## Addendum to ICM Problem D - Great Lakes Water Problem

## Additional Background Information

The levels of the Great Lakes of the United States and Canada tend to follow a rhythm: In the spring, snow and ice melt and drain into the lakes. By early summer, water levels are usually at their highest, then the warmth of the surface water results in increased evaporation, and by autumn water levels fall. Winter ice covers some parts of the lakes and rivers, and the degree of coverage and ice dams can create disruptions in these normal patterns. Though naturally influenced by precipitation and evaporation, lake levels are also greatly affected by the latency effects of moving water. Water that enters Lake Superior, flows to the east through the other lakes, and then into the St. Lawrence River before entering the Atlantic Ocean. This flow might take many years.

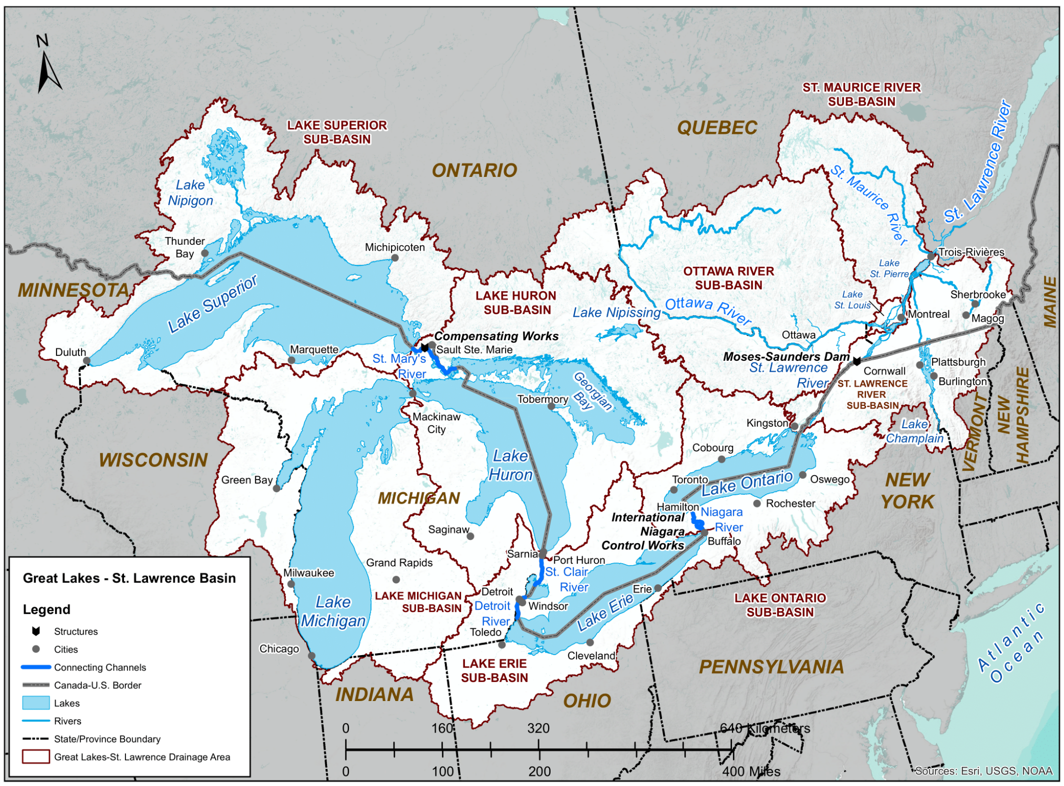


**Figure 1. Great Lakes Basin**[1]

The lake levels are influenced by dams that control the outflows from lakes Superior and Ontario. (See figures.) An international governmental agency, the International Joint Commission (IJC), regulates outflows in an effort to balance how water levels affect stakeholder interests in Canada and the United States. The goal is challenging, given environmental conditions, climate change, and just two primary water-level control mechanisms on the major flow path of the system – the Compensating Works (Soo Locks) at Sault Ste. Marie and the Moses-Saunders Dam at Cornwall. By means of control algorithms based on a vast amount of data on lakes' input and output flows, the IJC seeks to set dam outflows to keep the lake levels within a specific range, near their long-term averages.

Considerable data is available for the inflows, outflows, and water levels for the lakes.
***<u>See Problem D Great Lakes excel spreadsheet for some background data</u>.***

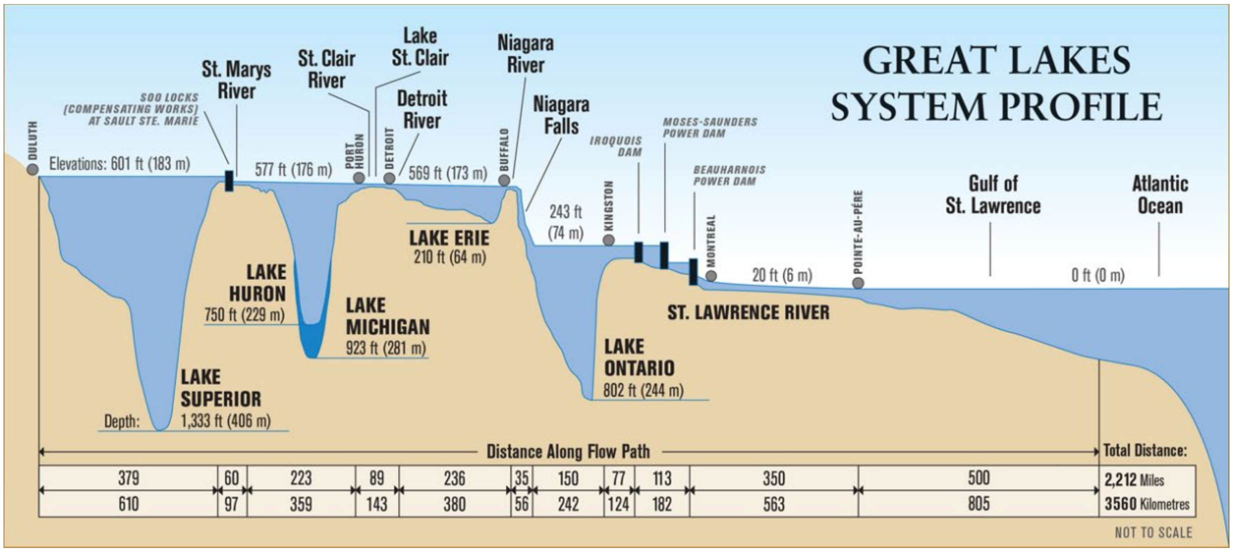


**Figure 2. Great Lakes System Profile**[2]

Additional databases (see the Reference List in the data file) contain past water levels under various water-level management protocols, at finer time intervals, at additional observation stations, and with other types of input factors, including levels of other lakes and reservoirs, flow rates, snowpack, forecasts, ice content, water temperatures, evaporation rates, and weather.

**Lake Ontario Sub-Problem**

A particular subproblem is control of the level of Lake Ontario. Use of an algorithm for its outflow along the St. Lawrence River via the Moses Saunders Dam, called Plan 2014, became controversial when record-high lake levels occurred in 2017 and again in 2019. Some of the stakeholders are.

1) shipping companies, which want high, static (no current) water in the St Lawrence River.
2) people who manage shipping docks or live near Montreal harbor, who want water in the river to be steady and low.
3) environmentalists, who want seasonal high high-water levels and low low-water levels on Lake Ontario to help maintain the habitat for species to thrive and clean out static bays and tributaries.
4) property owners on the shores of Lake Ontario, who want mid-level, steady water levels.
5) recreational boaters and fishing boats on Lake Ontario, who use facilities such as marinas and boat-launch ramps and, like the property owners, want mid-level, steady water levels; and
6) hydro-power generation companies would like more control over water levels to use high-level water as a storage system to maximize flows during high energy usage periods. Run-of-river power systems often have only a little control over water level.

Additionally, perhaps the most exposed major urban center in the entire Great Lakes system is Montreal, Canada, which is affected by the flows of both the St. Lawrence and Ottawa Rivers and their tributaries. As an example of nature's effects despite humans trying to control water flow, the Ottawa River has 50 major dams and hydro-electric generating stations and links with 13 large reservoirs. These reservoirs store a significant portion of the spring runoff to reduce downstream flooding, mainly for Montreal harbor. The background data file contains historical Ottawa River flow.

Some of the potential factors for the subproblem are:

1) current level of Lake Ontario and time of year.
2) flow of the Ottawa River and time of year.
3) snowpack and forecast for the flow of the Ottawa River.
4) water level, current rate, and amount of ice on the St. Lawrence River downstream from the Moses-Saunders Dam.
5) reservoir level along the Ottawa River.
6) water levels of the other four Great Lakes (eventual inputs to Lake Ontario); and
7) water temperature, evaporation rates, and weather data.

It is probable that every stakeholder will have the situation that they prefer at some time during the year, but it is very likely they will not be happy all year long. The algorithm of Plan 2014 is based on trigger points and thresholds for Lake Ontario levels, Ottawa River flow, and Montreal Harbor level, but may not adequately take into account other factors like the amount of snowpack in northern Canada, reservoir levels, and the water levels of the other Great Lakes. If trigger points are too high or do not take into account all the available data, the plan may be inflexible or unsatisfactory.

**References:**

**[1]** Great Lakes – St. Lawrence River Basin from IJC https://ijc.org/en/watersheds/great-lakes

**[2]** Great Lakes Profile from Vivid Maps https://vividmaps.com/great-lakes-profile/

**Data Examples**

These are possible sources for data. Some of which were used to populate the *Problem_D_Great_Lakes.xlsx* data set.

1. Current Water Levels and Flows as Monitored by the International Joint Commission: Water Levels and Flows. (2023). Retrieved from International Joint Commission : https://ijc.org/en/what/water-levels

2. Current Perspectives on Lake Ontario-St. Lawrence River: Water Levels. (2023). Retrieved from International Lake Ontario - St. Lawrence River Board: https://ijc.org/en/loslrb/watershed/water-levels

3. Reports on Great Lakes including water levels, forecasts, basin conditions and outflows: Great Lakes Information. (2023). Retrieved from US Corps of Engineers Detroit District: https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Information.aspx#ICG_ETH_22302

4. Historic Water Levels at all observation stations within the Great Lakes Basin: Monitoring Network and Observations. (2023). Retrieved from NOAA - Great Lakes Environmental Research Laboratory: https://www.glerl.noaa.gov/data/wlevels/#monitoringNetwork and https://tidesandcurrents.noaa.gov/

5. Historic Hydrologic Data such as evaporation, precipitation, and runoff for all Lakes: Great Lakes Hydrologic Data. (2023). Retrieved from NOAA - Great Lakes Environmental Research Laboratory: https://www.glerl.noaa.gov/ahps/mnth-hydro.html

6. Historic Water Levels and Hydrologic Data such as flows, forecasts, wind, ice, and temperatures: Great Lakes Water Data and Related Information. (2023). Retrieved from Environment and Climate Change Canada: https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/great-lakes-levels-related-data.html

7. Historic Products and Datasets such as water levels and flow: Products and Datasets. (2023). Retrieved from Great Lakes Coordinating Committee: https://www.greatlakescc.org/en/coordinating-committee-products-and-datasets/

8. Historic Water Use Data such as withdrawals, diversions and consumption: Great Lakes Regional Water Use Database. (2023). Retrieved from Great Lakes Commission: https://waterusedata.glc.org/index.php

9. Historic Perspectives specific to Ottawa River: Ottawa River at Carillon Station. (2023). Retrieved from Ottawa River Regulational Planning Board: https://ottawariver.ca/information/historical-water-level-streamflow-summary/ottawa-river-at-carillon/

10. Historic Products and Datasets for the USGS National Water Dashboard: Products and Datasets. (2023). Retrieved from United States Geologic Services: https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default