St. Lawrence River – Forecasted Drying Effects
Water Level and Flow Control Project

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F Pierre Gingras
Hydro-Québec (retired)
Canadian Academy of Engineers, Canadian Society for Senior Engineers

Abstract

Climate change experts forecast a 20 to 30% depletion of the flow of the St-Lawrence River by the end of the century. The St-Lawrence Seaway operation and the water intake of several towns are often in a critical condition as are some 18,000 kilometers of shoreline and over 1,200 square kilometers of precious wetlands.

The St-Lawrence River basin can be seen as a cascade of eight lakes four of which are already managed by dams. Building four additional control works would make it possible to manage the water levels independently from the flow available and mitigate the climate change effect.

Keywords: CCTC2015, St. Lawrence River Drying, St. Lawrence River flow control

Résumé

Les experts en changements climatiques anticipent une réduction de 20 à 30 % des apports hydriques au niveau des Grands Lacs. L'exploitation de la Voie Maritime est souvent critique de même que l'approvisionnement en eau potable des populations et l'état de 18,000 kilomètres de rives et de 1,200 kilomètres carrés de milieux humides.

L'ensemble du bassin du Saint-Laurent constitue une cascade de huit réservoirs dont quatre sont déjà contrôlés par des ouvrages. L'ajout de quatre ouvrages permettrait de gérer les niveaux indépendamment des débits et s'avèrerait la solution au changement climatique.

Mots clés : CCTC2015, assèchement du fleuve St. Laurent, gestion des niveaux d'eau du fleuve St. Laurent

1. Current and Anticipated Situations

1.1 Advance climate change

Water level management in different parts of the St. Lawrence River basin is presently made, although only partially, by flow management of the control works at Sault Ste-Marie, Niagara-Welland, Cornwall and Beauharnois. This partial control is becoming increasingly inadequate since according to the forecasts of climate change studies, experts predict a drying effect of up to 20 to 30% by the end of the century in the Great Lakes region. Environment Canada estimates that the reduction of the flows then available will be 24%.[1]

1.2 Issues at stake

The challenges of this situation concern the protection of the environment of more than 18,000 kilometers of shoreline as well as more than a thousand square kilometers of rich wetlands. Furthermore, there is an increasing difficulty about supplying water to municipalities along the river where water intakes are often limited, if not almost made dry, because of the low water levels. Even navigation is affected.

Therefore, it becomes obvious that the amount of water being released occasionally (wasted?) for the sole purpose of maintaining downstream water levels is increasingly limited while the population's needs are growing. Finally, it has already become a serious concern that at times significant volumes of flood water are lost.

2. Water Management Project for the St. Lawrence River Basin

2.1 Global view of the St. Lawrence river basin

It is possible to design the whole of the St. Lawrence River basin as a cascade of eight or nine bodies of water. Flows and water levels are already controlled on four of them.

This cascade of eight sub-basins, lakes and reservoirs, thus covers, from upstream, Lake Superior which is already managed by the works of Sault Ste-Marie, as well as lakes Michigan and Huron, which exhibit critical dewatering situations. Further downstream, Lake Erie, Lake Ontario and Lake St. Francois are controlled by structures located respectively in Welland-Niagara, Cornwall and Beauharnois-Valleyfield.

Further downstream, the worst consequences are already being felt in the part of the St. Lawrence River between Montreal and Quebec. The natural river bed is generally shallow with the exception of a narrow channel ten to 15 meters deep, which implies that such a reduced flow of 20-30% could restrict the width of the river by 30 to 50%.

2.2 Water management project: principle

The solution could be to make independent management of water levels and flow rates and that, by completing the series of dams needed to manage the flows and levels of all water bodies in the basin of the St. Lawrence, an alternative never really considered until now.

2.3 Project objectives

Having a water control structure for each of the lakes and reservoirs of the St. Lawrence River watershed will ensure that the following objectives are met:

1. Save and use the flood waters;
2. Ensure the availability of drinking water for 200 million people;
3. Preserve 18,000 kilometers of shoreline;
4. Preserve more than 1,200 square kilometers of wetlands;
5. Ensure the sustainability of the St-Lawrence Seaway;
6. Open the Port of Montreal to ships of great capacity, possibly 75 to 100 000 T;
7. Maintain the level of exploitation of hydroelectric power plants and increase productivity in periods of high demand, adding, with a reserve of water on lakes

Michigan and Huron, a production of additional energy of some 13 TWh / year , ensuring an annual income of some 2 to 2.4 billion dollars;
8. Create four strategic inter-shore links on each of the new structures;
9. Self-finance the project at first, and then generate stable and significant revenue in energy production on a long term basis..

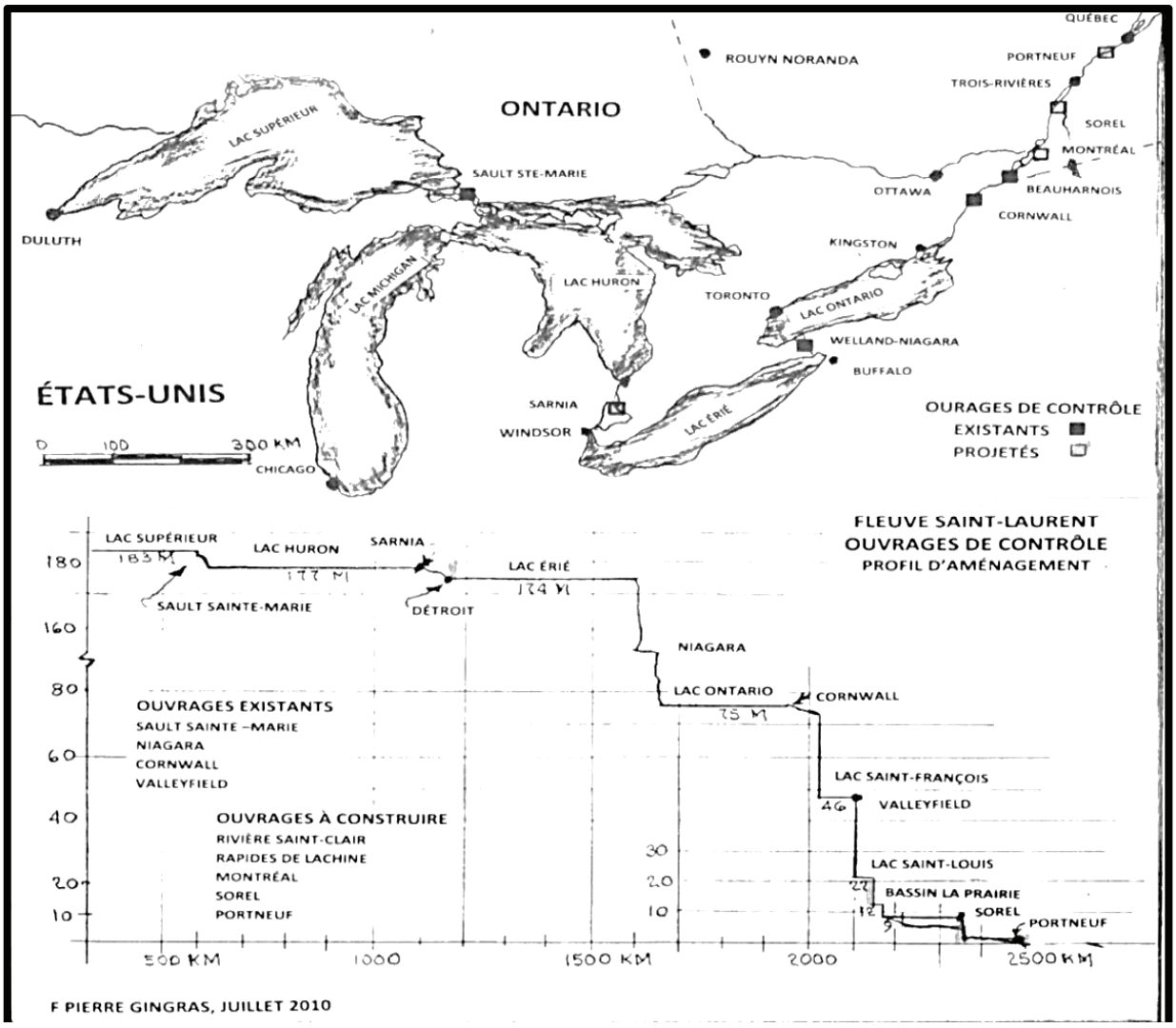

Figure 1 St. Lawrence River Watershed

Completing the control structures seems appropriate to manage first the water levels and flows in the major Michigan and Huron lakes. In addition, it is also necessary to manage the water flow at the Lachine Rapids to preserve Lake St. Louis, then at Terre des Hommes for the Laprairie Basin and finally, in front of Sorel and Portneuf, to save the environment of that portion of 250 kilometers of the St. Lawrence River between the cities of Montreal and Quebec City.

These measures will not only save the operation of the Seaway but will also increase appreciably the hydroelectric energy of the St. Lawrence basin to the point that a few years will repay the investment of some five billion dollars required by the four dams' project.

The oceans contain 97% of the water available on earth and glaciers 2%, leaving only 1% of water for all living beings, from men to vegetation; hence the urgency to address climate change using these waters rather than leaving them getting lost at sea.

2.4 Energy production

A control dam located just downstream of Sarnia would make possible the impounding of spring and fall floodwaters of the St. Clair River, facing Sarnia. Here, with an average flow of 4,800 CMS (cubic meter/second), the annual water volume is about 160 cubic kilometers of water, with a proportion of 50% or 80 cubic kilometers flow during floods. To impound 50% of the reserve flood flows represents a volume of water of the order of 40 to 45 cubic kilometers, which corresponds to a water level difference of 35 centimeters on lakes Michigan and Huron; a water volume now completely lost, even causing damages.

This new water reserve would increase the energy produced during periods of high energy demand, and restore the level of lakes Michigan and Huron in two or three years. The amount of energy in reserve would be about 13 TWh/year, equivalent to the production of two new nuclear plants of 15 billion of dollars in construction costs alone. Finally, this same volume of water now being lost could meet the needs of a population of 200 million people.

The value of this energy, from 8 cents/kWh in Quebec to 18 cents/kWh or more in Ontario is already of the order of a $ 2.4 billion, given the annual energy block 13 TWh

Installation	Height	TWh / year
Niagara	92.8 m.	7.00 (shared 50-50 Canada - United States)
Cornwall	27.2	2.57
Beauharnois	22.1	2.00
		Total 13.36 TWh / year

3. Description of Required Works

3.1 General characteristics of the works

The conceptual study of the Portneuf sites, Sorel and the Lachine Rapids reveals that it is technically and economically very feasible to achieve these control structures despite the scale of the St. Lawrence River. Optimizing will be performed during the project phase studies for aspects such as the passage of ice and accommodation of wildlife, for which multiple steps are already presumed here.

The bathymetry of the St. Lawrence River, with a width of 2,500 to 3,000 m at the sites of the structures, shows this river bed as being a few meters deep except for a deep channel more than a dozen meters deep and 500 to 700 meters wide. Already, it is clear that the reduction in anticipated flow rates of the order of 20 to 30%, would dry up the river bed in an even larger significant proportion of its width.

The proposed works aim to maintain the historical water levels and, therefore, the control works are of a small height of the order of three meters to which is added a two meters crest, with a total overall water level increase in the range of 5 to 6 meters. A first step is to make a first spillway on one side of the river, with a dozen passes, in a shallow area, to clear a bypass section. Then again, a second

spillway on the other side, still in shallow water, to limit the scope of the cofferdams, but this time including the navigation lock. It is only then that the deep center channel is finally closed with a fill volume.

Together, the structures represent a rockfill volume in the order of 2 to 3 million cubic meters and concreting in the order of 4 to 500,000 cubic meters. A significant portion of the cost is made up of management fees, financing and inflation for those long projects of six to seven years duration.

3.2 Technical Description of the control dams

3.2.1 Project of Portneuf - Deschambault

The first control dam of the development steps of the St. Lawrence River basin, at Portneuf, is located about 1.5 km upstream from the village of that name, with an upstream water level corresponding to the maximum tide level, which would not cause additional shore flooding. With this work, we finally safeguard the precious wetlands of Saint-Pierre lake, the most important of the entire St. Lawrence Valley.

At a cost of $ 1.1 billion at the end of 2022, including a 30% fee to cover inflation and financing, at a cost of 710 million if we could achieve it instantly, the proposed 3.2 kilometers wide dam comprises two spillways for a set of 30 passes of 10 by 14 meters wide, allowing a discharge capacity of 27,000 CMS. A lock of 350 meters long, 40 meters wide and 14 meters deep is incorporated on the left bank structures.

Concrete structures are located on the shallow areas of the riverbed to reduce the cofferdams to a minimum while the excavated material is immediately reused for the construction of dams. The sections of rockfill dams, of a total length of 2,500 meters, are of a volume of 2.5 million cubic meters, due to the low average depth of the river. The total volume of concrete for the project is 400,000 cubic meters.

On the crest, a road can easily be added to join the two river banks. This “bridge” would add a new access road to the south shore, halfway between the cities of Trois-Rivières and Quebec. The excess excavated material could be used to build a port some kilometres away from the Deschambault aluminum smelter.

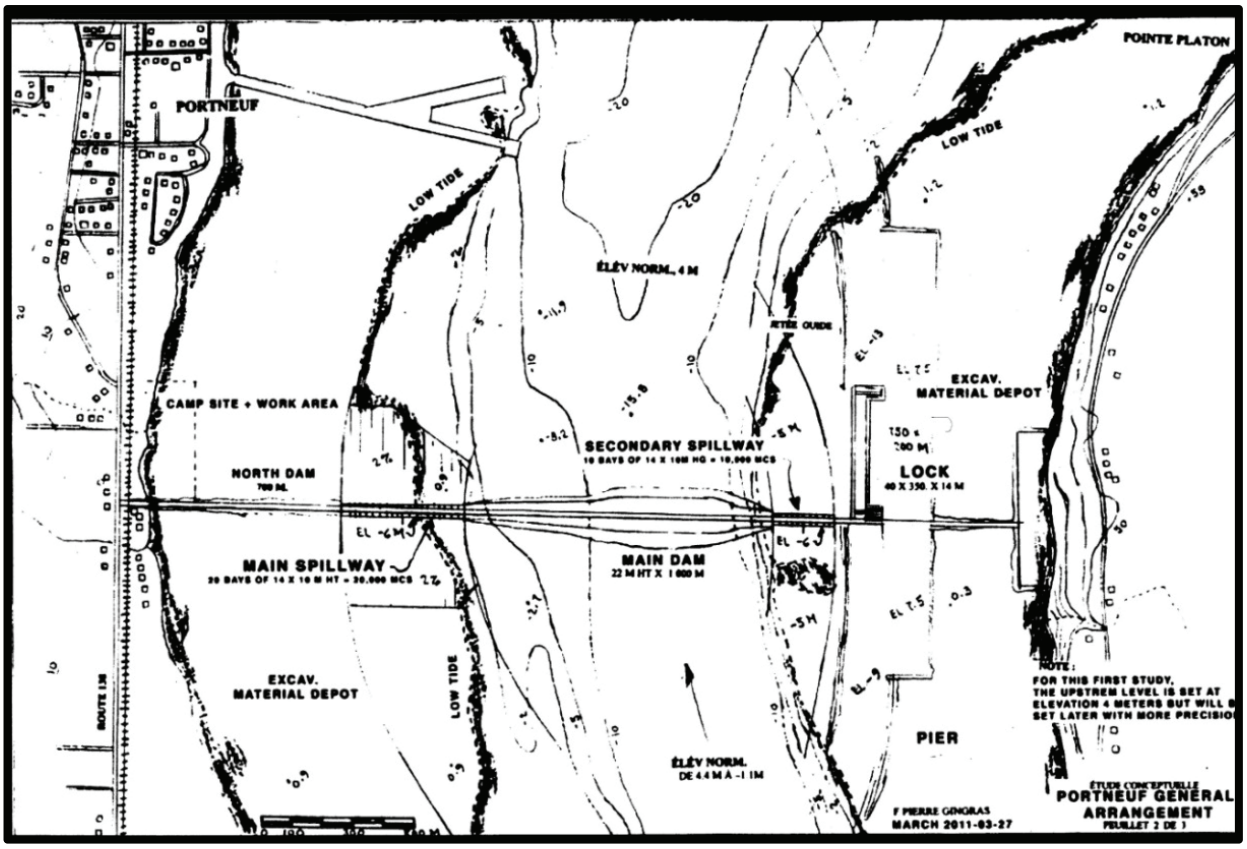

Figure 2 Control dam for Portneuf – General layout

3.2.2 Project of Sorel

The same design criteria apply to the Sorel project to a dam of 2.4 km in length, incorporating a second navigation lock of the same size. The forebay level would be set approximately at the level of extreme floods, or the elevation 9 meters, with an adjustable level for seasonal needs of the environment. Again, this prevents any flooding of the banks.

The two spillways are equipped with a total of 36 gates of 14 meters by 12 meters height. The works need 440,000 cubic meters of concrete. The various rockfill embankment sections have a total length of 1,380 meters and a volume of 3.96 million cubic meters. Obviously, a four-lane road connects Highway 30, located 500 meters east to Highway 40 on the north shore, located 3 kilometers away, making Sorel a major road junction. The two ferries currently in service would no longer be required.

Again, the works can easily be designed so as to constitute almost a two kilometers deep water dock with maneuvering areas required. The project cost is estimated at 1,167 million dollars for commissioning in 2024, or $ 896 million in 2013 as an instant cost when we ignore the effects of inflation and project financing costs during construction.

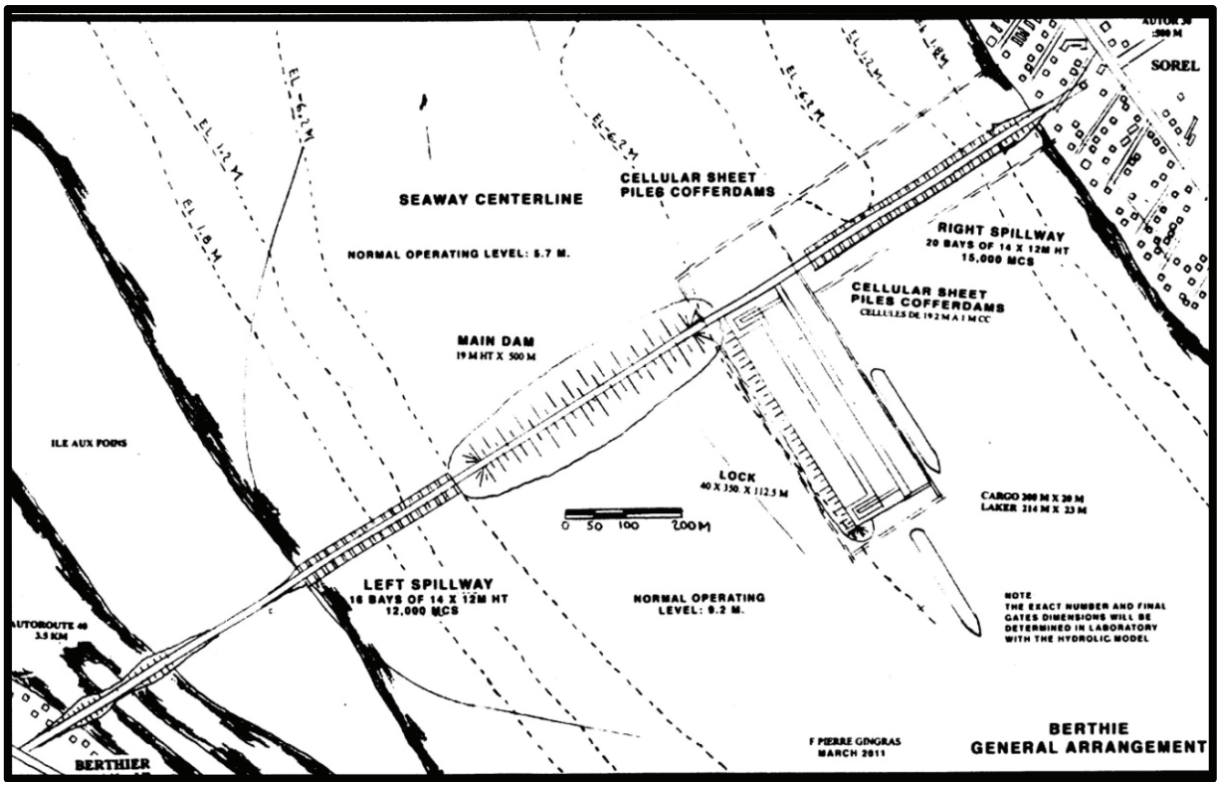

Figure 3 Control dam of Sorel-Berthier - General layout

3.2.3 Project of the Laprairie basin

A crest and two spillways could theoretically be built in front of Habitat-67 to safeguard the water level of the Laprairie Basin. Height difference there would only be of the order of one meter. Other alternatives will also need to be studied, including enhancement of the Laprairie Basin to the elevation 12.6 meters, level of the Seaway, in order to open the dike of the Seaway and give access to the river to the communities on the south shore of Montreal. For now, the works of Laprairie basin are not included in the overall project as they seem neither justifiable nor necessary to meet the project objectives. Moreover, none of the river banks of the Laprairie Basin is in its natural state.

3.2.4 Project of the Lachine Rapids

The forecasted flow reduction in the order of 20 to 30% would result in draining Lake St. Louis about 1.5 meters, which would be disastrous. To safeguard the natural level of Lake St. Louis to the elevation 21.18 m and protect the river banks from Beauharnois to Dorval and Kahnawake, the construction of a weir or crest is proposed which would be located about two kilometers downstream from the Mercier Bridge, where the difference in height of two meters is sufficient to discharge the normal flow of the river over the weir. The dam is also located two kilometers upstream from the popular part of the Lachine Rapids. A permanent bridge is required to be build to service the works. This bridge could then be opened to the public and provide access to the south shore, thus providing relief for the old Mercier Bridge.

The discharge capacity of this crest being 7,200 CMS, the passage of the spring floods estimated at 16,000 CMS, will still require building a spillway on the south shore with a capacity of 8,800 CMS.

This spillway is equipped with 11 gates 14 m x 8 m of height. Note that if the other projects required for the Great Lakes are built, these floods will be less in Quebec.

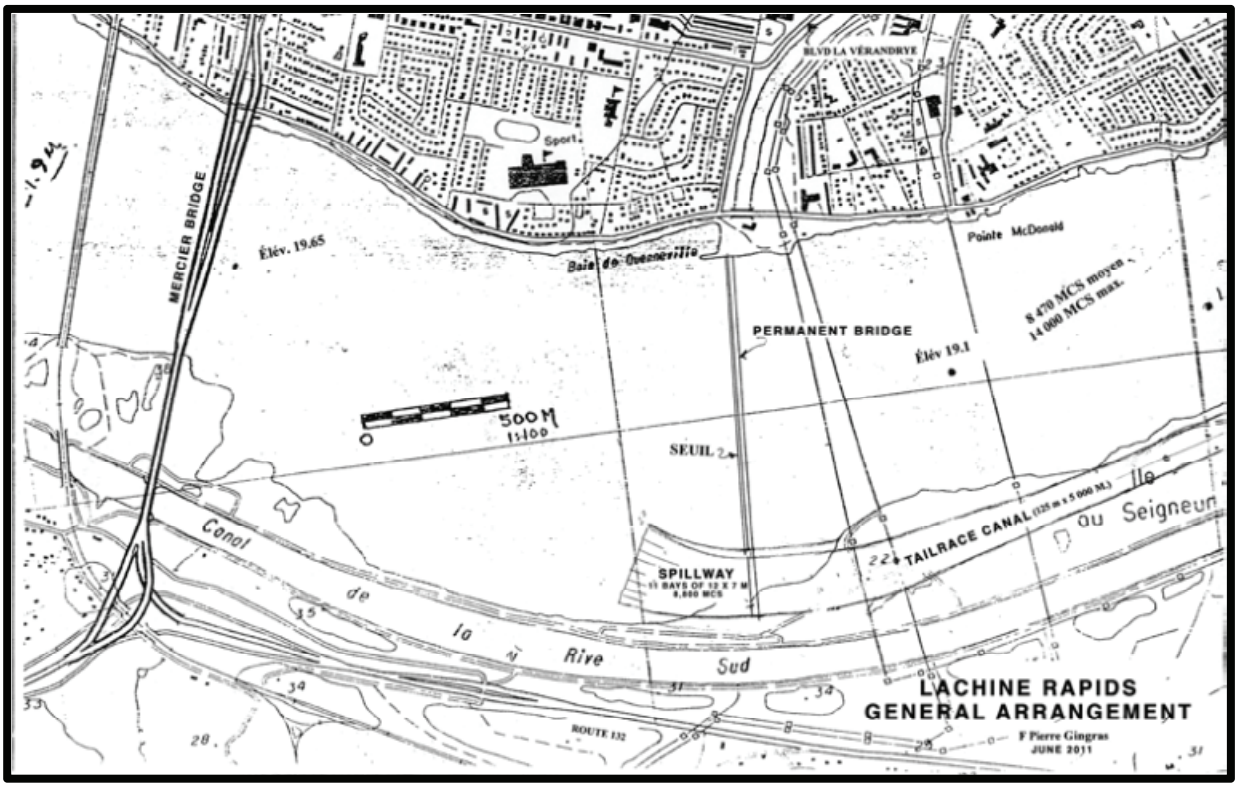

Figure 4 Lachine Rapids - General arrangement

An important tailrace channel will be necessary for the operation of the spillway, 5 km in length and 125 meters wide, with an excavation volume of 9.5 million cubic meters. This material will be used to enhance and develop the bank of the Seaway dike. This dike, 25 km in length, could then receive urban development of hundreds of thousands of people all along the south shore. The cost of the project is estimated at 857 million dollars at the end of the construction period in the year 2021.

3.2.5 The project of Sarnia

This brief study does not detail the design of the control structure needed for lakes Michigan and Huron because of the lack of sufficiently detailed technical data on the topography and geology of the site. With a drop height of three meters in height, it is reasonable to assume that the dam would be similar to the proposed works for the sites of Sorel and Portneuf. The implantation axis would be in the area of the City of Lambton.

This project, highly recommended by the "US Corps of Engineers" in 1964, was originally scheduled to be included in all structures of the St. Lawrence Seaway. It is assumed that at the time the project was postponed partly because of the then low value of the water. The current decreasing water levels of lakes Michigan and Huron, about 24 inches below its historical normal level, brings back the project to the agenda. In addition, the flow of the St. Clair River is still the same despite the

lowering of the level of Lake Huron, hence the probability of erosion at the outlet threshold of Lake Huron.

Once under control, these lakes Huron and Michigan, totalling an area of 114,000 square kilometers, would easily manage the entire flood water volume. The growing current decrease of about 60 cm or 24 inches, and possibly an anticipated 1.5 meters by the end of the century, is an ecological, community and economic disaster that stretches from Chicago to Georgian Bay !

4 Results and Achievement of Project Objectives

4.1 Project deliverables

To make independent the management of the flows from the water levels of the basins that make up the whole of the St. Lawrence River basin, four or five additional dams would give a complete and totally efficient control of the whole watershed of the St-Lawrence River. This would safeguard the environment of more than 18,000 kilometers of shoreline and some 1,000 to 1,200 square kilometers of precious wetlands throughout the basin. It would stop the repeated "wasting" of the already low volumes of water in reserve in Ontario and Lake Superior with the sole aim to temporarily achieve a level of downstream water, while using efficiently each single drop of water available.

On the other hand, avoiding the lowering of water levels possibly one to two meters, depending on the river sectors, the project assures forever the operation and profitability of the Seaway. Moreover, it would possibly open the Port of Montreal to ships of about 75,000 to 100,000 tons, allowing an almost unlimited economic development, creating thousands of jobs there. This could boost the Montreal petrochemical industry in the event of the likely development of the oil potential of the Gulf of Saint Lawrence or allowing oil export from Western Canada.

Finally, the effect of drainage and erosion of the river bed due in part to the excavation of the Seaway would be virtually eliminated by this new control of the water levels and flows, resulting in significant maintenance savings for the Seaway due to erosion currents becoming slower.

The study highlights the quality of the original design of the St.-Lawrence Seaway since it is relatively easy, sixty years later, to complete the works necessary to mitigate climate change effects, protecting and enhancing the environment, make optimal use of water resources and finally, increase opportunities to develop navigation.

Finally, with the independent management of levels and flows, future water needs of the people of the entire St.-Lawrence River basin could be met without any serious environmental consequences for populations located downstream, in the Quebec province. A flow of 1,000 CMS water could largely provide for the needs of the populations in the Great Lakes and Midwest, allowing a generous consumption of 400 gallons per day for a population of around 200 million people.

5 Conclusion: A Profitable and Sustainable Project, Independent of Climate Change Effects

Compared to the environmental and economic benefits of the project, an investment of five billion dollars, recoverable in the following years with the generated additional production of electrical energy, is recommended for the realization of this project which would achieve effective control of the waters for the entire watershed of the St. Lawrence River.

Major objectives would be to impound and make profitable the flood waters; to forever ensure the availability of drinking water for a population that could reach 200 million people including the Midwest; to safeguard 18,000 kilometers of shoreline and more than 1,200 square kilometers of wetlands and to create four strategic “inter-relationship bridges”.

The project sustains and even expands the St-Lawrence Seaway possibly opening the Port of Montreal to ships of greater capacity, possibly 75 to 100,000 T and, so, bringing a significant boost to the overall economy of the St. Lawrence River watershed from Duluth to Québec City, via Chicago, Sarnia, Toronto, Detroit and many other cities.

Adding 13 TWh of energy production to existing power stations installed on the St. Lawrence River, is the equivalent of the production of two nuclear power plants of fifteen million dollars construction cost alone, excluding a heavy operation cost and a very high demolition cost about thirty years later.

The profitability of the project at a cost of about $ 5 billion, including the control works of Portneuf, Sorel, Lachine Rapids and Sarnia, seems obvious enough to conduct further studies on the part of the Government of Canada that has the complete responsibility of the project.

6 References

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7. Biography

Pierre F. Gingras worked at Hydro-Québec from 1966 to 1997 as chief planning and cost engineer for the construction of hydroelectric projects, working on the Manic-Outardes complex, James Bay complex and major rehabilitation works. He participated in some 200 site studies.

At his retirement, he was involved in studies, research and projects with the Economic Institute of Montreal, the Canadian Academy of Engineering and the Canadian Society for Senior Engineers. Since retired, over the years, Mr. Gingras has made several conceptual studies including this project about the management of the St. Lawrence waters in view of climate change, on the proposed 735 kV Canadian Transport Network and the Concept Studies for the hydro development of the MacKenzie and Great Whale Rivers.