An Update Report on Climate Change Assessment Activities for the International Rainy - Lake of the Woods Watershed Board

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Background: IJC Climate Adaptation Guidance Framework

Starting in early 2016 through the International Watersheds Initiative (IWI), the International Joint Commission (IJC) contracted Alec Bernstein and Casey Brown from the University of Massachusetts and Bill Werick to begin developing a climate change guidance framework for its boards to address climate change through policy and operations using the best available science and stakeholder knowledge. The guidance framework can be found here: http://ijc.org/files/tinymce/uploaded/IWI/IWI_CAWG_2017_02.pdf

From a May 2017 update report by Bernstein and Brown, they describe the framework thus:

“The planning Guidance Framework consists of four primary steps: (1) organize, (2) analyze, (3) act, and (4) update. In the **organize** step, each board would formulate its climate change related objectives and assess what information is available and what is needed to prepare to meet those objectives successfully. In the **analysis** step, the board would produce quantified estimates of how a change in climate might produce different outcomes from board activities. The board would prioritize the most critical and evaluate the likelihood of the outcomes. In the third step, **act**, the board would use the tools and networks to evaluate different responses and based on this, the board would make decisions it believes would improve their preparedness for the potential impacts of climate change. The final step, **update**, is adaptive management, the establishment of a process to improve the board’s “act” decisions based on a formalized, ongoing effort to systematically assess the board’s challenges over time.”

Implementation: The St. Croix River Pilot for Water Levels

The IJC developed the climate change guidance framework to be useful for all of its boards, irrespective of their different mandates. Since 2017, board representatives to the Climate Adaptation Working Group have had several opportunities to gather to share information and plan for shared resources, tools and spaces that will help with the work. While some of these shared tools are still in development and will provide the backbone of ‘horizontal’ (i.e. across all boards) implementation of the guidance framework, each board will also have its own unique opportunities and challenges when it comes to applying the framework.

In 2018, the IJC selected the St. Croix River Watershed Board to be the first of its boards to pilot a vertical implementation - that is, more deeply testing the framework at the board level by running through a full cycle of each of the framework steps. The St. Croix pilot was done through a $20,000, 7-month IWI grant in 2018. Consulting researcher Alec Bernstein joined representatives from the St. Croix Board to present the outcome of this project at an IWI workshop in Ottawa in November 2018.

In their presentation, the St. Croix team explained that global climate models cannot be sufficiently well down-scaled to provide both a range of outcomes for a specific location as well as very high certainty around any of those outcomes. Furthermore, the more steps one adds to planning activities, the more the uncertainty compounds.

The alternative to the traditional top-down planning is to use a bottom-up, decision-scaling approach. With decision-scaling, planners look at a wide array of future scenarios, evaluate how their particular system works under each scenario, and then they look at what the likelihood might be for the most troublesome or concerning of possible future scenarios to come to fruition. Plans are made according to the likelihood and the extent of severity of particular impact scenarios to the successful ongoing function of the system.

The International St. Croix River Watershed Board, like the International Rainy - Lake of the Woods Watershed Board (IRLWWB), has responsibilities for the ecological health of the river system, as well as water levels regulatory responsibilities tied to four dams on the system. Not all boards share such a dual water quality / water quantity mandate, and in fact many IJC boards are solely concerned with managing and regulating water flows, levels or quantities. In order that the pilot implementation project would be most widely applicable to as many boards as possible, the St. Croix Board applied the climate change guidance framework only to water flows and water levels.

In the **organize** step, the St. Croix team evaluated its water flows / levels performance targets that are tied to the four dams under the Board's control. The team defined objectives and measures of success for the project, identified uncertainties and any factors that could have affected the study system, and they reviewed relevant past work on the system.

In the **analysis** step, the St. Croix team ran two different types of models: a climate weather generator model that drew on a range of daily precipitation, daily temperature and reservoir sample data; and a human hydrology model that looked at how often changes in the physical climate data parameters affected the system. Each model simulation was run at least 3600 times to establish a data set of prospective outcomes that might elucidate any evidence of problems tied to changing climate parameters. The key question the engineers running the models asked was, "What is the importance and uncertainty of these possible effects?"

The results of these simulations showed that for one of the four dams, under conditions where precipitation is high and the temperatures are low, that dam is likely to flood often. Global climate models suggest, though, that it is unlikely that this area will see that combination of climate change factors (high precipitation and low temperature), which suggests that the flood risk for this particular dam is negligible.

Further downstream, however, the minimum flow requirements can be more easily violated by climate perturbations. The models illustrated that the further downstream one travels, the range of conditions that leads to rule curve violations increases. The risks increase over time, with significant adverse impacts in the 2036-2065 range, although nothing particularly egregious in the very near term.

The study team noted that dam operators in the St. Croix do not get penalized for violations that happen that are beyond their control, provided they have done their due diligence to protect against these risks. This gives dam operators incentive to support this kind of modelling work so that they can better understand and try to manage risk.

In the **act** step, the team reviewed the model outputs, considered possible actions (e.g. implementing additional monitoring), and then determined a course of action to ensure the system was as well prepared as possible to both adapt to future climate change impacts, and to mitigate the worst of prospective harms that might come from climate change impacts to the system.

Among the actions the Board identified that it could take were to develop alternative operations or mandates that could be more robust under future climate scenarios, and to more meticulously monitor how conditions are changing.

In the **update** step, the team began incorporating the recommendations from the ‘act’ step into establishing a more robust formal and informal monitoring program for key uncertainties of interest. Thus, the St. Croix Board now has an adaptive management framework for addressing climate change impacts of priority concern in order to best safeguard the continued successful operation of the water regulation dams under its control.

The Board agreed to revisit this analysis frequently in the future. Such analysis would not require any rebuilding of models, although as other boards develop their own similar models, new tools or parameters may emerge that would also be useful here and could be incorporated into future renderings of the St. Croix models.

Implementation: What are other boards doing?

In mid-2020, the IRLWWB’s Adaptive Management Committee (AMC) reached out to the other IJC boards to learn how they are approaching climate change issues and whether and how they are implementing the IJC’s climate change guidance framework.

To date, the St. Croix Board is still the most advanced in terms of implementation of the guidance framework. Only a handful of other boards have indicated any progress to date on implementing climate change programming. These are detailed below.

International Osoyoos Lake Board of Control

David Hutchinson is the Regional Chief, Pacific and North Hydrometric Operations for the Monitoring and Data Services Directorate of Environment and Climate Change Canada (ECCC) and he is affiliated with three IJC boards including the Columbia, Kootenay and Osoyoos Lake Boards of Control. He reported to us that the Osoyoos Lake Board of Control is the only one of these three boards to have undertaken climate change assessments to date.

Here is David’s report to the AMC, from June 26, 2020:

"We are currently embarking on a phased approach to assessing climate change and impacts on the Orders of Approval for the International Osoyoos Lake Board of Control. The first phase of the investigation is to model the Similkameen watershed which is an unregulated tributary that plays an important role on regulating Osoyoos Lake at certain times of the year. During this phase we will examine the impacts of climate change on declaration of drought criteria specified within the Order.

The second phase will be to incorporate existing models of the Okanagan with the phase 1 Similkameen model to assess the resiliency of the Osoyoos Lake Order of Approval under expected changes to climate. We are mid-way through phase 1 and expect preliminary results by the end of summer 2020. Phase 2 will occur in 2021.”

Given the early state of work in this basin, David was unable to recommend any best practices or speak to challenges faced by the Board with respect to climate adaptation work. We will follow up in 2021 to share information and will provide updates to the IRLWWB.

International Lake Ontario - St. Lawrence River Board

Marc Hudon is a Canadian member of the Public Interest Advisory Group to the International Lake Ontario - St. Lawrence River Board, and he is one of that Board's representatives to the IJC's climate adaptation working group. He shared with the AMC an extensive and informative update on the Lake Ontario - St. Lawrence River Board's climate change assessment activities on July 13, 2020. Marc noted that this Board's adaptive management functions are largely covered through the work of the Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee, which will be described in the next section of this report.

Similar to the IRLWWB's 2015 rule curve review and subsequent 2018 update to the rule curves, the Lake Ontario - St. Lawrence River Board drafted a new water regulatory plan in 2014 to replace the outdated plan that had been in place since 1958.

Since 2017, the Lake Ontario - St. Lawrence system has been experiencing persistent extreme high water levels and flooding impacts have regularly made national and international news headlines given the scale and cost of damage that has resulted. As Marc describes, "Plan 2014 has been doing one thing: push(ing) out as much water as possible out of Lake Ontario through the St. Lawrence River to provide relief to Lake Ontario riparians while mitigating impacts for users around the lake, around Lake St. Lawrence (forebay of the Moses-Saunders dam) and downstream on the St. Lawrence River all the way to Lac St. Pierre near Trois-Rivières."

For this basin, climate change impacts are already a present and consequential reality. Persistent high rainfalls across the Great Lakes for several years, plus high water inflows from the Upper Great Lakes have compounded the flood situation for the lowest of the Great Lakes and the St. Lawrence. Spring freshets have been a historical reality, but these are changing as the climate changes. The Board is working to better understand how snow conditions are evolving over winter months, including how much water is held in the snow, when and how the snow melts in spring, and how other tributaries to the system such as the Ottawa River may impact the spring freshet under these changing conditions.

Meanwhile, floods have impacted waterfront homes and businesses, inundated marinas, caused severe shoreline erosion, affected municipal and industrial water intakes, and contaminated waterways with municipal sewage. The high outflows also caused very high water velocities that made for navigation challenges, particularly around the St. Lawrence Seaway lock system. During the winter months, ice formation has been unstable and problematic at times as temperatures warmed up and forced the Board to reduce outflows until ice reformed. When this has happened, communities and water users on Lake St. Lawrence have then been affected by very low water levels.

The extreme water levels situation in this watershed has compelled diverse users and stakeholders to meet regularly to try to share information and develop adaptation and risk / impact mitigation plans as quickly as possible. Some of those involved in these discussions include operators of municipal and industrial water intakes, owners of private wells, hydropower operators, commercial navigation interests, recreational boaters, and experts regarding environmental considerations for fish, habitats, flora and other fauna.

In 2019, the Board asked for and was granted approval by the IJC to deviate from Plan 2014 until the Lake Ontario level reached its spring peak. Marc shared that "the Board met as many times as was necessary (sometimes on a weekly basis) by conference call to understand how the conditions upstream and downstream were evolving, find consensus among ourselves and adjust our strategy in accordance with the latest and best weather events forecasting and conditions available. Reaching consensus in making a decision was difficult at times but never impossible given appropriate time; we had, for example, to refine our knowledge of some topics (i.e: risks for pilots to navigate in high currents, weigh shoreline protection against maintaining shipping, erosion issues for infrastructures along the system, numerous requests from the general riparians for assistance, etc.) and weigh the consequences of our decisions… One time, we could not make a decision because by then the right time to do it had passed and it would have conflicted with a major boat haul-out. At times, we needed to refer to the Boundary Waters Treaty to have exact understanding of priority for the water users. The IJC even had to give us some additional guidance on consensus making."

Following this chaotic experience, the IJC directed GLAM to accelerate its review of the regulatory plan from a 15-year cycle to an immediate review to be completed within 18-months. In the summer of 2020, the IJC struck a Public Advisory Group to the GLAM to assist with this review. The review is to assess whether water levels can be better managed through the use of different threshold values or timing and to look at physical and structural changes to the system that could be applied.

The IJC also added two new municipal representatives (one Canadian, one American) to the Lake Ontario - St. Lawrence River Board to better reflect the interests and impacts of water levels fluctuations on municipalities in the basin. The municipal representatives were able to bring in a wealth of expertise in working in a multi-jurisdictional context to address complex environmental and regulatory problems. Some of the areas in which the municipalities hold expertise include emergency response, preparedness, resilience and damage control and financial support.

While it is not always clear where responsibilities lie, the efforts of this Board focus very heavily on developing strong, collaborative relationships and building trust throughout the watershed among all stakeholders, user groups, and knowledge holders. Marc offered many insights about the value and structure of communications and engagement mechanisms his Board has employed to build success for this high-stakes work. The AMC has shared this information with the IRLWWB Engagement Committee to help inform our own Board's future activities. Finally, he underscored the value of the IWI, not just as a source of reliable funding, but as a platform for ensuring lessons learned within one board are shared and accessible to other boards.

Great Lakes - St. Lawrence River Adaptive Management Committee

Following our communication with Marc Hudon about the experiences on Lake Ontario and the St. Lawrence River, we talked with Wendy Leger, the Canadian co-chair of the Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee. Wendy is the head of the Boundary Waters Issues Unit, National Hydrological Services / Meteorological Service of Canada at ECCC.

In a meeting on July 23, 2020, Wendy described the scope of the GLAM's expedited review of the 2014 regulatory plan for Lake Ontario - St. Lawrence River. The GLAM would first review the Board's deviation decisions, before looking ahead to worst-case scenario planning that would involve modelling worst-case snow pack, precipitation and inflows - a set of conditions that essentially mimicked real world experiences from 2017. The IRLWWB AMC will continue to follow this work and will provide updates to the Board.

The GLAM is also involved in its own broader climate change assessment and planning activities.

Wendy reported that members of the GLAM, many of whom are also part of the Great Lakes Science Advisory Board, have been running a regional climate model called the Great Lakes Climate and Routing Model. This climate model is part of the Intergovernmental Panel on Climate Change (IPCC)'s Coordinated Regional Climate Downscaling Experiment (CORDEX), a platform that helps regional climate modellers downscale complex global climate models for use at the regional level.

Wendy noted that the GLAM's model has been run using older IPCC climate pathway models and scenarios, some of which pre-date the models more widely in use today (i.e. the RCP pathways from the IPCC's 2013 Fifth Assessment Report). She was not able to comment on whether or how the differences in scenario assumptions among these historical climate pathway models might differently impact the outcomes of the regional model's climate projections, but this might be an area for further inquiry by the IRLWWB's own climate modelling team as our work proceeds.

The Great Lakes Climate and Routing Model considered differences in flows, precipitation levels and other physical parameters to inform model regulation plans for the Great Lakes. Parameters are not only based on historical data, but also consider possible future conditions. The different scenarios are run through the Great Lakes rule curves to see how the rule curves respond to longer term climate change projections. The model considers both climate change projections and stochastic climate scenarios over a long future term to illustrate highest highs and lowest lows possible.

There are still some noteworthy gaps in the scope of what the Great Lakes model incorporates. For instance, the model cannot yet tell us anything about how species will adapt to different water levels scenarios, so the work is not yet capturing anything about emergent ecosystem feedback loops. Incorporating ecosystem impacts is the next priority for the GLAM climate modelling work. Another gap exists around fish data, as the model looks at water levels and temperatures, but misses overall ecological indicators for fish.

Other relevant modelling work in the Great Lakes includes ECCC/s Great Lakes Protection Initiative which is looking at wetland modelling and is considering water levels and ecosystem feedback loops. Wendy noted that this is more of a wetland response model than a climate model.

As of our conversation in July 2020, the GLAM had not yet run any climate scenarios for the Lake Ontario - St. Lawrence River 2014 regulation plan, but they were planning to do so for water level and flow parameters, at the very least.

Implementation for the IRLWWB

Given that the climate change guidance framework fundamentally relies on adaptive management approaches to integrate long-term climate change adaptation planning into boards' activities and operations, for the Rainy-Lake of the Woods watershed, the Board agreed that the best place to house this work would be within the mandate of the new AMC.

The AMC's mandate is primarily concerned with assessing the impacts of the 2018 rule curves on water levels and flows and the impacts these have on the affected interests in the boundary waters of the Rainy River basin. The AMC works with relevant stakeholders and agencies to gather information that informs its recommendations to the IRLWWB with respect to water level regulation relating to the 2018 rule curve.

As changes to climate parameters such as precipitation, temperature, ice formation / thaw and reservoir volumes affect the function of the rule curves, the IRLWWB is in a position very similar to that of the St. Croix Board with respect to the need to model these impacts on future performance of water level regulatory structures and the functioning of the rule curves. **For now, the AMC and the Board have agreed that, for the first stage of implementation of the climate change guidance framework, we will restrict our analysis to the Board's water levels mandate with respect to adaptive management and monitoring of the 2018 rule curves.**

In future, though, our Board will need to expand the scope of the application of the climate change guidance framework. For example, the water levels impact modelling could be expanded to encompass the entire watershed, through a collaboration with the Lake of the Woods Control Board and / or other relevant agencies with jurisdiction across the rest of the watershed. But perhaps more relevant to the IRLWWB mandate, the work will eventually have to address impacts of climate change on water quality for the entire watershed, too. Any future work the IRLWWB does to apply the climate change guidance framework to its water quality mandate must focus on performance indicators such as plants, fish, and wildlife, navigation and hydropower. During the review of the 2000 Rule Curves, the modelling team assessed the impact of various inflow scenarios (simulating climate change) on the full suite of performance indicators they had prepared for the review, and this experience will, no doubt, provide the foundation for future climate change assessment work in the basin. The AMC expects that the Board will need to look at revising existing models or developing new models that incorporate water quality indicators and alerts, such as are being identified and described by the Board's Aquatic Ecosystem Health Committee at present.

Step 1: Organize

As the AMC and the Board implement the climate change guidance framework, there are a number of questions we must ask during the initial 'organize' step:

- The rule curve review used models, which may be applicable to further climate change assessment work, to help assess impacts to water levels under a wide variety of environmental variables. The IRLWWB / AMC will have to assess whether these models incorporate all the necessary climate change variables of interest by looking at the report summarizing the rule curve review, and / or by talking with Aaron Thompson's modelling team (ECCC) and/or Jean Morin's modelling team. These are some of the variables of interest we will need to track:
    - Temperature
    - Precipitation
    - Ground water saturation
    - Land use changes / run-off changes
    - Other indicators

The AMC recommends that we / IRLWWB consult with other regional experts, such as climate researchers at the IISD Experimental Lakes Area or climate modellers at the Prairie Climate Centre, to identify additional high priority climate indicators.

- For private dam operators on the Rainy system, what happens if models show a high likelihood that future climate scenarios could result in rule curve violations and dams failing to perform optimally? Who bears the responsibility to remedy the risk?

- What additional indicators would we need to consider to extend this analysis to understanding *water quality* impacts from climate change? Would we want this to be more holistic (like ecosystem impacts or even socio-economic impacts in addition to ecosystem)?

- Thinking ahead to the ‘act’ and ‘update’ steps, where we will need to be able to act on recommendations and implement adaptive management mechanisms based on the results of this work, we need to plan for long-term, post-pilot funding to support this work.

Backgrounder: Understanding Climate Modelling

1. Global Climate Modelling

The Intergovernmental Panel on Climate Change (IPCC) is the body of global climate scientists whose contributions help us track climate changes and assess uncertainties and alternatives for the future, based on our knowledge of the interactions amongst social, economic, policymaking, and technological factors and Earth science.

IPCC scientists and climate modellers use Integrated Assessment Models (IAM), which are complex models that consider the human dimension of climate change. IAMs illuminate the impacts on climate outcomes of our policymaking, sociological, technological and economic actions, when these are combined with the Earth's geophysical processes. These models help us to learn about possible outcomes and inform planning for adaptation, risk mitigation, and action to protect people, places and ecosystems that are most vulnerable to climate change impacts.

IAMs are only one part of the climate modelling picture, though. A second piece, the climate scenarios, involves looking at the impacts that different levels of carbon emissions have on the Earth system (human, environmental, and geophysical) over time.

There have been many different kinds of climate scenario models over the decades, but some of the most widely used are the four Representative Concentration Pathways (RCPs). The RCPs were first described in the IPCC's fifth assessment report (AR5), which was published in 2013 and covered the time period 2007-2013. The RCPs are four plausible carbon emissions trajectories for this century, ranging from the worst-case scenario (RCP8.5), through two intermediate scenarios (RCP6 and RCP4.5) down to the most ambitious scenario (RCP2.6, also called RCP3-PD).

The numbers in the RCPs refer to radiative forcing, essentially a measure of carbon dioxide concentration in the atmosphere. Remember that climate change happens because atmospheric carbon is very effective at obstructing solar radiation as it tries to bounce off the Earth's surface back out into space. The more carbon molecules there are in the atmosphere, the more pronounced this radiative heating (or forcing) effect.

RCP8.5 describes a scenario in which radiative forcing from carbon molecules in the atmosphere reaches >8.5 W/m2 by 2100 and continues to rise for some amount of time thereafter. RCP6 and RCP4.5 assume radiative forcing stabilizes around 6 W/m2 or 4.5W/m2, respectively, by 2100, and RCP3-PD assumes radiative forcing peaks around 3 W/m2 before 2100 and then begins to decline, reaching 2.6 W/m2 by 2100.

Obviously, the amount of action humans take to reduce carbon emissions heavily influences how much carbon ends up in the atmosphere by 2100. For this reason, RCP8.5 is widely thought of as the 'do nothing' or 'business as usual' scenario - the result of policymakers, economies, and technologies doing nothing to change the rate and volume at which carbon is emitted for the rest of this century. With varying levels of policy, technological, economic and sociological interventions, emissions can be curbed to varying degrees, resulting in each of the other pathways.

As the IPCC described in the scenario process for AR5, the aim of modelling based on these scenarios is not to accurately predict the future. Rather, these scenarios give us a range of possible outcomes that can help us to better understand uncertainty and alternative futures and to make better decisions.

2. Regional Climate Modelling

The large-scale, whole-of-Earth climate modelling described above allows us to visualize trends on the continental or other large regional scale, but does not allow for highly detailed descriptions of local or regional climate changes. More granular regional models exist that scale down the global models to provide more detailed knowledge about climate impacts over a limited geographic area. Regional Climate Models (RCMs) can be run for a particular area and, over time, the simulations they produce generate regional climate projections.

CORDEX, the Coordinated Regional Climate Downscaling Experiment, is a global regional climate modelling platform coordinated by the IPCC. Global partners, including the IJC and its boards, use and contribute to the regional downscale climate models in CORDEX.

3. Further Reading

For further reading on IPCC climate models, here are some good resources:

CORDEX, the Coordinated Regional Climate Downscaling Experiment, 2020. https://cordex.org/

Hausfather, Z. for Carbon Brief, August 2019: Explainer: The high-emissions 'RCP8.5' global warming scenario. https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario

IPCC, 2013. Climate Change 2013: The Physical Science Basis, the Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar5/wg1/

IPCC Data Distribution Centre, November 2019. Scenario Process for AR5. https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/scenario_overview.html

Wayne, G.P. for Skeptical Science, August 2013: The Beginner's Guide to Representative Concentration Pathways. https://skepticalscience.com/rcp.php