SCIENCE STRATEGY
December 11, 2019

TABLE OF CONTENTS

1. CONTEXT

In Article 302 of the Great Lakes - St. Lawrence River Basin Sustainable Water Resources Agreement[1] (Agreement), the Great Lakes Governors and the Premiers of Ontario and Québec "commit to provide leadership for the development of a collaborative strategy with other regional partners to strengthen the scientific basis for sound Water management decision making under this Agreement." A similar commitment is included in Section 1.4 of the Great Lakes - St Lawrence River Basin Water Resources Compact[2] (Compact).

The Agreement/Compact requires the management of water resource withdrawals at a Great Lakes Basin and Watershed of a Great Lake or St. Lawrence River scale to protect the applicable Source Watersheds (see definition in Glossary). This is led through activities undertaken by the Great Lakes-St. Lawrence River Water Resources Regional Body (Regional Body) and the Great Lakes-St. Lawrence River Basin Council (Compact Council). Management, led by individual jurisdictions, also occurs at the local or regional scale to ensure withdrawals cause "no significant individual or cumulative adverse impacts to the quantity or quality of the Waters and Water Dependent Natural Resources." The Science Strategy, in line with Regional Body/Compact Council responsibilities under the Agreement/Compact, focuses on activities at the Basin and Source Watershed scales, as defined in the Agreement/Compact (see definition of scales in Glossary). Science activities in support of management approaches and decisions and assessment of impacts at the local and regional (sub-Source Watershed) levels are important, but are not intended to be addressed directly through this strategy. Rather, they will be addressed through ongoing information sharing between the Great Lakes - St. Lawrence States and Provinces.

Substantial work has been performed to date to meet these commitments. In 2013, a Science Strategy was put forward by the Regional Body and the Compact Council, and a number of actions were taken pursuant to advance that strategy. In particular, the Parties undertake a Cumulative Impact Assessment every 5 years to understand the impacts of changes, including consumptive uses and diversions, to the Great Lakes water balance at a Source Watershed and Great Lakes Basin scale. Two Cumulative Impact Assessments[3] have been performed since the Agreement and the Compact came into force. These are the first Cumulative Impact Assessments that have been performed on a watershed the size of the Great Lakes St. Lawrence River Basin.

Accordingly, improvement of the Cumulative Impact Assessment is a primary driver for this Science Strategy, and many of the priority actions listed below are included with the intention of improving future iterations of the Cumulative Impact Assessment.

In addition, water use information reporting has substantially improved since 2012, with ongoing coordinated activities that have both improved the rate of water use reporting compliance as

[1] Agreement: https://www.glslregionalbody.org/media/dgpplhtp/great_lakes-st_lawrence_river_basin_sustainable_water_resources_agreement.pdf
[2] Compact: https://www.glslregionalbody.org/media/vzabdxdr/great_lakes-st_lawrence_river_basin_water_resources_compact.pdf
[3] Assessments: https://www.glslregionalbody.org/media/jypfpjvb/2013-cumulative-impact-assessment-12-4-13.pdf and https://www.glslregionalbody.org/media/tasariud/2019-cumulative-impact-assessment-12-8-17.pdf

well as the quality of data that is reported. Furthermore, various focused studies have been undertaken, including a report on the potential changes in water use resulting from retirement of thermoelectric power plants in the Great Lakes Basin[4].

As identified in the 2017 Cumulative Impact Assessment of Withdrawals, Consumptive Uses and Diversions 2011-2015, the assessment requires more reliable data and information regarding the Basin water budget and how consumptive uses are measured or estimated. In the meantime, much of the current data has significant uncertainty associated with it. Nevertheless, the Agreement/Compact specify that the lack of full scientific certainty should not be used as a reason for postponing measures to protect the Basin Ecosystem.

As outlined in Article 302 of the Agreement/Section 1.4 of the Compact, the intended purpose of the Science Strategy is to guide the collection and application of scientific information to support:

a. An improved understanding of the individual and Cumulative Impacts of Withdrawals from various locations and Water sources on the Basin Ecosystem and to develop a mechanism by which impacts of Water Withdrawals may be assessed;
b. The periodic assessment of Cumulative Impacts of Withdrawals, Diversions and Consumptive Uses on a Great Lake and St. Lawrence River watershed basis;
c. Improved scientific understanding of the Waters of the Basin;
d. Improved understanding of the role of groundwater in Basin Water resources management;
e. The development, transfer and application of science and research related to Water conservation and Water use efficiency.

Furthermore, as a result of past reports and ongoing scientific work, this updated Science Strategy aims to strengthen scientific understanding on a continuing basis, address data gaps and reduce uncertainties by prioritizing actions that will improve the implementation of the Agreement/Compact, with a particular emphasis on improving the Cumulative Impact Assessment, the estimation of consumptive uses and the water conservation and efficiency programs. Where local or regional science and monitoring activities are included, it is for the purpose of informing management approaches and impact assessment at the Great Lakes Basin and Great Lakes Watershed scale as per the responsibilities of the Regional Body/Compact Council under the Agreement/Compact. However, it is recognized that these local science activities are often undertaken by a number of actors and will also be useful to jurisdictions in support of their local and regional water management.

The Science Strategy addresses water managers involved in the Agreement/Compact, Tribes, First Nations and Métis and any organization or research institute concerned with managing to conserve and restore the Waters of the Basin. It starts by identifying *needs and challenges* (Section 2) related to improving scientific understanding from which a series of *priority actions* (Section 3) are then detailed. A timeline for implementing the Science Strategy and *reporting*

[4] https://www.glslregionalbody.org/media/sfiff4i3/2017-thermoelectric-powerplant-report.pdf

(Section 4) on priority actions is proposed. A *glossary* of terms and a list of bibliographic *references* can be found in Sections 5 and 6 at the end of the document.

2. NEEDS AND CHALLENGES

The Science Strategy highlights a variety of needs and challenges to better implement the Agreement/Compact and, more specifically, improve the Cumulative Impact Assessment and its accuracy. Some needs and challenges focus on improved water quantity data collection and scientific analysis for the Waters of the Basin (see definition in Glossary). Some are related to improved tools for management decisions regarding consumption, conservation and efficient use, whilst several address overarching issues like climate change, indigenous engagement and outreach.

2.1 Surface Water

Developing an improved estimated Basin-wide water budget is a key component in increasing the accuracy of the Cumulative Impact Assessment. Surface water impacts are currently assessed by comparing inflows (surface water runoff, precipitation, interbasin diversions.) to outflows (withdrawals, evapotranspiration, interbasin diversions and consumptive uses). Although water elevation in the Great Lakes can be easily recorded, there are still many challenges and difficulties in estimating a water budget that accurately captures the spatial and temporal variability of Basin water levels whether associated with the variability in hydrologic and climate estimating techniques or with climate change. A water budget at a temporal scale finer than annual may also needed to capture hydrologic patterns and seasonal variation for each Great Lake. Quantifying outflows like evapotranspiration remains a challenge.

Some key challenges are related to the lack of long-term stream gauge data in some parts of the Basin. Improved monitoring coverage is needed to develop detailed and accurate modelling tools and improve understanding at local and regional scales from the perspective of both water quantity and quality. In turn, this will support a better understanding at the Lakes and Basin scales required for Agreement/Compact management decisions. In the meantime, in the absence of stream gauges, robust estimates need to be updated.

Many of these same challenges apply for jurisdictions at the sub-watershed scale in determining whether existing or proposed water withdrawals may create individual or cumulative adverse impacts to inland lakes, ponds, and wetlands, however, the necessary data to characterize the geologic and hydrologic settings of these surface water bodies doesn't exist in many areas. In addition to the hydrologic and ecological concerns, other uses of the water body (e.g., navigation, dockage, recreation) and rights or interests of Tribes, First Nations and Métis must be considered.

2.2 Groundwater

Groundwater is increasingly recognized as being an important element of the water budget and for maintaining chemical, physical, and biological integrity of the Great Lakes Basin. Direct groundwater discharge to the Great Lakes is a small proportion of the overall water budget,

however indirect groundwater discharge to the Great Lakes from the baseflow to tributary streams is a significant portion of the streamflow in many Basin tributaries. Groundwater discharge at the local scale is also responsible for maintaining streamflow and inland lake levels, particularly during the summer and fall months and during droughts (Grannemann G, Van Stempvoort D. (Eds.), 2016). Groundwater discharge at the local scale is also linked to supporting aquatic ecosystems.

Our understanding of the availability and extent of groundwater resources stored in multiple aquifer systems across the Great Lakes Basin is incomplete and inadequate for many areas. There are also unknowns related to the understanding of groundwater – surface water interactions on both quantity and quality. This information is critical in determining whether water is available and sustainable in the Great Lakes Basin to meet demands for drinking water, agricultural, industrial and other uses, and to support healthy ecosystems (IJC, 2018).

As part of the water budget used in the Cumulative Impact Assessment, indirect groundwater discharge is captured in the calculations of tributary surface water discharges to the Great Lakes. Direct groundwater discharge to the Great Lakes has not been included to date because there is limited data available. Direct groundwater discharge is a relatively small component of the Great Lakes water budget and is less than the uncertainty associated with major inflows and outflows of the Great Lakes.

A continually improved understanding of groundwater flow to the Great Lakes and tributaries, and groundwater – surface water interactions is needed to better determine where water management is needed. Furthermore, understanding of regional groundwater flow patterns is important to assess Intra-Basin Transfer and Diversion proposals and meet the Agreement/Compact requirements. These requirements include evaluating water supply alternatives as there can be a potential for groundwater outside of the topographical Great Lakes Basin to have a hydrogeological connection to Waters of the Basin.

2.3 Flow-ecology Impacts

As recognized in the 2017 Cumulative Impact Assessment, cumulative impacts of water withdrawals should consider impacts in addition to hydrologic ones. Changes in water flows, discharges and levels, over and above natural fluctuations, can lead to significant individual or cumulative adverse impacts on ecosystems (or Water Dependent Natural Resources). Likewise, a greater understanding is needed of how flow quantity can have an impact on water quality and in turn ecosystem health, for example relating to the dispersal of aquatic invasive species. There are multiple challenges related to flow-ecology relationships which are not only to collect and analyze information but also to transpose local or regional scale data to a Lake or Basin scale and include this in future Cumulative Impact Assessments.

2.4 Consumptive Use

Consumptive Use (see Glossary for definition) is small compared to natural flows at Basin scale. The hydrologic effects of consumptive use on water levels is likewise small and is less than the

uncertainty associated with major inflows and outflows of the Great Lakes. Accurately estimating the size of consumptive uses is important as it is directly related to the management of Great Lakes Basin and a key component of the management structure of the Agreement/Compact. At a local scale, jurisdictions may consider consumptive use looking at impacts of withdrawals on source groundwater and surface water that are not returned to the aquifer or returned to the same surface water system from which they are withdrawn.

Consumptive use is seldom measured directly and instead is based on a range of coefficients developed for use at Basin scale that are not necessarily applicable for tributary surface water and groundwater supplying the surface water discharge to the Great Lakes. Consequently, Parties make independent management decisions and apply a variety of coefficients. Consumptive use is then reported annually to the Great Lakes Commission as part of the States' and Provinces' annual water use reports.

Accordingly, consumptive use coefficients should be reviewed for each water use sector included in the Regional Body/Compact Council's water use reporting protocols[5] estimated for subcategories and reviewed for regional variation, similar to the exercise carried out for the thermoelectric sector (Nicolas, J and Posthumus, E. 2017).

2.5 Water Conservation and Efficient Use

The duty to protect and manage the waters of the Great Lakes Basin is identified as one of the findings and purposes of the Agreement/Compact. The Regional Body and Compact Council adopted Water Conservation Goals and Objectives in 2008 and each Party also adopted water conservation goals and objectives. The Agreement/Compact also calls for each Party to implement a water conservation and efficiency program and report on these programs annually. As the regional goals and objectives state, "efficient and responsible water use is a cornerstone of sound water management policy, whether the resource is considered abundant or scarce."

Water use trends in the Basin have been decreasing since the early 2000's, which in part may suggest the success of water conservation and efficiency efforts (USGS, 2018). However, there is no clear information on the implementation of water conservation and efficiency programs in the Great Lakes Basin and their overall effectiveness. Continued improvements in water conservation and efficiency can be made by focusing on key water users and the specific challenges to the development, transfer, and application of water use conservation and efficiency for these users. In recently reported data, the top three largest consumptive use sectors include public water supply; industrial; and irrigation. These three sectors account for 80% of the consumptive water use and over 90% of the groundwater withdrawals (Great Lakes Commission, 2018) in the Basin. Identifying how much water is available for use in hydrologic, economic, and ecological units is a critical but complex step for jurisdictions. Factors influencing the amount of water available for use range from climate conditions (i.e., current and future), water quality, and how efficiently we use water that is permanently or temporarily removed from the Source Watershed.

[5] Protocols: https://www.glslregionalbody.org/media/zeein4rr/water-use-reporting-protocols-12-8-16.pdf

Challenges to increasing water use conservation and efficiency also include identifying specific and measurable water use conservation and efficiency metrics for each sector and promoting research on how to increase water use conservation and efficiency in each sector, with a particular focus on those who consume the most.

2.6 Climate Change

In understanding and managing for long-term water sustainability, the integration of information about the impacts of climate change on the Great Lakes Basin water balance is a key challenge. Given the potential impacts of a changing climate on major components of the water cycle, including precipitation, temperature, evaporation and evapotranspiration, it is imperative to have a greater understanding through modelling of groundwater, surface water and their interactions (both quantity and quality) under present day climate conditions (see 2.1 and 2.2 above). Uncertainties remain with respect to the impact of climate change not only on water levels in the Great Lakes-St. Lawrence (see Cumulative Impact Assessment 2011-2015, 2017) but also regarding changes in water use and the timing of water availability, with some research predicting reduced net basin supply during late summer and early fall (Music, B et al, 2015.) The results of different climate change scenarios remain uncertain, but are important to document and communicate over time as forecasting future scenarios is necessary to plan for the effects of extreme events (drought and flood) in order to maintain water security for multiple water users as well as ecosystem health.

2.7 Indigenous Engagement and Traditional Ecological Knowledge

Ongoing Indigenous engagement is an important first step that will allow for better integration of Traditional Ecological Knowledge (TEK) - knowledge that is generated and passed on by Indigenous communities from generation to generation. TEK, in complement to Western science, will contribute to a better understanding of our environment and the Science Strategy will be all the richer for it.

To that end, the Great Lakes Indian Fish and Wildlife Commission has highlighted how TEK can contribute to understanding how changes to water quality and quantity can potentially impact ecosystems. Therefore, involvement and collaboration with members of the Federally recognized Tribes in the U.S., First Nations and provincially recognized Métis communities in Canada, will be key to better engagement, demonstrating the benefits of the Agreement/Compact to indigenous communities and understanding how TEK can be approached with appropriate respect and combined into the priorities of the strategy.

2.8 Outreach

Part of the challenge in a region with abundant water resources is to acknowledge and communicate that water, while a renewable resource, does have limitations to its sustainable use in certain areas and under certain circumstances. By using the principles of sustainability and adaptive management the Agreement/Compact does acknowledge that water is a limited

resource, and this is reflected in the references to water conservation and efficiency in the Agreement/Compact.

Regional water use data is reported and made available through the Great Lakes Commission's Regional Water Use Database[6]. Continued improvements to the format and accessibility of the regional water use data are needed, including improved connection to jurisdictional water use data, particularly spatial information. The Parties should also improve communication and outreach to the public about the scientific resources available now and in the future.

3. PRIORITY ACTIONS

To meet the needs and challenges described above, the following priority actions have been identified. For those interested in more specific research needs, please see Section 3.8 below.

3.1 Embed Science Team in Regional Body/Compact Council Work

Formalize the role and work plan of a science team in the annual calendar of activities of the Regional Body/Compact Council.

Actions include:

- Identify members of the Science Team from each Party (managers and technical staff).
- Plan for an annual face to face meeting that will focus on the annual priority identified in the Science Strategy (See Section 4 for timeline and reporting).
- Confirm the important role of the Regional Body and Compact Council's Advisory Committee, Resource Group and Observers, as well as Tribes, First Nations and Métis representatives at the annual meeting of the Science Strategy to assist with the ongoing implementation of the Science Strategy.
- Chair an International Association for Great Lakes Research (IAGLR) session based on the annual priority identified in the Science Strategy (call for proposals each fall, submit a proposal to IAGLR, and hold the proposed session at IAGLR, which is hosted each year in May or June).
- Share the Science Strategy with other groups that are working in similar fields on an ongoing basis, encouraging them to advance the Priority Actions through their own independent research.
- Communicate as appropriate with research institutes in the U.S. and Canada on any related Request for Proposals.
- Track and document the advances made by the Science Strategy to keep it up to date and review it periodically.

[6] Regional Water Use Database: https://waterusedata.glc.org/

3.2. Estimating Consumptive Water Uses

This priority aims at improving consumptive use estimation methodologies for different water uses within water use sectors to improve confidence intervals as well as consistent application of those methodologies. After initially evaluating how each jurisdiction estimates consumptive use, work should also include documenting water use projections for different water use sectors to consider climate change. Actions for this priority will also contribute to priority 3.3. ***This priority, which aligns with Sections 2. b. and c. of article 302 of the Agreement / Section 1.4.2 b. and c. of the Compact, will be the focus of the Science Team in 2020.***

Actions include:

- Organize the 2020 annual face to face meeting of the Science Team and focus on this priority.
- Propose this subject for the 2020 IAGLR conference (call for proposals by November 2019).
- Identify priority water use sectors based on those with the largest consumptive uses but also including the sectors where a lack of consistent estimation methodologies is critical to improving water reporting and the Cumulative Impact Assessment and where smaller uses have a big impact depending on when water is used, i.e. irrigation, livestock and industry.
- Identify external partners based on this prioritization and consult with them to best understand the current status of information.

3.3. Great Lakes Water Quantity

This priority tackles the need to improve the science and knowledge of water quantity in the Great Lakes - St. Lawrence, now and in the future. The next Cumulative Impact Assessment will cover 2016-2020 and should, as best as possible, address questions raised about water quantity uncertainties. Issues include gaining a better understanding of actual water quantities (inflow and outflow), improving water budget estimations, introducing methods to estimate individual and cumulative impacts to the Great Lakes Basin, and understanding critical thresholds.

Given the timeline of the next Cumulative Impact Assessment (due for publication by 2023), ***this priority will be the Science Team's focus in 2021. It aligns with Section 2. a., b., c. and d. of article 302 of the Agreement / Section 1.4.2 a., b., c. and d. of the Compact.***

Actions include:

- Organize the 2021 annual face to face meeting of the Science Team to focus on this priority.
- Propose this subject for the 2021 IAGLR (call for proposals by November 2020).
- Continue ongoing improvements to accuracy of water use data provided to the Great Lakes Commission by the jurisdictions and review of the data by the Great Lakes Commission.

- The Regional Body and Compact Council rely on United States and Canadian federal agencies for water budget data and estimates. The Regional Body/Compact Council appreciates the ongoing efforts of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data to coordinate these data.
- Identify data gaps and uncertainties in the water budget and gains (i.e. uncertainties with the largest errors) from which specific actions will be identified.
- Identify gaps in surface gauging networks on key tributaries and prioritize based on best gains for improving the Cumulative Impact Assessments.
- Focus discussion and identify more immediate actions to improve the 2023 Cumulative Impact Assessment:
    - Reconsider how the uncertainty associated with the water budget parameters is reported, for example by reporting water budget parameters as a range or by expanding the uncertainty section of the Cumulative Impact Assessment.
    - Explore the feasibility including an assessment of cumulative impacts by water source (Great Lakes, other surface water, groundwater, surface water) rather than just by Great Lakes Basin.
    - Consider, if feasible, integrating groundwater discharge and induced aquifer recharge from streams into the Basin water budget.
    - Use the Large Lake Statistical Water Balance Model (L2SWBM) for the Cumulative Impact Assessment water budget components.
    - Discuss flow-ecology science needs to include the cumulative impacts of water use on water dependent ecosystems.
    - Use NOAA forecasts to include discussion of climate change implications on the Great Lakes water budget.
    - Summarize the Cumulative Impact Assessment in a short factsheet.
- Exchange information with organizations like the International Joint Commission to explore the feasibility of integrating modeling information regarding interactions between surface water and groundwater in the Basin water budget.
- Work with climate change experts to investigate the impact of climate change on the water budget parameters to determine which parameters are most sensitive to inform future management needs.
- Explore the feasibility of creating an overarching hydrologic and hydrogeologic framework for the entire Great Lakes - St. Lawrence basin scale.
- Examine the technical requirements and benefits to creating a repository for climate, geology, and real-time groundwater, and surface water data (flows and quality) and lake levels that is accessible to all interested parties at Basin, sub-watershed and local levels.

3.4. Water Conservation & Efficient Use

This priority includes understanding water conservation and water use efficiency successes and further opportunities specifically in the Great Lakes Basin, developing and evaluating alternative conservation methods and best management practices, and benchmarking for water use by various sectors (ex. per capita residential water use, maximum to average day ratio, water foot

printing, etc.). ***It aligns with Section 2. e. of article 302 of the Agreement / Section 1.4.2 e. of the Compact. This priority will be the Science Team's focus in 2022.***

Actions include:

- Organize the 2022 annual face to face meeting of the Science Team to focus on this priority.
- Propose this subject to share regional research and outreach programs on water use efficiency among the Great Lakes parties for the 2022 IAGLR (call for proposals by November 2021).
- Each jurisdiction collates research projects and findings as related to water conservation and use efficiency for each sector of activity so that jurisdictions can share experiences/best management practices/success stories and establish priorities at the 2022 Science Team face to face meeting.
- Lead discussions with Science Team members and external partners to identify metrics that measure water use efficiency for public water supply, irrigation/agricultural uses, and industrial water use.
- Discuss and determine potential water conservation and efficiency benchmarks that could be used by jurisdictions for evaluating water conservation efforts. For example, for the public water supply sector these benchmarks may include unaccounted water, water use intensity metric and maximum day to average day ratio.
- Support research, whether at Basin scale or jurisdiction scale, that integrates water demand forecasts, potential climate change impacts on water availability, and water conservation and water use efficiency measures.

3.5 Indigenous Engagement and Traditional Ecological Knowledge

This is an overarching and ongoing priority of the Science Strategy. It aims firstly to engage with Tribes, First Nations and Métis over science issues recognizing the resource and capacity issues faced by Tribes, First Nations and Métis (Natural Resource teams) that limit their ability to actively participate in forums such as this. Secondly, it aims to understand what TEK is and how it could be incorporated within the Science Strategy.

Actions Include:

- The Science Team actively encouraging Tribes, First Nations and Métis to implement the Science Strategy, and will invite them to attend the Science Team's annual face to face meeting. Opportunities to allow for constructive remote participation in those meetings will be explored.
- Working on how to demonstrate and communicate the benefits of the Science Strategy to Tribes, First Nations and Métis, and better understanding the benefits of indigenous participation to the Science Team.

- Identifying opportunities for increased engagement and for the Science Team to learn about western science conducted by indigenous communities and about TEK by asking the Tribes, First Nations and Métis to keep the Science Team apprised of such opportunities.
- Using the Science Team's annual meeting as an opportunity to learn about ongoing water quantity research carried out by Tribes, First Nations and Métis.
- Science Team keeping informed about ongoing TEK work, e.g. through the U.S. Caucus of the TEK Task Team of the Science Annex 10 Subcommittee under the Great Lakes Water Quality Agreement, as well as similar initiatives in Canada.
- Being prepared to update the Science Strategy through ongoing engagement with Tribes, First Nations and Métis.

3.6 Outreach

Outreach to the broader scientific community is also an overarching and ongoing priority of the Science Strategy. It should be included in the discussions related to each of the priorities listed above. Opportunities should be identified to improve the dissemination of information and data using the existing Regional Body, Compact Council and Great Lakes Commission websites, ensuring that information and concepts are clearly understandable for a range of audiences.

3.7 Forum for Information Exchange between Regional Body/Compact Council Members

Provide one or two webinars annually for jurisdictions to present and discuss local management issues related to the jurisdictional implementation of the Agreement/Compact in order to share best practices, identify common questions, request informal feedback on management questions, and discuss local management strategies. Collaborate with national and international science organizations to share information.

3.8 Research Needs

The Regional Body/Compact Council have a variety of research needs to advance water quantity management at the Great Lakes Basin scale and implement the Agreement/Compact. In addition, jurisdictions have a variety of research needs to assist with implementing management programs at the jurisdictional level. The following is a list of topics that would assist implementation of the Agreement/Compact at either the regional or jurisdictional scale. The broader research community across the Great Lakes - St. Lawrence Basin is encouraged to undertake activities that advance these research needs. The Regional Body/Compact Council may consider reviewing and prioritizing these research needs based on feasibility from technical and cost perspectives.

- Refinement of climate change impacts on water resources at the Great Lakes Basin scale.
- Refinement of Great Lakes or Source Watershed scale consumptive use calculations and estimation methodologies on a sector specific basis.
- Assessment of current streamflow and groundwater monitoring and estimation at the Great Lakes Basin scale, Lake scale, sub-watershed scale and recommendations for additional streamflow gage and integrated groundwater – surface water monitoring needs.

- Improve consideration of the role of groundwater in the Great Lakes water balance to allow Parties to learn from and adopt water management methodologies used by others that are terrane specific:
    - Understanding of groundwater-surface water interaction in groundwater dependent surface waters such as headwater streams, seepage lakes, and springs.
    - Mapping the Basin's principal groundwater terranes and 3D mapping of glacial deposits.
    - Developing better tools to assess groundwater – surface water interaction, including regional and scaled-up models based on local scale assessments and mapping.
- Social science research on best methods for communicating to the public and water use sectors about water conservation and water use efficiency.
- Develop a method to improve and track cumulative downstream streamflow depletion.
- Investigate the impact of climate change on the water budget parameters to determine which parameters are most sensitive to different climate change scenarios.
- Identify how much efficiency can be gained by various water conservation and efficiency measures with consideration that the conservation and efficiency measures be environmentally sound and economically feasible.
- Integrate research on water demand forecasts, potential climate change impacts on water availability, and water conservation and water use efficiency measures at the Basin and jurisdiction scale.

4. REPORTING

The Science Team will report on advances for each priority action. Reporting will be submitted to the Great Lakes - St. Lawrence River Water Resources Regional Body / Great Lakes - St. Lawrence River Basin Water Resources Council secretariat on an ongoing basis. Reporting will be disseminated on the Great Lakes - St. Lawrence River Water Resources Regional Body / Great Lakes - St. Lawrence River Basin Water Resources Council public webpage as appropriate.

The proposed timeline for implementing the Science Strategy and priority actions is as follows:

Priority Action	2019	2020	2021	2022	2023
1 - Science Team					
2 - Consumptive Use					
3 - Water Quantity					
4 - Conservation and Efficiency					
5 - Indigenous					
6 - Outreach					
Cumulative Impact Assessment					
		Focus on priority			
		Work on elements of priority may continue			

5. GLOSSARY

The following definitions are primarily taken from Article 103 of the Agreement; and, Section 1.2 of the Compact.

Basin or ***Great Lakes—St. Lawrence River Basin*** means the watershed of the Great Lakes and the St. Lawrence River upstream from Trois-Rivières, Québec within the jurisdiction of the Parties.

Basin Ecosystem means the interacting components of air, land, Water and living organisms, including humankind, within the Basin.

Consumptive Use means that portion of Water Withdrawn or withheld from the Basin that is lost or otherwise not returned to the Basin due to evaporation, incorporation into Products, or other processes.

Cumulative Impacts mean the impact on the Great Lakes—St. Lawrence River Basin Ecosystem that results from incremental effects of all aspects of a Withdrawal, Diversion or Consumptive Use in addition to other past, present, and reasonably foreseeable future Withdrawals, Diversions and Consumptive Uses regardless of who undertakes the other Withdrawals, Diversions and Consumptive Uses. Cumulative Impacts can result from individually minor but collectively significant Withdrawals, Diversions and Consumptive Uses taking place over a period of time.

Direct discharge of groundwater means the discharge of groundwater directly into a Great Lake through the lakebed into a Great Lake

Indirect discharge of groundwater discharge means the discharge of groundwater into streams, wetlands or inland lakes that flow into the Great Lakes

Scale:

Lake scale means the scale of a Great Lake or the St. Lawrence River.
Sub-watershed scale means the scale of a watershed within a Source Watershed.
Local scale means the scale equivalent equal to a community.
Regional scale means the scale equivalent to multiple states and/or provinces.
Basin scale see definition of ***Basin***.
Jurisdictional scale means the scale of a state or province.

Source Watershed means the watershed from which a Withdrawal originates. If Water is withdrawn directly from a Great Lake or from the St. Lawrence River, then the Source Watershed shall be considered to be the watershed of that Great Lake or the watershed of the St. Lawrence River, respectively. If Water is Withdrawn from the watershed of a stream that is a direct tributary to a Great Lake or a direct tributary to the St. Lawrence River, then the Source Watershed shall be considered to be the watershed of that Great Lake or the watershed of the St. Lawrence River, respectively, with a preference to the direct tributary stream watershed from which it was Withdrawn.

Water Dependent Natural Resources means the interacting components of land, Water and living organisms affected by the Waters of the Basin.

Water of the Basin means the Great Lakes and all streams, rivers, lakes, connecting channels and other bodies of water, including tributary groundwater within the Basin.

6. REFERENCES

Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., and Linsey, K.S. 2018. Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, 65 p., https://doi.org/10.3133/cir1441

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.
https://binational.net//wp-content/uploads/2016/05/GW-Report-final-exec-sum-EN.pdf
https://binational.net//wp-content/uploads/2016/05/GW-Report-final-EN.pdf

Great Lakes Commission. 2018. Annual Report of the Great Lakes Regional Water Use Database: representing 2017 water use data. https://waterusedata.glc.org/pdf/2017-Water-Use-Report.pdf

Great Lakes – St Lawrence River Basin Sustainable Water Resources Agreement. December 13, 2005. https://www.glslregionalbody.org/media/dgpplhtp/great_lakes-st_lawrence_river_basin_sustainable_water_resources_agreement.pdf

Great Lakes – St Lawrence River Basin Water Resources Compact. December 13, 2005. https://www.glslcompactcouncil.org/media/ud2domov/great-lakes-st-lawrence-river-basin-water-resources-compact.pdf

Great Lakes – St Lawrence River Water Resources Regional Body and Council. 2013. Cumulative Impact Assessment of Withdrawals, Consumptive Uses and Diversions 2006-2010. https://www.glslregionalbody.org/media/jypfpjvb/2013-cumulative-impact-assessment-12-4-13.pdf

Great Lakes – St Lawrence River Water Resources Regional Body and Council. 2017. Cumulative Impact Assessment of Withdrawals, Consumptive Uses and Diversions 2011-2015. https://www.glslregionalbody.org/media/tasariud/2019-cumulative-impact-assessment-12-8-17.pdf

International Joint Commission. 2018. Great Lakes Surface and Groundwater Model Integration Review. Literature Review, Options for Approaches and Preliminary Action Plan for the Great Lakes Basin. Prepared by the Great Lakes Science Advisory Board Research Coordination Committee and submitted to the IJC October 2018.
https://ijc.org/sites/default/files/2019-01/Great_Lakes_Surface_and_Groundwater_Model_Integration_Review_Oct2018.pdf

Music B, Frigon A, Lofgren B, Turcotte R, Cyr J-F. 2015. Present and future Laurentian Great Lakes hydroclimatic conditions as simulated by regional climate models with an emphasis on Lake Michigan-Huron. Climate Change 130:603-618
https://link.springer.com/article/10.1007/s10584-015-1348-8

Nicolas, J and Posthumus, E. 2017. Potential Changes in Water Use Resulting from Retirement of Thermoelectric Power Plants in the Great Lakes Basin. Prepared for the Conference of Great Lakes and St. Lawrence Governors and Premiers. Nicolas-h2o.
https://www.glslregionalbody.org/media/sfiff4i3/2017-thermoelectric-powerplant-report.pdf