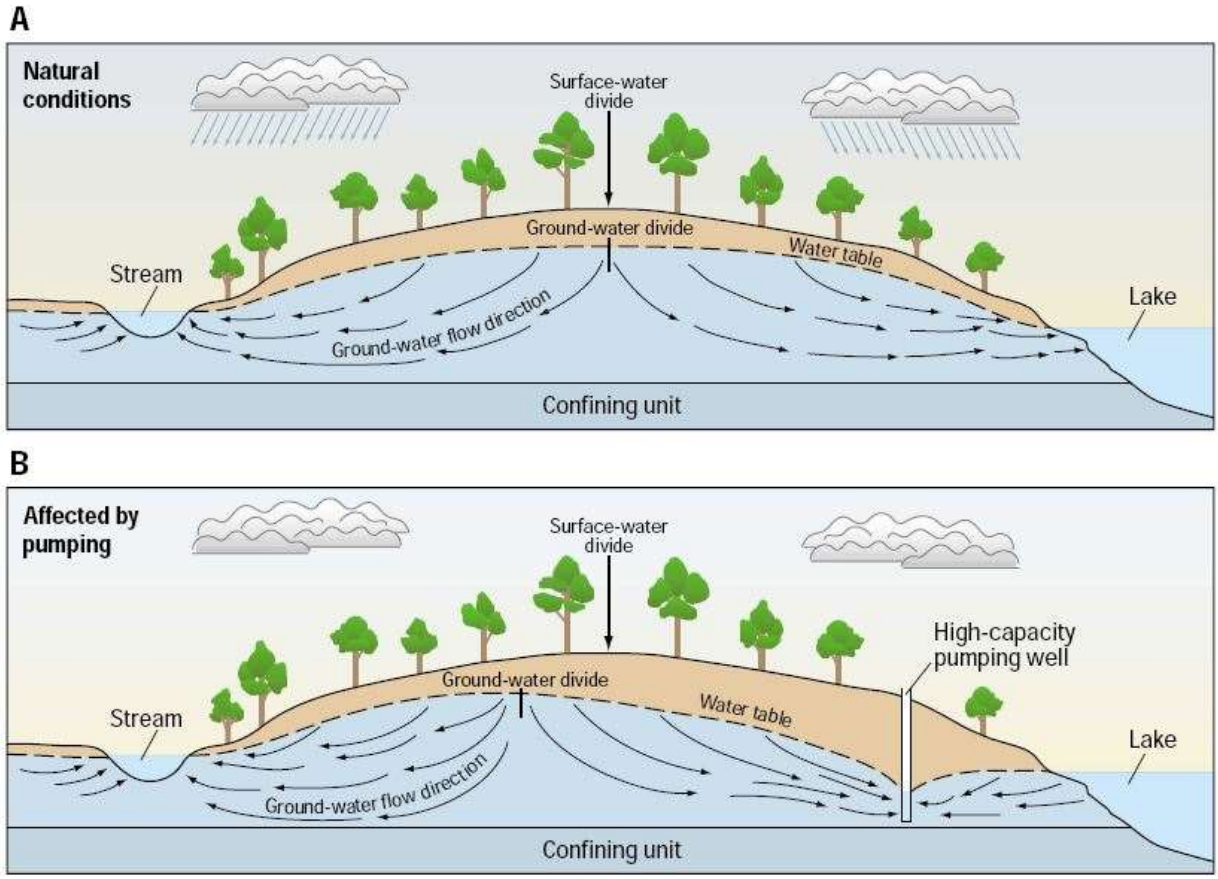

Figure 3.8.1 – Generalized Groundwater - Surface Water Interactions (A) under natural conditions and (B) affected by pumping (*Source: USGS, 2000*)

The role of groundwater and its impacts on the Great Lakes were not fully recognized in the establishment of the original GLWQA in 1972. The 1978 GLWQA introduced the "ecosystem approach", recognizing the interconnectedness of all components of the environment, and created Annex 16 to address pollution from contaminated groundwater. (The 2012 GLWQA establishes Annex 8, an updated groundwater Annex that recognizes the interconnection between groundwater and the waters of the Great Lakes and that preventing groundwater contamination is critical in protecting the physical, chemical and biological integrity of the Great Lakes. Annex 8 seeks to support the achievement of Objective 8 by promoting the coordination of groundwater science and management actions.

3.8.2 Assessment of indicators

1. Assessment

The SOGL report is expected to include a groundwater quality indicator (GLPF 2016) to assess the general status of the quality of shallow groundwater in the Great Lakes basin. Previous 2011 SOGL reporting did not include a groundwater quality indicator, but rather a "Base Flow due to Groundwater Discharge" indicator. The SOGL 2016 indicator will report on two key groundwater contaminants – chloride (representative of urban contamination) and nitrate (representative of rural contamination). These chemicals are monitored in shallow wells, as this groundwater has the greatest potential to impact surface water quality.

The groundwater quality is assessed with a status of "fair" with an "undetermined" trend. There are limited data to determine long-term groundwater trends.

2. Improvements for indicator reporting

The IJC's proposed ecosystem indicator for "Contaminants in Groundwater" suggests measuring several chemical and physical parameters, representative of agricultural and urban areas (IJC, 2014). These include: water level and/or flow, temperature, pH, Total Dissolved Solids (TDS) , nitrate, chloride, sulfate, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, total chlorinated compounds, BTEX (benzene, toluene, ethylbenzene, xylenes), arsenic, cadmium, zinc, phosphorus and triazine herbicides .

A Research Coordinating Committee (RCC) report with suggestions to improve SOGL reporting found that the data for some of the additional measures proposed by IJC for the groundwater indicator already exist and would improve upon the SOLG indicator reporting (RCC, 2016). However, RCC also notes that the level of effort and time required to resolve all the issues with this indicator is high (for example, developing the methods to calculate the metrics) and due to resource constraints the Parties may not be able to adopt every suggested measure. This highlights the challenges in assessing progress towards the groundwater Objective. This is further underscored by the delay in the development of the 2016 SOGL groundwater contaminants indicator.

During the time that the RCC work was undertaken, those developing the SOGL report undertook the development of a draft indicator that includes the reporting of nitrate and chloride parameters, as a

starting point for indicator reporting, with additional parameters to be included in future reporting. These two parameters are included in the IJC indicator. The reporting of additional groundwater parameters, mentioned above and discussed in the IJC ecosystem indicator report (IJC, 2014) would be helpful.

3.8.3 Assessment of Progress Report of the Parties

1. Assessment

The Parties established the following Binational Priorities for Science and Action for 2014-2016 to guide their work under Annex 8 of the GLWQA:

- By 2015, publish a Groundwater Science Report of available groundwater science to understand and manage groundwater and its impacts on the waters of the Great Lakes.
- Identify science gaps and research needs concerning groundwater impacts to the waters of the Great Lakes.
- Analyze contaminants, such as nutrients, and other factors, such as climate change, that affect groundwater's impact on the waters of the Great Lakes.
- Undertake surveillance of groundwater quality for priority areas.
- Coordinate binational groundwater activities under the GLWQA with domestic groundwater programs to assess, protect and manage groundwater impacting the waters of the Great Lakes.

The Parties, through the Annex 8 subcommittee, released the draft report *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report* in late 2015 for public comment, with the final report completed in May 2016 (Granneman and Van Stempvoort, 2016). The release of this report meets the first three of the five Binational Priorities for Science and Action noted above. The report also meets the commitments of the Parties under the "science" mandate outlined in Annex 8 of the GLWQA. The PROP indicates that discussion with other Annex subcommittees, via the Annex 8 subcommittee, will be undertaken to determine if there needs to be a focus on coordinating specific binational groundwater activities and to determine the need for surveillance of groundwater quality in priority areas.

2. Publication of groundwater science report and Identification of Science Priorities

The Annex 8 report examines threats and stresses to groundwater quality as well as the impacts of groundwater quantity and flows on the lakes. The scope of the report also informs and supports the efforts of other GLWQA Annexes. The report discusses the effects of groundwater in nearshore regions of the lakes (Annex 2); the storage, transport and discharge of nutrients (Annex 4); the dependency of Great Lakes habitats on groundwater (Annex 7); and the current understanding of climate change on groundwater and its potential impacts on Great Lakes water quality (Annex 9).

Many priority science needs are identified throughout the report and are grouped into eight overarching categories:

- assessing regional-scale groundwater discharge to surface water;
- assessing the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality, and the efficacy of mitigation efforts;
- monitoring and surveillance of groundwater quality in the Great Lakes basin;
- advancing research on local-scale interaction between groundwater and surface water;
- developing better tools for monitoring, surveillance and assessment of groundwater/surface water interactions;
- advancing research on the role of groundwater in aquatic habitats in the Great Lakes basin;
- improving the understanding of effects of urban development on groundwater; and
- developing scale-up models of regional effects of groundwater on Great Lakes water quality.

The priority science needs identified in the Annex 8 groundwater report were used to help identify the Parties' draft 2017-2019 Binational Priorities for Science and Action, in consultation with other Annex subcommittees. Of the eight broad science priority needs identified in the report, the first three are reflected in the draft 2017-2019 Binational Priorities for Science and Action listed below:

- develop better tools to assess groundwater – surface water interaction and use them to advance assessment of regional-scale groundwater discharge (quantity) to surface water in the basin;
- establish science-based priorities to advance the assessment of the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality, and the efficacy of mitigation efforts; and
- advance monitoring, surveillance, and assessment of groundwater quality in the Great Lakes Basin.

However, the PROP does not specify the process undertaken to evaluate and select the binational priorities for science and action, the reason for their selection, or the actions that will be taken to address these priorities. It is also not clear when (or how) the remaining priority science needs identified in the Annex 8 report will be addressed. The IJC's Science Advisory Board (SAB), in its review of the DRAFT 2017-2019 Binational Priorities for Science and Action, concludes that a better understanding of how groundwater influences the nearshore is needed to improve the management of that zone.

The priority science needs identified in the Annex 8 report are consistent with previous recommendations made in several recent IJC and IJC Board reports including, *the IJC's 15th and 16th Biennial Reports on Great Lakes Water Quality* (IJC, 2011; IJC, 2013) the IJC's Science Priority Committee report that selected *Key Recommendations from the last two IJC Biennial Reports* (SPC, 2016), the IJC's report on *Protection of the Waters of the Great Lakes (IJC, 2015)* , and the IJC's Science Advisory Board's *Groundwater in the Great Lakes Basin* report (SAB, 2010). In general, these reports all identify the need for improved groundwater research and monitoring to better understand and manage groundwater quality and subsequently its impacts on surface waters of the Great Lakes. This includes groundwater quantity and its connection to surface waters, which is not well understood. Below are excerpts of the recommendations from those reports:

> *Designate a lead agency with responsibility for compiling and regularly reporting to the Commission on relevant research, monitoring and program information on key groundwater*

issues because of the importance of groundwater quality to human and ecosystem health. ((IJC, 2011 and SPC, 2016))

Federal, state and provincial research should continue to improve mapping and understanding of groundwater aquifers in the basin, determining where groundwater supplies may be degraded in the future, identifying management methods for avoiding these problems, and achieving an improved understanding of the relationship among land uses and groundwater and surface water quality and stream habitat. (IJC, 2015)

Recognize and reflect the relationship between the quantity and the quality of groundwater and the interactions between groundwater and surface water in respect to both quality and quantity. (SAB, 2010)

3.8.4 Assessment of key government programs

1. Assessment

Achieving the objectives of the GLWQA requires coordination and collaboration among federal, state and provincial, Tribal, First Nations and municipal governments, watershed management agencies and non-government organizations, both domestically and binationally. Table 4.8.1 provides examples of programs and initiatives that support the protection of groundwater in the Great Lakes through improving the understanding of groundwater quality and quantity and prevention efforts.

In Canada, the provinces have direct responsibility for managing groundwater, unless there is a "significant national interest in the water resource management" (per the *Canada Water Act, 1985*), such as international boundary waters with the United States. In such cases the federal government would share the responsibility of managing these waters with the provinces. In the United States, groundwater allocation and use are regulated by individual states, whereas ground water quality protection is a mixture of state and federal laws.

Table 3.8.1
Examples of programs contributing to the protection of groundwater in the Great Lakes

Program	Year
Canada	
Natural Resources Canada Groundwater Geoscience Program - Groundwater Information Network	**2002**
Canada Water Act	**1985**
Ontario Provincial Groundwater Monitoring Network	**2000**
Ontario Low Water Response Program	**2001**
Ontario Water Resources Act	**1961**
Ontario Clean Water Act	**2006**
Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health	**2014**
Ontario Great Lakes Strategy	**2012**
United States	
Underground Storage Tank Program (Resource Recovery and Conservation Act)	**1988**
Underground Injection Control Program (Safe Drinking Water Act)	**1977**
Wellhead Protection Program (Safe Drinking Water Act)	**1986**
Great Lakes-St. Lawrence River Basin Sustainable Water Resources Compact	**2008**
Eight Great Lakes States - groundwater monitoring programs	
Binational	
Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement	**2005**

2. Groundwater quantity

Groundwater use and withdrawal are regulated by individual states and provinces, with requirements varying among jurisdictions. Some jurisdictions regulate groundwater withdrawals through permit requirements, while others require registration of withdrawals for specified thresholds (SAB, 2010). With the enactment of the 2008 Great Lakes St. Lawrence River Basin Sustainable Water Resources Compact (Great Lakes Compact) and Great Lakes St. Lawrence River Basin Sustainable Water Resources Agreement, all ten Great Lakes states and provinces are called upon to develop a program to regulate new and increased water withdrawals, including a registration and reporting requirement

for all withdrawals in excess of 378,541 liters (100,000 gallons) per day (for both surface waters and groundwater) (Schulte, 2013).

The IJC has commended the states and provinces for the enactment of the Great Lakes Compact and the parallel Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement and concludes that if fully and rigorously implemented, the measures will provide a solid foundation for managing Great Lakes diversions and consumptive uses into the future (IJC, 2015). The IJC's Protection of the Waters of the Great Lakes report (IJC, 2015) discussed the impact of groundwater withdrawals on groundwater supply. The report also considered the impact of withdrawals on groundwater quality. Over-pumping of aquifers can degrade groundwater quality by pulling in contaminants, such as naturally occurring radium or fluoride, from adjacent aquifers. The report recommended that Great Lakes states and provinces should fully factor the adverse ecological and water quality impacts of groundwater withdrawals into both water use permitting procedures and decisions regarding consumptive use.

The state of Michigan, for example, has developed a Water Withdrawal Assessment Tool to determine the potential impacts of large quantity water withdrawals on nearby water sources, including potential impacts to fish habitats and populations (MDEQ, http://www.michigan.gov/deq/0,4561,7-135-3313_3684_45331-201102--,00.html, Accessed September 2016). This tool has been used by Michigan since 2009 to regulate large quantity withdrawals and is required to be used by anyone proposing to make new or increased large water withdrawals from either surface water or groundwater in the state. This tool is currently being evaluated by other Great Lakes states for potential implementation (PROP, 2016).

3. Groundwater quality

The quality of groundwater used for public drinking water supply is well regulated in the United States and Canada (Ontario). The US Environmental Protection Agency (USEPA) has several programs for the protection of groundwater from contamination sources, including the Underground Injection Control program (UIC), Wellhead Protection program (WHP) and Underground Storage Tank program (UST). The UIC program regulates the underground injection of fluids and fluid wastes through wells to protect underground sources of drinking water. The WHP program requires states to develop a program that will minimize pollution of public water supply wells by identifying and managing potential contaminant sources in the area that contributes water to a well. The UST program includes requirements for tank inspections and reporting of leaks. Leaking underground storage tanks were identified as a serious threat in the SAB's 2010 groundwater report and IJC's 15th Biennial Report (IJC, 2011). In 2015, the USEPA strengthened its UST regulations to include, among other provisions, secondary containment and interstitial monitoring (*i.e.*, leak detection) requirements for new and replaced tanks.

In Ontario, the Ministry of the Environment and Climate Change has programs in place to protect groundwater including, regulation of the construction and abandonment of wells and Environmental Compliance Approvals to regulate releases of pollutants to the environment and source water protection. At the end of 2015, Ontario completed the development of Source Water Protection Plans (SWPP) for the protection of drinking water, including groundwater, in watersheds throughout the province. These plans identify sources vulnerable to contamination and actions to protect them. The

plans include legally binding policies to mitigate source water threats, to be implemented by various bodies (such as ministries/government agencies, municipalities, Conservation Authorities[4]). These mitigation policies can include land-use planning, regulations, and stewardship (such as education and best management practices). Once a SWPP is in place, municipalities or planning authorities cannot undertake any activity that conflicts with that plan.

4. Groundwater monitoring, mapping and research

In Canada, the Groundwater Information Network (GIN) provides web access to national standardized groundwater information, including groundwater monitoring data, well databases and maps. Collaboration with the US Geological Survey (USGS) is also underway to enable cross-border sharing of information. Ontario, which is also a collaborator with the GIN, has a Provincial Groundwater Monitoring Network that provides access to information on groundwater levels and chemistry data from monitoring wells.

In 2016, Natural Resources Canada, through its Groundwater Geoscience Program, completed a study to determine a strategy for a regional water resources modeling platform for the Great Lakes basin and Southern Ontario (Frey *et al*., 2016). The report notes that such a platform, which integrates groundwater and surface water systems for the Great Lakes basin, can be utilized as a decision-support tool for surface water and groundwater sustainability and Great Lakes water quality. The report also notes there are limitations in the availability of data needed to develop the model at the scale of the Great Lakes basin. However, identified data gaps help to inform field-data collection and monitoring needs. This need for additional data, particularly that of the role of groundwater-surface water interactions in the Great Lakes, is underscored by the science priority needs identified in the Annex 8 report.

In the United States, the USGS has continuing groundwater studies in the Great Lakes region to evaluate the groundwater quantity and quality, which can subsequently impact the surface waters of the Great Lakes. For example, the USGS is currently undertaking the Glacial Aquifer System Groundwater Availability Study, which includes areas of the Great Lakes basin. The study, to be completed in 2016, is intended to provide information on the status of groundwater resources in the system, how they have changed over time and how they will respond to future changes in environmental and anthropogenic conditions (USGS, http://mi.water.usgs.gov/projects/WaterSmart/, Accessed September 2016). Additionally, the USGS, through the National Water Data Information System, provides access to national water resource data on quantity, quality, distribution and movement of surface water and ground water. Each of the Great Lakes states also maintains groundwater monitoring networks and databases of information on groundwater levels and quality. This includes the collection of groundwater withdrawal data as part of their responsibilities under the Great Lakes Compact.

[4] Local watershed management agencies, mandated to ensure the conservation, restoration and responsible management of Ontario's water, land and natural habitats.

3.8.5 Section Summary

- The Parties are undertaking many activities to improve the understanding of groundwater quality and its connectivity to surface waters along with the relationship between quantity and quality. This is reflected through their activities under Annex 8, the establishment of their Binational Priorities for Science and Action, as well as their domestic programs.

- The Parties established five Binational Priorities for Science and Action for 2014-16. Three of these five priorities were accomplished with the release of their report on *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report* (May 2016), which examines threats and stresses to groundwater quality as well as the impacts of groundwater quantity and flows on the lakes. This report also meets the Parties' commitments under the "science" mandate outlined in Annex 8 of the GLWQA. The two remaining Binational Priorities for Science and Action are expected to be addressed by the end of 2016.

- The Parties' groundwater report identifies eight over-arching priority science needs, which encompasses the need for improved groundwater research and monitoring to better understand and manage groundwater quality and subsequently its impacts on surface waters of the Great Lakes, including groundwater quantity and its interactions with surface waters. Three of these priority science needs are reflected in the draft 2017-19 Binational Priorities for Science and Action for groundwater. However, it is not clear when (or how) the remaining priority science needs will be addressed. As noted in several IJC and SAB reports, a better understanding of how groundwater influences the nearshore is needed to improve the management of that zone.

- The IJC has commended the work of the Great Lakes states and provinces for the enactment of the Great Lakes Compact and the parallel Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement. However, the impacts of withdrawals on groundwater quality, and ultimately surface waters and the lakes, are increasingly important. The Great Lakes states and provinces should fully factor the adverse ecological and water quality impacts of groundwater withdrawals into both water use permitting procedures and decisions regarding consumptive use.

- The status of groundwater quality in the Great Lakes basin is undergoing assessment through the development of a groundwater quality indicator under the SOGL report. The expected 2017 groundwater indicator will more appropriately report progress toward the achievement of Objective 8 of the GLWQA by reporting on the quality of shallow groundwater in the basin, and specifically the contaminants chloride and nitrate. Future reporting of this indicator is expected to expand the number of parameters to be analyzed and the Parties have been encouraged to consider the parameters identified under the IJC's ecosystem indicator for groundwater,

- Key actions to improve the protection of groundwater quality in the Great Lakes basin could include USEPA's strengthening of is UST regulations for new and replaced tanks (2015) and the completion of SWPPs for the protection of drinking water, including groundwater, in the province of Ontario (2015).

3.8.6 References

Frey, S.K., Berg, S.J., and Sudicky, E.A., 2016. A Feasibility Study of Merits and Development Strategies for a Regional Water Resources Modelling Platform for Southern Ontario – Great Lakes Basin; Geological Survey of Canada, Open File 8021 doi:10.4095/29881

Grannemann G, Van Stempvoort D.(Eds.), 2016. Groundwater science relevant to the Great Lakes Water Quality Agreement: A status report. Prepared by the Annex 8 Subcommittee for the Great Lakes Executive Committee, Final version, May, 2016.Published (online) by Environment and Climate Change Canada and U.S. Environmental Protection Agency.

Great Lakes Public Forum, 2016.State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada. Available at https://binational.net/2016/11/25/glpf-fpgl-2016-presentations-videos/

International Joint Commission, 2006. A guide to the Great Lakes Water Quality Agreement: Background for the 2006 governmental review.

International Joint Commission, 2014.Great Lakes ecosystem Indicator project report.

International Joint Commission (IJC), 2015. Protection of the Waters of the Great Lakes: 2015 review of the recommendations from the February 2000 report.

Research Coordination Committee (RCC) Contractor, 2016. DRAFT Identifying future improvements to Great Lakes ecosystem and human health indicators. Prepared for the IJC's SAB-RCC.

Science Advisory Board (SAB), 2010.Groundwater in the Great Lakes basin.Prepared for the IJC.

Science Priority Committee (SPC), 2016.Key recommendations from the IJC's 15th and 16th Biennial Reports for the governments to implement.Prepared for the IJC.

Schulte, P. 2013. The Great Lakes Water Agreements.The World's Water Volume 7, Water Brief 2. (http://worldwater.org/wp-content/uploads/2013/07/water_brief_great_lakes_water_agreement.pdf, Accessed August 2016)

U.S. Geological Survey, 2000. The Importance of Ground Water in the Great Lakes Region, N.G. Grannemann, R.J. Hunt, J.R. Nicholas, T.E. Reilly, and T.C. Winter, Water-Resources Investigations Report 00–4008

3.9 Other Substances, Materials and Conditions

This section reviews and assesses progress toward achieving general objective 9 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 9 states that the waters of the Great Lakes "should be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes".

Objective 9 captures topics not covered by the other GLWQA objectives. Specifically, these topics include: Areas of Concern (AOCs) (Annex 1); Lakewide Management (Annex 2); Climate Change Impacts (Annex 9); the Cooperative Science and Monitoring Initiative (part of Annex 10); Great Lakes adaptive management; and microplastics.

3.9.1 Assessment of progress on Areas of Concern

1. Background

The 1987 Protocol to the GLWQA established 43 AOCs throughout the Great Lakes basin. The AOC program has been continued through successive versions of the GLWQA, including the 2012 version, which includes an Annex specifically related to AOCs. Annex 1 requires that the Parties designate AOCs and for each AOC, Remedial Action Plans (RAP) must be developed and implemented to address each of the 14 beneficial use impairments (BUI) that apply to the AOCs. The GLWQA specifies that AOC remediation plans adopt "…a systematic and comprehensive ecosystem approach to restoring beneficial use". More information on the AOC process, BUIs, status of progress and additional information can be found in Annex 1, or at the IJC's website at http://ijc.org/en_/aoc, or the Parties AOC websites at http://www.ec.gc.ca/raps-pas/ and https://www.epa.gov/great-lakes-aocs.

Annex 1 commits the Parties to triennial reporting on the status of BUIs in each AOC, the actions completed, and the remaining actions required, for each AOC. The PROP includes this information, and presents the status of actions to address each BUI (actions complete at 100 percent, 75 percent and more, 50 percent and more/less levels).

The 2014-2016 Priorities for Science and Action developed by the Parties committed the Parties to completing two AOC-related analyses: to develop AOC guidance documents to (i) provide additional knowledge and tools to enhance and advance the restoration and delisting of AOCs, and (ii) develop practices or mechanisms (such as RAP reports, lessons learned, or BUI information) for sharing information among AOC communities and the broader public. In August 2016, two Annex 1 task team reports were released by the Parties – a situational analysis and guidance related to AOCs in recovery. Those reports were distributed via GLIN-announce, a widely used subscriber list server hosted by the Great Lakes Commission, and other means. However at the time of this report, these reports do not appear to be posted to websites maintained by the Parties.

The experience with AOCs serves as a strong reminder of the principle of prevention included in the GLWQA. Over the last 30 years, hundreds of millions of dollars have been spent cleaning up legacy pollutants and other degradation in AOCs, requiring a significant additional investment of volunteer

and agency staff time. These investments could have been directed to other activities had degradation of AOCs been better anticipated and prevented in the first instance.

2. Assessment of indicators

Many indicators discussed elsewhere in this report also relate to this section of the report. The one indicator that is not discussed elsewhere is Remediating Contaminated Sediments which is presented in the 2011 State of the Great Lakes report (ECCC and USEPA, 2014). The indicator notes an increasing trend in remediation between 1997 and 2010, which should be expected, as remediation projects in AOCs that were planned and permitted earlier in remedial action plan (RAP) processes were implemented during the period being examined.

3. Assessment of progress of the Parties

Progress Towards AOC Remediation and Restoring Beneficial Uses

Between 2013 and 2016 the following progress has been made towards AOC delistings and Beneficial Use Impairment removals/redesignations:

As of 2013 (from IJC, 2013):

- US - 33 of 255 BUIs removed, 1 AOC delisted and 1 AOC in Recovery out of 26 AOCs
- Canada (at May, 2011) - 54 of 154 BUIs removed, 3 AOCs delisted and 2 AOCs in Recovery out of 12 AOCs
- Binational – 0 of 5 AOCs delisted

As of 2016 (from Situation Analysis Task Team, 2016):

- US - 62 of 255 BUIs removed, 4 out of 26 AOCs delisted
- Canada - 65 of 146 BUIs removed, 3 AOCs delisted and 2 AOCs in Recovery out of 12 AOCs (note: the total number of Canadian BUIs is different between 2013 and 2016 (146 vs. 154) due to changes in the way Environment and Climate Change Canada reported BUIs requiring further assessment. Additional refinements to BUI accounting is expected in ECCC's forthcoming Canadian Environmental Sustainability Indicator – Restoring the Great Lakes Areas of Concern
- Binational – 0 of 5 AOCs delisted

Since the Parties' AOC programs were codified in the 1987 Agreement, seven AOCs have been delisted and two have been designated as Areas in Recovery. However, three of those delistings occurred since the current version of the GLWQA was signed by the Parties in 2012 (two of them since it came into effect in 2013), which illustrates the accelerated progress that has occurred in the United States since the Great Lakes Restoration Program was initiated in 2010. Of the remaining 34 AOCs, 22 are in the United States, seven are in Canada and five are binational. Additionally, 13 more AOCs are expected to have all management actions completed and/or be delisted within the next five years. The Parties' priority AOCs are as follows (from Situation Analysis Task Team, 2016 and PROP, 2016):

- *United States* – Management actions have been completed at SheboyganRiver, AshtabulaRiver, WaukeganHarbor and St. Clair River. By 2019, management actions will be completed at River Raisin, St. Marys River, Menominee River, Rochester Embayment, BuffaloRiver, ClintonRiver, ManistiqueRiver, MuskegonLake and Black River.
- *Canada* – By 2019, priority actions will be completed at NipigonBay, PeninsulaHarbour, Niagara River, Bay of Quinte, and St. Lawrence River (Cornwall).

Progress since 2010 in US Areas of Concern has been accomplished primarily through the US Environmental Protection Agency's (USEPA) Great Lakes Restoration Initiative (GLRI). The initiative relies on partnerships and in some cases matching funding with other federal and state agencies and other organizations. Approximately $1.9 billion has been invested in Great Lakes restoration from fiscal years 2010-2015, with nearly $600 million going directly towards AOC cleanup (Table 4.5.4 Annex 1 Situation Analysis, 2016). Additional investments in wastewater and stormwater infrastructure are also occurring. Direct investments have led to a rapid acceleration of BUI removal, completion of cleanup actions for several AOCs, and the delisting of two AOCs in 2014. Completion of cleanup actions for eight additional AOCs is expected in the next few years, subject to continued funding from the GLRI.

Progress in the Canadian AOCs has been accomplished through the Environment and Climate Canada's (ECCC) Great Lakes Action Plan, which included a direct investment of $16 million for 2010-2012 to clean up AOCs. The PROP includes additional financial information on wastewater and stormwater spending in AOCs through infrastructure programs not tied directly to AOCs. Canada has made significant recent investments in Hamilton Harbour AOC ($139 million for sediment remediation and $484 million for wastewater treatment infrastructure) and Port Hope Harbour AOC (1.28 billion for contaminated sediments remediation). Progress on AOCs is also being made through the Government of Canada's partnership with the Province of Ontario, as described in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health*, and partnerships and matching funding with other organizations. Completion of cleanup actions in five Canadian AOCs is expected by 2019. Base funding for AOC remediation through the Government of Canada's Great Lakes Action Plan is less than that of the United States, when measured on a per capita and per AOC basis. While the federal governments are making the largest investments in AOC cleanup, the aggregate investments of state/provincial and local organizations in AOC remediation is substantial.

Annex 1 is one of a small number of the Annexes that focuses on multiple activities. AOCs are strongly founded on interrelationships among scientific questions -- assessment of conditions to characterize BUIs, ecological risk assessments, monitoring to confirm ecosystem response following implementation of management actions, all of which must be done an appropriate spatial scale to capture local conditions (Yurista*et al.*, 2016), implementation (management actions to address one or more of the 14 BUIs) and community engagement (establishing and supporting Public Advisory Councils [PACs]).

Thus, interaction between the organizations associated with these activities is important and necessary to ensure that current scientific approaches and best practices related to remedial projects and community engagement are shared. This also holds true for RAP practitioners working on similar issues at different locations across the basin. Although there are many opportunities for this to occur at a domestic level (see text box), opportunities at a binational level are limited, in large part because

Annex 1 is the only Annex without an associated Great Lakes Executive Committee structure. For each of the other nine Annexes, the Annex Committees and Extended Subcommittees provide regular and recurring opportunities for agency staff from multiple levels of government, academics, NGOs, consultants, and others with a professional interest in the Annex topic to discuss Annex-related issues. This opportunity does not exist on a binational basis for AOCs.

For the five binational AOCs - St. Marys River, St. Clair River, Detroit River, Niagara River and St. Lawrence River - two parallel domestic processes are in place. Progress towards completion of management actions in these binational AOCs is generally uneven between the two domestic processes. This is inconsistent with the ecosystem approach principle included in the GLWQA. Further, there is only limited formal and contemporary guidance for binational AOCs to inform BUI removals and AOC delisting across the boundary. Meanwhile, the need for such guidance is great because management actions have been completed on one side of several of the binational AOCs, and therefore delisting approaches are under active consideration. This includes the possibility of designating one side of a binational AOC to an AOC in Recovery designation while management actions are completed on the other side of the same AOC.

The most urgent need to coordinate activities is in those binational AOCs where progress towards delisting is most uneven despite active domestic RAP programs. Examples include the St. Lawrence River AOC, where ECCC has determined that all management actions have been completed in the Cornwall, ON area, while actions are ongoing in the Massena, NY area; and the St. Clair River AOC, where the USEPA has determined that all management actions have been completed in the Port Huron, MI area, while actions are ongoing in the Sarnia, ON area.

Sharing Areas of Concern Best Practices and Technical Transfer

There are many excellent examples of opportunities for interested residents and those with a professional interest in AOCs to learn more about science, implementation, community engagement and related topics. A few examples are highlighted below:

- Many individual RAP teams hold regular events to discuss themes of local relevance, and expand local interest in the AOC. For example, the Detroit River Canadian Cleanup holds an annual Detroit River Evening which includes a status update on the beneficial use impairments in the AOC, and a guest speaker discussing a topic of particular interest in the AOC. On the US side, the Friends of the Detroit River hold an annual Shiver on the River event to increase awareness about the river.

- The Michigan Public Advisory Council (MPAC) is comprised of the Chair and Vice Chair (or designates) of each of the state's AOC PACs. The MPAC meets about twice per year to share information about the status and priorities of individual AOCs, and best practices. One MPAC meeting typically occurs in the state capital, which includes a breakfast meeting with state legislators.

- The annual US AOC conference organized by EPA includes concurrent sessions on a range of science, management, and community engagement topics for US AOCs. The last conference was held in March, 2016.

- Environment and Climate Change Canada hosts regular Canadian AOC conferences, which explore a range of themes related to Canadian AOCs. The last conference was held in February, 2014.

4. IJC activities

The AOC program was developed by the Parties in response to an IJC Water Quality Board report in 1985. Since the AOC program was established by the Parties through the 1987 Agreement, the IJC has periodically reported on progress towards restoring AOCs. In 2003, the IJC completed a special report which examined how much has been done in restoring beneficial uses in AOCs, and offered a number of recommendations (IJC, 2003). The 16th IJC biennial report included an account of the number of AOCs delisted and the numbers of beneficial use impairments removed (IJC, 2013).

Annex 1 (AOCs) of the 2012 Protocol to the *Great Lakes Water Quality Agreement* requires that the Parties solicit a review and comments from the IJC and others prior to the designation of an AOC in Recovery and prior to the removal of a designation as an AOC or an AOC in Recovery. Since the 2012 Protocol came into effect in 2013, the IJC has reviewed and commented on Delisting Reports for Deer Lake AOC (MI) and White Lake AOC (MI), and a draft Delisting Report for Nipigon Bay AOC (ON). The IJC's comments are available at http://www.ijc.org/en_/Reports_and_Publications. Although each report addressed a specific AOC, several themes were relevant to all AOCs:

- The importance of ongoing monitoring to ensure no slippage on environmental conditions, which is consistent with the anti-degradation principle included in the GLWQA. This may require monitoring activities that extend beyond reliance on the ongoing monitoring programs of federal and state/provincial agencies. The IJC included recommendations to the Parties on this topic in its advice on the Parties' 2017-19 Priorities for Science (http://ijc.org/files/publications/SAB_advice_on_Parties_science_priorities.pdf).
- The importance of Public Advisory Councils (PACs) preparing for the transition to the post-delisting era so that community momentum gained through the RAP process can continue. This will have several benefits, including the possibility of greater community involvement in the lakewide management process (LAMP) associated with an AOC. Federal and/or state/provincial support for this transition improves the likelihood it will be successful. This is consistent with the public engagement principle included in the Agreement.
- Delisting reports should clearly summarize and reference available science and related information that demonstrates that all reasonable actions have been taken to eliminate local sources of contamination. In some cases, contaminants or influences from outside the AOC may prevent full remediation of beneficial uses (for example, fish consumption advisories related to mercury contamination from atmospheric sources).

The considerable resources being directed to implementation of remedial actions should logically lead to an eventual outcome of delisting for all AOCs. However, once the cleanup is complete, communities are faced with the question of how to maintain the remediated site and continue community participation in environmental stewardship, which prior to delisting often occurred through the AOC's PAC or equivalent. A report completed for the IJC included an initial assessment of issues related to 'life after delisting' (Mandelia, 2016), and found that several challenges exist. These include a loss of momentum following delisting due to the loss of a tangible reason to organize, diffuse sources of funding for stewardship projects with uneven eligibility requirements (some funding sources require an AOC designation to qualify), and less frequent environmental monitoring than existed prior to delisting, which makes it more difficult to detect any worsening of environmental conditions. The report found that many PACs that were able to successfully transition to 'life after delisting' did so by including a focus on economic revitalization associated with their environmental projects, pursuing funding from a broader range of funding sources (in one case by incorporating as a charitable not-for-profit), and shifting from a reliance on agency monitoring programs to partnerships with universities and citizen scientists to ensure no backsliding of environmental conditions. The initial assessment also found that there is little awareness by the public of the larger lakewide management context where their AOC is situated and little involvement in the LAMP.

Delisting reports prepared for the AOCs delisted (or proposed for delisting) since the current GLWQA came into effect describe how environmental conditions at delisted AOCs will be characterized moving forward through ongoing long-term monitoring programs of the Parties and other agencies. It is generally the case that the intensity of monitoring activities in an AOC diminishes substantially once an AOC is delisted. Thus, there is a risk that deterioration of conditions in an AOC following delisting may not be detected in a timeframe that is appropriate. Given that the Parties plan to complete management actions and/or delisting numerous AOCs in the coming years, the importance of this issue is likely to increase.

3.9.2 Assessment of progress on lakewide management and cooperative science and monitoring

1. Background

Annex 2 (Lakewide Management) of the GLWQA commits the Parties to "(assess) the status of each Great Lake, and (address) environmental stressors that adversely affect the Waters of the Great Lakes which are best addressed on a lakewide scale through an ecosystem approach". Specific program commitments include establishing lake ecosystem objectives, undertaking science and monitoring activities, developing binational strategies to address substance objectives, developing an Integrated Nearshore Framework by 2016, and documenting and coordinating necessary management actions through the development of LAMPs.

Directly related to the Annex 2 commitments, Annex 10 (Science) includes a commitment to "implement a cooperative science and monitoring initiative for each of the Great Lakes on a five-year rotational basis. The Parties shall focus monitoring activities on the science priorities identified through the Lakewide Management Process. The Parties will coordinate these activities across government and non-government organizations."

Thus, the LAMP and Cooperative Science and Monitoring Initiative (CSMI) processes are inextricably linked in an iterative cycle of advancing the science needed to inform management decisions, which once implemented, alter system conditions that can be measured and quantified through a subsequent cycle of science activities.

The 2014-16 Priorities for Science and Action for Annex 2 provide additional, time-bound details on the Agreement commitments, and include (but are not limited to) the following:

- Identify and address lake-specific priorities for science through the CSMI and LAMP processes. CSMI-focused science and monitoring field work will be undertaken in 2013 in Lake Ontario, 2014 in Lake Erie, 2015 in Lake Michigan, 2016 in Lake Superior, and 2017 in Lake Huron;
- Draft lake ecosystem objectives for each Great Lake as benchmarks to measure status and trends, including a guidance document by July 2014 and draft objectives for Lake Erie by July 2015.

The Annex 2 section of the PROP includes a summary of the actions and outputs related to lakewide management for 2014-16. Many of the commitments and timelines included in Annex 2 have been met.

2. Assessment of indicators

The 2011 SOLEC indicator report (ECCC and USEPA, 2014) included an indicator on hardened shorelines. Due to data limitations, this indicator included an assessment of only Lake Ontario. No other comprehensive datasets other than the sets used for Lake Ontario were identified in the preparation of this report. Binational hardened shoreline assessments for Lake Erie including its

upstream (Huron-Erie corridor) connecting channel, as well as for southwest Lake Michigan and eastern Lake Huron would be helpful in understanding the condition and trends along the most intensively developed sections of Great Lakes shoreline.

3. Assessment of progress on lakewide management

The work of the Parties has served to elevate the prominence of lakewide management under the GLWQA. The 2012 Protocol includes lakewide management as a stand-alone Annex, and assigned ambitious programs and measures to that Annex. Through that action, the Parties appear to share the IJC's view that LAMPs have "the potential to be the core instrument to engage a broader array of governments, agencies and programs in the watershed and in nearshore and offshore waters of the Great Lakes Basin Ecosystem" (IJC, 2009, 12).

Progress on lakewide management in the United States has been largely resourced at a federal level through the US GLRI. The GLRI was launched in 2010 to accelerate efforts to protect and restore the largest system of fresh surface water in the world. Since then, EPA's website reports that the GLRI has funded more than 2,930 projects totaling over $1.5 billion directed towards restoration work in highly contaminated AOCs, nutrient reduction, invasive species control and habitat restoration. Based on the lack of publicly available data, it is difficult to determine what level of investment is being specifically directed to LAMP priorities. This is also the case in Canada, where ECCC's resourcing for LAMP priorities is evidently diffuse and not centrally reported. It is important to note that in addition to federal investments in LAMP priorities, substantial support is provided by other project partners, including state/provincial governments.

In 2014, the Parties confirmed the LAMP and CSMI reporting rotational schedule, wherein CSMI reporting is produced two years prior to the LAMP so that science findings can be used to inform management prescriptions (Table 3.9).

Table 3.9.1
LAMP and CSMI Schedule*

Year	CSMI					LAMP
	Year 1: Priority Setting	**Year 2: Cruise Logistics**	**Year 3: Sampling**	**Year 4: Data Analysis**	**Year 5: Management Synthesis/Reporting**	
2016	Ontario	Huron	Superior	Michigan	Erie	Huron
2017	Erie	Ontario	Huron	Superior	Michigan	Ontario
2018	Michigan	Erie	Ontario	Huron	Superior	Erie
2019	Superior	Michigan	Erie	Ontario	Huron	Michigan
2020	Huron	Superior	Michigan	Erie	Ontario	Superior
2021	Ontario	Huron	Superior	Michigan	Erie	Huron
2022	Erie	Ontario	Huron	Superior	Michigan	Ontario

*Per Annex 2 of the Agreement, the associated connecting channel is included in the CSMI and LAMP activities related to the applicable lakes - Lake Huron includes the St. Mary's River, Lake Erie includes the St. Clair River, Lake St. Clair and the Detroit River, and Lake Ontario includes the Niagara River and the St. Lawrence River to the international boundary.

In 2015, the Parties released the draft Lake Superior LAMP for input, which was the first LAMP issued under the current GLWQA. The final Lake Superior LAMP was issued in September, 2015 and the IJC's advice and recommendations on that report are forthcoming.

The LAMP does an excellent job describing lakewide threats. These include aquatic invasive species, climate change, legacy chemicals, the eight established chemicals of mutual concern, and additional substances of concern (e.g. pharmaceuticals). The report also discusses other threats including mining, oil transportation, and coastal development.

In December 2015, the IJC provided its comments on the draft LAMP in consultation with its Great Lakes Advisory Boards. Those comments noted that available science information was well reflected in the LAMP, though the IJC highlighted the need for greater specificity in identifying priority projects, including details related to project objectives, lead, timelines, and required resources and sources. The IJC also noted that the Lake Superior LAMP would benefit from a more detailed discussion of engaging relevant constituencies and communities; indeed, this is something that all subsequent LAMPs should do as well.

It is notable that almost four years after the 2012 Protocol came into effect, the LAMP partnerships have only recently begun to establish their work group outreach and engagement subcommittees. It has been observed that while Tribes are engaged in LAMPs in the United States, the participation of First Nations in Canada is limited.

These organizations with local knowledge have much to offer and could substantially improve the LAMPs. Engaging with indigenous, minority and subsistence communities that consume Great Lakes fish in greater quantities than the rest of the population are particularly important to include in these discussions.

In 2015, the IJC also provided its input to the Parties regarding their proposal to restructure the Lake Superior Binational Program (LSBP) into the Lake Superior Partnership. The LSBP's most important contribution was arguably the Zero Discharge Demonstration Project (ZDDP), which has made important progress towards zero release of the nine designated persistent, bioaccumulative toxic substances in Lake Superior. Because only two of the nine ZDDP critical pollutants have been designated by the Parties as Chemicals of Mutual Concern, the Parties will need to clarify how the remaining seven ZDDP critical pollutants will be addressed through the Annex 3 process or through processes unique to Lake Superior. Additionally, the IJC recommended that the Parties report on the progress made towards each of the individual policy and action commitments contained in the LSBP, and which goals, policies and actions will be continued through the Lake Superior LAMP.

Annex 2 of the 2012 Protocol included a new requirement that LAMPs include a lake's associated connecting channel, where one exists (Lake Huron and the St. Marys River, Lake Erie and the St. Clair River, Lake St. Clair and Detroit River, and Lake Ontario and the Niagara River and the St. Lawrence River to the international boundary). This provision will be applicable to the Lake Huron LAMP due in 2016. An expanded focus on the connecting channels is expected to result in a description of stressors and priority management actions which allow for greater integration of AOCs and LAMPs where connecting channels include AOCs, since both address similar stressors at different spatial scales within the same geographic areas. It will also bring greater focus to the influence of connecting channels on the physical, chemical and biological integrity of downstream waters.

Development of an Integrated Nearshore Framework

In accordance with their Annex 2 commitments in the GLWQA, in September 2016 the Parties published an Integrated Nearshore Framework (Canada and U.S., 2016). The framework reflects considerable effort by the Parties and its partners, and builds on the IJC's earlier analysis and recommendations (IJC, 2011). The guiding principles included in the report are appropriate and comprehensive. The Lake Partnerships should play a central role in influencing the actions of individual agencies' projects and the voluntary actions of communities, and the Parties should commit to providing resources for the restoration or protection priorities for sections of coastline, as identified in the framework. The Parties could also play a larger role in centralizing information on nearshore stressors, since the view expressed by an IJC workshop: "Although there are exceptions, there is no coordinated or easily accessible database to monitor and tabulate loadings of pollutants from direct dischargers and from diffuse and land-based sources. Data dealing with shoreline development, remediation and land use change are not centralized or provided in an inventory. Hence, understanding progress or priorities in nearshore areas is difficult" (IJC, 2009, 7).

Progress in this area is consistent with the coordination principle included in the GLWQA. A comprehensive and coordinated approach to tracking nearshore stressors would also assist with an assessment of the cumulative effects of multiple stressors, which is referenced in the nearshore framework but not discussed in detail.

4. Cooperative Science and Monitoring Initiative

The development of LAMP management activities relies heavily on science information developed through the CSMI. The program was established by the Parties in 2002 to coordinate monitoring, and in 2006 that program was expanded to include research coordination. Connecting channels were added in 2009 where those connecting channels affect the downstream lake. The CSMI was designed to coordinate binational priority science and research activities in the Great Lakes basin with an emphasis on enhanced monitoring and research field activities which are conducted on one lake per year on a five-year rotating basis.

In the 2012 GLWQA, the CSMI was formalized in Annex 10 which states "Lake-Specific Science and Monitoring: In addition to ongoing science and monitoring activities that are routinely carried out by the Parties and other government and non-government entities, the Parties shall implement a cooperative science and monitoring initiative for each of the Great Lakes on a five-year rotational basis. The Parties shall focus monitoring activities on the science priorities identified through the Lakewide Management process. The Parties will coordinate these activities across government and non-government organizations."

The Parties' PROP includes a useful description of the CSMI activities for the reporting period. The Parties reporting would be enhanced if the PROP could describe how the science information completed through the CSMI was used to inform management decisions, using specific examples to illustrate the science-management linkage on which the CSMI is founded.

In addition to the CSMI, ongoing monitoring is conducted by the Parties in coordination with state/provincial agencies and others for various environmental compartments, including nearshore and offshore water quality, sediment quality and fish tissue contaminant concentrations. Temporally- and spatially-extensive monitoring activities completed by the Parties and others outside of CSMI are critical to understanding the status and trends of conditions in the lakes. Analysis completed by the IJC's Science Advisory Board on the Parties' open lake water quality monitoring, including ECCC's Great Lakes Surveillance Program ,which monitors open lake water quality for each binational lake every other year during spring and fall, and the USEPA-GLNPO's Open Lake Water Quality Survey, which currently surveys Lake Michigan annually in spring and summer, found that data from the Canadian side are generally comprehensive for a number of contaminants, including legacy contaminants, and to some extent chemicals of emerging concern. Data collection dates back to the mid-1980s, providing long-term coverage. However, data are lacking from the United States due to the termination of the USEPA's chemicals in water monitoring program approximately seven years ago. This limitation mainly affects Lake Michigan, as ECCC continues to monitor the other four lakes for contaminants (IJC, 2016). Additionally, there are challenges in comparing Lake Michigan to the other lakes due to differences in survey techniques between ECCC and the USEPA (Roth *et al.*, 2016).

The CSMI supplements the Parties' ongoing monitoring activities. Under Annex 2, individual Binational Lake Partnerships identify research, monitoring and other science priorities to assess threats to water quality and support management actions. To address these priorities, the Annex 10 CSMI Task Team works with governmental and academic scientists to develop, coordinate, and allocate resources for specific research activities for each lake on a five-year rotating basis.

The CSMI process relies on comprehensive and binational planning and reporting at two points in the CSMI cycle. Workshops are typically held: during the 'priority identification' phase (year 1 of the five-year CSMI cycle) when key agencies, organizations and researchers meet to assist the lake partnerships in finalizing lake-wide science and monitoring priorities; and at the 'reporting out' phase (year 5 of the five-year CSMI cycle) when key organizations and researchers present their key findings, which are used to inform LAMP reporting and the identification of required management actions for the next cycle. Through its Science Advisory Board's Research Coordination Committee, the IJC supports priority identification CSMI workshops, which helps fulfill the IJC's role described in Article 7 (1.d) of the GLWQA. The Great Lakes Sea Grant Network also supports reporting out workshops which helps fulfils its extension mandate.

The CSMI program expands the range of science activities for a specific lake which are primarily funded by federal and state/provincial agencies. For example, for the last CSMI cycle for Lake Ontario for which comprehensive reporting is available (2008), investigations focused on the nearshore, including an assessment of nearshore/offshore gradients for multiple parameters under the influence of three different land use patterns, and an estimation of the biomass of *Cladophora*, dreissenid mussels, cyanobacteria and round gobies and investigation of the factors influencing those species (Richardson *et al.*, 2012). The Parties' PROP notes that 2013 priorities for Lake Ontario include lower food web assessment, nutrient loadings and nearshore to offshore movement of nutrients. In November, 2016 a CSMI workshop was held to identify priorities for Lake Ontario's next monitoring year, scheduled for 2018.

A review of completed and planned CSMI activities that suggest that the CSMI is focusing primarily on the lakes proper, with only limited focus on the associated connecting channels. Given that connecting channels can act as sources of stressors to the downstream lake and/or modify in-lake processes, the Binational Lake Partnerships and Annex 10 Cooperative Science and Monitoring Task Team could strengthen their assessments by increasing effort on the connecting channels in the CSMI cycle. Connecting channels did receive attention at the November 2016 Lake Ontario CSMI priority identification workshop.

The IJC has heard from different groups with different interests that the CSMI has significantly improved coordination amongst federal science agencies and that some progress has been made coordinating involvement with state/province agencies. This encouraging progress towards research and monitoring coordination could be built upon in other areas, including academic partner involvement. Where coordination with academic researchers has occurred, it has tended to be through contractual relationships between federal agencies and universities. In some cases, CSMI resources have been used to leverage additional resources from non-CSMI funders to increase the amount of activity accomplished in support of CSMI priorities. The Lake Ontario CSMI is a good example where a strong lead role has been played by several universities and academic institutions. Continued efforts to expand the coordination role of CSMI to include universities either through continued contractual relationships or through expanded efforts to ensure university researchers understand CSMI priorities and, as appropriate, address them through their research activities could reap rewards. Greater academic involvement in the CSMI is likely to enrich the pursuit of priority science activities and/or appropriately adjust recurring CSMI activities. Similarly, greater emphasis on joint agency-academic activities would enlarge the network of experts focusing on advancing science related to the Great Lakes.

Broader engagement in the CSMI is expected to evolve with the relatively recent involvement of the Great Lakes Sea Grant Program and the International Association for Great Lakes Research (IAGLR) in CSMI-related activities.

The IJC has also heard during various consultations that reporting associated with CSMI often extends well beyond the reporting year (year 5 of the CSMI cycle) and is widely diffuse across agency reports, journals and conference presentations. Sample processing, data analysis and the science report peer-review process takes time. However, the consolidation of preliminary CSMI findings is required on a timely basis, particularly for management decisions which must be made immediately following the CSMI cycle for a particular lake. The management synthesis report could incorporate results of previous CSMI cycles to identify trends and highlight long term accomplishments.

A key challenge related to the CSMI is the management and flow of information resulting from the process. The IJC's Science Priority Committee is conducting an analysis of issues related to information coordination and flow, which was informed by an expert workshop held in March 2016. Preliminary findings from that analysis found that there are many organizations that play a role in the data collection and information delivery continuum, and there is a need to have an overarching institution to play a coordination role. The Data Management and Sharing Task Team of the GLWQA's Annex 10, Great Lakes Blue Accounting, the IJC's Information Coordination and Flow Workgroup, the Great Lakes Observing System (GLOS) through the Data Management and Communications (DMAC) subsystem, and Great Lakes Advisory Board's Science and Information Subcommittee are examples of such an institution. The Parties could participate in future efforts to improve the Great Lakes information flow from goal setting through information management and delivery.

The year 2016 marks the ten-year anniversary of the CSMI program being expanded to include research coordination. Two cycles of the CSMI have occurred during this period. Therefore, it is an opportune time to review the program and assess the success of the program and the extent to which the initiative has provided new data and information otherwise lacking or absent from 'off year' monitoring. As noted in the IJC's advice on the Parties' 2017-19 Priorities for Science, this assessment should include an examination of:

- What assets have been employed, and how are they deployed differently than off years?
- Are under-sampled periods (*e.g.*, winter conditions) or regions (*e.g.*, nearshore) or processes (*e.g.*, air-water exchange, nitrogen biogeochemistry) being identified and addressed?
- Does a five-year cycle make the most sense? To what degree does this preclude an examination of certain dynamics, such as comparisons across five years within an individual lake across a large range of processes?
- How can the focus on the connecting channels and St. Lawrence River be improved?
- How much is being invested in the CSMI effort and how is it apportioned?
- Is there a readily available repository of CSMI data and results?
- Is there merit in considering a 'Comparative Science and Monitoring Initiative' that examines processes and issues across the basin rather than on a lake-by-lake basis?

3.9.3 Assessment of progress on climate change

1. Background

Annex 9 of the GLWQA commits the Parties "to identify, quantify, understand, and predict the climate change impacts on the quality of the Waters of the Great Lakes," and to "sharing information that Great Lakes resource managers need to proactively address these impacts." Specific program commitments include:

- taking into account climate change impacts on the chemical, physical and biological integrity of the waters of the Great Lakes;
- using their domestic programs to address climate change impacts to achieve the objectives of the GLWQA; and
- communicating and coordinating on a binational basis.

The Annex also commits the Parties to coordinating actions where appropriate with water quantity management actions taken by or in conjunction with the IJC. There are additional science commitments, including:

- develop and improve regional-scale climate models to predict climate change in the Great Lakes basin ecosystem at appropriate temporal and spatial scales;
- link projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes;
- enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts;
- develop and improve analytical tools to understand and predict the impacts, and risks to, and the vulnerabilities of, the quality of the waters of the Great Lakes from anticipated climate change impacts; and
- coordinate binational climate change science activities (including monitoring, modeling and analysis).

2. Climate change indicators

Several indicators developed by the Parties are signals of climate change. The USEPA observes that "water level and water temperature are two important and interrelated indicators of weather and climate change in the Great Lakes. Water level (the height of the lake surface above sea level) is influenced by many factors, including precipitation, snowmelt runoff, drought, evaporation rates, and people withdrawing water for multiple uses. Water temperature is influenced by many factors, too, but most directly by air temperature" (USEPA, 2016.) Assel observes, "The ice cover is also a sensitive indicator of climate change integrating fall, winter and spring energy exchanges between the lake and the planetary boundary layer" (Assel, 1999).

- Surface Water Temperatures: *Increasing*. The Parties use the onset of stratification as the indicator. All three upper lakes have experienced earlier stratification, Lake Superior onset of stratification has occurred 4 +/-2 days earlier since 1979 and both Lakes Michigan and Huron

onset of stratification has occurred 5+/-2 days earlier since 1980. The trend is undetermined for Lakes Erie and Ontario because of insufficient data.

- Water levels: *Decreasing*. Using a 30-year period as the basis for measurement, levels have decreased in all five Great Lakes. However, the five-year trend is increasing for Lakes Michigan and Huron and no significant change for the other Great Lakes. The most recent levels are all within the range of historical variation (USEPA 2016).

- Ice cover: *Declining*. The basin-wide loss of average ice cover from 1973 to 2015 was 26 percent.

3. Assessment of the Progress Report of the Parties

The Parties note that five items included in the binational priorities for science and action released on March 10, 2014 correspond to Annex 9 commitments. These are:

Science
Compile existing knowledge on Great Lakes climate change.
After compiling Great Lakes climate change knowledge, assess and identify critical information needs and develop strategies to address those gaps.

Action
Address the needs of other GLWQA annexes for improved climate change science (*e.g.*, understanding positive and negative impacts predicted under climate scenarios, monitoring of climate variables, improving tools for the analysis of climate change).
Communicate and share climate change information with key user groups throughout the Great Lakes basin.
Refine existing "Great Lakes Climate Summaries and Outlooks" factsheets with enhanced binational collaboration to produce and deliver climate information on a regular basis.

In the PROP, the Parties identify a variety of initiatives to carry out the priorities. For example, to enhance understanding and compile knowledge on Great Lakes climate change, the Great Lakes Evaporation Network has deployed *in situ* measurements – including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms – through binational collaboration to reduce uncertainties in the Great Lakes water balance, provide a more robust basis for short- and long-term projections, and fill a significant gap in over-lake flux measurements, including evaporation and water temperatures, and related meteorological data.

Another example of compliance with Agreement priorities is the *Quarterly Climate Impacts and Outlook: Great Lakes Region*, jointly prepared by the US National Oceanic and Atmospheric Administration (NOAA) and ECCC. Published approximately four weeks after the end of each season, it summarizes the latest season's weather and water level conditions and impacts over the Great Lakes and provides an outlook for the upcoming quarter.

Perhaps the most important action was the *State of Climate Change Science in the Great Lakes Basin Report*, (released in October 2015) which will support Annex 9 commitments. The report captures

available science on impacts of climate change in the Great Lakes Basin and inventories the climate change assessment methods applied in the region (McDermid*et al.*, 2015).
The report is paired with a companion database with summaries of more than 250 recent climate change studies. A binational executive summary of this report will be developed for posting on binational.net.

The Progress Report of the Parties also identifies a significant number of domestic actions taken in fulfillment of GLWQA commitments on climate change. For example, Canada is developing Regional Climate Change models for the Great Lakes – St. Lawrence River system. Fisheries and Oceans Canada, Hydro-Quebec, Centre of Water Expertise of Quebec, OURANOS and ECCC are conducting a coordinated evaluation of the impacts of climate change on the levels and flows of the St. Lawrence River from 1961-2100.

The NOAA GLERL developed and released a basin wide Water Level Dashboard in 2014. The dashboard is an interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes. The dashboard reflects relationships between hydrology, climate, and water level fluctuations in the Great Lakes.

Actions reported by the Parties strongly emphasize physical and chemical parameters associated with climate change. Only two of the eight actions identified by the Parties are associated with potential biological impacts.

The Parties have satisfactorily addressed the science commitments made in Annex 9, cooperating successfully on numerous measurement and communications projects and meeting timelines. However, the Parties have not implemented some of the program commitments in Annex 9, especially “using their domestic programs to address climate change impacts to achieve the objectives of this Agreement.” There has been inadequate effort to date to deal with existing impacts on the Great Lakes. For example, federal water quality standards for waterways in urban areas may not be met under climate scenarios with more frequent heavy precipitation events.

4. IJC activities

The IJC’s Great Lakes Water Quality Board undertook a review of government policies associated with climate change resiliency in the region. The board sought to identify roles and actions that US. and Canadian jurisdictions can undertake to: reduce the impact of climate change and/or support adaptive capacity within existing authorities; identify gaps in the regulatory framework leading to degradation of water quality, failure to achieve GLWQA objectives, or resulting in negative ecosystem effects; and identify roles that non-government actors and sectors can play to complement government action in addressing these issues.

The board’s report included a summary of climate-related projections in the Great Lakes region and their likely environmental impacts, as summarized in the table below.

Table 3.9.2 CLIMATE PROJECTIONS AND LIKELY ENVIRONMENTAL IMPACTS IN THE GREAT LAKES REGION [1]

Climate-relatedProjections in theGreatLakesRegion	LikelyEnvironmentalImpacts
Warmer air temperatures (esp. warmer nights; warmer winters: even *warmer* water temperatures)	• Less ice cover; less stratification and oxygen distribution in the lakes • More lake evaporation year-round (trending to lower lake levels) up by 25% since 1980 • More favorable conditions for algae and bacteria • Loss of habitat and/or increased stress for cool and cold-water fish • Increased likelihood of heat waves and urban heat-island effects; heat-related illnesses • More warm weather pests, including invasive species • Stress on livestock and crops; reduced productivity • Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to streamside habitat; loss of important populations. • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years. • Risks for coastal development during low water years and "hardening" shorelines.
More precipitation and more extreme precipitation events	• Increased polluted runoff, especially from intense spring storms • Sediment and nutrient "flushes;" rapid increased loading in Great Lakes watersheds and the lakes themselves • Algal blooms oxygen depletion, dead zones, cyanobacteria • Loss of safe drinking water supplies • Degraded wetlands and coastal habitat
More extreme swings between periods of drought and drench	• Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to streamside habitat; loss of important populations. • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years. • Risks for coastal development during low water years and "hardening" shorelines.
Increasing variability in lake levels	• Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to stream side habitat; loss of important populations. • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years. • Risks for coastal development during low water years and "hardening" shorelines.
Changes in vitality and distribution of cold-climate-	• Changes in species range and relative abundance, especially for cool and cold-water fish; • Likely range expansion for warm-weather invasive species, including diseases,

species—both aquatic and terrestrial	Crop pests, expanded ranges for zebra and quagga mussels. • Changes in terrestrial tree and plant species along coastal areas and Great Lakes tributaries that will likely alter wildlife species distribution**.**
Nutrient and invasive species challenges exacerbated	• Polluted runoff from extreme storms enriches nutrient and bacteria loadings into near-shore waters • Zebra and quagga mussels filter near-shore waters, increasing light penetration; • Sunlight penetration and warmer air temperatures warm the waters faster, deeper, and to higher temperatures; • Sunlight and warm water supports growth of algae and other phytoplankton • With plenty of nutrients, warm water and sunlight, algae growth "explodes" • Massive blooms die off and use up dissolved oxygen = dead zones
Changes in seasonal wind directional (vector) patterns	• Reduced exchange between waters in bays with low oxygen levels and open lake waters; potential increase in dead zones, especially Green Bay, Western Lake Erie
Negative Synergies from multiple effects	• Polluted runoff from extreme storms enriches nutrient and bacteria loadings into near-shore waters • Zebra and quagga mussels filter near-shore waters, increasing light penetration; • Sunlight penetration and warmer air temperatures warm the waters faster, deeper, and to higher temperatures; • Sunlight and warm water supports growth of algae and other phytoplankton • With plenty of nutrients, warm water and sunlight, algae growth "explodes" • Massive blooms die off and use up dissolved oxygen = dead zones

[i]**Information in this table is summarized from the following sources:**

"Climate Change in the Great Lakes Region" summaries on temperature, precipitation, extreme precipitation, Great Lakes ice coverage, algal blooms, fish and wildlife, forests, lake levels, Great Lakes ice cover and agriculture, produced by the Great Lakes Integrated Sciences and Assessments Program (GLISA), a collaboration of the University of Michigan and Michigan State University .http://glisa.umich.edu/climate, accessed July 2016.

"The Wisconsin Initiative on Climate Change Impacts" including its website summaries and report, *Wisconsin's Changing Climate: Impacts and Adaptation*. 2011. And the report from its, "Water Resources Working Group," accessed July, 2016, http://www.wicci.wisc.edu/water-resources-working-group.php. See also other resources on this site http://www.wicci.wisc.edu/ accessed July 2016.

Hanrahan, J.L., Kravtsov, S.V., and Roebber, P.J. (2010), "**Connecting past and present climate variability to the water levels of Lakes Michigan and Huron"** Geophysical Research Letters 37, L01701, doi:10.1029/2009GL041707.

Val Klump, "**Green Bay Hypoxia: Biogeochemical Dynamics, Watershed Inputs, and Climate Change**" (presentation, Our Water World: The Nutrient Challenge, a Waters of Wisconsin Public Forum, Green Bay, WI, May 7,2013).

USEPA, "**Understanding the Link Between Climate Change and Extreme Weather"** https://www3.epa.gov/climatechange/science/extreme-weather.html

The board's report provides recommendations to the IJC corresponding to the tasks above, including:

- The IJC should advise the Canadian and US governments to demonstrate global leadership by jointly developing a Binational Approach to Great Lakes Climate Change Adaptation and Resilience in the Great Lakes.
- The IJC should advise the governments to Invest in research, information sharing and knowledge management are needed to carry out a Vulnerability Assessment, to engage stakeholders and rights holders, and to identify priorities for responsive actions in the Great Lakes region.
- The IJC should recommend to governments that they create a staff-supported *Network of Networks* (or augmentation of an existing network) to collect, aggregate and share information that can support climate adaptation response strategies at federal, regional, state/provincial, and local scales.

3.9.4 Assessment of progress on adaptive management

1. Background

In outlining principles and approaches to be employed in the implementation of the GLWQA, Article 2(4)b defines adaptive management as "implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood."

There are two specific mentions of adaptive management elsewhere in the document. Annex 3(b)(6) seeks progress "toward the sound management of chemicals of mutual concern using approaches that are accountable, adaptive, and science-based." Annex 7(b) (2) calls for "lakewide habitat and species protection and restoration conservation strategies that use adaptive management approaches."

Assessing the deployment of an approach like adaptive management is difficult to do across the full range of the GLWQA and its Annexes. The integration of adaptive management with discrete tasks is only measurable after the fact. However, several examples illustrate the efforts of the Parties with respect to implementing adaptive management measures in support of the GLWQA objectives.

The Interagency Task Force implementing the USEPA's GLRI has developed a conceptual framework for science-based adaptive management as guidance for the GLRI Action Plan II.

The framework consists of the following elements:

- Conduct annual planning (*i.e.*, the five-year GLRI Action Plan) to identify projects to address priority ecosystem problems;
- Fund projects in accordance with the GLRI Action Plan and annual planning process;

- Assess project effectiveness on multiple scales and use this information in the annual planning process;
- Assess Great Lakes ecosystem health and identify ecosystem problems and use this information in the annual planning process;
- Communicate the GLRI progress through a number of outreach strategies; and
- Prioritize ecosystem problems to be targeted through GLRI in the annual planning process.

The Task Force has developed a GLRI Adaptive Management Implementation Pilot for Western Lake Erie Basin as an extension of the *Science-based Adaptive Management Process for GLRI Action Plan II* described above. A US federal interagency task team will test an adaptive management framework and refine processes and methods for multi-agency coordination of science to improve restoration outcomes for western Lake Erie.

The Parties are also applying adaptive management to the setting of phosphorus reduction targets for Lake Erie. The USEPA is currently working with other federal, state and Canadian partners to develop a long-term plan that will identify the monitoring, data and analyses needed to support implementation and evaluation of these nutrient reduction goals as part of an ongoing, adaptive management approach.

In the latest iteration of the 2014 Canada Ontario Agreement regarding the Great Lakes, the federal and provincial governments agreed to "shareinformationaboutclimatechangeimpacts,advancethe integrationof thisinformationinto Great Lakesmanagementstrategiesand promoteadaptationactions" (COA, 2014).

2. IJC activities

In March2012, the International Upper Great Lakes Study (IUGLS) Board concluded a five-year study reviewing the regulation of water levels on the upper Great Lakes. The IJC then issued a directive to the International Great Lakes-St. Lawrence River Adaptive Management Task Team (Task Team) to develop an Adaptive Management Plan for the Great-Lakes St. Lawrence River system. In April 2013, the IJC provided its report to governments regarding the IUGLS and endorsed the implementation of a comprehensive Adaptive Management approach supported by science and monitoring. The Task Team's 2013 Adaptive Management Plan (AMPlan) proposed two interconnected initiatives:

1. Ongoing review and evaluation of the effectiveness of the IJC's regulation plan rules at meeting their intended objectives; and
2. Collaboration on developing and evaluating solutions to problems posed by extreme water level conditions that cannot be solved through lake regulation alone.

The IJC shared the Task Team's report and proposed AM plan with the Parties. As the first of these proposed initiatives related to the Commission's existing orders of approval, the IJC in January of 2015 launched the Great Lakes – St. Lawrence River Adaptive Management Committee (GLAM) as an ongoing body to apply an adaptive management approach to the Commission's Great Lakes - St. Lawrence water level regulation responsibilities. The GLAM

Committee will monitor, model and assess conditions to provide on-going information on how the regulation of water levels and flows affects socio-economic interests and the environment. As more is learned, and as climate and other conditions change over time, this information will help determine whether the IJC should consider changes to the methods used to regulate flows and levels.

3.9.5 Assessment of progress on microplastics

1. Background

Numerous studies have documented plastic debris, such as plastic bags, bottles, boxes, fibers, microbeads, and cigarette butts, in marine and fresh waters, including the Great Lakes. This larger plastic debris can degrade into smaller particles. Particles that are smaller than 5-mm in diameter are known as microplastics.There are several categories of microplastics, including preproduction plastic pellets and flakes, microfibers, breakdown materials from larger plastics and microbeads. Microbeads, the most well-known of these categories, are small plastic beads that are added as an abrasive to personal care products, including cosmetics, face washes, toothpastes, deodorants, hair coloring, shaving creams and sunscreens.

These smaller plastic particles, the microplastics, are of particular concern. They can be easily ingested by aquatic organisms, leading to a range of potential impacts including physiological effects, toxicological effects from adsorbed chemicals, and the trophic-transfer of plastics and toxins along the food web, potentially to humans. Laboratory studies have shown that chemicals, such as PCBs and PBDEs, can bioaccumulate in the tissues of fish (Rochman*et al.*, 2013; Wardrop*et al*., 2016)

Microplastics became a significant concern for the Great Lakes in 2013 with the publication of research by a team from the State University of New York – Fredonia that found high volumes of plastic pollution in the open waters of the Great Lakes. Microplastics comprised 98 percent of the plastic items captured, a proportion much higher than that found in the world's oceans (Eriksen*et al*., 2013).

The Province of Ontario has undertaken research to examine the sources and composition of microplastics in and entering the Great Lakes and to determine what happens to them when they enter the Great Lakes -- whether they wash up on shore, settle to the bottom, or remain in the water. In 2014, staff from Ontario's Ministry of the Environment and Climate Change (MOECC) collected surface water samples from nearshore areas in Lake Erie downstream of Detroit-Windsor, near the mouth of the Grand River, and near Fort Erie. Samples from Lake Ontario were collected in Hamilton Harbour, Humber Bay near Toronto, and in Toronto Harbour. Up to 6.7 million particles of plastic per km^2 (17.35 million per $mile^2$) were found with the highest count occurring in Humber Bay of Toronto. Greater amounts of microplastics were present after rainstorms, indicating that runoff of debris from the landscape through storm water is an important source to the lakes. Microbeads were present in wastewater effluent samples, comprising up to 30 percent of the microplastics found in the effluent samples.

Cooperative Canadian research to determine whether microplastics reach bottom sediments found that microplastic particles are present in sediment cores from the center of Lake Ontario and from near the Niagara River, but that microbeads are not present in these samples. Polyethylene was the most abundant polymer type, even though it typically floats rather than sinks to bottom sediments. Sampling of sediments in the St. Lawrence River found that microplastics, and specifically microbeads, were present in samples ranging from as little as 7 beads per m^2 to as high as 136, 926 beads per m^2, where areas received municipal and industrial effluent discharges (Rowsyra*et al*., 2014).

2. Assessment of activities of the Parties

No Annex or specific provision of any Annex in the GLWQA explicitly addresses microplastics. However, one of the principles and approaches outlined in the GLWQA, the precautionary approach, does have implications for addressing microplastics. The GLWQA defines precaution as set forth in the Rio Declaration on Environment and Development: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." The potential impacts of microplastics on the Great Lakes ecosystem are significant enough to warrant measures be taken at the earliest possible opportunity.

The Parties have undertaken a number of activities related to marine debris, including researching, understanding and developing program and policy options to deal with microplastics.

The NOAA operates the Marine Debris Program, which supports marine debris projects in partnership with state and local agencies, tribes, non-governmental organizations, academia, and industry (https://marinedebris.noaa.gov/*)*. The program also spearheads national research efforts and works to change behavior in the public through outreach and education initiatives. In addition, the NOAA Marine Debris Program supports locally-driven marine debris prevention and removal projects each year. Within the Marine Debris Program is a Great Lakes specific, “Great Lakes Land-based Marine Debris Action Plan” that establishes goals, objectives, and strategies to promote coordinated action to address the threats posed by land-based marine debris, in the Great Lakes from 2014 through 2019. This comprehensive framework for action is meant to ensure that the Great Lakes, its coasts, people, and wildlife are free from the impacts of marine debris.

The USEPA Trash Free Waters program focuses on understanding the different types, sources and conveyances of marine debris throughout a watershed. The program addresses improper disposal of waste on the water and onshore, trash entering waterways through storm drains and when sewers overflow, promotion of proper trash disposal and recycling, and monitoring of debris trends in the environment. The program has a goal of approaching zero-loading of trash into US waters within ten years.

The US Geologic Survey studied the quantity of plastics in 29 Great Lakes tributaries and found that 98 percent of the plastic particles were microplastics (Baldwin *et al.*, 2016). Fibers and lines

were the most common item found and this differs from lake studies that found fragments to be more common. That may be because fibers and lines may settle when they get to the more lentic lake waters. This project is another example of Great Lakes work funded by the GLRI through the USEPA's Great Lakes National Program Office.

ECCC administers several federal laws and programs promoting sound waste and wastewater management, provides funding opportunities for community activities such as beach clean-ups, and waste and wastewater infrastructure and technology innovation, and collaborates with the other jurisdictions through the Canadian Council of Ministers of the Environment to improve waste diversion and management, including an action plan for Extended Producer Responsibility. ECCC has also made international commitments including theG7Action PlantoCombatMarineLitter, which identifies15priorityactionstoaddressmarine litterin fourkeyareas:land-basedsources;sea-based sources;removal;andresearch,outreachandeducation. On December 28, 2015, the *Microbeads-Free Waters Act*became law in the United States. The act eliminates the uncertainty over biodegradability. It defines microbeads as "any solid plastic particle that is less than 5 millimeters in size," pre-empts all state laws and removes the biodegradable loophole. It prohibits soaps, body washes, toothpaste and other personal care products from containing the traditional plastic or biodegradable plastic beads as of July 1, 2017. The law also prohibits the sale of products containing microbeads as of July 1, 2019, which means all existing stock of products with microbeads must be eliminated from store shelves by that date.

In August 2015, the Canadian government announced it was adding microbeads to its List of Toxic Substances, which would allow the government to regulate microbeads under the *Canadian Environmental Protection Act*. On February 9, 2016, ECCC released a public consultation document on proposed regulations that would ban microbead-containing personal care products for manufacture and sale by December 2017 and December 2019, respectively. The ban targets "plastic microbeads that are > 0.5 μm but ≤ 2 mm in size". Draft regulations are expected to be released in fall 2016 for public comment, with the final regulations expected to be published in mid-2017. The US and Canadian governments have made great strides in addressing the issue of microbeads. However, microbeads are a subset of the much broader issue of microplastics, which is a more complex problem requiring more complex solutions.

3. IJC activities

The IJC is concerned about the potential ecological and human health impacts of microplastics in the Great Lakes. To explore the issue, the IJC convened a two-day workshop in April 2016 to develop recommendations for the IJC to consider forwarding to the governments of Canada and the United States to help address the challenges posed by microplastics pollution in the Great Lakes. This as an opportunity for the governments to implement the principles of "prevention" and "precaution" that guide them in achieving the objectives of the GLWQA.

Workshop participants agreed that the presence of plastics, in any form, is not acceptable in the environment and therefore needs to be properly managed. It was also clear from the workshop that the science and knowledge on microplastics is evolving, particularly for freshwater systems

and the Great Lakes specifically. Governments will need a better understanding of the issue in order to make informed decisions on policies and programs to effectively manage plastics and ultimately microplastics. As a result, prevention of plastic debris in the Great Lakes should be accomplished through binational planning that combines various approaches and tools, including science and research, policy, market-based instruments and education and outreach.

3.9.6 Section Summary

Objective 9 of the GLWQA addresses a wide range of important current and emerging challenges to the quality of the waters of the Great Lakes.

Areas of Concern

- Progress on AOCs has been substantial in the triennial period, particularly in the United States, due to USEPA's GLRI funding. For example, the GLRI has helped implement RAPs. Canada has also made progress, include large investments in Hamilton Harbour and Port Hope Harbour AOCs. Increased ongoing investments on the Canadian side to parallel increased ongoing US investments would accelerate binational progress on AOCs. Additional technical transfer between AOCs, and coordination between the domestic processes occurring on both sides of binational AOCs, also are required.

- Annex 1 is the only Annex in the GLWQA without an associated Great Lakes Executive Committee structure. For each of the other nine Annexes, the Annex Committees and Extended Subcommittees provide regular and recurring opportunities for agency staff from multiple levels of government, academics, NGOs, consultants, and others with a professional interest in the Annex topic to discuss Annex-related issues. This opportunity does not exist on a binational basis for AOCs.

Lakewide Management and Cooperative Science and Monitoring

- Progress in lakewide management has been mixed. In the triennial period, the Parties developed an Integrated Nearshore Framework and have initiated a pilot project to apply it. The first LAMPs were prepared, though it is still uncertain whether agencies and communities are sufficiently invested in the LAMPs, and whether their recommended actions are sufficiently prescriptive, for them to serve as the lens through which management actions are planned and implemented.

- Public consultation and outreach related to the LAMPs is currently underdeveloped. The Parties need to reaffirm their commitment to the principles and approaches of public participation and accountability in carrying out activities in support of lakewide management.

- The CSMI is a key mechanism to achieve the science priorities identified through the lakewide management process. The CSMI has significantly improved coordination among federal science agencies, and notes progress at the state/provincial level as well. This progress could be built upon by better engaging academic partners.

- Progress in the timely reporting and dissemination of preliminary CSMI findings that can inform the management decisions that must be made immediately following the CSMI cycle for a particular lake, but before full peer-reviewed science reports are published, is encouraged.

Climate Change

- The Parties have satisfactorily addressed the science commitments made in Annex 9, cooperating successfully on numerous measurement and communications projects and meeting timelines. However, the Parties have not implemented some of the program commitments in Annex 9, especially "using their domestic programs to address climate change impacts to achieve the objectives of this Agreement.

- Evidence of climate change impacts on the Great Lakes system is indisputable.

Adaptive Management

- The Parties have made considerable effort to incorporate adaptive management into key Great Lakes programs, including the GLRI and the Canada Ontario Agreement respecting the Great Lakes (COA).

Microplastics

- Microplastics are an emerging and challenging issue in the Great Lakes basin. The presence of plastics, in any form, is not acceptable in the environment and therefore needs to be properly managed.

- The science and knowledge on microplastics, including their impacts on the ecosystem and human health is evolving, particularly for freshwater systems and the Great Lakes specifically.

- Binational planning to prevent microplastic pollution is needed and should include monitoring and research, pollution prevention, and education and outreach.

3.9.7 References

Assel, R.A., 1999. Great Lakes Ice Cover in *Potential Climate Change Effects on Great Lakes Hydrodynamics and Water Quality* (edited by D.C.L. Lam and W.M. Schertzer). American Society of Civil Engineers, Reston, VA, pp. 6-1 to 6-21.

Baldwin, A.; Corsi, S.; Mason, S. Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology *Environmental Science & Technology*. 2016 Sept. 14; 10.1021/acs.est.6b02917

Canada and U.S., 2016.The Great Lakes Nearshore Framework.Accessed at https://binational.net/wp-content/uploads/2016/09/Nearshore-Framework-EN.pdf on November 18, 2016.

Environment and Climate Change Canada and United States Environmental Protection Agency, 2014.State of the Great Lakes 2011.

Eriksen, M. et al., 2013.Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine Pollution Bulletin 77: 177-182

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Cat. No.: En164-53/1-2016E-PDF. ISBN: 978-0-660-06365-2. Available at https://binational.net/2016/09/28/prp-rep/

Mandelia, A., 2016. Great Lakes Areas of Concern: Life after Delisting. An investigation conducted at the IJC Great Lakes Regional Office.

International Joint Commission, 2017. INSERT MICROPLASTICS REPORT CITATION HERE

International Joint Commission, 2016.An Assessment of the Communicability of the IJC Ecosystem Indicators and Metrics.Science Advisory Board Communication Indicator Workgroup report.60pp + appendices.Accessed January 13, 2017 at http://www.ijc.org/files/publications/ScienceAdvisoryBoard_CommunicationIndicatorsReport_en.pdf.

International Joint Commission, 2013. Assessment of Progress Made Towards Restoring and Maintaining Great Lakes Water Quality Since 1987: 16th Biennial Report on Great Lakes Water Quality.

International Joint Commission, 2011.Great Lakes Water Quality Agreement Priorities 2009-11 Priority Cycle Report.Workgroup Report on the Nearshore Framework.16 pages + appendices.

International Joint Commission, 2009.Great Lakes Water Quality Agreement Priorities 2007-09 Series.Workgroup Report on the Nearshore Framework.15 pages. Accessed May 24, 2016 at http://www.ijc.org/files/publications/C224.pdf

International Joint Commission, 2003. Status of Restoration Activities in Great Lakes Areas of Concern: A Special Report. 47 pages. Accessed on May 19, 2016 at http://www.ijc.org/php/publications/html/aoc_rep/english/report/pdfs/aoc_report-e.pdf

McDermid,J.L.,S.KDickin, C.L.Winsborough, H.Switzman, S. Barr,J.A.Gleeson,G.Krantzberg,P.A.Gray.2015. StateofClimate ChangeScienceintheGreatLakesBasin: AFocusonClimatological, Hydrological andEcological Effects.PreparedjointlybytheOntario ClimateConsortiumandOntarioMinistryofNatural Resources and Forestry toadviseAnnex9–Climate ChangeImpacts undertheGreatLakes WaterQualityAgreement, October2015.

Richardson, V., Warren, G.J., Nielson, M., Horvatin, P.J., 2012. Cooperative Science and Monitoring Initiative (CSMI) for the Great Lakes – Lake Ontario 2008. Journal of Great Lakes Research 38, 10-13.

Rochman CM, Hoh E, Kurobe T, Teh SJ. 2013 Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3, 3263. (doi:10.1038/srep03263)

Castañeda RA, Avlijas S, Simard MA, Ricciardi A (2014) Microplastic pollution in St. Lawrence River sediments. Can J Fish AquatSci 71:1767–1771.

Roth, B.M., Riseng, C.M., Sparks-Jackson, B.L., Fetzer, W.W., Infante, D.R., 2016. Great Lakes Indicator Data Accessibility and Data Gaps Analysis for Assessing Progress Towards Achieving the GLWQA Objectives. Contractor report prepared for the IJC Science Advisory Board (Research Coordination Committee).

Situation Analysis Task Team, 2016.Areas of Concern Situation Analysis. Submitted to the Annex 1 Co-Chairs.

United States Environmental Protection Agency, 2016. Climate Change Indicators: Great Lakes Water Levels and Temperatures. Accessed at https://www.epa.gov/climate-indicators/great-lakes January 23, 2017.

Wardrop P. et al., 2016. Chemical Pollutants Sorbed to Ingested Microbeads from Personal Care Products Accumulate in Fish. Environ. Sci. Technol.50, 4037–4044.

Yurista, P.M., Kelly, J.R., Scharold, J.V., 2016. Great Lakes nearshore-offshore: Distinct water quality regions. Journal of Great Lakes Research 42, 375-385.

Chapter 4
Informing the Public about Great Lakes Status and Trends

4.0 Introduction

1. Purpose

This chapter discusses the challenges of using the State of the Great Lakes report for communicating status and trends with the public and provides ideas for the Parties to consider. The Agreement requires the IJC's triennial assessment of progress report to include "consideration of the most recent State of the Lakes Report." Because the Parties had not released a State of the Great Lakes Report at the time this draft technical appendix was prepared, this chapter discusses the Parties' presentation of State of the Great Lakes reporting at the Great Lakes Public Forum (GLPF) in October 2016. The chapter also reviews why indicators are used, presents the work of IJC advisory boards on indicators and discusses challenges related to informing the public about the status and trends of the Great Lakes.

2. Background

Assessing and reporting on the condition of a large scale regional ecosystem such as the Great Lakes Basin is challenging and communicating the findings to the public can be equally demanding. For the first Triennial Report, the International Joint Commission (IJC) sees value in having a small set of indicators that could easily communicate to the public the progress made by the Parties towards the nine General Objectives under the GLWQA. In addition, the small set of indicators should be able to answer the key question: *are the Great Lakes getting better or worse?*

One of IJC's responsibilities under the Great Lakes Water Quality Agreement (GLWQA) is to assess the progress made by the Parties towards achieving the objectives of the agreement. However, for IJC to issue its own independent third party-assessment in its Triennial Assessment of Progress Report, it needs to work in collaboration with the Parties, because IJC does not collect monitoring data.

The IJC's focus on improving reporting to the public about status and trends accelerated in the last reporting cycle under the 1987 GLWQA. In the IJC's 16th (and final) Biennial Report on Great Lakes Water Quality, the IJC sought to develop a comprehensive assessment, to communicate all the technical findings about the status and trends of the Great Lakes to the public, and to issue guidance for the Parties to help improve public communication and reporting under the new GLWQA (IJC, 2013).

Only a small set of indicators is needed for effectively communicating with the public. By contrast, providing policy makers with scientifically-sound information that can be used to make better monitoring, restoration, and prevention decisions requires more indicators (or sub-indicators, or measures or metrics). Therefore, the IJC recognizes additional monitoring data and indicators are needed beyond those needed for communicating in a concise manner with the

public (IJC, 2013). The topics of monitoring, collecting data, and indicators for decision making are discussed more fully in Chapter 5 – Other Advice and Recommendations.

4.1 Using indicators to describe status and trends

Indicators are commonly used to describe the condition of the environment in the same manner as indicators are used to describe human health (*e. g*., blood pressure) and economic status (*e.g*., Dow Jones Index). The Heinz (2008) report on the state of the US ecosystems notes that the United States has an official suite of indicators for the economy and concludes that the environment needs one too. Clearly, that message could apply to any country, and most certainly Canada, or to any large regional system such as the Great Lakes.

This challenge to communicate technical information is not unique to ecological assessment but to other branches of science as well. Two examples are discussed by Tufte (1997). For instance, the 1854 Cholera epidemic in London was solved by creating a map of deaths and community pump wells to determine which well was causing the mortalities. The Challenger disaster of 1986 could have been averted by not launching on an abnormally cold day in January because O-ring failure (the cause of the disaster) is far more likely to occur in cold weather. Showing decision makers a simple line graph with temperature on one axis and O-ring failure on another, would have clearly conveyed the risk of launching on a cold day. The briefing given to decision makers included more complex charts making it harder to visualize the association between cold temperatures and O-ring failure.

All branches of science have challenges communicating technical information. Communicating ecological information adds another level of complexity, because by its very nature ecology reflects the interaction of a multitude of organisms with each other and their environment. While studying any one organism (such as humans), or any one ecosystem (such as the nearshore), or any one process (such as meteorology), is complex enough, additional effort is needed to communicate environmental indicators that consider biotic and abiotic factors and their interrelationships.

To resolve environmental problems, it is necessary to consider the complexities of ecology. At the same time, for non-specialists to grasp this information and see its application to important public decisions, it needs to be presented in a less complex manner. Ecologists may be best-suited to make this complex information understandable (Norton 1991). Ecologists can communicate complex information most effectively when using graphics (such as line and bar graphs, maps, drawings and models) and combining them with text features such as headings, bullets points, topic points, transitions, and figurative language (*e.g.*, “Wetlands are nature’s kidneys, they filter pollutants” [Rowan 1999]). It is also important to describe in the text what each indicator conveys about the environment. For example, the indicator “lichen communities” shows the effects of air pollution on the forest including changes in the numbers and types of plants that are found in the forest (Schiller *et al*., 2001).

Maps, line graphs, and the other techniques described previously by Norton (1991) have been used by both countries even at the national scale. However, it is a challenge narrowing down the set of indicators used for getting a quick status and trends assessment. The United States

Environmental Protection Agency (USEPA) Report on the Environment (2016) is a web-based report that uses 85 indicators to report on five areas: air; water; land; human health and exposure; and ecological condition. The web-based report uses a hierarchical structure to obtain more specific information under any of these themes. Similarly, Environment and Climate Change Canada (ECCC, 2016) groups the indicators on their web site into three categories: air and climate; water; and nature. Within each of these categories there are more indicators and the ability to get details such as maps and data sets. For instance, the water quality of rivers section categorizes the proportion of all Canadian rivers as excellent or good, fair, marginal or poor and has deeper levels of detail.

Other regions besides the Great Lakes also produce status and trends reports and even at a regional scale, a sizeable number of indicators are needed to track progress. The Chesapeake Bay Program (2016) tracks more than 30 environmental indicators to gauge the success of efforts to protect and restore the Bay, its tributaries and the lands that surround them. Some indicators, such as blue crab abundance, water quality and forest cover, track aspects of watershed health. Others including public access, protected land and open fish passage, track restoration and protection work. Each indicator includes text bar, graphs and even videos. For instance, the American Shad indicator has a video showing how population has changed over time and what scientists are doing to restore the anadromous fish to the Bay.

Even at the individual lake scale, several indicators are needed to communicate status and trends to the public. The Lake Champlain Basin Program is another binational program based on collaboration between the United States and Canada. The program periodically publishes the State of the Lake report to update the public and policy makers on the condition of Lake Champlain, its sub-basins, and its watershed. The 2015 State of the Lake Ecosystem Indicator Report (Lake Champlain Basin Program, 2015a) uses line graphs, bar graphs, maps and a combination of other pictures and pulled out facts. In the report, a vast array of information is presented in an eye-catching manner and clear format to enable understanding by non-experts. One must recognize that even this “one lake report” does use a couple dozen indicators but does select nine of the most pertinent indicators to present in a briefer handout (Lake Champlain Basin Program, 2015b).

4.2 Process to select a core set of Great Lakes indicators

In the 16th Biennial Report (IJC, 2013), the IJC stated that the State of the Lakes Ecosystem (SOLEC 2014a) indicator reports are broad in scope and highly useful and would be even more useful if organized in a manner that clearly linked to the GLWQA objectives. In addition, the IJC recommended that for communicating with the public the governments should use a core set of indicators related to the objectives of the 2012 GLWQA. Other indicators are needed for a thorough investigation but a smaller set of indicators to share with the public could be appropriate for the SOGL version of what was the SOLEC 2011 Highlights Report (SOLEC, 2014b). The IJC also recommended that the governments should create a useful reporting and communication system in a report card format, to provide to the public plain language descriptions of core indicators and discussion of trends (IJC 2013). Coincidentally, the decision

by the Lake Champlain basin to issue a report is consistent with the direction issued by IJC in its 16th Biennial Report. The Lake Champlain report is a good model to consider for developing an IJC status and trends report for the public. The presentation of data of the 2011 SOLEC Highlights Report (2014) is high quality in terms of communicating with the public. The highlights report used a relatively small set of indicators, plain language, and basic graphics to communicate with the public the status and trends of water quality, aquatic dependent life, and landscapes. The approach is consistent with some of the literature that has been presented in this technical appendix.

4.3 Summary of the SOGL Highlights Report

The 2011 Highlights Report showed data from 16 indicators with many of them matching up with the IJC (2013) indicators. Four indicators were used to describe water quality, nine to describe aquatic life, three to describe landscapes and three more addressed human health. For most indicators, a lake-by-lake assessment was presented showing trends labeled as improving, deteriorating, unchanging, or undetermined. Both the summary version of the IJC 16th Biennial Report and the 2011 SOLEC highlights report (SOLEC 2014b) took important steps forward towards communicating to the public about the status and trends of the Great Lakes. Now as the Parties develop their first SOGL report, they can build upon their earlier work and improve communication to the public about the status and trends of the Great Lake.

As noted, the governments have replaced the SOLEC report, with a State of the Great Lakes Report (SOGLR). For the SOGLR highlights report, the governments could continue to use the presentation of the 2011 SOLEC Highlights Report, showing the lake-by-lake status and trend data, but not necessarily the same indicators. Further improvements are desirable in both SOGLR and IJC reporting

The Parties presented their plans for their first State of the Great Lakes Report at the Great Lakes Public Forum (GLPF 2016). The Parties plan to adopt the IJC's recommendation to reorganize the SOGL reporting for 2017 by linking indicators to the GLWQA General Objectives (Table 4.1). The nine indicators selected by the Parties are a core set of indicators. By having indicator data for each objective, there is a logical connection to clearly understand Great Lakes status and trends. Indicators that are understandable and responsive to public concerns also foster informed public participation in Great Lakes policy development.

Table 4.1. Indicators correspond to each General Objective of the Agreement

Source: Great Lakes Public Forum (2106).

General Objectives and Indicators

GLWQA General Objectives	Great Lakes Indicators
Be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity ...	**Watershed Impacts and Climate Trends**
Support healthy and productive wetlands and other habitats to sustain resilient populations of native species.	**Habitats and Species**
Be free from the introduction and spread of aquatic ... and terrestrial invasive species ...	**Invasive Species**
Be free from nutrients ... in amounts that promote growth of algae ...	**Nutrients and Algae**
Be free from the harmful impact of contaminated groundwater.	**Groundwater**
Be free from pollutants ... that could be harmful to human health ...	**Toxic Chemicals**
Allow for human consumption of fish and wildlife.	**Fish Consumption**
Be a source of safe, high-quality drinking water.	**Drinking Water**
Allow for swimming and other recreational use.	**Beaches**

2. Sub-indicators and measures for trend analysis

As presented at the Great Lakes Public Forum (2016), the Parties plan to describe each indicator with a series of sub-indicators and develop a SOGL highlights report to continue the concise communicating with the public that occurred with the SOLEC Highlights report. It is a challenge to summarize the status and trends of several sub-indicators in a succinct manner, especially when dealing with a large spatial scale such as the Great Lakes. The next step involves devising a technique to quantitatively or qualitatively express the indicators into a score or categorical ranking.

Others have pursued the effort to quantitatively combine various sub-indicators into one indicator, such as the Fish Index of Biotic Integrity devised by Karr (1981). This index combines several metrics about fish to quantitatively describe the condition of the fish community and it can be applied to making resource management decisions (Karr, 1991). Other indices have been developed for particular communities even within the Great Lakes region. For example, the Index of Community Integrity for the benthic community is used to categorize the quality of various benthic communities of the Northern Lakes and Forests Ecoregion, which is characterized by mixed conifer and deciduous forests and wetlands (Butcher *et al*., 2003).

A quicker approach that could be used for this first State of the Great Lakes Report is to categorically rank each sub-indicator and then come up with an indicator rank (*e.g.*, good, fair, poor). This approach was presented at the Great Lakes Public Forum (2016) and is an excellent approach to convey all the key information succinctly when no index or quantitative approach exists. The Parties have done an outstanding job developing a set of tables including a one-page summary that presents the ranking and trend for each indicator, another nine page summary (one page for each indicator) that presents the ranking and trend for each sub-indicator, and a five-page summary that presents the condition of each indicator at each lake (as presented at GLPF 2016). This approach provides three different sets of public information with varying levels and types of details in only 15 pages.

The public prefers common language indicators and concise statements to convey the condition of the environment (Schiller *et al*., 2001) and the Parties have achieved that with their indicator reports (Table 4.2). There would be value in using arrows up (improving conditions) or down (declining or deteriorating condition) in addition to the word messages, as was done in the SOLEC Highlights Report (2014b) and the Lake Champlain report (Lake Champlain Basin Program 2015).

Table 4.2: Status and Trends of each Food Web Sub-Indicator. Source: Great Lakes Public Forum (2016).

Habitat and Species #2 (Food Web)

Status: GOOD FAIR POOR

SUB-INDICATORS	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Zooplankton	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Benthos	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging
Diporeia	Unchanging	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Lake Trout	Unchanging	Improving	Improving	Improving	Improving
Phytoplankton	Unchanging	Deteriorating	Deteriorating	Deteriorating	Unchanging
Preyfish	Unchanging	Deteriorating	Undetermined	Improving	Deteriorating
Walleye	Unchanging	Unchanging	Unchanging	Improving	Unchanging
Lake Sturgeon	Improving	Improving	Improving	Improving	Improving
Fish Eating and Colonial Nesting Birds	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging

3. Science Advisory Board indicators and measures

Besides the outstanding approach displayed by the Parties at GLPF (2016), another approach that could be used to convey information to the public is to select one sub-indicator per indicator to act as a surrogate to reflect the condition of the indicator. The IJC's Science Advisory Board (SAB) developed a process for selecting a smaller set of indicators and metrics that can tell meaningful and compelling stories to the public about the health of the Great Lakes and to reflect the progress made by the governments towards the objectives of the GLWQA.

Though initiated separately and before the Parties presented their plan to have one indicator for each objective, the work of the SAB could supplement the work done by the Parties by helping to identify the sub-indicator that would be most useful for communicating with the public. The SAB agreed that it needed to develop a process that would be objective, repeatable, defensible and transferable to other types of indicators (*e.g.*, human health) and developed a report on what it called "communication indicators" (SAB, 2016). Communication indicators and sub-indicators were selected based on whether they told a compelling story (relationship to public interest), were visible (ability to see or sense changes), were easy to understand, and are a direct measure of lake health.

The SAB selected the best metric for eight indicators using seven filter categories, related to availability of data including frequency of data, sample design, and statistical reliability, spatial and temporal scale, relevancy of data to a goal and decision making, and cost of data collection. Using this approach, the SAB found that all the metrics have some data availability, resolution, or data quality issues that impact their communicability. Many metrics do not have sufficient data to assess and report on individual lakes or their subunits, making it a challenge to identify trends. To meet the time constraints for the 2017 IJC Triennial Report and the Parties' SOGL report, the SAB selected the best eight indictors and metrics for communicating the status and trends of the Great Lakes ecosystem with the public. The SAB recommended that this process be repeated on a regular basis, perhaps every six to nine years, and that for the next triennial the process be applied to human health indicators. The IJC reviewed the SAB recommendations, compared them to the SOLEC (2014b) and GLPF (2016) presentation, and then reached its own conclusions on the information to provide to the public (Table 4.3). These figures and associated explanations would supplement the previously suggested components of the Highlights Report. (*i.e.*, one-page summary for all nine objectives, nine-page summary [one page for each indicator] and lake-by-lake summaries). This would expand the Highlights Report, but it provides the public another option to see another set of highlights.

Table 4.3 shows that in many instances, the IJC, SAB, and the Parties all present similar data for a particular indicator or sub-indicator that corresponds to a general objective. For instance, all three organizations have used or support using PBTs in whole fish as the set of data to communicate with the public the concerns about chemical levels in fish. In other cases, there is a similar perspective, but the IJC supports an additional parameter be presented. For chemical levels in water, all three organizations support showing the public mercury levels, but the SAB supports including atrazine (SAB, 2016). Atrazine is commonly used to control weeds, is commonly measured, and is increasing in concentrations (ECCC and USEPA, 2014) and can help reflect the general trend in herbicide use and levels.

With respect to algal blooms, one could make the point that the public is more concerned about harmful algal blooms (HABs) than nuisance algal blooms and that HABs are a better measure because no nuisance algae target exists. The development of a Cladophora biomass target could help develop management strategies and supports expanding the use of eutrophic severity indexes to Green Bay and Saginaw Bay.

SAB members have more expertise in ecosystems than human health and did not pick measures for the three General Objectives related to human health. The SAB did not select an indicator or metric for groundwater because its members believed that it was more important to select indicators that better resonated with the public around chemical, physical, and biological integrity.

The SAB recommends that more emphasis be placed on the effective management and delivery of information, including identifying the appropriate target audience. The topic of delivery of information is covered in more detail in Chapter 5.

The Parties' SOGL Highlights Reports should include the eight SAB-recommended metrics to show progress towards five of the six ecosystem-related General Objectives.

Table 4.3 Set of sub-indicators that are most informative for the public.

Agreement Objective	SAB Selected Indicator and Metric (SAB, 2016)	Relationship to SOLEC (2014) or GLPF (2016)	Potential Sub-indicators to use based on SAB(2016), SOGL (2104) and GLPF (2016)
4. Keep Great Lakes free from pollutants that could be harmful to human health or aquatic organisms	Persistent bioaccumulating toxics (PBT) in biota – PBTs in whole fish	SOLEC 2014 presents PBTs in whole fish; lake trout and walleye.	PBTs in whole fish is most useful data and graphic to present to public about progress towards general objective #4.
	Chemical levels in Water – Mercury and Atrazine *	Mercury was presented in the SOLEC Highlights Report and GLPF.	Both mercury and atrazine levels in water should be shown in the highlights report.
5. Trends in populations of native species	Fish species of interest – Lake trout / lake whitefish abundance (walleye for Lake Erie)	These were two of the species presented in the SOLEC report and at GLPF.	These species best reflect objective #5. The Commission supports using figures showing their abundance in each lake in a highlights report. Other communities (e.g.., benthos) and species (e.g., sturgeon) are important but not as useful for communicating with the public.
6. Controlling impacts from nutrients.	Harmful and nuisance algae – nuisance algal blooms.	The SPC ranked Nuisance algal blooms as one of two measures to present to the public.	The Commission sees value in using harmful algal bloom data for western Lake Erie, Saginaw Bay, and Green Bay. The Lake Erie Severity Index and the pictures showing the extent of the bloom that were presented at GLPF (2016) are suggested for the highlights report and so are similar severity indexes for Green Bay and Saginaw Bay.
	Total phosphorus in lakes	Spatial distribution of Total P in lakes was included in GLPF.	Based on other SAB work (RCC 2016) the Commission recommends showing ***concentrations of dissolved reactive phosphorus in the nearshore and offshore*** as the second set of important measures for Objective 5, as opposed to Total P. This would help explain the nearshore shunt (Hecky et al 2003).
7. Control impacts from Aquatic Invasive Species (AIS)	Aquatic Invasive Species – Sea lamprey abundance*	SOLEC and GLPF showed these data.	The Commission agrees with the SAB that these are the key data to present related to communicating trends about this objective and suggests that the Parties present the figure showing Sea Lamprey abundance in each lake

			in their Highlights report similar to Figure 4.1.
8. Keep the lake free from other conditions that may impact the Great Lakes, including climate change.	Maximum ice cover; and Water level – Long term water level variability	Maximum ice cover presented at GLPF.	These two sets present data related to communicating trends about climate change. The GLPF figure (See Figure in Section 3.9) showing annual maximum ice coverage effectively portrays this. The figure would be enhanced by including an ordinary least squares regression line to help visualize the decreasing trend in ice coverage over time.

* An abbreviated process that considered the filters but relied on best professional judgement was used to select the metrics for Chemical Levels in Water and Aquatic Invasive Species.

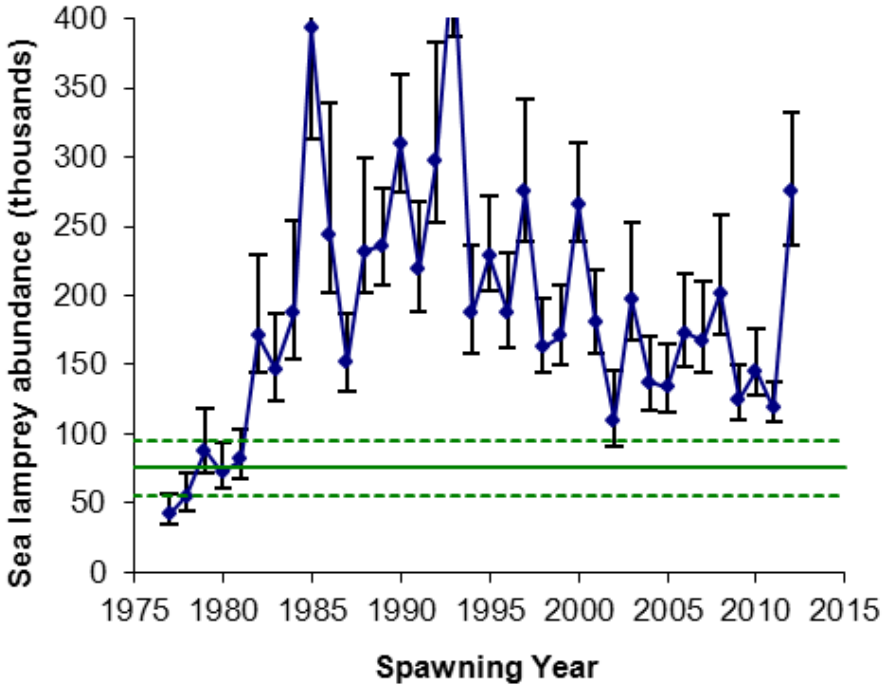

Figure 4.1. Annual lake-wide population estimates of adult sea lampreys in Lake Huron, 1980 – 2012 with 95% confidence intervals (vertical error bars). Target level is indicated by the solid horizontal line with 95% confidence intervals (dashed horizontal lines). Source: Great Lakes Fishery Commission (2012)

STORYTELLING

Indicators trends are one key part of communicating with the public, but as SOLEC (2014a) explains, the indicator trends do not tell the whole story. The governments made good use of storytelling in the SOLEC Technical Report. The stories told on pages 9-26 of the SOLEC Technical Report (2014a) include why harmful algal blooms are recurring despite lower total phosphorus levels, why native fish species are struggling to survive, and how land use many kilometers away from the lakes may influence the water quality of the Great Lakes. The report also includes stories about clear water, chemical levels in water, biota and sediment, invasive species, coastal wetland communities, dam removals, and land use. These are excellent stories and the kinds of stories that need to be told to adaptively manage the Great Lakes.

The IJC, along with the SAB (2016), recognizes that a concise set of status and trends of indicators are needed to communicate with the public. However, these indicators cannot provide all the information needed to adaptively manage the Great Lakes or describe to the public how well government programs are accomplishing all of their Specific Objectives described in the GLWQA. Both the SAB and the IJC recognize the importance of telling complete stories to communicate with the public. Such storytelling could be included as part of the forthcoming SOGL Highlights Report, since the highlights report is more accessible and legible to the public.

Telling these stories requires more than nine indicators. Accordingly the Parties plan to use tiers of indicators; that is, using several sub-indicators to better describe each particular indicator. Governments could continue telling stories, and in SOGLR use the sub-indicators to tell stories, and present those stories in the Highlights Report.

4.4 Section Summary

- This chapter reviewed some of the history of IJC's and the Parties work towards improving the use of using indicators for communicating the status and trends of the Great Lakes ecosystem with the public. The chapter also reviewed relevant literature on approaches for communicating environmental information with the public and a few other assessment efforts outside the Great Lakes.

- The IJC proposed recommendations to the Parties in its 16th Biennial Report (IJC 2013) about having a small set of indicators and linking them to the Objectives of the Agreement. The Parties now plan to do this and this approach could improve communication with the public about status and trends.

- At the GLPF (2016) the Parties presented additional plans for the SOGL report. The Parties plan to have varying levels of details for the public. These include a one page summary that describes the status and trends of progress towards achieving the objectives of the Agreement, a nine page summary that describes the progress made towards sub-indicators associated with each of the nine indicators, and a five page summary that describes the status and trends of indicators in each Great Lake.

- Government proposals for SOGL reporting (GLPF 2016) could lead to an excellent report. In addition to the proposals presented at the GLPF, there would be value in including graphics and narrative discussion on the eight metrics selected by the Science Advisory Board because of their value in communicating information that will resonate with the public. There would also be value in including stories in the SOGL Highlights report, similar to the style presented in the SOLEC Technical Report but reaching more readers.

- The Parties SOGL Highlights Report has the potential to communicate with the public a multitude of complex ecological information and concepts.

4.5 References

Butcher, JT; Stewart, PM; and Simon, TP. 2003. A Benthic Community Index for streams in the Northern Lakes and Forests Ecoregion. *Ecological Indicators. 3(3)*

Chesapeake Bay Program, 2016. Track Our Progress. http://www.chesapeakebay.net/trackprogress Accessed on September 30, 2016.

Environment and Climate Change Canada, 2016.Environmental Indicators.https://www.ec.gc.ca/indicateurs-indicators/. Last Modified on July 27, 2016

Great Lakes Fisheries Commission (2016). Annual Report.Great Lakes Fisheries Commission.Accessed on November 23, 2016.http://www.glfc.org/sealamp/ANNUAL_REPORT_2012.pdf

Great Lakes Public Forum (2016).State of the Great Lakes.Presentation at the Great Lakes Public Forum.October 4, 2016, Toronto, Canada.

Hecky, R.E; R.E. Smith; d.R. Barton; S.J. Guildford. 2004. The nearshore shunt: A consequence of ecosystem engineering by dreissenid mussels in the Great Lakes. **Canadian Journal of Fisheries and Aquatic Sciences**Can. J. Fish.Aquat. Sci. **61**: 1285–1293 (2004) doi: 10.1139. http://conservationontario.ca/great_lakes_workshop/PDF/Nearshore_Phosphorus_shunt_04.pdf

Heinz Center. 2008. The State of the Nation's Ecosystems. Heinz Center for Science, Economics, and the Environment. Washington, DC. www.heinzcenter.org/ecosystems

IJC. 2013. Assessment of Progress Made Towards Protecting and Restoring Great Lakes Water Quality since 1987. 16th Biennial Report on Great Lakes Water Quality.hhttp://www.ijc.org/files/publications/16th%20BR%20long%2020130514.pdf Accessed on September 30, 2016.

IJC 2014.Great Lakes Ecosystem Indicator Report.A Report from the Science Advisory Board to the International Joint Commission.http://www.ijc.org/en_/AOP/Ecosystem. Accessed on September 30, 2016.

Karr, James R. (1981). "Assessment of biotic integrity using fish communities".*Fisheries.**6**: 21–27. doi:10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2. ISSN 1548-8446.*

Karr, James R. 1991. "Biological integrity: A long-neglected aspect of water resource management."*Ecological Applications* 1:66–84.

Lake Champlain Basin Program. 2015. Introduction. http://sol.lcbp.org/Introduction_en.html Accessed on September 30, 2016.

Lake Champlain Basin Program. 2015. Ecosystem Indicator Scorecard. http://sol.lcbp.org/ecosystem-indicators-scorecard.html Accessed on September 30, 2016.

Norton, BG. Improving ecological communication: The role of ecologists in environmental policy formation.*Ecological Applications* 8(2), 1998; pp. 350-364.

Rowan, KE. 1999. Effective explanation of uncertain and complex science. In S. Friedman, S. Dunwoody, and C.L. Rogers (eds.), Communicating new and uncertain science (pp.201-223). Erlbaum.Kahwah, NJ.

Schiller A., Hunsaker CT, Kane MA, Wolfe AK, Dale VH, Suter GW, et al. 2001. Communicating Ecological Indicators to Decision Makers and the Public. *Conservation Ecology*.5(1) 19.www.consecol.org/vol5/iss1/art19

Science Advisory Board. 2016. An assessment of the communicability of the International Joint Commission ecosystem indicators and metrics. Accessed September 30, 2016.http://www.ijc.org/files/publications/ScienceAdvisoryBoard_CommunicationIndicatorsReport_en.pdf.

SOLEC 2014a.Technical Report.State of the Great Lakes 2011.Environment Canada and U.S. Environmental Protection Agency.Toxic Chemical Concentrations.Accessed September 30, 2016.http://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdf

SOLEC 2014b.State of the Great Lakes Highlights Report.Environment Canada and U.S. Environmental Protection Agency.Accessed September 30, 2016.https://binational.net//wp-content/uploads/2014/11/SOLEC2011Highlights_e.pdf

Tufte. 1997. Visual Explanations. Chapter 2, Visual and Statistical Thinking: Displays of Evidence for Making Decisions. pp. 27-54. Graphics Press. Cheshire, CT.

US EPA. 2016. Report on the Environment. Accessed September 30, 2016. https://cfpub.epa.gov/roe/chapter/water/ground.cfm

Chapter 5

Other Advice

5.0 Introduction

Chapter 5 assesses key challenges that are critically important for making progress toward achieving the objectives of the Great Lakes Water Quality Agreement (GLWQA) but that are not directly addressed in any of the preceding Chapters. Specifically, this chapter seeks to:

- identify future improvements to the Great Lakes indicators used for decision making;
- evaluate Great Lakes indicator data availability and accessibility for making recommendations to the Parties on monitoring and information synthesis;
- review how governments and society could strengthen efforts to prevent future harm to the Great Lakes ecosystem; and
- discuss the importance of coordination and public engagement principles in GLWQA implementation and the reporting of their implementation.

5.1 Assessing Great Lakes indicators

5.1.1 Background

Article 7 of the GLWQA charges the IJC with the responsibility of assessing and reporting upon the progress of the governments of Canada and the United States in their implementation of the agreement. It calls for the IJC to provide other advice and recommendations as appropriate. Recognizing the importance of indicators in assessing progress, as well as managing and communicating data and information, the IJC has undertaken efforts to identify improvements and refinements to Great Lakes indicators (IJC 2013, IJC 2014a, HPAB 2014, SAB 2016, RCC 2016). Chapter 4 discussed improvements to indicators used for communicating status and trends to the public. This chapter discusses improvements for the indicators used for decision making.

As better monitoring data become more available and improvements to indicators can be instituted over time, increased understanding of the Great Lakes ecosystem will provide well-informed management decisions. This will also ensure that the IJC is well placed to fulfill the assessment and reporting responsibilities assigned by the GLWQA.

During the past three years, the IJC, through its Water Quality Board (WQB), Science Advisory Board (SAB), and Health Professionals Advisory Board (HPAB), has conducted extensive scientific analyses and consultations with experts in the Great Lakes region from both countries with a view of improving existing indicators for measuring the health of the Great Lakes. This effort is built on the many years of experience and products accumulated from the indicator development process of the State of the Lakes Ecosystem Conference of the governments of the Canada and the United States. As a result of this effort, the IJC recommended 16 ecosystem and five human health indicators, each consisting of multiple measures, to the Parties in 2014 (IJC,

2014a, HPAB, 2014). These indicators provide good coverage of the GLQWA objectives with a small number of indicators. In recommending these indicators, the IJC recognized that data are not available for some of the indicators but believes that most of the recommended indicators can be used as sub-indicators in the Parties' State of the Great Lakes reporting (SOGLR).

After determining how indicators recommended by the IJC could be applied or "operationalized", the Parties plan to include in SOGLR those indicators for which there are readily available data, along with additional climate and human population indicators (GLPF, 2016). As a result, the Parties plan to include nine high-level indicators and 44 sub-indicators. For the purposes of assessing progress on the GLWQA, the nine indicators are aligned to the nine General Objectives. A sub-indicator is defined by the Parties as a measurable feature that provides outcome-oriented, managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality (GLPF, 2016). For the purpose of this chapter, the indicators and measures recommended by IJC are equivalent to the Parties' sub-indicators.

To fulfill its assessment and reporting responsibilities assigned by the GLWQA, the IJC has recognized the need for continuous improvement of indicators for future assessments of progress reports beyond 2016. Since the SOGLR will only use indicators with available data, additional indicators and their associated measures that currently have partial or no data may be useful to improve the assessment and reporting responsibilities. Given that data collection is expensive and time-consuming, evaluation of the necessity of the additional indicators and measures proposed by IJC is critical.

An IJC Science Advisory Board Research Coordination Committee (SAB-RCC) led a workgroup consisting of members from the IJC's SAB, HPAB, and WQB, assessed potential improvements to the draft SOGLR (GLPF, 2016) related to reporting progress toward achieving the GLWQA objectives and identified additional indicators needed to fill those gaps (RCC, 2016).

5.1.2 Indicator gaps

After consultation with Great Lakes regional indicator experts who are familiar with the GLWQA objectives, it was found that the sub-indicators currently used by the Parties generally well represent the nine GLWQA General Objectives (Table 5.1).

Table 5.1. IJC indicators and associated measures, with recommendations to the Parties identified in blue font

GLWQA General Objectives	IJC	
	Indicators	Measures
Objective 1: Be a source of safe, high-quality drinking water	Biological hazards of **source water**	*E. coli*
		Nitrate
		Turbidity
	Chemical integrity of **source water**	Atrazine
		Estrogenicity

		Cyanotoxins
Objective 2: Allow for swimming and other recreational use, unrestricted by environmental quality concerns	Illness risk at beaches	95th percentile of numbers of *E. coli* per 100 ml at beaches
	Source of risk at beaches	Percent of beaches with beach sanitary survey
Objective 3: Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants	Contaminate levels in edible fish species	Concentrations of PCBs, DDT, mercury, chlordanes, toxaphane, mirex in edible portions of lake trout, walleye, yellow perch, whitefish, and smallmouth bass
Objective 4: Be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife or aquatic organisms, through direct exposure or indirect exposure through the food chain	PBT in biota	PBT in whole fish
		PBT in herring gull eggs and bald eagle
	Chemicals of Mutual Concern in water	Chemical of Mutual Concern in water
	Atmospheric deposition of toxic chemicals	Atmospheric deposition of toxic chemicals
	Abundance and distribution of fish-eating and colonial nesting birds population status and health status	Population status
		Health status
Objective 5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species	Coastal wetland extent, composition and quality	Coastal wetland invertebrates
		Coastal wetland fish
		Coastal wetland plants
		Coastal wetland amphibians
		Coastal wetland birds
		Coastal wetland area and extent
	Shoreline alteration index	Shoreline alteration index
	Lower food web productivity and health	Phytoplankton biovolume
		Zooplankton biomass; **Mysis biomass**
		Benthos abundance
		Preyfish biomass and diversity index
	Fish species of interest (recruitment and abundance)	Lake trout and whitefish
		Walleye
		Lake sturgeon
		Nearshore predators (largemouth/smallmouth bass, northern pike)
Objective 6: Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem	Phosphorus loads and in-lake concentrations	In-lake Water TP and DRP concentrations
		Nearshore water TP, DRP, and nitrate concentrations
		Tributary TP and DRP loadings
	Harmful and nuisance algae	Harmful algal blooms
		Nuisance algal blooms
Objective 7: Be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the waters of the Great Lakes	Aquatic invasive species (invasion rates and impacts)	Rates of invasion
		Status and impacts of **invasive plankton, Asian carp, round goby, ruffe, sea lamprey, Dreissenid mussels**
Objective 8: Be free from the harmful impact of contaminated groundwater	Contaminants in groundwater	Measure of chemical and physical parameters from agricultural and urban watersheds
Objective 9: Be free from other substances, materials or conditions that may negatively impact the chemical,	Water level	Water level variability
		Timing of water level minimum and maximum

physical or biological integrity of the waters of the Great Lakes		Magnitude of seasonal rise and decline
	Water temperature	Summer average
		Stratification date
		Turnover date
		Maximum and average ice concentrations
	Land cover and fragmentation status	Land conversion rate
		Land fragmentation
	Tributary physical integrity	Hydrologic alteration (flashiness index)
		Tributary connectivity to Great Lakes
		Sediment-turbidity measure

The SAB-RCC work group identified four areas that could potentially be enhanced for future triennial progress reports and state of the lakes reporting (RCC 2016), and IJC supports these recommendations.

1. Drinking water indicators

The GLWQA General Objective 1 states that the Great Lakes should "be a source of safe, high-quality drinking water," while the Parties used the sub-indicator of treated drinking water. Because this objective specifies the Great Lakes to be a "source" of safe, high quality drinking water,the SAB-RCC recommends***using the HPAB (2014) proposed indicators of biological hazards and chemical integrity of source water*.** Since the purpose of the GLWQA is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes, reporting progress on the condition of sources of drinking water, rather than treated drinking water, is more appropriate. Additionally, with the highly advanced technology and associated cost, even sewage water can be treated to reach drinkable standards. Hence, measuring treated drinking water does not measure progress in protection and restoration of the health of the Great Lakes. This opinion was also expressed by members of the public participating in the public engagement session at the Great Lakes Public Forum (GLPF 2016).

2. Nutrient indicators

The GLWQA General Objective 6 states that the Great Lakes "Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem." The Parties used the indicator of nutrients in lakes, which includes the concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in open water. The SAB-RCC suggests ***measuring concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in the nearshore and offshore***. Due to the invasion of Dreissenid mussels, the nutrient concentrations in four of the Great Lakes in offshore regions have been decreasing, which has been a concern for fisheries productivity (Hinderer et al., 2011). In contrast, the nutrient concentrations in some nearshore areas have been increasing due to watershed and coastal human activities. Given the difference in the trend in nutrient concentrations between nearshore and offshore, the IJC suggests reporting on nutrient concentrations not only from offshore but from nearshore areas, as well.

The major nonpoint source nutrients for the Great Lakes waters are from tributaries. As a result, reporting on the trend of nutrient loading from tributaries is critically important for identifying pollutants' sources and developing effective management practices and policies in controlling such sources. Hence, the SAB-RCC recommends adding an additional sub-indicator to report on ***loadings of total phosphorus and dissolved reactive phosphorus from the major Great Lakes tributaries***.

3. Food web indicators

The GLWQA General Objective 5 states that the Great Lakes "support healthy and productive wetlands and other habitats to sustain resilient populations of native species." Because this objective includes both physical and biological aspects of the ecosystem, this objective is associated with the largest number of indicators. Although preyfish is used to indicate the health of wetlands, and preyfish and predators are used to indicate food web health in the offshore area, certain aspects of the nearshore food web indicator are missing. Hence, the SAB-RCC recommends ***adopting the IJC measure of recruitment and abundance of nearshore predators*.** This is because the nearshore area is the most productive and ecologically diverse zone of the Great Lakes, and is the most vulnerable zone to anthropogenic disturbances. The health of the food web in this area provides good signals of progress to restore and maintain the chemical, physical, and biological integrity of the Great Lakes.

4. Aquatic invasive species

GLWQA General Objective 7 states that the Great Lakes shall "be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes." The indicators used by the Parties include a host of measures (sub-indicators), including aquatic invasive species rate of invasion and status and impacts of sea lamprey and Dreissenid mussels. In addition to these measures, the SAB-RCC suggests also ***reporting on the status and impacts of Asian carp*** since those species pose a major threat to the Great Lakes ecosystem and economy. Addressing Asian carp status and impacts in the SOGLR would also provide context and support for the Progress Report of the Parties, which addresses prevention and control programs (Governments of the United States and Canada, 2016).

5.2 Assessing data availability and accessibility

5.2.1 Background

Under the GLWQA, the Parties are required to assess progress toward achieving the general objectives. Hence, the selected indicators must have adequate quantitative data for reporting progress consistently over time to enable tracking changes of the Great Lakes health. The SOGLR used only indicators with available data and was not able to use additional indicators identified by the IJC to improve reporting because data were not available. Accordingly, there is a need to identify the resources necessary to fill indicator data gaps for future improvements in data collection, synthesis, sharing, and management.

Additionally, the SOGLR and the previous State of the Lake Ecosystem Conference reports have been synthesized by authors who have subject expertise from government agencies, academia institutions, and non-government organizations. Those authors are either the data holders or they synthesize data from others who have access to them. After writing the reports, the data stay with the authors and are not stored and managed by a data-system that can be accessed by other users or updated. This may hinder consistency in data synthesis, summary, and interpretation for future SOGLR reporting when the same indicators were reported by different authors in different reporting years.

5.2.2 Indicator reporting improvements

In consultation with more than 150 scientists, managers, and human health experts in the Great Lakes region, the SAB-RCC conducted a detailed analysis and assessment on data availability and data accessibility for the ecosystem and human health indicators and their associated measures that were recommended to the Parties (RCC, 2016). Based on the analysis and assessment of SAB-RCC, the IJC identified the following key areas related to data availability and accessibility that could be enhanced in the future.

1. Sub-indicators in use but need additional data

The majority of the sub-indicators for the draft SOGLR have reasonable data coverage for status assessment, while some sub-indicators do not have sufficient data for detecting long-term trends. Two sub-indicators are of particular importance:

- *Coastal wetlands extent and composition sub-indicator*
  Mapping and estimation of the areal coverage of the Great Lakes coastal wetlands was done in 2004. As there has not been a complete update to the estimation of areal extent in over 10 years, the status and trend are undetermined for this sub-indicator. Hence, a complete update of such data is essential.

- *Harmful algal bloom sub-indicator*
  There are few long-term data collected on harmful algal blooms and more specifically, toxins, in the Great Lakes, making trend analysis difficult. The data sources presented at the GLPF (2016) are varied and in many cases used different sampling and analytical methods. Monitoring in Lakes Erie and Ontario is generally good but monitoring in Lakes Michigan, Huron, and Superior is sparse and largely reactive to algal blooms. Well planned systematic sampling is needed.

2. Sub-indicators recommended and needed data

Integrating, synthesizing, or collecting data for the following sub-indicators that are not used in the SOGLR are critically important for meeting the responsibility of assessing progress identified by the GLWQA.

- *The biological hazards and chemical integrity of source water*

The data for these indicators currently are collected by municipal or state agencies using inconsistent methods and temporal intervals, although the Ontario Ministry of the Environment and Climate Change has monitored most drinking water plants across the province in a more consistent sampling frequency and approaches. Hence, readily available data for indicator calculation or trend detection are limited. Efforts are needed to harmonize municipal or state future sampling methods, and to integrate and synthesize existing data for detecting trends. The current use of treated water to assess status and trends of drinking water in the SOGLR does not meet the requirement of assessing progress toward achieving the GLWQA objective of "The Waters of the Great Lakes should: be a source of safe, high-quality drinking water."

- *Illness risk at beaches and source of risks at beaches*
  These two indicators consist of calculating 95th percentile of numbers of *E. coli* per 100 ml at beaches and percentage of beaches with beach sanitary survey. Both US and Canada waters have available data, but efforts are needed to assemble and synthesize such data into consistent forms for indicator calculation or trend detection. According to the GLPF (2016), the SOGLR will use beach advisories to assess status and trends, which may not be adequate for assessing progress toward achieving the GLWQA objective because the criteria of beach advisories have not been standardized among Great Lakes states of US and between Canada and the United States.

- *Tributary total phosphorus and soluble reactive phosphorus loadings*
  Tributary total and soluble reactive phosphorus loadings have been considered controlling factors for the harmful algal bloom in the Great Lakes and they are the recommended additional indicator measures by the IJC to be used to fill the assessment gaps. Currently, data for this indicator measures are available for the major tributaries of Lake Erie, but limited data are available for the other lakes. Efforts are needed to monitor the long-term trend of total and soluble reactive phosphorus loadings from all the major tributaries of the Great Lakes.

- *Nearshore total phosphorus and soluble reactive phosphorus concentration*
  The GLPF (2016) reported that while phosphorus concentrations were elevated throughout many parts of the Great Lakes in the past, problems of excess phosphorus are largely confined to some nearshore areas and parts of Lake Erie. In Lakes Michigan, Huron, and Ontario, the offshore total phosphorus concentrations may be too low and may negatively impact lake productivity. Nearshore nutrient enrichment persists in some locations of the Great lakes, and nutrient targets are frequently exceeded and conditions are deteriorating for Lake Erie. Given that nearshore nutrient concentrations are much more influenced by local pollutant discharges and the offshore and nearshore nutrient concentrations show opposite trends in many parts of the lakes, there is a need to report on the status and trends of nearshore nutrient concentrations. Many federal and local programs have collected such data. However, these data are spread across many agencies and data collectors, and a consistent and coordinated effort to synthesize and integrate them is needed.

5.2.3 Data accessibility

There is not a central repository or single data portal for the data synthesized that have been used in the SOGLR and in the previous State of the Lake Ecosystem Conference reports. As a result, the summarized data for calculating the indicators of the reports are not accessible by anyone other than the authors of the reports themselves. The authors for the 2011 State of the Lake Ecosystem Conference report and the forthcoming 2016 SOGLR have changed substantially, which may hinder the consistency in data synthesis, summary, and interpretation for future SOGLRs. Hence, the IJC encourages the Parties to store the summarized data for the calculation of the sub-indicators into a centralized system, or an accessible distributed database that has public access and can be updated periodically, at least every assessment cycle. This system would improve transparency of the SOGLR and enhance scientific understanding and management decision making.

The majority of the indicator data are from federal programs, and the data management of these programs has not been integrated. The open data system effort of Canada and the data harvesting portals of the US Geological Survey, the Illinois-Indiana Sea Grant, the Great Lakes Observing System, the Great Lakes Aquatic Habitat Framework, and the US Environmental Protection Agency Great Lakes Environmental Database are promising initiatives. However, these initiatives are inconsistent, non-integrated, and sometimes redundant, and do not reflect the principles of accountability, coordination, and innovation established in the GLWQA.

A considerable portion of critical indicator data has been collected by local programs. This includes the human health source of drinking water data that have been collected by municipal or state programs. It will require sustained, binational efforts to synthesize, integrate, and harmonize these data to make them accessible and easily interpreted.

Overall, there is an urgent need to store and better manage the summarized data used by the SOGLR at a centralized location or a single database portal that can be accessed by others in the future. There is a need to establish a binational effort to synthesize and harmonize the needed indicator data that have been collected or will be collected by municipality and other local programs and to store the data in a publicly-accessible central location. These accessible data will not only increase the efficiency, consistency, and transparency of the assessment of progress, but also enhance the effectiveness of information delivery for public awareness and science-based policy and management decision making.

5.3 Prevention of harm to the Great Lakes

5.3.1 Anticipation and prevention of emerging threats

Governments have had to devote significant resources to correct or remediate damage to the Great Lakes ecosystem for decades. Examples include newly introduced chemicals that cause unforeseen impacts, the arrival of invasive species such as zebra and quagga mussels that have altered the aquatic food web, and the sharp increase in runoff of bioavailable dissolved reactive phosphorus that has contributed to an unexpected rise in harmful algal blooms in western Lake Erie.

The need for anticipatory mechanisms to consider potential ecological threats has been noted. In 1995, the USEPA Science Advisory Board issued a report, *Beyond the Horizon: Using Foresight to Protect the Environmental Future*, which recommended, among other things, that the agency create a "look-out panel" with members from both inside and outside government to provide the USEPA and the nation with an early warning of environmental issues that may emerge in the future (USEPA, 1995). Other studies and documents have highlighted the need for greater anticipatory capacity to protect the Great Lakes through prevention.

Prevention is one of the principles and approaches in the 2012 Protocol to the GLWQA, which also charges the Great Lakes Water Quality Board, the principal advisor to the IJC, with "identifying emerging issues and recommending strategies and approaches for preventing and resolving the complex challenges facing the Great Lakes." The IJC's Great Lakes SAB advises the Water Quality Board and the IJC on the science underpinning Great Lakes matters.

The SAB, in partnership with the IJC's Great Lakes Water Quality Board, will explore this issue and advise the IJC. The SAB will synthesize current knowledge and evaluate existing approaches that may be suitable for anticipating and preventing potential threats to the Great Lakes. The Board is also expected to provide a report identifying potential environmental threats to the health of the Great Lakes ecosystem. The IJC, in turn, will advise the Parties as appropriate.

5.3.2 Public trust principles

The courts of both the United States and Canada have embraced common law principles regarding water use and management founded, explicitly or implicitly, on the public trust doctrine. Under the laws of both countries, the doctrine prohibits alienation, subordination and/or interference or material harm to basic public uses of navigable waters like the Great Lakes. It also imposes an affirmative obligation on government as trustee to protect the integrity of these waters and the associated ecosystem.

Public trust principles (Olson, 2014) that apply to navigable waters like the Great Lakes, connecting waters, and tributary waters include:

- Public trust waters and protected uses cannot be alienated by government and may never be transferred or controlled for private purposes; that is, a public purpose is required.
- A proposed diversion or use cannot materially impair the flow, level, integrity or quality of public trust water, tributary water, or public trust resources or protected public uses.
- The substantial value of public trust waters, natural resources, and uses is presumed, and the burden of proof is on those who seek to use or alter the public trust commons or uses.
- There is no *deminimis* harm that is exempt from the public trust doctrine. Cumulative effects must be accounted for.
- Government has a continuing duty to determine that there will be no impairment or harm to the flows, levels, quality, and integrity of public trust waters, uses, and ecosystem before it approves or denies a governmental or private action.
- Government as trustee and affected interests must balance competing uses such that the public trust is not impaired and public trust uses are not subordinated to private uses. Private uses, while lawful if reasonable, are correlative but cannot override the public trust in these waters, natural resources, or the public uses dependent on them.

Public trust principles can be traced from Rome to the present through the common law systems of both Canada and the United States (Sohm, 1970). As a result of the heritage of Roman Justinian codes that deemed water a *juspublicum*, a limitation was established on the Crown's broad powers over public waters and natural resources of a special or unique character that served substantial public needs. Generally, then, the waters of the Great Lakes are in the public domain in the name of the Crown in Canada and held or owned by the sovereign state for the benefit and welfare of its citizens in theUnited States.

In 1892, the United States Supreme Court, in *Illinois Central Rail Road Co. v. Illinois*, ruled that all of the Great Lakes were subject to the public trust doctrine and a navigational servitude in favor of the federal government. The courts in all eight Great Lakes states in theUnited States and the two Canadian provinces making up the basin have recognized the public trust doctrine, either expressly by naming the Great Lakes and the connected or tributary waters subject to a public trust or through application of the public's paramount right and use of public or navigable waters. Protection of public waters for public purposes has been called by a Michigan court "a high, solemn, and perpetual trust, which it is the duty of the state to forever maintain" (Collins *v*. Gerhardt, 1926).

More recently, the Canadian courts have begun to recognize the potential of public trust principles, and several Canadian water law and policy experts have urged the adoption of explicit public trust principles by the courts or the provincial governments. Canadian federal and provincial governments also have begun to explore the incorporation of public trust principles into specific water and natural resource laws. The doctrine also has been applied by the courts of other countries to protect common bodies of water from abuse or private control.

Despite the expansive and court-backed authority of common law public trust principles, governments have occasionally been reluctant to apply them to prevent harm to public trust resources such as navigable waters and Great Lakes bottomlands, relying instead on specific statutory enactments. Public trust principles underlie some of these statutes but the statutes are at times narrow in scope and do not fully empower governments to prevent harm.

In a time of unprecedented and uncertain changes resulting from the complex interaction of climate change, non-native species, water demands and other factors, public trust principles could play a significant role in preventing harm to the Great Lakes ecosystem. For example, in considering first-time proposals to use open waters of the Great Lakes for net-pen aquaculture, governments have not only the option, but also the duty of acting as a trustee of these waters for the public. If the effects of such a use are not fully understood or it is clear that the intended occupancy or subordination of an area of public waters would be for primarily private purposes, governments are obliged to deny the proposed use under public trust principles. If such a use would materially impair the flow, level, integrity or quality of public trust waters, tributary waters, or public trust resources, then governments are also obliged to deny that use. In this way, public trust principles can support and promote a *first, do no harm* management ethos to the world's largest freshwater ecosystem.

The IJC has previously encouraged Great Lakes jurisdictions to consider applying a public trust framework to the protection of Lake Erie (IJC, 2014b) and to the protection of the Great Lakes

from potential harm caused by water withdrawals and consumptive uses (IJC, 2016). Support for a public trust framework was also expressed during the public engagement session at the Great Lakes Public Forum by those opposed to what are perceived as unsustainable commercial withdrawals of Great Lakes ground water.

5.4 Engagement and coordination

5.4.1 Engagement and coordination in the 2012 GLWQA

In the preamble to the 2012 GLWQA, the Parties recognize that the involvement and participation of state and provincial governments, Tribal governments, First Nations, Métis, municipal governments, watershed management agencies, local public agencies, and the public are essential to achieve the Agreement's objectives. The public is defined in the GLWQA as "individuals and organizations such as public interest groups, researchers and research institutions, and businesses and other non-governmental entities."

The Parties also acknowledge the importance of the Great Lakes public by identifying public engagement as an approach to guide them as they implement the GLWQA. In Article 2.4(k), public engagement means "incorporating Public opinion and advice, as appropriate, and providing information and opportunities for the Public to participate in activities that contribute to the achievement of the objectives of this Agreement." Under Article 4.3(e), the Parties also commit to seeking public input and advice on all pertinent matters, as appropriate, in their implementation of the GLWQA.

They also identify the public's role in GLWQA coordination, which is defined in Article 2.4 (e) as developing and implementing coordinated planning processes and best management practices by the Parties, as well as among state and provincial governments, Tribal governments, First Nations, Métis, municipal governments, watershed management agencies, and local public agencies. In Article 4.1, the Parties incorporate the approach of coordination into Agreement implementation by committing to develop and implement programs and other measures in cooperation and consultation with the same governments and groups, as well as the public.

Thus, the GLWQA commits the Parties to four of the five levels of involvement in the public participation spectrum, as outlined by the International Association for Public Participation (Sheedy 2008).

Inform	Consult	Involve	Collaborate	Empower
Public Participation Goal				
To provide the public with balanced and objective information to assist them in understanding the problem, alternatives and opportunities and/or solutions	To obtain public feedback on analysis, alternatives and/or decisions	To work directly with the public throughout the process to ensure that the public concerns and aspirations are consistently understood and considered	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution	To place final decision-making in the hands of the public
Promise to the Public				
We will keep you informed	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible	We will implement what you decide

Increasing level of public impact

Figure 5.4.1 Public Engagement, Source: International Association for Public Participation (Sheedy 2008)

It also reflects the widespread acceptance of public information, consultation and participation as beneficial for policy decision making, including decisions related to water quality management (EEA, 2014). Meaningful public involvement yields a range of benefits, including:

- Builds relationships based on trust, transparency, accountability, openness and honesty
- Integrates a wider range of public needs, interests and concerns into decision making
- Resolves problems more effectively, through collaborative means
- Ensures that decisions and solutions incorporate perspectives, knowledge and technical expertise that would not otherwise be considered
- Places issues and projects within a broader technical, social, cultural or ethical context

• Increases the level of public acceptance and ownership of decisions and policies. (PHAC 2013).

The complexity of Great Lakes governance and management systems makes the inclusion of and coordination among the many different governments and organizations involved with Great Lakes waters a necessity for successful management. McLaughlin and Krantzberg (2011) set out the challenges for policy implementation in the Great Lakes, noting the number of governments, non-governmental organizations and individual citizens involved. They conclude that a lack of adequate coordination between these various groups and authorities is the root of the problem in successful and thorough implementation.

5.4.2 Assessing engagement and coordination

The Progress Report of the Parties (PROP) (Governments of the United States and Canada, 2016) reported on public engagement and coordination in the implementation of the GLWQA in Chapter 2, which outlined the extended coordination between federal, state and provincial bodies but provided less evidence of coordination beyond these bodies. Chapter 2 suggested that broader coordination could be demonstrated through reporting on the composition of extended subcommittee membership for each Annex and the larger range of organizations working on binational and domestic actions.

The PROP does not show significant amounts of public engagement across GLWQA implementation. Despite repeated mention of the principle of public engagement at the beginning of the PROP, discussion of actual engagement conducted as a part of policy development and implementation is limited.

The Parties should be commended for making the biannual meetings for the Great Lakes Executive Committee (GLEC) open to the public. However, public attendance is generally limited to the informed public and no outreach or promotional attempts designed to attract a larger public are conducted in conjunction with or during the meetings.

The PROP repeatedly mentions the Great Lakes Public Forum (GLPF) as a mechanism for public engagement. The GLPF was an informative, well organized event with attendance and reach well beyond the GLEC meetings and the potential for involving a broader array of stakeholders. The inclusion of students and First Nations and Tribes is to be commended. Opportunities for public engagement were primarily question and answer periods at the end of presentations, however, which significantly limited public input – let alone engagement – on key items such as the proposed priorities for binational science and action. The PROP was not released until shortly before the Forum and little mention was made of the report during the conference. Thus, citizens who attended the Forum were not fully aware of the PROP or did not have sufficient time to adequately reflect on the governments' reported progress before the event. It is notable that the reach of the GLPF as a public information mechanism was greatly increased by the streaming of the event's first two days online and the resulting press and television coverage.

As a part of the IJC's public comment session at the GLPF as well as at the two public meetings held in Toronto and Milwaukee in October 2016, citizens expressed the need for enhanced public

engagement by governments, which was identified as low, process-oriented, underfunded, and often missing the voices of those communities where the least Agreement progress has occurred, including indigenous communities.

With respect to Annex implementation, engagement on Lakewide Action and Management Plans (LAMP) is discussed in section 3.9. The eight webinars involving 800 participants regarding progress under Annex 1 provided good opportunities to inform and consult the public, or stages one and two of the public participation spectrum, and in some cases invited involvement in plan development as well. However, it is notable that almost four years after the 2012 Protocol came into effect, the LAMP partnerships have only recently begun to establish their work group outreach and engagement subcommittees. The first LAMP issued, the Lake Superior LAMP, would have benefited from a more detailed discussion of how relevant constituencies and communities were engaged and involved in the plan's development.

The PROP mentions the opportunities for public input in the Chemicals of Mutual Concern (CMC) process, however as reported in section 3.4, lack of transparency and engagement have been issues of concern in the implementation of Annex 3 to date.

A more successful example of public consultation was in the establishment by the Parties of phosphorus reduction targets for Lake Erie. As noted in section 4.6, as part of the process the Parties undertook a robust public engagement process to explain and justify the proposed targets.

As well as setting out binational activities undertaken by GLWQA Annex committees, the PROP also lists domestic actions undertaken in support on the Agreement. Looking at public engagement in the listed domestic activities, Canadian action in support of the aquatic invasive species annex was most notable in its mention of public engagement. The mention of public engagement in US actions under the Agreement was most notable with respect to nutrients.

The commitments the Parties agreed to in the GLWQA to inform, engage and cooperate with the public as they strive to accomplish the Agreement's goals are laudable, and reflect the value and proven benefits of incorporating the public into public policy development and implementation. However, based on a review of the PROP, it is difficult to conclude that significant public engagement has been incorporated into either country's policy development or implementation for the GLWQA. Additional information on such engagement was requested from the Parties but IJC staff was referred to the information available in the PROP. Additional information on engagement in the following areas would assist in this evaluation:

- Direct public involvement in the work of the Annex committees, and/or
- Ongoing advisory relationships with the Annex committees, and/or
- Other opportunities for the expression of views on the subjects and work of the Annex committees, including webinars, consultations on documents, meetings, or requests for public comments on particular topics, proposed projects or other elements of Agreement implementation, and/or
- Other planned public engagement activities that are not captured in bullets 1-3 above, and
- Any further information regarding over-arching engagement activities across the breadth of the Agreement or in relation to its articles.

5.5 Section Summary

- SOGLR could be improved by including the indicators, sub-indicators, or measures proposed by the RCC, specifically,
  - biological hazards and chemical integrity of source water, proposed by HPAB (2014);
  - concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in the nearshore and offshore,
  - recruitment and abundance of nearshore predators, and
  - status and impacts of Asian carp.

- There is an urgent need to improve the storage and management of data used in SOGLR. More accessible data will increase the efficiency, consistency, and transparency of the assessment of progress toward the objectives of the GLWQA, as well as enhance the effectiveness of information delivery for public awareness and science-based policy and management decision making. Specific needs include: strengthening storage and management of summary data at a centralized and accessible location; and establishing a binational effort to synthesize and harmonize indicator data that have been collected or will be collected by municipalities and other local programs.

- The courts of both Canada and the United States have embraced common law principles regarding water use and management founded on the public trust doctrine. Under the laws of both countries, the doctrine prohibits alienation, subordination and/or interference or material harm to basic public uses of navigable waters like the Great Lakes. It also imposes an affirmative obligation on government as trustee to protect the integrity of these waters and the associated ecosystem. In a time of unprecedented and uncertain changes resulting from the complex interaction of climate change, non-native species, water demands and other factors, public trust principles could play a significant role in preventing harm to the Great Lakes ecosystem.

- The commitments the Parties agreed to in the GLWQA to inform, engage and cooperate with the public as they strive to accomplish the Agreement's goals are laudable, and reflect the value and proven benefits of incorporating the public into public policy development and implementation. However, based on a review of the PROP, it is difficult to conclude that significant public engagement has been incorporated into either country's policy development or implementation for the GLWQA.

5.6 References

Collins v. Gerhardt, 1926.237 Mich. 38, 49, 211 N.W. 115, 118 (1926).

EEA (European Environment Agency), 2014. Public participation: contributing to better water management. Experiences from eight case studies across Europe.European Environment Agency, Copenhagen.

GLPF (Great Lakes Public Forum), 2016. The Great Lakes Public Forum 2016 held in Toronto, Canada, on October 4-5, 2016.

Governments of the United States and Canada. (2016). Progress Report of the Parties: Pursuant to the Canada-United States Great Lakes Water Quality Agreement. Cat. No.: En164-53/1-2016E-PDF. ISBN: 978-0-660-06365-2. Available at https://binational.net/2016/09/28/prp-rep/.

Hinderer, J.M., Murray, M.W., Becker T., 2011. Feast and Famine in the Great Lakes: How Nutrients and Invasive Species Interact to Overwhelm the Coasts and Starve Offshore Waters. National Wildlife Federation.

HPAB (Health Professional Advisory Board), 2014.Recommended Human Health Indicators for Assessment of Progress on the Great Lakes Water Quality Agreement.

IJC (International Joint Commission), 2013. Assessment of Progress Made Towards Protecting and Restoring Great Lakes Water Quality since 1987. 16th Biennial Report on Great Lakes Water Quality.http://www.ijc.org/files/publications/16th%20BR%20long%2020130514.pdf Accessed on September 30, 2016.

IJC (International Joint Commission), 2014a.Great Lakes Ecosystem Indicator Report.A Report from the Science Advisory Board to the International Joint Commission.http://www.ijc.org/en_/AOP/Ecosystem. Accessed on September 30, 2016.

IJC (International Joint Commission), 2014b. A Balanced Diet for Lake Erie: Reducing Phosphorus Loadings and Harmful Algal Blooms. Report of the Lake Erie Ecosystem Priority.

IJC (InternationalJoint Commission), 2016.Protectionof theWatersoftheGreatLakes:2015Reviewof the Recommendationsin theFebruary2000report.

McLaughlin, Chris and Krantzberg, Gail, 2011.An appraisal of policy implementation deficits in the Great Lakes. Journal of Great Lakes Research 37, 390-396.

Olson, J. 2014. All Aboard: Navigating the Course for Universal Adoption of the Public Trust Doctrine, 15 Vermont J. of Envl. Law, 136, at 170-173, 174-179, (2014).

PHAC (Public Health Agency of Canada), 2013."Public Involvement – Health is Everyone's Business." http:www.phac-aspc.gc.ca/ph-sp/collab/collab2-eng.php.

PROP (Progress Report of the Parties), 2016. 2016 Progress Report of the Parties, Pursuant to the Canada-United States Great Lakes Water Quality Agreement.Cat. No.: En164-53/1-2016E-PDF, ISBN: 978-0-660-06365-2.

RCC (Research Coordination Committee), 2016.Future Improvements to Great Lakes Indicators. A report submitted to the International Joint Commission by the Great Lakes Science Advisory Board Research Coordination Committee.

SAB (Science Advisory Board), 2016.An assessment of the communicability of the International Joint Commission ecosystem indicators and metrics.Accessed September 30, 2016.http://www.ijc.org/files/publications/ScienceAdvisoryBoard_CommunicationIndicatorsReport_en.pdf.

Sheedy, Amanda, MacKinnon, M.P., Pitre, S., Watling, J., 2008. Handbook on citizen engagement: Beyond consultation. Canadian Policy Research Networks, 7.

SOLEC 2014a.Technical Report.State of the Great Lakes 2011.Environment Canada and U.S. Environmental Protection Agency.Toxic Chemical Concentrations.Accessed September 30, 2016.http://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdf

SOLEC 2014b.State of the Great Lakes Highlights Report.Environment Canada and U.S. Environmental Protection Agency.Accessed September 30, 2016.https://binational.net//wp-content/uploads/2014/11/SOLEC2011Highlights_e.pdf

Sohm, R., 1970. The Institutes: A Textbook of the History and System of Roman Private Law. Translated by James Crawford Ledlie.With an introduction by Erwin Grueber 3rd edition. London: Clarendon Press, 1940; reprint, New York: Augustus M. Kelley, 1970.

USEPA (United States Environmental Protection Agency), 1995. Beyond the Horizon: Using Foresight to Protect the Environmental Future. United States Environmental Protection Agency, Science Advisory Board, Environmental Future Committee, EPA-SAB-EC-95-007.

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Glossary

ADAPTIVE MANAGEMENT -- A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modelling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

AQUATIC INVASIVE SPECIES (AIS) – As defined in the Great Lakes Water Quality Agreement, AIS refers to any non-indigenous species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that threatens or may threaten the diversity or abundance of aquatic native species, or the ecological stability, and thus water quality, or water quality of infested waters, or commercial, recreational, or other activities dependent on such waters.

AQUATIC NUISANCE SPECIES (ANS) – Generally, ANS refers to AIS that may cause problems from a human perspective, such as threats to commercial, agricultural, aquacultural or recreational activities dependent on the infected waters.

ALGAE – Aquatic organisms that survive through photosynthesis; they can range in size from microscopic organisms to large seaweed and giant kelp.

ALGAL BLOOMS – An excessive and relatively rapid growth of algae on or near the surface of water. It can occur naturally as the result of a change in water temperature and current or as a result of an excess of nutrients in the water.

AQUATIC VEGETATION GROWTH – Plant growth beneath the surface of water that can generate resistance to water flow in a channel; commonly referred to as weed retardation.

AREA OF CONCERN (AOC) – Ageographic area designated by the Parties under the Great Lakes Water Quality Agreement where water quality and ecosystem health have been severely degraded by human activities at the local level.

BASIN – The region or area of which the surface waters and groundwater ultimately drain into a particular course or body of water.

BENEFICIAL USES –Uses and benefits of Great Lakes water quality and ecosystem resources, as identified in the Great Lakes Water Quality Agreement. They include fish and wildlife health and habitat, drinking water, and recreation.

BENEFICIAL USE IMPAIRMENT (BUI) – Under the Great Lakes Water Quality Agreement, a BUI is a reduction in the chemical, physical or biological integrity of the waters of the Great Lakes sufficient to cause any of 14 identified outcomes (impairments). These outcomes include: restrictions on the human consumption of fish and wildlife; eutrophication or undesirable algae; restrictions on drinking water consumption; and beach closings.

BEST MANAGEMENT PRACTICES (BMP) –A range of practical methods, techniques and other actions that allow individuals or organizations to prevent or reduce the risks of water pollution resulting from their activities. Best practices typically evolve over time, as new approaches are introduced, proven to be effective and adopted. Also known as beneficial management practices.

BIOAVAILABLE – That portion of a nutrient in the environment, such as phosphorus, that is available to foster algae growth. For example, a high percentage of dissolved particulate phosphorus generally will be bioavailable to algae, while only a much lower percentage of particulate phosphorus will be bioavailable.

BOUNDARY WATERS TREATY OF 1909 – The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

CHEMICALS OF MUTUAL CONCERN – Under the Great Lakes Water Quality Agreement, the Parties agree to mutually determine those chemicals originating from anthropogenic sources that are potentially harmful to human health or the environment and to take cooperative and coordinated measures to reduce the release of these chemicals.

CLIMATE – The prevalent weather conditions of a given region (temperature, precipitation, wind speed, atmospheric pressure, etc.) observed throughout the year and averaged over a number of years.

CLIMATE CHANGE – A change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

DISSOLVED REACTIVE PHOSPHORUS (DRP) – The fraction of phosphorus that is dissolved in the water column and generally available to support algal growth.

ECOSYSTEM – A biological community in interaction with its physical environment, and including the transfer and circulation of matter and energy.

ENVIRONMENT – Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

EUTROPHICATION – The process by which a body of water becomes rich in dissolved nutrients, such as phosphorus, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms; also known as nutrient enrichment.

GENERAL OBJECTIVES – As defined in the Great Lakes Water Quality Agreement, General Objectives refer to the broad descriptions of water quality conditions consistent with the protection of the level of environmental quality which the Parties desire to secure and which provide a basis for overall water management guidance. The Agreement identifies nine categories of General Objectives.

GREAT LAKES EXECUTIVE COMMITTEE – Established by the Parties under the 2012 Great Lakes Water Quality Agreement to help coordinate, implement, review and report on programs, practices and measures undertaken to achieve the purpose of the Agreement. The committee is co-chaired by representatives of the two Parties. Membership includes representatives from federal, state and provincial governments, Tribal governments, First Nations, Métis, municipal governments, watershed management agencies, and other local public agencies.

GREAT LAKES WATER QUALITY AGREEMENT --The Agreement expresses the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem. The most recent protocol amending the original 1978 Agreement was signed in 2012.

GROUNDWATER – Underground water occurring in soils and in pervious rocks.

HABITAT – The particular environment or place where a plant or an animal naturally lives, feeds and grows.

HARMFUL ALGAL BLOOMS (HABS) – HABs result from the proliferation of blue-green algae (including cyanobacteria) in environmentally stressed systems, where conditions favor opportunistic growth of one or more noxious species, displacing more benign ones. The blooms are considered harmful because excessive growth can harm ecosystems and produce poisons (or toxins) that can cause illness in humans, domestic pets and wildlife.

HYPOXIA – A condition where excessive nutrients contribute to algal growth and subsequently high oxygen consumption during decomposition of the algae. This process creates "dead zones", typically near the lake bottom, where dissolved oxygen levels are so low that fish and other aquatic life cannot survive.

INDICATOR – A numerical value that helps provide insight into the state of the environment or human health. Environmental indicators are developed based on quantitative measurements or statistics of environmental conditions that are tracked over time. They can be developed and used at a variety of geographic scales, from local to regional to national levels.

INTERNAL LOADING – Transport of a pollutant from sources within the lake, such as from bottom sediments.

INTERNATIONAL JOINT COMMISSION (IJC) - International independent agency formed in 1909 by the United States and Canada under the *Boundary Waters Treaty* to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects. It also has a permanent reference under the Great Lakes Water Quality Agreement to help the two national governments restore and maintain the chemical, physical, and biological integrity of those waters.

LAKEWIDE MANAGEMENT ACTION PLAN (LAMP) – Under the Great Lakes Water Quality Agreement, a LAMP is an action plan for cooperatively restoring and protecting the ecosystem of a Great Lake. LAMPs are developed and implemented in consultation with US state governments and the Ontario provincial governments, and may include participation from local government agencies. LAMPs are in place for Lakes Superior, Michigan, Erie and Ontario.

LOADING –Entry of a pollutant, such as phosphorus, into a water body.

MICROPLASTICS – Plastic particles that are smaller than 5-mm in diameter, such as preproduction plastic pellets and flakes, microfibers, breakdown materials from larger plastics and microbeads.Microbeads, the most well-known of these categories, are small plastic beads that are added as an abrasive to personal care products, including cosmetics, toothpastes, deodorants, shaving creams and sunscreens. Microplasticscan beingested byaquaticorganisms, leadingtoa rangeof potential impacts includingthe trophic-transfer ofplastics andtoxins alongthe food web,potentiallyto humans.

NEARSHORE –The marginal zone of a lake consisting of two areas: the coastal margin, that is, the shoreline, wetlands and very shallow open-waters extending some distance from the shoreline; and the nearshore open-water area where the water still is shallower and warmer than in the open waters.

NON-POINT SOURCES – Sources of pollutants associated with many diffuse locations and origins, typically transported by rainfall and snowmelt runoff over land; for example, excess fertilizers, herbicides and insecticides from agricultural lands and residential areas.

NUTRIENT – A food or any nourishing substance assimilated by an organism and required for growth, repair, and normal metabolism. For example, phosphorus and nitrogen are nutrients for algae.

PARTICULATE PHOSPHORUS – The fraction of phosphorus that is attached to suspended sediment and organic matter.

PARTIES – The parties or signatories to the Great Lakes Water Quality Agreement. That is, the Governments of Canada and the United States.

PHOSPHORUS – An element used in a wide range of agricultural, industrial and domestic products; a key nutrient limiting the amount of phytoplankton and attached algae in the Great Lakes.

POINT SOURCES – Sources of pollutants, such as phosphorus,associated with a specific location; for example, an industrial or sewage treatment plant.

PROGRESS REPORT OF THE PARTIES (PROP) – Under the Great Lakes Water Quality Agreement, the Parties agree to prepare a triennial progress report documenting actions taken domestically and binationally in support of the Agreement. The report is to be prepared in consultation with the Great Lakes Executive Committee. The government production of the PROP and the IJC review of it is a key government accountability feature under the Agreement.

PUBLIC INFORMATION AND ENGAGEMENT – A proactive, coordinated process of informing the public throughout the course of a study and providing opportunities to interested individuals and organizations to make their views known and to review and comment on preliminary findings.

REGULATION PLANS – Control of land and water use in accordance with rules designed to accomplish certain goals. The IJC has introduced a series of regulation plans since 1916 to regulate the outflows from Lake Superior to meet the needs of various water-using interests in the upper Great Lakes basin. These plans have incorporated the specific objectives established in the IJC's Orders of Approval, established monthly outflow levels from Lake Superior, and allocated flows to various water-using interests, such as hydroelectric generation and fisheries.

REMEDIAL ACTION PLAN (RAP) – Under the Great Lakes Water Quality Agreement, plans designed to restore beneficial uses that have become impaired due to local conditions at Areas of Concern. Developed and implemented in cooperation with state and provincial governments, RAPs include: an identification of BUIs and causes; criteria for restoring beneficial uses, established in consultation with the local community; and remedial measures to be taken.

SPECIFIC OBJECTIVES –The narrative or numeric interim or long-term ecological conditions and targets agreed upon by the Parties under the Great Lakes Water Quality Agreement. Specific Objectives are to be developed for the lake ecosystems of each Great Lake and for substances that may pose a threat to human health and the environment.

STATE OF GREAT LAKES REPORTING (SOGLR) – A process in which the governments of Canada and the United States regularly report on progress towards achieving the overall purpose of the Great Lakes Water Quality Agreement through reporting on ecosystem conditions and trends. A key component of SOGLR is the State of the Lakes Ecosystem Conferences, hosted by the US Environmental Protection Agency and Environment and Climate Change Canada on behalf of the two countries. These conferences are a culmination of scientific information gathered from a wide variety of sources and engage a variety of organizations. The conferences: report on the state of the Great Lakes ecosystem and the major factors impacting it; provide a forum for exchange of this information among Great Lakes decision-makers; and provide information to people in all levels of government, corporate, and not-for-profit sectors.

TOTAL PHOSPHORUS – Refers to all forms of phosphorus in a given volume of water, including particulate and dissolved forms.

WATERFOWL – Birds that are ecologically dependant on wetlands for their food, shelter and reproduction.

WETLAND(S) – Area characterized by wet soil and high biologically productivity, providing an important habitat for waterfowl, amphibians, reptiles and mammals.

List of Acronyms

The following is a list of common acronyms used in the Technical Appendix:

AIS	Aquatic Invasive Species
ANS	Aquatic Nuisance Species
AOC	Area Of Concern
BSDG	Binational Strategy Development Group
BUI	Beneficial Use Impairment
BWM	Ballast Water Management
BWWG	Ballast Water Working Group
C3	Chemicals of Mutual Concern Sub-Committee
CAFO	Confined animal feeding operation
CAISN	Canadian Aquatic Invasive Species Network
CAWS	Chicago Area Waterway System
CEARA	Centre of Expertise for Aquatic Risk Assessment
CMC	Chemicals of mutual concern
COA	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
CSMI	Cooperative Science and Monitoring Initiative
CSO	Combined Sewer Overflow
CWQ	Clean Water Act
DFO	Fisheries and Oceans Canada
DRP	Dissolved reactive phosphorus
DWQS	Drinking water quality standards
DWSP	Drinking Water Surveillance Program
EC3	Extended Sub-Committee
ECCC	Environment and Climate Change Canada
EDRR	Early Detection & Rapid Response Network Ontario
GLEC	Great Lakes Executive Committee
GLEEM	Great Lakes Environmental Effectiveness Metric
GLERS	Great Lakes Ecological Reserve System
GLFS	Great Lakes Fisheries Commission
GLMRIS	Great Lakes Mississippi River Interbasin Study
GLNPO	Great Lakes National Program Office
GLOS	Great Lakes Observing System
GLPC	Great Lakes Phragmites Collaborative
GLPF	Great Lakes Public Forum
GLRI	Great Lakes Restoration Initiative
GLRO	Great Lakes Regional Office
GLWQA	Great Lakes Water Quality Agreement
GIN	Groundwater Information Network
HABs	Harmful Algal Blooms
HBCD	Hexabromocyclododecane
HPAB	Health Professionals Advisory Board

IAGLR International Association for Great Lakes Research
IAS Invasive Alien Species
IJC International Joint Commission
IMO International Maritime Organization
ISC Invasive Species Centre
ITT Identification Task Team
LAMP Lakewide action management plan
LEEP Lake Erie Ecosystem Project
LSBP Lake Superior Binational Program
LTM Long-Term Monitoring
MEPC Marine Environment Protection Committee
NAS Nonindigenous Aquatic Species
NCCA National Coastal Condition Assessment
NOAA National Oceanic and Atmospheric Administration
NSERC Natural Sciences and Engineering Research
OMNRF Ontario Ministry of Natural Resources and Forestry
PAC Public Advisory Council
PBDEs Polybrominated Diphenyl Ethers
PBiT Persistent, Bioaccumulative and inherently Toxic
PCBs Polychlorinated Biphenyls
PROP Progress Report of the Parties
RAP Remedial Action Plan
RCC Research Coordination Committee (SAB)
SAB Great Lakes Science Advisory Board
SBCI Saginaw Bay Coastal Initiative
SPC Science Priority Committee (SAB)
SDWA Safe Drinking Water Act
SOGLR State of the Great Lakes Report
SOLEC State of the Lakes Ecosystem Conferences
SSO Sanitary Sewer Overflow
SWAP Source Water Assessment Program
SWPP Source Water Protection Plan
TMDL Total Maximum Daily Load
TOR Terms Of Reference
USACE United States Army Corps of Engineers
USCG United States Coast Guard
USEPA Environmental Protection Agency
USGS United States Geological Survey
VGP Vessel General Permit
WHO World Health Organization
WQB Great Lakes Water Quality Board
ZDDP Zero Discharge Demonstration Project

Metric System – United States Customary System Units

(with abbreviations)

Length

1 metre (m) = 3.2808 feet (ft)
1 ft = 0.3048 m
1 kilometre (km) = 0.6214 mile (mi)
1 mi = 1.6093 km

Area

1 square kilometre (km^2) = 0.3861 square mile ($mile^2$)
1 $mile^2$ = 2.59 km^2
1 hectare (ha) = 2.47 acres
1 acre = 0.405 ha

Weight

1 metric tonne (MT) = 1.1 short tons (2,200 pounds)