International Missisquoi Bay Task Force

Final report to the International Joint Commission

October 20, 2004

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Executive Summary

On June 15, 2004, the International Joint Commission (IJC) appointed the International Missisquoi Bay Task Force. The four-member Task Force, with equal representation from the United States and Canada, was asked to examine and report to the IJC on questions regarding possible transboundary implications of the Missisquoi Bay Bridge project.

The Task Force proceeded to review existing available information. They carried out a scientific and technical review of the hydrodynamic modeling previously completed for the state of Vermont. With the IJC, they also held public information meetings in both Quebec and Vermont to hear the concerns of the public. The Task Force found general support for the construction of the new bridge itself.

With respect to the causeway, the Task Force concluded that it did not act as a dam but rather as an obstacle that changes water flow and circulation patterns in the area near the causeway.

Levels of phosphorus are very high in Missisquoi Bay. Over the past five years (1999-2003) they have averaged 0.045 mg/l in Missisquoi Bay and 0.018 mg/l in the Northeast Arm. For comparison, the water quality criteria for phosphorus endorsed by the governments of Vermont, Quebec and New York are 0.025 mg/l for Missisquoi Bay and 0.014 mg/l for the Northeast Arm. The Task Force concluded that the presence of the causeway changes the distribution pattern of phosphorus concentrations over a few miles largely in the U.S. portion of the bay. Modeling indicated that the presence of the causeway leads to a 1% increase in phosphorus concentration and sedimentation rate on the Missisquoi bay side. Removal of the causeway would redistribute the phosphorus but would not remove any phosphorus from the overall system. This must be done by reduction of inputs of phosphorus into the bay. The presence of the causeway leads to a very small but finite amount of pollution in Canada and in the United States but it is not the fundamental cause of the important water quality and health problems (associated with blue green algae) experienced by local residents.

The Task Force offers the following recommendations for considerations by the IJC Commissioners: (1) rely on the scientific findings, (2) encourage ongoing and planned actions to reduce phosphorus loading to the bay from the watershed (3) take into account other public considerations when determining their recommendations to governments about the project, (4) encourage further research in the three areas where information gaps were identified: turtle biology, the relationship between blue green algae blooms and phosphorus levels and the impact of multiple causeway removals.

Section 1 Background

Creation of the Task Force and Initial charge

The International Joint Commission (IJC) is an international Canada-United States organization established by the Boundary Waters Treaty of 1909. It assists the governments in managing waters along the border for the benefit of both countries in a variety of ways including examining issues referred to it by the two federal governments.

On June 15th, 2004, the IJC appointed the International Missisquoi Bay Task Force. The four-member Task Force, with equal representation from the United States and Canada, was asked to examine and report to the IJC on questions regarding possible transboundary implications of the Missisquoi Bay Bridge, which crosses the waters connecting Missisquoi Bay with the rest of Lake Champlain in the state of Vermont.

By letters dated May 7th, 2004 and May 11th, 2004, respectively, the Canadian and United States federal governments asked the IJC to review plans by the state of Vermont to modernize the Missisquoi Bay Bridge Bridge, involving the partial removal of the existing causeway, and to provide advice on whether this complies with the terms of the Boundary Waters Treaty of 1909 as concerns causing pollution to the injury of health or property in Canada or the United States. The residents of the region have expressed great concern with regards to the degradation of lake water quality and the effect on people's health.

The request from governments was made as a reference under Article IX of the Boundary Waters Treaty. While further discussions between the IJC and the governments may refine the issues to be examined, the governments asked that the IJC review consider the following matters:

1. Whether the original causeway in the United States affects water levels/flows in Canada;
2. Whether the original causeway in the United States causes pollution to the injury of health or property in Canada;
3. Whether the removal of the original causeway in the United States might cause pollution to the injury of health or property in the United States; and
4. Whether the proposed project in the United States will cause pollution to the injury of health or property in Canada.

Members of the Task Force acted in their personal and professional capacities and not as representatives of their countries, agencies, organizations, or other affiliations. The Co-Chairs were responsible for organizing and executing the work of the Task Force, and for coordinating with and reporting to the IJC. In addressing issues raised by the Governments, the Task Force coordinated its investigations with organizations in both countries to access the full breadth of available information. It evaluated and analyzed available information regarding the Missisquoi Bay Bridge project, and informed the Commission of any additional information necessary to address pertinent issues.

The IJC and Task Force agreed that public outreach and consultation was important. The Task Force when necessary coordinated such matters with the IJC.

The Task Force was asked to submit its report to the Commission in early fall 2004. The final report should contain the Task Force's findings and conclusions regarding the questions posed by governments based upon available information and public input. The IJC would hold public hearings on this matter in both Quebec and Vermont so that all interested parties could provide information and views regarding the project.

Task Force Work Plan

The Task Force met with the IJC Commissioners on June 14th and 15th 2004 to discuss the work plan. The Task Force and the IJC recognized that scientific work had already been completed that provided information relevant to the four questions in the reference. A two-phase study by Applied Science Associates, Inc. (ASA) completed for the State of Vermont in 1997 included a hydrodynamic and water quality modeling analysis of the effects of causeway removal on Missisquoi Bay. These studies were part of the technical information used by the Vermont Agency of Natural Resources (VANR) in issuing permits for the bridge reconstruction project that limited the amount of the existing causeway that could be removed to a 100 meter (330 ft) section. The Task Force decided that a key part of its work would be to determine whether these findings were valid and well-supported by the analysis, or whether corrections or additional information were needed.

Task Force members subsequently identified scientific and technical reviewers of the hydrodynamic studies. Three reviewers or groups of reviewers were identified respectively by Environment Canada and the United States Environmental Protection Agency (EPA). Environment Quebec reviewers were asked either to provide new comments or to update earlier opinions that had already been provided with respect to the modelling studies. Since the studies were completed for the State of Vermont and already evaluated by the VANR in collaboration with a Project Advisory Committee (PAC), the Task Force member from Vermont did not participate in the selection of additional reviewers, to ensure that the review process provided new technical perspectives.

The following questions were sent out to reviewers:

1. Are the hydrodynamic and water quality models appropriate to determine flow/water levels (circulation), water quality effects of causeway removal?
2. Are the results/recommendations valid?
3. Is there sufficient technical information to help in decision making of this magnitude? If not, what are major information needs?

The request was accompanied by three key reports:

- Applied Science Associates, 1997. Hydrodynamic modeling of Missisquoi Bay in Lake Champlain[1].
- Applied Science Associates, 1997. Missisquoi Bay field study and hydrodynamic model verification[2].
- Vermont Agency of Natural Resources, July 16 2003. Water Quality Effects of the Missisquoi Bay Bridge. A summary of research findings as the basis for the Agency's position on causeway removal and water quality[3].

The Task Force agreed to hold public information sessions with the IJC in both Quebec and Vermont on August 25th and 26th respectively. The purpose of these informational meetings was to explain to the public the work that the IJC and the Task Force was doing to assess the transboundary water quality effects of the Missisquoi Bay causeway and also to listen to concerns that the public wanted to express.

Description of Missisquoi Bay

Missisquoi Bay is a shallow embayment located in the northeast corner of Lake Champlain on each side of the boundary between the State of Vermont in the United States and the Province of Quebec in Canada. The bay encompasses an area of approximately 77.5 km^2 (19,150 ac) and has a maximum depth of approximately 4 m (14 ft). Major tributaries entering the bay from its 3,105 km^2 (767, 246 ac) watershed are the Missisquoi, Pike and Rock Rivers.

The Missisquoi Bay watershed is shared between the Province of Quebec (42% of the watershed area) and the State of Vermont (58% of the watershed area). Overall, the land use in the Missisquoi Bay watershed is 62% forested, 25% agricultural, and 5% urban. The detailed distribution of land use in the watershed is given in Appendix 1.

Missisquoi Bay is an important vacation area for the region. Water quality is important to many people for drinking water (municipalities of Bedford and St Armand in Philipsburgh sector) and to businesses related to agriculture, recreation and tourism.

The quality of the bay has deteriorated over time. Citizens speak of degradation in bottom quality, changes in sediment distribution and aquatic vegetation growth. They mention that the bay bottom that was primarily sand with vegetation clumps with a series of sandy beaches throughout the bay is now silt and organic material and that many areas are now filled with vegetation. Several clean cobble areas in shallow water used for fish habitat (walleye) no longer exist.

A potential cause of this degradation is increased nutrient and sediment loading into the bay from rivers and runoff. Missisquoi Bay and the Northeast Arm of Lake Champlain are both listed as impaired waters in Vermont (swimming, recreation, water supply). The pollutants of concern for Missisquoi Bay are phosphorus and mercury. Based on water quality monitoring data collected by the Lake Champlain Basin Program, the phosphorus concentrations over the past five years (1999-2003) have averaged 0.045 mg/l in Missisquoi Bay and 0.018 mg/l in the Northeast Arm. For comparison, the water quality criteria for phosphorus endorsed by the governments of Vermont, Quebec and New York are 0.025 mg/l for Missisquoi Bay and 0.014 mg/l for the Northeast Arm.

The Missisquoi Bay watershed was determined to be the largest contributor of phosphorus to the lake, compared to all other lake segments. It is estimated that over 90% of the phosphorus load to Missisquoi Bay comes from nonpoint sources. About 25% of the watershed is used for agriculture, yet 79% of the nonpoint source phosphorus originates from agricultural areas. Nonpoint source phosphorus loading estimates developed by Hegman et al. (1999) for each land use category in Quebec and Vermont can be found in Appendix 1. The Appendix also gives information on the base year (1991) rates of water inflow and phosphorus loading from each tributary to Missisquoi Bay.

The amount of phosphorus flowing into the bay from its tributaries and present in sediment at the bottom of the bay contributes to the excessive growth of blue green algae and vascular aquatic plants. The situation was serious enough to have prompted the Regional Health and Social Services Board in Quebec to ban swimming at the region's public beaches in summer 2001, 2002, 2003 and 2004 and to recommend that any activities or practices that involved direct contact with the water cease. The Vermont Department of Health has also issued warnings to avoid swimming in the bay at times during recent years. Moreover, aquatic vascular plants form dense beds that significantly limit recreational water activities in the bay (swimming, boating, windsurfing, etc).

The 1937 Bridge and causeway

The Swanton-Alburg Route 78 Bridge is located at the southern end of the bay and crosses the waters connecting Lake Champlain (Northeast Arm) and Missisquoi Bay. The bridge is 5 km (3 miles) south of the Canadian border. It is nearly 1.5 km (0.93 miles) long and consists of two causeway sections of 500 m (1600 feet) and 650 m (2100 feet) long respectively extending from each shore and a bridge section 170 m (558 ft) long. The bridge was built in 1937. In 1997, the average daily traffic crossing the bridge was 4,170 vehicles per day.

Unfortunately there is little data relative to the condition of Missisquoi Bay before the construction of the bridge. There is no conclusive way, other than by modeling to determine the potential adverse effects of the construction or the presence of the causeway on the bay.

However, the causeway has, for some time now, been considered by the public as one of the possible causes of the degradation of Missisquoi Bay and the economic and tourism decline on both Vermont and Quebec sides of the bay. Many citizens believe that the causeway restricts flushing sufficiently to cause the observed changes (see Section 2).

The existing drawbridge, roadway and causeway have deteriorated over time. The existing draw span is not operational, the bridge deck is narrow and weak and the roadway has no shoulders. The bridge only provides 4.0 m (13 ft) of clearance above the ordinary high water level. The U.S. Coast Guard has determined that the inoperable draw span endangers, unreasonably obstructs, and makes hazardous the free navigation of vessels between Missisquoi Bay and the Northeast Arm of Lake Champlain.

The causeway is considered rocky fish habitat. The existing causeway provides physical habitat for the spiny soft shell turtle (*Apalone spinifera*) which is a Vermont state listed threatened species. The turtle is also listed as threatened under the provincial Species at Risk Act in Canada. Estimates are of 124 individuals in the area. The causeway may contribute to favourable environmental conditions (flow velocity, dissolved oxygen) that have created a winter hibernaculum for the turtles. The causeway and associated area acts also as habitat for the map turtle, gaint floater mussel (*Pyganodon grandis*), fragile papershell mussel (*Leptodea fragilis*) and the pink heelsplitter mussel (*Potamilus alatus*).

The New Missisquoi Bay Bridge project

A new fixed-span bridge on piers is being built by the Vermont Agency of Transportation (VAOT) on a new alignment over Lake Champlain on Vermont Route 78 between Alburg and Swanton. The site is immediately south (17 m or 55 feet) of the existing causeway. The project involves the removal of the old drawbridge (deck and 6 piers), the two bridge abutments and 330 feet (100 m) of the lakeward end of the eastern (Swanton) causeway arm. Removal of the existing piers and 330 feet (100 m) of causeway should help restore approximately 63,406 square feet (5,890 m^2) of lake bottom aquatic habitat.

The new bridge will be 3,584 feet long (1,092 m) with a width 46 feet (14 m) and a height of 35 feet (10.7 m). Two solid fill approaches for the bridge, each approximately 330 feet (100 m) long will be constructed in the lake and tie into the side of the existing causeway. The bridge will be supported by concrete abutments at both ends and 22 piers. The new piers and solid fill approaches will impact approximately 81,386 square feet (7,561 m^2) of lake bottom.

During 2004, the first year of construction, it is expected that shafts for all 22 piers will be drilled and at least some of the piers will be built. Work will also be done on the roadway approaches to the new bridge. The project is expected to be completed by 2005.

The permits issued for the project by the Vermont Agency of Natural Resources (VANR) require that most of the existing causeway be left in place after the new bridge is completed because the causeway provides habitat for the spiny soft shell turtle. In order to protect the endangered turtles, and because the hydrodynamic and water quality modeling analysis predicted only very small water quality benefits from causeway removal, the state permit limited causeway removal to the two old bridge abutments and 330 feet (100 m) of the lakeward end of the eastern (Swanton) causeway arm. The Vermont Department of Fish and Wildlife determined that 100 m (330 ft) was the maximum amount of causeway that coould be removed without causing unacceptable impacts to the protected species.

An assessment of the impact on the spiny soft shell turtle and some shellfish species will be undertaken once construction of the new bridge is complete and the portion of the causeway is removed. The project includes the construction of permanent basking habitat for turtles to use after construction of the new bridge is complete (minimum of 576 square feet or 54 m^2).

The VAOT (D. Scott, October 11th 2004) provided the Task Force with an estimate of what it would cost to completely remove the causeway. Based on the range of bids received for partial removal of the causeway as part of the current bridge construction project, the VAOT estimated a cost of $1,305 (US$) per meter of additional causeway length to be removed, plus 20% for mobilization costs, engineering and contingencies. Using this estimate, the cost to remove the additional 900 meters (2,953 ft) of causeway that is not being removed under the current project would be $1,409,400 (US$). The VAOT cautioned that there are factors that could increase the actual cost above this estimate. The bid rates assumed the causeway removal work would be done as part of the overall bridge construction project. A project to come in later solely to remove the remaining causeway may not be as desirable to potential contractors. Furthermore, difficulties associated with disposal of such large quantities of causeway fill material could drive the costs up higher than this estimate.

Hydrodynamic studies related to the presence of the causeway

Various studies were conducted to respond to the public interest in the idea of removing the exiting causeway as part of the Missisquoi Bay Bridge reconstruction project. First, the VANR Water Quality Division conducted a phosphorus mass balance modeling analysis of Missisquoi Bay to help advice the VAOT and inform the general public. Additional studies were conducted by scientific consultants independent of state government to develop a true hydrodynamic model that directly simulated changes in water currents in response to causeway removal, and modeled sedimentation changes and phosphorus concentrations in the bay. The results of these studies are summarized below.

A phosphorus mass balance modeling analysis of Missisquoi Bay was conducted by the VANR in 1993 and 1994 to simulate the enhanced mixing effects of causeway removal. The results indicated that removal of the causeway would produce an 8% reduction in average total phosphorus concentrations in Missisquoi Bay (from 0.035 to 0.032 mg/l), and a proportionate increase in phosphorus concentrations in the Northeast Arm region of the lake to the south (from 0.014 to 0.015 mg/l). Because the water quality benefits to Missisquoi Bay would be offset by adverse impacts on the Northeast Arm with no net phosphorus removal benefit to Lake Champlain as a whole, and because of the poor cost/benefit ratio at that time, the report concluded that causeway removal was not justified by water quality considerations.

There was strong public desire for an additional study that (1) was conducted by a scientific consultant independent of state government, (2) developed a true hydrodynamic model that directly simulated changes in water currents in the bay in response to causeway removal, and (3) modelled sedimentation changes in the bay as well as phosphorus concentrations. A Project Advisory Committee (PAC) composed of scientific professionals, elected local officials, and concerned citizens from both Vermont and Quebec was formed to promote better public acceptance of the findings of the hydrodynamic modeling study.

The results of the first phase of hydrodynamic modeling, completed by Applied Science Associates Inc. (ASA) in 1997, indicated that the causeway does not hydraulically restrict the flow of water between the bay and the Northeast Arm. Water did not "pile up" behind the causeway as it would have in the case of a dam. Although they found rather substantial circulation differences between different scenarios (changing wind speed, wind direction and river flow rate) very little difference was found between the with and without causeway cases. Also, a speed difference analysis found that the variations between with and without causeway cases were limited to a thin strip approximately 200 meters (656 ft) wide both south and north of the causeway. In general, velocities in the region of the causeway would be decreased if the causeway was removed because there would be an increase in the cross-sectional area.

For the majority of cases modeled, there was a small improvement in the flushing and sedimentation in Missisquoi Bay with causeway removal. Differences when they occurred were generally confined to the region in the vicinity of the causeway (North Hero Island to Chapman Bay). Phosphorus and sediment reductions in Missisquoi Bay were matched by increases in the Northeast Arm, but these increases were more dispersed. The differences between the with and without causeway cases were substantially smaller than differences caused by variations in environmental forces such as wind speed and direction.

The PAC determined that a second study phase was needed to obtain field data to verify model predictions against actual current measurements and to conduct model runs using realistic time-varying environmental conditions for the entire summer season.

Description of the model

The study consisted of four components; modeling hydrodynamics, flushing, suspended sediment transport and phosphorus concentrations. The study used a three-dimensional, boundary-fitted, general curvilinear coordinate system, hydrodynamics and mass transport model system to perform simulations. The model was first used to simulate the hydrodynamic conditions (currents) in the bay and to investigate circulation patterns and effects for cases with and without the causeway. Sediment transport and phosphorus model components were then used to study transport, deposition and flushing attributes of the basin for similar conditions with and without the causeway.

The long term model simulation run was carried out for the period between April and October 1991 using real, time-varying data on wind speeds and directions as well as river flows for that entire time period. It was found that the model developed during the second phase of the study did a good job of simulating the volume of flows through the bridge opening. The model results indicated that removal of the causeway will reduce Bay wide average phosphorus concentrations and sedimentation (fine fractions only) by about 1%.

After participating in the contractor selection process and the review of the project reports, the PAC determined that, "*Although it has some limitations, the study was well planned and executed and the data and information provided by the study (are) valid and should be useful for going forward in the future of the project.*" The committee recommended "*that the study be used to assess the merits of actions of removing the causeway or leaving it in or any other design choices related to the construction of the new bridge, as one element (of) the process.*" However the committee felt that the significance of the predicted water quality effects on Missisquoi Bay resulting from causeway removal "*is a value judgment which cannot be determined by this committee alone relying solely on the results of the study.*"

Lake Champlain Basin Program and Vermont and Quebec cooperation

Regardless of any decisions regarding the causeway, it will be necessary to achieve some very substantial reductions in the phosphorus loading to Missisquoi Bay from its watershed in order to restore acceptable water quality to the bay. Many actions have been taken with this goal in mind.

In 1988, the Governors of Vermont and New York and the Quebec Premier signed a *Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain*[4]. The Lake Champlain Basin Program is a U.S. federally-funded program that works in partnership with government agencies from New York, Vermont, and Quebec, private organizations, local communities, and individuals to coordinate and fund efforts which benefit the Lake Champlain Basin's water quality, fisheries, wetlands, wildlife, recreation, and cultural resources. These efforts are guided by the comprehensive basin plan *Opportunities for Action*[5], which has phosphorus reduction as one of its top priorities.

Phosphorus water quality criteria and phosphorus loading targets

In 1993, a New York, Quebec, and Vermont Lake Champlain Phosphorus Management Task Force[6] recommended that the three jurisdictions adopt a consistent set of in-lake phosphorus concentration criteria for each segment of Lake Champlain to serve as joint management goals for the lake. The subsequent Water Quality Agreement was signed by representatives of each government, adopting a phosphorus concentration criterion of 0.025 mg/l (annual mean) for Missisquoi Bay and of 0.014 mg/l for the Northeast Arm. These criteria are also included in Vermont's State Water Quality Standards[7]. Under this agreement, Vermont and Quebec are working to achieve the same water quality goal in Missisquoi Bay.

The 1996 *Opportunities for Action* basin plan established preliminary phosphorus loading targets for each major watershed in Vermont, New York, and Quebec. These loading targets were derived from a phosphorus budget, model, and load reduction study for Lake Champlain[8], conducted by Vermont and New York.

In order to develop a Quebec-Vermont phosphorus reduction agreement for Missisquoi Bay, the two governments formed a Missisquoi Bay Phosphorus Reduction Task Force. The purpose of this Task Force was to propose a fair division of responsibility between Vermont and Quebec for phosphorus reduction in Missisquoi Bay. The Task Force agreed that the overall phosphorus loading rate to Missisquoi Bay must be reduced to 97.2 metric tons per year (mt/yr) from the 1991 baseline rate of 167.3 mt/yr in order to achieve the 0.025 mg/l phosphorus concentration criterion for Missisquoi Bay. The Task Force used the results of a land use and phosphorus export study[9] to determine that about 60% of the existing phosphorus load to Missisquoi Bay came from point and nonpoint sources in Vermont, and 40% came from sources in Quebec.

The governments of Quebec and Vermont signed an *Agreement Concerning Phosphorus Reduction in Missisquoi Bay*[10] in 2002 based on the Task Force recommendations [11,12]. This agreement accepted the 60/40% basis for a division of responsibility, and assigned a 58.3 (60%) mt/yr target load to Vermont and a 38.9 mt/yr (40%) target load to Quebec to achieve the total allowable load of 97.2 mt/yr.

These target loads for Missisquoi Bay were subsequently incorporated into the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL) document[13] completed in 2002 by the States of Vermont and New York, and approved by the U.S. EPA. Vermont and Quebec committed in the 2002 agreement to achieve their respective target loads by 2016 for the Missisquoi Bay watershed in a manner consistent with the implementation plan «*Opportunities for Action*» developed by the Lake Champlain Basin Program and with the Quebec, Vermont, and New York Memorandum of Understanding on Lake Champlain.

On August 3rd, 2004 Governor James Douglas and Premier Jean Charest presented a progress report under the Cooperation Agreement signed on December 4th, 2003 between the Government of the State of Vermont and the Government of Quebec. They agreed to accelerate to 2009 all pollution reduction measures in their action plans so as to reduce phosphorus inputs which are the main factor behind the proliferation of blue green algae.

Vermont Action Plan

The Lake Champlain Phosphorus TMDL document included a comprehensive implementation plan for Vermont describing the phosphorus reduction actions that will be necessary to achieve the required load reductions throughout the Vermont portion of the Lake Champlain Basin. The TMDL estimated the cost of these actions to be $139 million (US $) over 14 years. In 2003, the Governor of Vermont announced the "Clean and Clear Action Plan[14]," which has as its primary focus the phosphorus clean-up of Lake Champlain on an accelerated schedule. Missisquoi Bay was given special priority within the Clean and Clear Action Plan because of the severity of the phosphorus and algae problems in the bay and the desire to work in cooperation with Quebec to address the situation.

At the Governor's request[15], the Vermont General Assembly approved $1.8 million (US $) in funding during state fiscal year 2005 dedicated specifically for phosphorus reduction actions in the watersheds of Missisquoi Bay and St. Albans Bay. An additional $5.8 million (US $) in state funding was approved for phosphorus reduction actions throughout the basin and the state, much of which will be used for work in the Missisquoi Bay watershed. Some of the actions funded under the Clean and Clear plan include the following:

- Assistance to farmers to reduce agricultural runoff and improve riparian zone management.
- Implementation of a science-based strategy for stream stability to reduce erosion of sediment and phosphorus from stream banks and river channels.
- Assistance for municipalities in improving back road maintenance and local water quality protection.
- Wastewater treatment plant upgrades for phosphorus removal.
- Citizen-based action planning for watershed management and protection.
- Erosion control at construction sites.
- Wetland restoration and protection.

Funding for the Clean and Clear Action Plan will need to be sustained and enhanced over the coming years in order to meet the Governor's goal of accomplishing the necessary phosphorus reduction measures in every possible instance by 2009, in time for the 400-year anniversary of the exploration of the lake by Samuel de Champlain. Additional state, federal, and private funding sources are being actively sought.

Quebec Action Plan

On September 1st, 2004 the Minister of Environment, Mr. Thomas J. Mulcair announced the results achieved during the current year in their 2003-2009 Action Plan. The Ministry of the Environment (MENV) invested $770 000 (CDN $) from April 2004 to March 2005. Together with other partners, a total of $2.3 million (CDN $) has been invested.

The 2003-2009 Action Plan[16] was developed in cooperation with other agencies, including the departments of Agriculture (MAPAQ) and of Municipal Affairs (MAMSL). The Government of Quebec estimated the cost of the 2003-2009 Action Plan to be approximately $10 million (CDN$).

- **Application of the regulation respecting agricultural operations:** As of September 1st, 2004, 450 of 550 farm visits have been conducted, within the Missisquoi Bay watershed. Through the Canadian Strategic Agricultural Framework, the MAPAQ plans to develop at least 115 agro-environmental plans to assist farmers with fertilizer management.
- **Management of protected natural lands:** In 2004, the MENV provided approximately $485,000 (CDN$) to Nature Conservancy-Quebec ($400,964 for 190 ha of bog in Clarenceville) and to Ducks Unlimited ($83,765 for 37 ha on the shores of the South River) for them to acquire 227 hectares of wetland.
- **Soil conservation and protection of streams:** The MAPAQ hopes to carry out several projects on soil conservation practices in the Pike River watershed, using the Prime-Vert Program and Agroenvironmental Advisory Clubs. It also aims to plant approximately 10 km of windbreak. The MAPAQ will invest about $223,500 (CDN $) in 2004-2005. Information meetings about the Policy for the protection of banks and shores and its application were held with municipalities and follow-up is in progress to pursue the actions begun in the spring of 2004. Technical support was provided by the MENV to municipalities.
- **Municipal wastewater:** The waterfront municipalities of Saint-Georges-de-Clarenceville, Venise-en-Québec and Saint-Armand were asked by the MENV to inspect the compliance of residential installations with the wastewater regulations. The municipalities agreed to cooperate and the MENV will follow-up with them. Furthermore, the MENV inspected private commercial and industrial wastewater treatment systems and 29 out of 40 inspections have been completed and corrective measures recommended.
- **Cooperation with local partners**: The Missisquoi Bay Watershed Corporation (CBVBM) received $65,000 (CDN$) from the Quebec Water Policy Watershed Program to develop a water management plan with local partners and to hold information forums on water quality and health, similar to one held on June 19th, 2004. A draft plan is currently under review.
- **Research and Development Projects :** Using a Nature and Technology Fund a three year $225,000 (CDN$) research project will be carried out in cooperation with McGill University, Sherbrooke University, University of Vermont, CBVBM, MENV, MAPAQ and a research institute (IRDA). The purpose is to develop a "decision making system" for the Pike River watershed. It will consist of contaminant transport models (phosphorus, nitrates and sediments) and data on the nature and the use of the land, which will be integrated into a geographic information system (GIS), to facilitate the identification of areas that are most likely to contribute to the environmental problems of Missisquoi Bay.

SECTION 2 – Public meetings and written comments submitted to the Task Force

The International Joint Commission (IJC) and the International Missisquoi Bay Task Force held public information meetings in Saint-Georges-de-Clarenceville, Quebec and Swanton/Highgate,Vermont on August 25th and 26th. All members agreed that public comment would be particularly helpful while the work of the Task Force was under way and that it would help assure that important issues were not overlooked.

The public meetings were attended by about 250 people from around Missisquoi Bay. People were mostly cordial and seemed to appreciate the opportunity to address the IJC and its Task Force. About 30 people made statements to the IJC and Task Force. They spoke with passion and sincerity. Many had knowledge of the area over a long period of time. Documents were submitted expressing their concerns (see Appendix 2).

U.S. and Canadian citizens who live near the bay all spoke of severe water quality problems. They raised public health concerns associated with blue green algae blooms. Public opinion was almost unanimously in favour of removing the causeway, sooner rather than later. They, however, were supportive of the new bridge.

Reasons mentioned to support causeway removal were: to restore the natural exchange mechanisms in Northern Lake Champlain (to allow the free circulation of water); to improve water quality; to reduce phosphorus concentrations in Missisquoi Bay (or disperse phosphorus); to decrease the population of toxic blue green algae affecting Canadian and American citizens; to ensure public safety and health; to decrease harm to the aquatic environment; to reduce silt; to increase wave action in Chapman Bay and also for aesthetic reasons. It was mentioned that causeway construction would never be approved in Vermont or Quebec in 2004 and that we should pick up after ourselves when we leave a site. This action would be a visible sign of clean-up efforts.

People mentioned that the removal of the jetty would not cause permanent damage to the rest of the lake. Another view was that keeping it in place would only slow but not stop pollution from leaving the bay. One person spoke of a need for a fair and equitable resolution for all parties.

An important part of the comments by the public dealt with their concerns about the health of the lake, human health and the economic and social impacts of the presence of blue green algae.

Comments on health

Citizens pointed out that over the past twenty years, the bay has become seriously overloaded with phosphorus. In recent years, this has given rise to the proliferation of potentially toxic cyanobacteria which form algae blooms. They cited recent studies that demonstrated that populations of toxic strains of blue green algae increased exponentially when phosphorus concentrations increased. For example, a reduction of 10% phosphorus would decrease the levels of cyanobacteria by 20 % and the associated toxicity by 25 %.

Many consider that the growth of cyanobacteria has become the most serious threat to public health. We were reminded that in Quebec, the presence of cyanobacteria prompted authorities to close beaches over the past four years (2001 to 2004) and to advise residents to curtail aquatic activities (direct contact with the water). It was also mentioned that in August 2004, the Vermont Department of Health issued public health warnings due to the presence of cyanobacteria.

The citizens of Bedford, St-Armand – Philipsburg and Standbridge Station could not drink their tap water for many weeks during the past years and new treatment systems have been put in place. Despite tremendous efforts, citizens say that they have lost confidence in their drinking water. Problems of odor and color were also mentioned.

People associated symptoms such as fever, headaches, dizziness, vomiting, and diarrhoea and skin irritation with the presence of cyanobacteria and their toxins in water. They spoke of cases when injury occurred from unintentional contact with water.

Comments on the local economy, property, recreation and tourism

Missisquoi Bay is an economic engine for the area. There were many examples given of loss of uses of the bay. Fewer people use the bay area due to the early closure of beaches. Fishing and boating are almost non-existent as are diving and wind surfing. The shorelines are pea-green. People even go to beaches in other areas instead of using their own water front access. Some campsites still operate but campers use the pools not the lake. Friends no longer visit during the summer.

Many people are finding it difficult to sell their waterfront properties and people consider that property value has decreased. Local businesses are having a hard time. Some Venise-en-Québec businesses have experienced an economic regression with revenues falling by 40 to 80 %. Water pollution has damaged a way of life and affected the "*joie de vivre*" of the residents.

Comments on the modeling studies

Very few comments were related to the validity of the previous scientific and technical studies. Some of the technical issues raised by speakers were: the fact that some modelling runs were unpaired, that input from Dead Creek was not considered and that modelling did not take into account spring runoff, storm surges or strong south winds. The opinion that the causeway is not a problem was definitely a minority view during the meetings. IJC was asked to look at the work and identify weakness in the modeling if the exist.

Scientific evidence or not, some people were clearly of the opinion that the removal of the causeway would bring about a large or even dramatic improvement in water quality. Although others did not openly disagree with the study results, they used vocabulary that indicated their disbelief of the science such as: strangulation, choking north south flow, return to former water flow, better natural cleansing actions of the bay, more beneficial effects of the prevailing south-west winds.

People strongly voiced the opinion that although changes may be small with the removal of the causeway, they none the less considered them important enough to take the causeway out:

- *It would provide relief while waiting for the impact of phosphorus source reduction programs to be felt;*
- *Even 1% might be enough for other things to happen in the bay;*
- *Even a small improvement is good;*
- *A natural first step in clean-up;*
- *Any item we can correct, we should;*
- *Any little bit will go a long way.*

People also spoke of the fact that clean-up will take a long time.

Other comments

"There simply is no single, simple way to deal with the problem, but rather a range of solutions that will enable us to reduce the phosphorus load in the bay, each measure contributing a little to the overall solution."

Considerable effort (tens of millions of dollars) has been put into purifying domestic wastewater in lakefront communities. Beford has invested $10 million (CDN$) in their sewer system. There are new provincial regulations covering agricultural practices and measures have been adopted by farmers (soil erosion control, better spreading of manure). Citizens have spent thousands of dollars to comply with regulations. Altogether, several millions of dollars have been invested to reduce phosphorus load to the bay.

The cost for removing the fill that makes up the causeway is considered insignificant while the construction of the bridge is underway. It is believed that maintenance costs of $20,000 annually will be required to prevent erosion of material from the causeway.

Speakers had strong and almost unanimous opinions on the turtles. They are considered to be the official reason behind the refusal by the State of Vermont to remove the causeway. People pointed out that the survival of the spiny soft shell turtles depends not only on the wintering grounds and summer basking associated with the causeway but also on clean beaches for nesting, clean water and a clean food supply. It was pointed out that the turtles will probably move to an alternate site for wintering during the construction of the new bridge and that local residents would cooperate in the construction of suitable perches that the turtles could use for basking in the sun as a replacement for the causeway. "*The turtles have more areas to move to than the human inhabitants*". Representative of people on the Quebec side said they are aware of the importance of protecting endangered species, provided priority is given to the protection of public health. This led to the suggestion of gradually removing the causeway over 7 years leaving 350 feet next to each shore. A bubbling system could also be installed on both ends.

One person in both Quebec and Vermont indicated that removal of the causeway would violate Vermont state law protecting the turtle.

A person asked if the original causeway had received approval by the IJC in 1937. Commissioners replied that they had not found any documentation in the IJC files related to the construction of the causeway.

The following suggestions were made to the IJC and Task Force:

- Set up a joint panel to monitor the spiny soft shell turtle and also study the impacts that blue green algae may have on the turtle life cycle;
- Set up a joint panel to monitor the hydrology of the bay and to study the combined impacts on hydrology if both the Missisquoi and Carry Bay causeways were removed;
- Set up a joint panel to monitor phosphorus levels in the bay until 2016;
- The IJC recognize and encourage action in the watershed.

A petition requesting the removal of the causeway, signed by approximately 2,500 citizens from both Quebec and Vermont was submitted to the IJC and the Task Force. It is noted that this is the same petition that was submitted to government officials several years ago.

SECTION 3 – Scientific and technical review of the impacts of the causeway on water flow and quality

The Task Force recognized that the hydrodynamic and water quality modeling studies of Missisquoi Bay completed in 1997 by Applied Science Associates (ASA) provide information relevant to the questions presented in the reference to the IJC. The ASA studies are the most scientifically advanced and definitive work done on this issue to date. Accordingly, the Task Force asked a number of technical reviewers to examine the reports and advise them as to whether the modeling methods were appropriate and the results valid. The full responses received from all eight scientific reviewers and a review of those comments by the principle authors of the ASA studies can be found in Appendix 3.

The three questions that were sent to reviewers were:

- Are the hydrodynamic and water quality models appropriate to determine flow/water levels (circulation), water quality effects of causeway removal?
- Are the results/recommendations valid?
- Is there sufficient technical information to help in decision making of this magnitude? If not, what are major information needs?

The reviewers generally considered the modeling tools used appropriate, supported the validity of the modeling results as presented in the two ASA reports, and agreed with the basic conclusions about the causeway's impact. Six of the reviewers (Hudon, Geib, Dettmann, Simoneau, Thibault, Cantin) responded affirmatively to the three questions regarding the appropriateness of the models, the validity of the results, and the sufficiency of the data, without significant reservation.

One reviewer (Abdelrhman) judged that the model results were valid qualitatively, but possibly not quantitatively, because of limited model calibration and verification, but felt that further data collection would not likely change the final assessment or recommendations. One reviewer (Sydor) was in general agreement with the hydrodynamic findings of the ASA modeling, but expressed concerns about the water quality aspects due to inadequate chemical and biological data, period of record and coverage, and absence of internal and boundary calibration data for model development and verification. Several of the reviewers (Abdelrham, Simoneau, Thibault, Cantin) noted that reducing phosphorus loads to Missisquoi Bay from its watershed is essential to improving water quality in the bay.

While the scientific review comments generally supported the validity of the ASA model findings, there were some specific technical concerns raised by some of the reviewers. Some of the more significant technical issues raised by one or more reviewers included :

(1) insufficient consideration of thermal stratification and seiching (both internal and external), (2) lack of definition of open boundary conditions in the model, (3) poor correspondence between model predictions and observed drogue tracks, (4) lack of consideration of the effects of aquatic macrophytes on currents in the bay, (5) insufficient water quality data for model calibration, and (6) insufficient data for a numeric, mass-balance model of phosphorus in the bay. All of the technical reviews were sent to the two authors of the reports, Craig Swanson (Applied Science Associates) and Dan Mendelsohn (Applied Technology Management), to give them the opportunity to respond to the comments.

The response to review comments provided by ASA addressed each of the specific technical concerns as summarized briefly below. Readers should refer to the full response from ASA provided in Appendix 3 for details.

Data collected during the ASA study and during previous surveys indicated no evidence of significant thermal stratification in Missisquoi Bay. There was no reason to include thermal stratification in the model.

ASA reanalyzed the data on winds, water surface elevations and currents at the causeway opening to determine whether the effects of internal or external seiches (periodic changes in water surface levels or flows) were apparent. There was evidence of a rocking motion of the water surface in the bay caused by wind set-up which occurred on a frequency of about 16 cycles per day around a single node, and 30 cycles per day around two nodes. These frequencies were consistent with theoretical expectations based on the bay's geometry, and the hydrodynamic model used by ASA was capable of predicting this surface seiche activity in both Missisquoi Bay and the Northeast Arm. There was no evidence found in the data at the causeway opening of any effects of the four-hour surface seiche that exists in the Main Lake portion of Lake Champlain.

The ASA model domain included the entire Northeast Arm so that model predictions in Missisquoi Bay and the causeway area would not be inappropriately influenced by the boundary condition assumptions. A constant surface elevation boundary condition was applied in the model at the three open boundaries in the Northeast Arm (Carry Bay, The Gut, and Sandbar Bridge).

There are a number of reasons why a good match between the model predictions and the observed drogue tracks might not be expected. Drogues are subject to local, small-scale forces that are not readily modeled, with small differences in the initial placement of the drogues resulting in large differences in the final position. On the other hand, the ADCP current meter data obtained at the causeway opening produced very good agreement with the model predictions, with only minor exceptions that were possibly related to differences in wind conditions across the study area.

The effects of aquatic plants in slowing water flows would be confined to the near-shore areas, with little bay-wide impact. Any such effects were indirectly incorporated into the model through the bottom current drag coefficient.

The available water quality data were sufficient for the purposes of the modeling analysis. The data included two full years of inflow, phosphorus loading, and chloride tracer data from the Lake Champlain Diagnostic-Feasibility Study as well as additional lake data from the Lake Champlain Long-Term Water Quality and Biological Monitoring Program.

After carefully considering the comments from all eight scientific reviewers and the response to comments provided by ASA, the Task Force has concluded that the modeling studies conducted by ASA, while not perfect, provide a sound basis for assessing the impacts of the causeway on water flows and water quality in Missisquoi Bay. The studies represent the most advanced scientific information currently available about these matters, and the findings are very likely to be correct.

SECTION 4 Conclusions and Recommendations

Question 1: Does the original causeway in the United States affect water levels/flows in Canada?

Conclusion 1:

According to the most advanced hydrodynamic modeling and other scientific information currently available and the technical reviewers, water levels and flows are not significantly impacted in Canada. The causeway does not act as a dam causing water to "pile up", and does not hydraulically restrict water flow between Missisquoi Bay and the rest of Lake Champlain. It is merely an obstacle that water must go around.

Flow and circulation patterns are very slightly affected in the area near the causeway. This area is mainly located in the United States. The Canadian border is 5 km (3 miles) north of the bridge. The Applied Science Associates (ASA) studies indicated that the presence of the causeway causes no significant changes in current patterns that far north of the bridge.

Question 2: Does the original causeway in the United States cause pollution to the injury of health or property in Canada?

Conclusion 2:

Phosphorus levels in Missisquoi Bay are excessively high and are well above the water quality criteria adopted for the bay by the State of Vermont and the Province of Quebec, so any structure or action that increases phosphorus concentrations in the bay can be considered as going in the wrong direction. Too much phosphorus stimulates the growth of aquatic plants and algae, which can turn water green, cause foul odors, impair drinking water and deplete oxygen as the plants and algae decay. Low oxygen levels can cause fish kills and wipe out insect and microscopic organisms that provide the all-important base of the bay's food chain. The average phosphorus levels in Missisquoi Bay of 0.045 mg/l are already quite above the water quality criterion of 0.025 mg/l and the bay is not getting better.

The causeway is not the fundamental cause of the water quality and health problems experienced in Canadian portions of the bay. According to the most advanced hydrodynamic modeling and other scientific information currently available, the presence of the causeway leads to a 1% increase in phosphorus concentration (bay wide average) and sedimentation rate (fine fractions only) in Missisquoi Bay, relative to scenarios without the causeway present. Phosphorus and sedimentation differences caused by the causeway are bounded for the most part by North Hero Island to the south and Chapman Bay to the north. Thus, the water quality impacts of the causeway are confined primarily to the U.S. portion of the bay.

The original causeway causes a very small but finite amount of pollution in Canada and in the section immediately north of the causeway in the United States. However, we should not expect major water quality improvement in Missisquoi Bay to result from removal of the causeway. Phosphorus load reduction from the watershed is the primary water quality management action on which Quebec and Vermont should focus, particularly with respect to nonpoint sources.

The relationship between phosphorus levels and algal concentrations may not be linear, and it is possible that a 1% increase in phosphorus could lead to something more than a 1% increase in algal populations or bloom potential. However, even considering this possibility, the causeway is not the primary contributor to the cyanobacteria problem in the bay. The causeway does not change the overall amount of phosphorus in Lake Champlain, but only slightly changes the distribution pattern over a few miles.

Question 3: Will the removal of the original causeway in the United States cause pollution to the injury of health or property in the United States?

Conclusion 3:

According to the most advanced hydrodynamic modeling and other information currently available, removal of the causeway would lead to a 1% decrease in phosphorus concentration and sedimentation levels (fine fraction only) in Missisquoi Bay that would be matched south of the causeway by increases in the Northeast Arm. These increases in phosphorus concentration and sediment would be smaller and more dispersed south of the bridge than north.

Phosphorus levels in the Northeast Arm have been increasing in recent years and are now above the water quality criteria adopted by State of Vermont. Any increase in phosphorus in the Northeast Arm can be considered as going in the wrong direction. However, any adverse impacts of causeway removal would be very small and incremental in U.S. waters south of the bridge.

No phosphorous would be removed from the overall system by taking out the causeway. Because of the amounts already present, any movement of phosphorus is just adding to the existing problem either north or south of the causeway. However, the phosphorus and algae problem is currently much more severe in Missisquoi Bay than in the Northeast Arm.

Question 4: Will the proposed project in the United States cause pollution to the injury of health or property in Canada?

The Task Force, in this study, has defined the proposed project as maintaining the causeway in place with the removal of 100 m (330 ft) of fill. We thus consider this to be practically the same question as question 2.

Task Force Recommendations:

The Missisquoi Bay Task Force would like to offer the following recommendations for consideration by the IJC Commissioners:

1. The IJC can rely on the basic findings of the Applied Science Associates studies which we found to be scientifically accurate, even though they may be counter-intuitive to some. The presence of the causeway leads to a 1% increase in phosphorus concentration (bay wide average) and sedimentation rate (fine fractions only) in Missisquoi Bay.

2. Phosphorus levels in Missisquoi Bay are excessively high and are well above the water quality criteria adopted for the bay by the State of Vermont and the Province of Quebec. Reducing phosphorus loading to Missisquoi Bay from the watershed according to the agreements and plans in place in Quebec and Vermont should be the major focus of government action to improve water quality in the bay.

3. Other public policy considerations (endangered species law, aesthetics, the principle of cleaning up after oneself, cost/benefit, the importance of incremental actions and strong public opinion) are legitimate factors in the final decision about causeway removal, but are beyond the scope of the Task Force study.

4. The public information sessions identified some knowledge gaps, and the Task Force agrees that further scientific research by the State of Vermont and the Province of Quebec is needed in the following areas:
   - Information on turtle biology (impact of cyanobacteria on the health of the turtles, alternate hibernation areas, etc.).
   - Relationship between blue green algae blooms and phosphorus levels.
   - Impact of multiple causeway removals (e.g. Carry Bay, The Gut) on water quality in northern Lake Champlain.

References

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[3] Vermont Agency of Natural Resources, 2003. Water Quality Effects of the Missisquoi Bay Bridge: A Summary of Research Findings as the Basis for the Agency's Position on Causeway Removal and Water Quality, July 16 2003 5 p.

[4] New York, Quebec and Vermont Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain. 1988, updated and renewed 2003.

[5] Lake Champlain Steering Committee. 2003. Opportunities for action. An evolving plan for the future of the Lake Champlain Basin. Lake Champlain Basin Program. Grand Isle, VT. http://www.lcbp.org/impofa.htm

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[10] Agreement between the Gouvernement du Québec and the Government of the State of Vermont concerning phosphorus reduction in Missisquoi Bay. Signed August 26, 2002. http://www.lcbp.org/phospsum.htm#missbay

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[12] Missisquoi Bay Phosphorus Reduction Task Force. October 5, 2001 Addendum on the target load and new load allocation in Missisquoi Bay. http://www.lcbp.org/phospsum.htm#missbay

[13] Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 2002. Lake Champlain Phosphorus Total Maximum Daily Load. Waterbury, VT and Albany, NY. http://www.vtwaterquality.org/lakes/htm/lp_phosphorus.htm

[14] Governor James H. Douglas. September 30, 2004 remarks. Clean and Clear Action Plan. http://www.vermont.gov/governor/speeches/clean-and-clear-water.html

[15] Governor James H. Douglas. January 20, 2004. Clean and Clear Action Plan. Summary of actions presented in the FY05 budget address. http://www.vermont.gov/governor/priorities/Clean-and-Clear-Plan.pdf

[16] Comité interministériel de concertation sur la baie Missisquoi – Région Montérégie 2004. Plan d'action 2003-2009 sur la réduction du phosphore dans la baie Baie Missiquoi (Octobre 2003, version du 9 septembre 2004), 21 pages

Other documents consulted by the Task Force :

Vermont Agency of Natural Resources 1993. Vermont Route 78 Swanton-Alburg Bridge Project Water Quality Assessment: The effects of a wider bridge opening on water quality in Missisquoi Bay and the Northeast Arm of Lake Champlain, Waterbury, VT (March 31, 1993), 16 pages

Vermont Agency of Natural Resources 1994, Vermont route 78 Swanton-Alburg Bridge project Water Quality Assessment – Update July 1994 – 6 pages

Vermont Agency of Transportation 1999, Alburg-Swanton BRF 036-1 (1), Missisquoi Bay Bridge VT Route 78 Environmental Assessment, 54 pages + appendices. Montpelier, VT

Vermont Department of Environmental Conservation 2002, Water Quality Certification (33 U.S.C. # 1341) Application for Bridge over Lake Champlain Missisquoi Bay Bridge Alburg-Swanton BRF 036-1 (1). Waterbury, VT

Vermont Department of Fish and Wildlife 2002, Endangered and Threatened Species Taking Permit – Missisquoi Bay Bridge. Waterbury, Vermont

Internet Sites:

www.lcbp.org/phospsum.htm
www.aot.state.vt.us/progdev/sections/structures/MBB/Index.htm
www.ijc.org (2 ASA reports through Information sheet)
http://www.tahoma.com

Appendix 1 – Land use and sources of phosphorus in the Missisquoi Bay watershed

Table 1. Distribution of land use in the Missisquoi Bay watershed (ca. 1993)

	Land use areas								
	Vermont				Quebec				Total Area
	Area (km^2)	For (%)	Agr (%)	Urb (%)	Area (km^2)	For (%)	Agr (%)	Urb (%)	(km^2)
Missisquoi	1,594	66.0	19.3	4.7	646	80.5	10.5	4.1	2,240
Rock	92	37.4	39.2	5.4	55	44.4	45.0	5.4	147
Pike	102	47.2	30.9	4.6	565	42.3	48.0	4.6	667
Direct	2	46.2	16.2	19.7	49	20.3	58.0	12.4	51
Total	1,790	63.0	21.0	4.7	1,315	60.3	29.8	4.7	3,105

Land Use/Land Cover: For=Forested, Agr=Agricultural, Urb=Urban
Data from Hegman et al. 1999[9].

Table 2. Distribution of nonpoint source phosphorus loading between major land uses in the Missisquoi Bay watershed.

	Phosphorus loading (metric tons/year)								
	Vermont				Quebec				Total
	For	Agr	Urb	Total	For	Agr	Urb	Total	
Missisquoi	2.9	53.9	12.4	69.2 (75.9%)	1.5	1.2	4.9	7.7 (13.7%)	76.9 (52.1%)
Rock	0.1	9.3	0.8	10.1 (11.1%)	0.1	6.5	0.5	7.1 (12.6%)	17.2 (11.7%)
Pike	0.1	10.8	0.8	11.8 (12.9%)	0.7	33.9	4.4	39.0 (69.2%)	50.8 (34.4%)
Direct	0.0	0.0	0.1	0.1 (<0.1%)	0.0	1.5	1.0	2.5 (4.4%)	2.6 (1.8%)
Total	3.1 (3.4%)	74.1 (81.2%)	14.1 (15.5%)	91.2 (100%)	2.3 (4.1%)	43.2 (76.7%)	10.7 (19%)	56.3 (100%)	147.5 (VT = 62%) (QC = 38%)

Land Use/Land Cover (Circa 1993): For=Forested, Agr=Agricultural, Urb=Urban (As presented in Hegman et al. 1999)[9].

Table 3. Tributary flows and total phosphorus loading rates to Missisquoi Bay during 1991

Tributary	Mean flow (10^6 m^3/yr)	Nonpoint source phosphorus concentration (mg/l)	Mean phosphorus load (mt/yr)
Missisquoi River	1,307	0.057	84.5
Pike River	296	0.150	50.3
Rock River	69	0.419	28.9
Ungaged Areas	36	0.096	3.5
Total			167.2

From: Vermont DEC and New York State DEC. 1997. A phosphorus budget, model, and load reduction strategy for Lake Champlain. Lake Champlain Diagnostic-Feasibility Study final report. Table 28.

Appendix 2 Public information

Public information meetings

Date	August 25th 2004	August 26th 2004
Location	Saint-Georges-de-Clarenceville, Quebec	Swanton/Highgate Vermont
Chairperson	Commissioner Gourd Commissioner Olsen	Commissioner Schornack Commissioner Gourd
Communication officers	Frank Bevacqua and Nick Heisler	Frank Bevacqua and Nick Heisler
Attendance	About 150	About 100
Length	7 pm to 8:30 pm	6 pm to 8:15 pm

List of documents received at the August 25th and 26th 2004 Public Meetings and also submitted to the IJC as of October 1st, 2004

#	Title	From
1.	Conservation Baie Missisquoi inc. presentation to IJC (French and English)	Pierre Leduc
2.	Corporation Bassin Versant Baie Missisquoi - Brief presented to the public hearings VTRANS route 78 Bridge Alburg to Swanton Project (Missisquoi Bay Bridge) (English) / Mémoire présenté aux audiences publiques (French)	Chantal D'Auteil
3	Conservation Baie Missisquoi inc (English)	Louis Hak
4.	Map of Champlain Lake (English)	Kenneth Miller
5.	Conservation Baie Missisquoi inc, IJC Public Hearings (English)	Nathalie Fortin
6.	Photos of blue green algae	Lise Berry
7.	Letter to Kenneth Miller from Joel Bonin (English)	Kenneth Miller
8.	Petition of 2,500 names	Kenneth Miller and others
9.	Conservation Baie Missisquoi inc., August 26 2004(English)	Louis Hak
10.	Lake Champlain, Inland Sea, Causeway, # Three Draft	David Borthwick-Leslie
11.	Soft Shell Turtle and Causeway	Ron Haskel

Appendix 3 Scientific and technical review:

Scientific and technical reviewers:

Mohamed A. Abderhman,
Research Physical Scientist
U.S. Environmental Protection Agency, Narragansett, R.I.

Jean-François Cantin
Regional Hydrologist
Environment Canada, Quebec City, Quebec

Edward Dettmann
Research Environmental Scientist
U.S. Environmental Protection Agency, Narragansett, R.I.

Mark Geib
Team Leader, Water Management Section
US Army Corps of Engineers Office
New England District Office, Concord, Ma

Christiane Hudon
Research Scientist
Environment Canada, St. Lawrence Center, Montreal, Quebec

Marc Simoneau
Analyste des milieux aquatiques
Quebec Ministry of Environment, Quebec City, Quebec

Maurice Sydor
Chief, Data Integration, Modelling and Analysis
Environment Canada, Gatineau, Quebec

André Thibault
Project Officer
Quebec Ministry of Environment, Quebec City, Quebec

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS
RESEARCH LABORATORY
ATLANTIC ECOLOGY DIVISION
27 TARZWELL DRIVE, NARRAGANSETT, R.I. 02882
July 15, 2004

MEMORANDUM

SUBJECT: Review of Hydrodynamic models for Missisquoi Bay, Lake Champlain,Vermont

FROM: Mohamed A. Abdelrhman
Research Physical Scientist,
Habitat Effects Branch

TO: Erik Beck
US EPA, New England Regional Office

CC: Timothy Gleason
Branch Chief
Habitat Effects Branch

Region 1 requested technical assistance in reviewing circulation models that were done for Missisquoi Bay and the controversial Missisquoi Bay Bridge and its causeway that connects Swanton VT and Alburg VT. The current causeway partially obstructs the opening of Missisquoi Bay, a shared US and Canadian water, into the rest of Lake Champlain, and potentially prevents nutrient flushing into the rest of the lake. A previous model of water, P, and sediment circulation estimated the potential impact if the causeway was removed. That model was later verified by work that was done by Applied Science Associates. Region 1 is looking for help in reviewing these models with an eye to answering the following questions:

1. Are the hydrodynamic and water quality models appropriate to determine flow-water levels (circulation), water quality effects of causeway removal?
2. Are the results-recommendations valid?
3. Is there sufficient technical information to help in decision making of this magnitude? If not, what are major information needs?

To meet the requested deadline, I skimmed the three hydrodynamic reports then I concentrated on the last one by Applied Science Associates (ASA's 1997 hydrodynamic field study and model verification, Phase 2). My evaluation is as follows:

A) Concerns about Hydrodynamic Modeling:

1. Forcing: - Effects of stratification and seiching were not included. Previous studies indicate a 4-h oscillation.
   - Forcing at the three open boundaries was not defined

2. Field Data:
   - Measured current velocity should be analyzed by spectral analysis to identify periodic oscillations, if any
   - Averaging should not be performed before analysis of field data
   - Water level gauges should be properly referenced to a common datum

3. Calibration:
   - The presented qualitative comparisons between simulated and observed velocities were very poor both in magnitude and direction, which may cause incorrect mixing and transport in the water body.
   - There is a time lag between model results and observations.
   - Low r^2 value (0.36) between model and observation.
   - Drogue tracks not reproduced by model
   - There is no comparison for water surface elevation.

B) Effects on Water Quality Modeling

The current velocity transports and mixes water quality parameters. Incorrect velocity field will produce incorrect transport and mixing within the bay. Even though the predicted fluxes of "water" under the bridge are close to observations, the flux of water quality "constituents" carried by this water depends on proper mixing within the bay, that was not demonstrate by the results.

C) Causeway Analysis:

Causeway analysis may be approached in two ways: (1) Qualitatively, without model calibration as presented in ASA's 1997 Hydrodynamic model (Phase 1); (2) Quantitatively, after model calibration and validation, as presented in the ASA's 1997 Hydrodynamic Field Study and Model Verification (phase 2). Nonetheless, either approach may be valid for qualitative insights about the effects of removing the Causeway. However, quantitative values may not be accurate unless model calibration is satisfactory, which is not the case here.

D) Worst case scenario and ultimate solution:

Assuming that Missisqoui Bay is completely blocked at the causeway and, thus, acts as a lake, the recommendations by "Vermont Agency of Natural Resources" for the Long-Term Water Quality Solution would be the ultimate solution: upgrades of wastewater treatment facilities, implementation of agricultural best management practices, actions to improve the stability of streambanks and stream channels, enhanced storm-water discharge permitting, erosion control at construction sites, and better back-road maintenance. Sooner or later these recommendations would have to be considered for any water body.

E) Answers to questions:
Q1: Are the hydrodynamic and water quality models appropriate to determine flow-water levels (circulation), water quality effects of causeway removal?
Answer: The hydrodynamic model is appropriate, but the presented calibration/verification is poor

Q2: Are the results-recommendations valid?
Answer: The general results-recommendation may be valid qualitatively, but not quantitatively.

Q3: Is there sufficient technical information to help in decision making of this magnitude? If not, what are major information needs?
Answer: After four years of researching this subject with six related reports and assessment by an advisory committee, most of the information is available with a degree of uncertainty. Better calibration would produce more accurate results, however, the impact on the final assessment and recommendations may not be significant.

Environnement Canada | Environment Canada

Note de service Memorandum

À/TO: Madeleine Papineau
Environment Canada

PRÉPARÉ PAR/
PREPARED BY:

SÉCURITÉ/
SECURITY:

DE/
FROM: Jean-François Cantin
Chief, Hydrology Section
Canadian Meteorological Service

DOSSIER/FILE:

DATE: 2004-24-08

OBJET/
SUBJECT: **Advice on the hydrodynamic model applied by ASA consultants to Missisquoi Bay**

Madeleine;

I reviewed the ASA studies related to the hydrodynamic component and pollutant transport published in March 1997 (ASA Project 95-136) and October 1997 (ASA Project 96-73). I also reviewed several briefing notes written since 1996 dealing with the conclusions of the studies and their quality, and here is my advice with respect to the three questions that were stated in your June 18, 2004 letter.

Question 1 :
In my opinion YES, the hydrodynamic and water quality models that were used are appropriate for the problem being analyzed. The baseline data that was used to establish the terrain model seem to be of good quality and, according to the map of aquatic plants provided by the Quebec Department of the Environment, the impact of the latter on flow in the bay is mostly seen along the shoreline, but remains small on the whole. The calibration and validation data were obtained using methods and instruments that are state of the art. Concerning the poor performance by the model in reproducing the trajectory of the drogues and velocity measurements, I agree with the analysis provided by the authors of the report, in that the simulated zones of high or low concentrations of phosphorus may be slightly different locally from reality, that changes in flow are fast and may not be well reproduced by the model but on the scale of the whole Missisquoi Bay and over longer periods, the flow in the section by the bridge, that controls the water residence time in the bay and phosphorus concentration is correctly reproduced. Also, the comparisons between the different scenarios with the causeway / without the causeway are all carried out using the results of models between themselves.

Question 2 :
I agree with the conclusions of the authors of the studies, that is to say that the presence of the causeway creates resistance to flow increasing water residence time in Missisquoi Bay up to a maximum of 10%, and that it’s complete removal would bring a decrease in phosphorus concentrations of about 1%, with the net flow being unchanged because a new equilibrium would be established between the available hydraulic energy and different

solicitations (wind, friction). The different solicitations such as wind velocity and direction, as well as the flow entering the system have substantially more impact on model results than the presence or absence of the causeway. I do not believe that it is realistic to expect a major improvement in water quality by intervening on the geometry of the causeway.

Question 3 :
I believe the conclusions of the authors of the studies with respect to the small impact of the causeway are valid and that this aspect has been analyzed with diligence and professionalism on the part of ASA, who used valid data in the construction, running and calibration of their models. I believe that the problem of the Missisquoi Bay should be examined as a whole, including the inputs of nutrients stemming from uses within the watershed of the bay. The historic use of land for agriculture and homes and/or others uses, future development plans, agricultural practices currently in place, the plans to improve them, the increase in livestock, legislation, etc. are all aspects that contribute to the Missisquoi Bay matter and for which the impact could be quantified.

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Translation from the original letter in French

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS
RESEARCH LABORATORY
ATLANTIC ECOLOGY DIVISION
27 TARZWELL DRIVE, NARRAGANSETT, R.I. 02882
July 18, 2004

MEMORANDUM

SUBJECT: Review of Water Quality Analysis in Missisquoi Bay, Lake Champlain, based on Hydrodynamic Modeling Performed by Applied Science Associates

FROM: Edward H. Dettmann, Research Environmental Scientist, Watershed Diagnostics Branch

TO: Erik Beck
US EPA, New England Regional Office

CC: Marilyn ten Brink, Branch Chief
Watershed Diagnostics Branch

The following review is based on an assessment of the report *Missisquoi Bay Field Study and Hydrodynamic Model Verification*, submitted to the Vermont Geological Survey/Vermont Agency of Natural Resources by Daniel Mendelsohn, Henry Rines, and Tatsusaburo of Applied Sciences Associates, Inc., Narragansett, RI in October of 1997, and on an assessment by Mohamed A. Abdelrhman of the U.S. Environmental Protection Agency, Atlantic Ecology Division (dated July 16, 2004) of the hydrodynamic models described in the above-mentioned report by Applied Sciences Associates. My review focuses on the water quality aspects of the three questions that you posed in your 7/15/2004 email concerning this review. In what follows, I restate each of your three questions, followed by my comments.

Question 1. *Are the hydrodynamic and water quality models appropriate to determine flow-water levels (circulation), water quality effects of causeway removal?*

As to the hydrodynamic modeling, I defer to M. Abdelrhman's analysis. He noted some deficiencies in the modeling effort, namely that stratification and seiching were not included, and that forcing at the open boundaries was not forced. He also pointed out some aspects of the calibration (in particular time lag between model results and observations, low r^2 between model and observation, and difficulties in reproducing drogue tracks), were in some ways unsatisfactory.

My assessment of the implications for modeling of water quality are as follows.

For the period of the field studies, October, 1996, the uniform surface-to-bottom distribution of the ADCP data suggest that there was little or no stratification in the area of deployment, so this is probably not a problem for the time frame modeled. The maximum depth of the bay (4 m) is considerably less than half the depth of the summer thermocline in the main body of the lake, so that any of effect of stratification in Missisquoi Bay is likely transitory, and not likely to strongly affect mixing processes within the bay. It is possible that there never is strong stratification at the site of the ADCP - at the center of the bridge opening, since water there is relatively shallow, and currents are strong, which would likely locally disrupt any stratification that might exist. Nevertheless, the fact that forcing at the model boundary was not defined implies that the model does ignore some effects (such as currents generated by the 4-day internal seiche in the main basin of Lake Champlain) that might exert some attenuated influence in Missisquoi Bay.

The lack of consideration of the 4-hour surface seiche could introduce some errors in the model results, although the small amplitude of this seiche suggests that the errors would not be major.

The time lags between model results and observations noted by M. Abdelrhman are real and indicate that some aspects of the bay's response are not captured by the model. However these time delays are not significant for bulk modeling of contaminant transport, and do not preclude the use of the results of hydrodynamic modeling to calculate such transport.

To summarize, the model that was used was adequate, but there are some aspects of the model application that limit the accuracy of the results of phosphorus transport calculations. There are questions about the accuracy of the modeled differences between the scenarios with and without the causeway. However, my professional judgement is that none of the questions raised reveal fatal flaws in the modeling effort. The judgements drawn are likely to be qualitatively correct.

Question 2. *Are the results-recommendations valid?*

Given some of the omissions in model application and the differences between model results and observations noted by Mr. Abdelrhman, there are some uncertainties in the quantitative details of the reported results. However, the results appear to be qualitatively valid and to support the recommendations.

Question 3. *Is there sufficient technical information to help in decision making of this magnitude? If not, what are major information needs?*

My judgement is that there is sufficient technical information to help in this decision making. Only a more complete, and likely more-highly funded field and modeling program than that evaluated here could add more information. While such an effort would likely reduce scientific uncertainty, the effects on the overall results and recommendations are unlikely to be significant.

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Note : Mr. Mark Geib reviewed the information the IJC provided on the
Mississquoi Bay, Vermont modeling.  Mark Geib is team leader of Water
Management Section at the US Army Corps of Engineers Office New England
District office. The Corps at the request of the IJC provided a technical
assistance to the IJC in the form or a review of material provided to the Corps
by the IJC.  See attached Review by Mr. Geib. This review is not intended to
represent the views of the Corps on this matter and the attached review by Mr.
Geib is supplied only as technical assistance to the IJC.
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Missisquoi Bay IJC review
30 June 2004

As requested, Water Management Section has performed a cursory review of two reports presenting results of hydrodynamic modeling of Mississquoi Bay in Lake Champlain. This review was requested by the IJC and was to focus on whether the models used were appropriate tools to evaluate circulation and WQ impacts, are the results – recommendations valid and is there sufficient technical information to aid decision makers.

The modeling and reports were prepared by Applied Science Associates, Inc.(ASA) from Narragansett RI. The purpose of the studies was to investigate the affect of the removal of the Route 78 causeway that is located at the southern end of the bay. There are concerns that the causeway is impacting the flushing and water quality of the bay.

The first report is dated March 27, 1997 and presents the results of the WQMAP modeling. WQMAP is listed as a PC based model which integrates geographic information (land use, watershed attributes, point sources), environmental data (water quality parameters, stream flows, bathymetry) and process models (hydrodynamic, pollutant transport, sediment transport, wave). For the Missisquoi project they used a three-dimensional boundry fitted hydrodynamic model linked with a three dimensional single constituent mass transport configured to simulate the flushing of a conservative substance, sediment transport and a simplified phosphorus reaction. The grid for the model extended throughout the entire Northeast Arm of Lake Champlain with a finer grid in the causeway area and Missisquoi Bay. Boundary conditions were at the three connections to the main portion of Lake Champlain. Input to the model included recorded wind and stream flow data as well as suspended sediment data. ASA analyzed 35 cases with and with out the causeway for different wind speed and direction as well as differing river flow conditions and different assumptions of total or partial causeway removal. They concluded that the causeway does not hydraulically restrict water between Missisquoi Bay and the Northeast Arm. They also found that the causeway has only minor localized affects. Looking at the size of Missisquoi Bay and the relatively narrow approach and exit from the causeway area as well as the current vectors with and without the causeway this appears to be a reasonable conclusion. One item identified as lacking in the original model as stated in the recommendations is “The model needs field verification and would benefit from long term, time variable simulation with real winds and real river flow data.”

Given the last statement above ASA conducted the “Missisquoi Bay Field Study and Hydrodynamic Model Verification” study with the report dated October 1997. ASA collected a month of current readings at the causeway, water levels upstream and downstream of the bridge as well as the northern end of the bay, installed a weather station and collected wind speed and direction, obtained recorded river flow data, obtained water samples for bay concentrations of phosphorus and total suspended solids (carried out by Vt. ANR personnel) and conducted drogue studies on the open bay for two days. This data was used to calibrate the model and additional simulations were conducted.

<u>Conclusions:</u> ASA is a reputable, well know firm and has conducted numerous studies of this type. We’re familiar with the work they’ve done in Narragansett Bay, Providence River, and other studies along the Rhode Island coast. The Corps experts at Waterways Experiment Station have hired them in the past to conduct studies. The studies conducted to address Missisquoi Bay appear to be very comprehensive, and the modeling tools and approach appear to be appropriate to address the stated concerns. Given the level of effort and the comprehensive nature of the studies conducted it would appear, based on this limited review, that sufficient technical information has been developed to allow for informed decisions regarding the causeway issue.

Mark Geib
Water Management Section
US Army Corps of Engineers Office New England District

Environment Canada Environnement Canada

July 5, 2004

To: Madeleine Papineau, Marc Berthelet, Alex Vincent
From: Christiane Hudon

Subject: Missisquoi Bay IJC Referral

I fully agree with the account of the situation provided in the Summary of Research Findings from Vermont Agency of Natural Resources (July 16, 2003 document).

I outline below the specific implication of EC-QC in the early part of the process.

The « Project Advisory Committee » (PAC) met between March 1996 and May 1997, to follow the progress of the hydrodynamic study of Missisquoi Bay. Committee members included representatives from Vermont Agency of Transportation, Vermont Agency of Natural Resources, the Northwest Regional Planning Commission and mayors of Quebec municipalities. I attended PAC meetings as technical advisor (Environment Canada representative) regarding water quality issues and received the help of Jean-François Cantin (MSC) with respect to matters dealing with hydrodynamic modelling.

A hydrodynamic model study was presented in the spring of 1996, outlining the potential outflow from the bay under different environmental conditions. Comments from Environment Canada (see notes attached – Jean-Francois Cantin and Christiane Hudon July 25 and 29, 1996), focussed on the need for a field validation of the study and various technical issues. These comments were acknowledged by the representative of Vermont Agency of Natural Resources and taken into account for the field measurements that took place in late summer and fall of 1996 (see August 28, 1996 note by Eric Smeltzer).

The results of the field validation of the hydrodynamic model study of Missisquoi Bay were presented by ASA Inc. in the spring of 1997. The final report was reviewed by Environment Canada staff (see note dated April 23 and letter to Larry Becker dated May 6, 1997), concluding that the data was adequate and supported the conclusions of the reports to the effect that the causeway exerts little restraint (in the order of 10%) to the flow of water between Missisquoi Bay and the northwest arm of Lake Champlain.

In the absence of any new information regarding the matter of hydrodynamic modelling of Missisquoi Bay, it would thus appear that the answer is NO to the four questions formulated by Mr. Bill Graham to Mr. Herb Gray:
1) whether the original causeway affects water levels/flows in Canada;
2) whether the original causeway in the U.S. causes pollution to the injury of health or property in Canada;
3) whether the removal of the original causeway in the U.S. might cause pollution to the injury of health or property in the United States; and

4) whether the proposed project in the U.S. will cause pollution to the injury of health or property in Canada.

To conclude, I would like to re-iterate the conclusion of my letter to Larry Becker (May 6, 1997)to the effect that "Changing the general perception through public information should be among the priorities of the Missisquoi Bay Bridge Steering Committee."

Christiane Hudon
St. Lawerence Center
Environmental Conservation Branch
Environment Canada

Translation from the original letter in French

Environnement Québec
Direction du suivi de l'état de l'environnement

July 29, 2004

Mrs Madeleine Papineau
Environment Canada
1141, route de l'Église
Quebec (Quebec) G1V 3W5

Subject: Modernization of the Alburg–Swanton road bridge and partial or complete removal of its two causeways

Dear Madam:

We would like first of all to share with you our comments on the two reports listed below dealing with the hydrodynamics of Missisquoi Bay with the two causeways present and on partial or complete removal of the causeways. The two reports are:

1. Mendelsohn, D. *et al*., 1997. Hydrodynamic Modeling of Missisquoi Bay in Lake Champlain, Applied Science Associates. Project 95-136, 106 p. and 5 appendices.

2. Mendelsohn, D. *et al*., 1997. Missisquoi Bay Field Study and Hydrodynamic Model Verification, Applied Science Associates. Project 96-73, 91 p. and 1 appendix.

Comments will then be provided concerning the following document:

3. Vermont Agency of Natural Resources, 2003. Water Quality Effects of the Missisquoi Bay Bridge: A Summary of Research Findings as the Basis for the Agency's Position on Causeway Removal and Water Quality, 5 p.

Lastly we intend to answer the three questions raised in the document dated June 21, 2004, of which a copy is attached.

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Our comments following an analysis of report no. 1:

Unless the term is not being used correctly, every instance of the expression “wind direction” refers to the origin of the wind; sometimes in the text the origin of the wind is in fact being discussed, whereas in the figures, tables and appendices that are referred to, the expression “wind direction” is used. This situation creates confusion and complicates the task of analysing and understanding the content of the document.

Page 16 and subsequent pages. A description is provided of the three-dimensional numerical modelling system used for the different modelling runs (WQMAP); it consists of a coupled hydrodynamic and water quality model. The hydrodynamic model solves equations governing conservation of mass (water and constituents) and momentum using the finite difference method; it can be assumed that these are Saint-Venant equations. This is the most widely used method for horizontal and vertical discretization of a study area. This discretization can also be performed in terms of finite elements or volumes; however, regardless of the method employed, the same equations are usually solved and the results should be more or less the same. The transport model has been configured to evaluate the flushing time of a conservative substance, sediment transport and a simplification of phosphorus dispersion;

Page 25, point 4.4. It is mentioned that the mean value of 35µg/L was used for total phosphorus in Missisquoi Bay; this value is slightly below the median value of 42 µg/L for the period from May 1992 to October 2003.

The results of the different hydrodynamic modelling runs (**point 6.1**) (current speed and direction) are plausible and rational; this is also true for the modelling of flushing time (**point 6.2**). With regard to the sediment transport model (**point 6.3; page 79**), for cases B1 and B2, I believe it would have been better to write “expected” instead of “not unexpected,” since the model predicts what is predictable.

Our comments following an analysis of report no. 2:

In this document, the author is more careful in indicating whether the origin of the wind or the direction in which it is blowing is being discussed. This obviously facilitates comprehension and analysis of the content. However, there are numerous instances in which some doubt persists, forcing the reader to correct the inaccuracies or errors involved;

Page 29 “drogue study”. I noticed that the speeds are low and the directions different from those obtained with the model (Figure 6.3a). The question is whether the presence of macrophytes could partly explain this difference. At no time does the author document the presence of macrophytes in Missisquoi Bay, which is unfortunate. Furthermore, the author does not mention whether the hydrodynamic model takes account of the resistance to flow attributable to macrophytes;

Page 55, point 6, **calibration of the hydrodynamic model**. We understand that the model is conservative in deriving estimates of current speed. I assume that the model was calibrated using drogue-derived current-measuring data, which, as I mentioned earlier, appear very low to me. May I point out that these current meter measurements are point measurements and they comprise flow components that are probably not incorporated in the model. This could explain the discrepancy between the drogue studies and the model predictions;

Page 66, third paragraph. Unlike the author, I do not believe that a reduction in flow would translate into an increased possibility of stratification in the bay; in fact, wind-induced mixing and the limited average depth suggest the contrary;

- Reviewing the field surveys conducted in October 1996, we find the following:

  - The current measurements (speed and direction) made with a current meter (Acoustic Doppler current profiler - ADCP) were limited to the zone between the two causeways of the bridge; it is unfortunate that this equipment was not used for several cross sections within the bay as this data could have been used to calibrate the model;

  - The S4 current meter which was supposed to take Eulerian current measurements failed to work;

  - The Lagrangian current measurements (speed and direction) performed using drogues provided results differing from expectations and from the results obtained through modelling. In my opinion, the presence of macrophytes could explain this difference;

  - The results of the two phosphorus sampling campaigns cannot easily be used to calibrate the model since the sample includes total phosphorus from sediments which is resuspended by wind-induced mixing of the water—an aspect that is not considered in the model;

  - Finally, few data from these two survey campaigns can be used to calibrate the model, which is disappointing in hindsight.

Effect of partial or complete removal of the two causeways on the water quality in Missisquoi Bay

<u>Our comments following an analysis of report no. 3:</u>

We agree fully with the conclusions of the studies evaluating the effects of the Alburg–Swanton bridge on water quality in Missisquoi Bay and in the northeastern arm of Lake Champlain. We feel that removing the causeway will not reduce the sediment and phosphorus inputs to Missisquoi Bay at all. As long as the Missisquoi, Aux Brochets and De la Roche rivers continue to discharge large quantities of sediments and nutrients into the bay, the water quality will be poor and the problems with aquatic plants and cyanobacteria will persist. It appears moreover that a large part of the substances discharged into the bay settle out in this water body and are not exported toward the northeastern arm of the lake. They therefore contribute to sediment enrichment in the bay.

Nicolas Gidas, a hydrodynamics expert with the aquatic ecosystems directorate of the Quebec Department of the Environment (Ministère de l'Environnement), already issued similar advice in May 1996. At the time, Mr. Gidas estimated that the real reduction in phosphorus in the bay was between 1% and 8%, in contrast with the estimate of 8%.

Furthermore, we back the request made by the Quebec Department of the Environment to the Vermont Agency of Transportation that water quality monitoring be carried out during and after the work, with total phosphorus and chlorophyll *a* being included among the parameters to be monitored. The water quality station established in Missisquoi Bay in 1992 provides a means of tracking the temporal trends in phosphorus concentrations. However, there are no measurement stations around the Alburg-Swanton bridge which would enable us to assess the current state of water quality and the changes that partial removal of the causeway might cause. The results of such monitoring would help to show the effect of the causeway at the present time and the impact of partial dismantling of this structure.

Answers to questions raised in attachment no. 1

Question no. 1

I think that the modelling system used by Applied Science Associates, namely the WQMAP, is completely suitable for determining the effects that removing all or part of the two causeways would have on the water levels, flows (current speed and direction) and water quality. The hydrodynamic model solves the wavelength equations using the finite difference method, while the other models function with an acceptable degree of realism.

This model by itself can generate modelling results as long as the external factors impinging on the system, such as the wind, water level and inputs from tributaries (flows, quality) are properly accounted for. It is unfortunate that the survey campaign of October 1996 that was supposed to be used to calibrate the model did not allow this objective to be attained.

Question no. 2

I believe that the results and conclusions of the two documents are valid. However, the modelling system does not account for the phosphorus in sediment which could potentially be resuspended by wind-induced mixing of the water column. Consequently, the dispersion zone may extend beyond a 200-metre wide strip south of the two causeways. The same applies for the suspended sediments.

Question no. 3

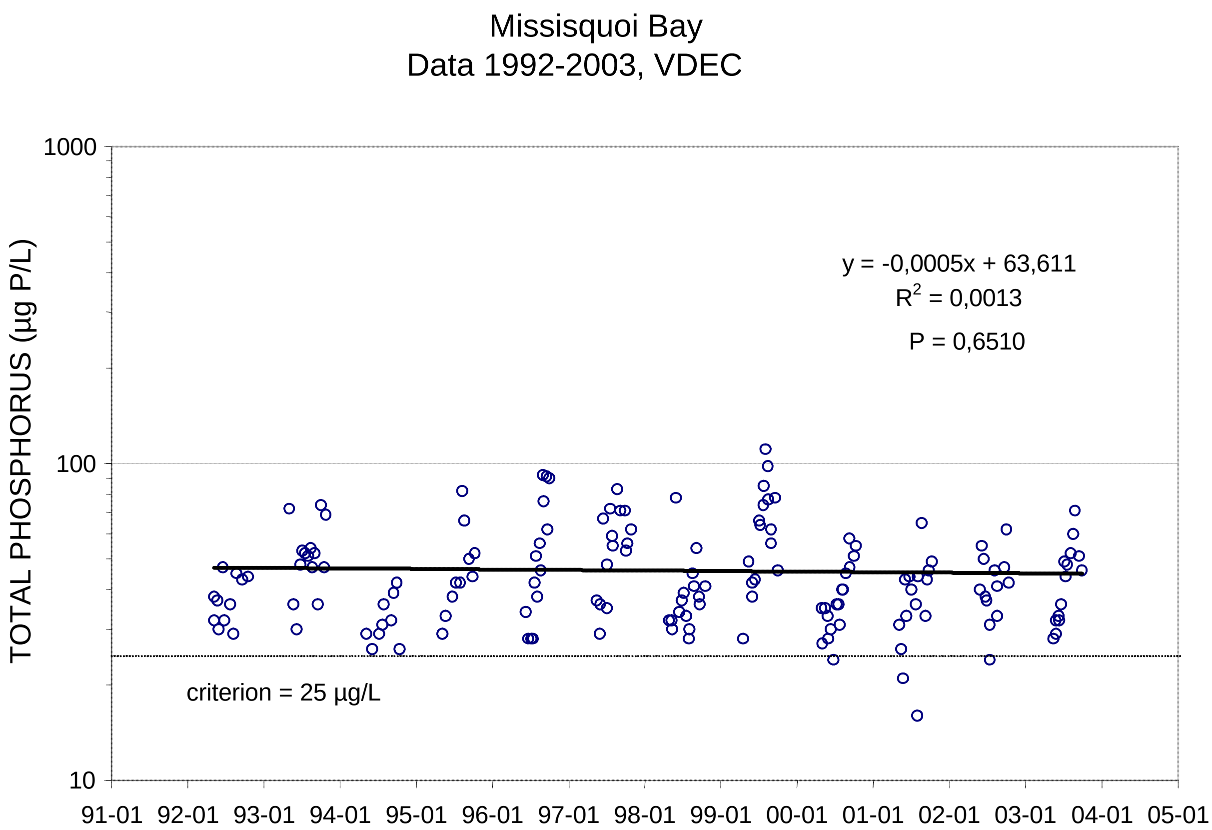
I believe that the International Joint Commission now has enough technical information to make an informed decision regarding the partial or complete removal of the two causeways.

Marc Simoneau, M. Sc. Analyste des milieux aquatiques	André Thibault, Chargé de projets

MS/AT/mv

Inc. (2)

c. c. M. Yves Grimard
M. Jacques Dupont
M. Pierre Aubé
M. Simon Dubé
M. Marcel Laganière
M. Martin Mimeault


Missisquoi Bay
Data 1992-2003, VDEC
TOTAL PHOSPHORUS (µg P/L)
1000
100
10
y = -0,0005x + 63,611
R^2 = 0,0013
P = 0,6510
criterion = 25 µg/L
91-01
92-01
93-01
94-01
95-01
96-01
97-01
98-01
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Environment Canada Environnement Canada

August 25, 2004

To: Madeleine Papineau and Terence McRae

Hello Madeleine,

Since I have quickly reviewed the literature you had sent to us earlier, that is "A Division of Responsibility Between Quebec and Vermont for the Reduction of Phosphorus Loads to Missisquoi Bay", it is evident from the conclusions that there exists a significant water quality problem in this region. I am repeating in summarized form the recommendations of the Task Force as follows: 1. Vermont and Quebec should ensure all wastewater treatment facilities are monitored regularly for flow and phosphorus loading; 2. a database of non-point sources should be enhanced and be consistent for accounting purposes; and 3. river flow and phosphorus monitoring be expanded as well as continued at existing monitoring points.

The report also states that there has not been a constituent WQ budget model done for the bay and the re-cycling of nutrients in this area are yet to be determined for appropriate understanding of the system.

With this brief introduction I would like to address the three questions in the following manner.

1. There are models that can take into account both the hydrodynamic component of the bridge very accurately. Addressing the entire area is more challenging because it requires more data which currently is scarce or non-existent. The water quality question is much more difficult to address. It would require the knowledge of the water quality entering and leaving the system plus the understanding of the area significantly well to determine what components are more mobile than others. For example, conservative substances such as salts as NaCl etc., can be included and readily simulated if all boundary conditions are known. It is also possible to simulate these parameters with time and even during periods of ice-cover when they are concentrated and mobile.

On the other hand, constituents that are assimilated or taken up by biota are more difficult to follow. A complete life cycle of the element must be understood sufficiently well to do modeling justice. Nutrients must be followed through the use re-use cycle and also the impact of retention and storage in the sediments. Modeling is once again possible but this requires data for specific sites throughout the study area and for a period of at least one or more years to see any trends.

Current studies have clearly stated, in the ASA report, that continuous simulations were not carried out nor requested. Personal contact with ASA has determined that this is possible but tributary flow and quality input is essential. Data from point sources can be used to determine values for non-point sources. A calibration of certain river sections can enhance this understanding so that monitoring can be achieved in the most cost-effective manner.

Hydraulic impact of the causeway on a local level is readily achievable. Water quality impacts are much more difficult and nearly impossible unless much more information is made available above and below the structure in a coordinated and continuous fashion. Water quality models can only address those parameters that are monitored but can provide theoretical answers with information that can be determined from indirect means. For instance water temperature through surface air temperature and water intake sites where temperature is at times collected by operators responsible for these structures.

2. Results and recommendations at the level of hydraulics are much more certain because the results can be readily monitored and checked. Simulations of wind fields and drogue field verification are again common. The impact of weed growth on circulation patterns need to include the impact of weeds, etc. and time of year. These are normally considered continuous simulations and are directly affected by the duration and frequency of winds for example. Persistence in winds and storms can greatly affect change to the flow patterns in any shallow lake system.

Results and conclusions are only valid if they can be verified both numerically and in the field and that sensitivity tests show that the results do not greatly change during the validation process.

3. The ASA report clearly shows the impact causeway in terms of the hydraulics or water flow due to specific wind driven currents. It has not been determined what might be the longer-term impacts from a continuous modeled period that includes changing parameters within the system such as weed growth for example. Clearly hydraulics alone is insufficient to answer the impact of suspended loads versus partially deposed loads at the mouth of tributaries.

From a water quality point-of-view, there definitely needs to be a better understanding but the data associated with hydraulics may not always be "in sink" with water quality data. Both need to be properly coordinated so as to obtain the maximum amount of consistency within the system as well as at those points considered to be the boundary limits of the problem area.

It is still a major presumption on my part to determine what are those major information needs. I still do not know what data and what exact methodologies would be used to resolve these questions satisfactorily but I do know from the reports that I have read is that we are no where near saturated in data in this particular project.

I hope I have shed some light on my limited review of the reports provided. Should you have any questions or comments, please feel free to address them directly to me.

Regards,

Maurice Sydor, P. Eng., M.Sc.
Chief, Data Integration, Modelling and Analysis
Watershed Management & Governance Branch
Environmental Conservation Service
Environment Canada

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To: International Missisquoi Bay Task Force, International Joint Commission

From: Craig Swanson, ASA
Dan Mendelsohn, ATM

Date: 12 October 2004

Re: Response to comments on ASA Missisquoi Bay studies

Introduction

This memorandum is in response to a series of review comments on ASA study publications on Missisquoi Bay in Lake Champlain. As explained in the cover letter form Potamis, Papineau, Mimeault and Smeltzer to Swanson and Mendelsohn dated 2 September 2004 there were a series of specific technical concerns raised by the reviewers:

> …insufficient consideration of thermal stratification and seiching (both internal and external), lack of definition of open boundary conditions in the model, poor correspondence between model predictions and observed drogue tracks, lack of consideration of the effects of aquatic macrophytes on currents in the bay, insufficient water quality data for model calibration, and insufficient data for a numeric, mass-balance model of phosphorus in the bay.

Although these technical comments deserve a response, it should be remembered that the concluding comments of the reviewers indicate that, regardless of the authors' response, none of the technical issues would influence any significant change to the conclusions. A subsequent comment from David Borthwick-Leslie was also reviewed and a response prepared.

Each comment will be addressed below.

Comment: Insufficient Consideration of Thermal Stratification
Response:

Thermal stratification occurs during the summer months in several portions of Lake Champlain including the main body of the lake and occasionally in the Northeast Arm. It has been demonstrated through observations and modeling that the presence of stratification and a well defined thermocline can produce an internal seiche, (Myer and Gruendling, 1979; Mendelsohn et al., 1992; Manley et al., 1999; Hunkins et al., 1999). In addition a strong thermocline can essentially disconnect the surface currents from the bottom producing considerably different flow patterns between a stratified and a non-stratified system.

In Missisquoi Bay however there is evidence that thermal stratification rarely develops due to its shallow depths and relatively high local wind speeds, (Myer and Gruendling, 1979). Myer and Gruendling go on to state that "the thermal structure observed in the Bay is strongly related to the inflowing rivers and apparently wind induced currents". In that the purpose of the study under discussion was to model the circulation and transport within Missisquoi Bay and through the causeway opening thermal stratification was not considered an issue. As noted in Mendelsohn et al. 1997, the ADCP data showed that the water column was nearly homogenous with no apparent stratification effects. The details of the circulation in the Northeast Arm were considered secondary, more like an extended boundary condition.

Comment: Insufficient Consideration of Seiching

Response:

An evaluation of the Missisquoi Bay field program observations has been performed to evaluate the response of the system to forcing and to determine what the important forcing functions are. This was done to help in answering questions from the reviewers regarding the seiche effects in Missisquoi Bay. The evaluation focused on the water surface elevations in the bay and the acoustic Doppler current profiler measured currents at the Rt. 78 causeway opening. The variability in these signals provides the best indication of what is driving the physical response of the Missisquoi Bay/Northeast Arm system.

The following plot (Figure 1) compares the water surface elevation (WSE) difference between the north end of the bay and the causeway as a function of the local wind speed and direction. Note that for winds from the south, the WSE difference is positive, indicating that the WSE at the north end of the bay is higher than at the south. Similarly, for winds from the north, the WSE at the causeway is higher. There also appears to be threshold of approximately +/-2 m/s below which there is no distinct trend.

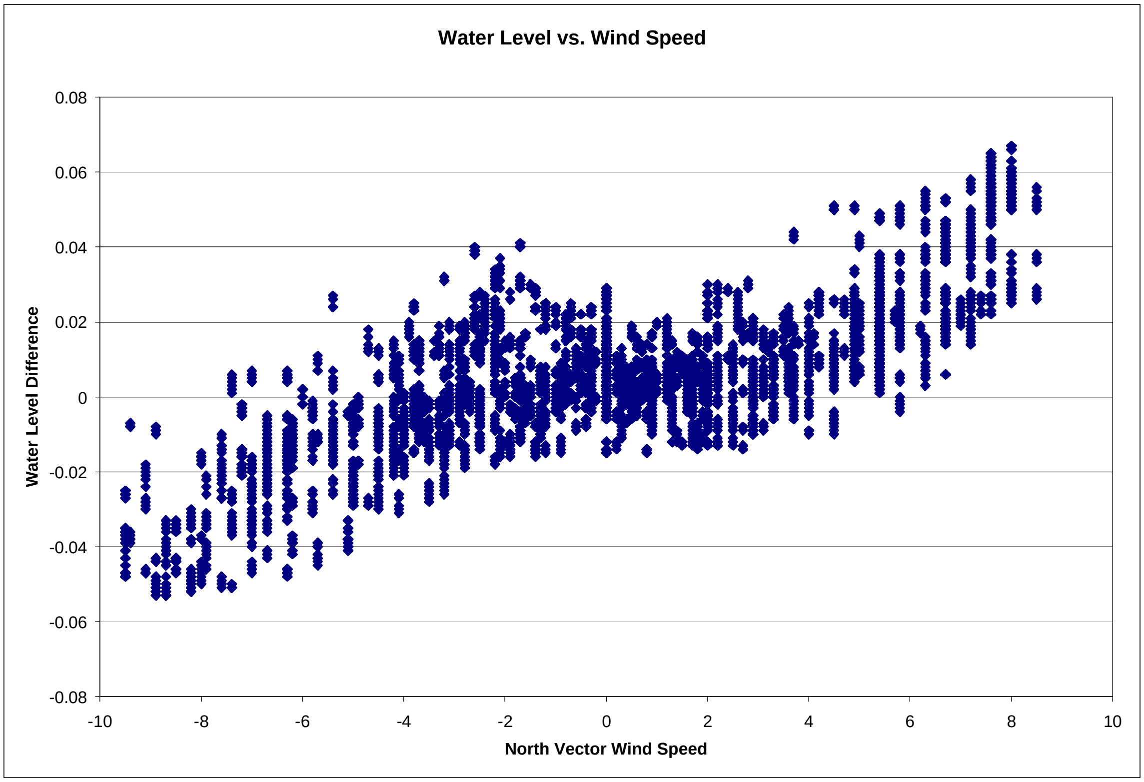

Figure 1 **Water surface elevation difference between the north end of Missisquoi Bay and the Rt. 78 Bridge plotted versus the north component of the wind.**

A power spectral density analysis was done on the WSE difference between the two sites in the bay from the data in the figure above and the results are shown in Figure 2. Referring to Figure 2 it can be seen that there is a clear increase in the response of the basin centered around 16 cycles/day (1.5 hrs) and another increase centered around 30 cycles/day (0.8 hrs).

A similar response is seen in the spectral density of the ADCP measured currents, also shown in Figure 2, clearly indicating an increase in energy in the 16 cycles/day frequency range, although there is a smaller response around the 30 cycles/day range.

(a)

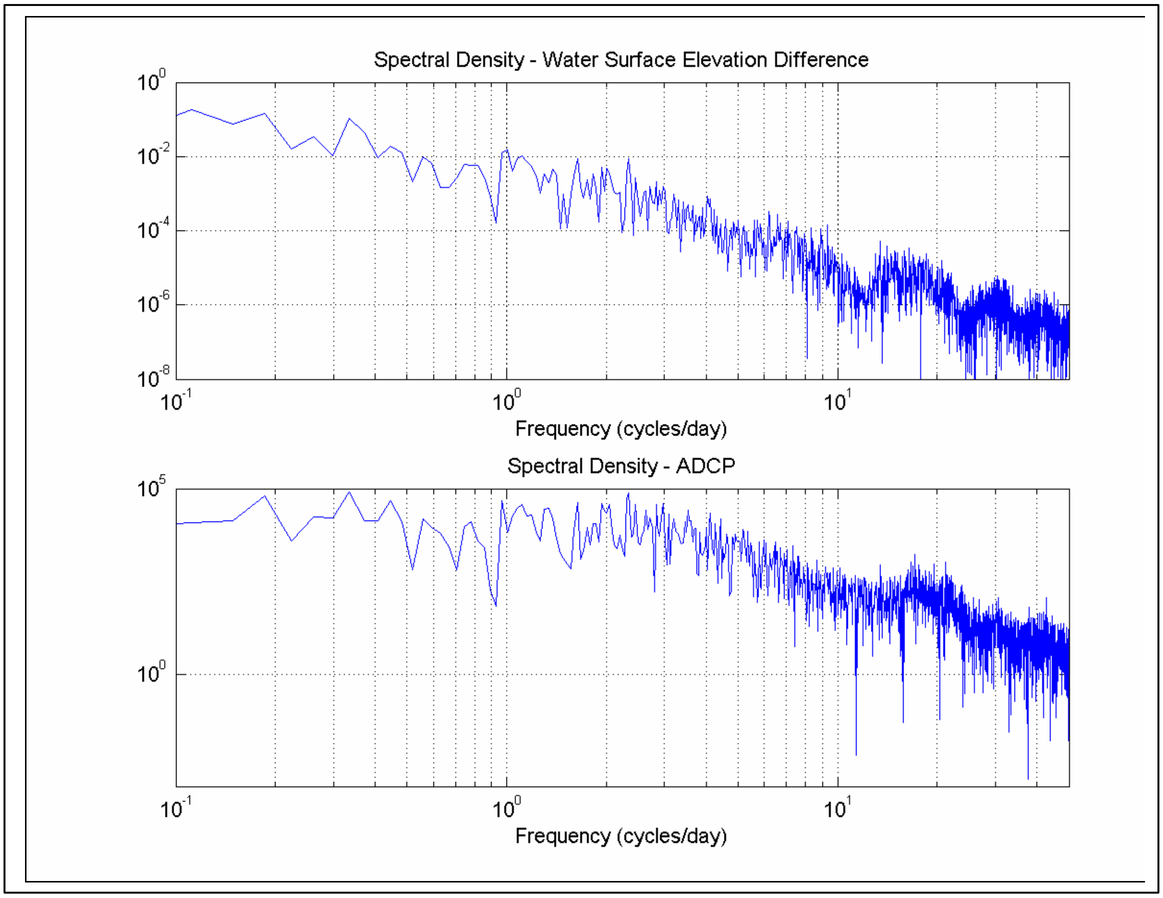

Figure 2 **Power spectral density of (a) the water surface elevation difference between the Rt. 78 causeway and the north end of Missisquoi Bay, and (b) the ADCP measured currents at the Rt. 78 causeway opening.**

Finally, the spectral density of the wind at the causeway was also estimated as shown in Figure, 3 along with the ADCP spectral density plot for reference. As opposed to both the WSE and the ADCP currents, the wind does not appear to have any significant response at either of the noted frequencies for the WSE or currents. Although from Figure 1 we can deduce that the wind forcing is responsible for the WSE and current response it appears not to be on a per frequency basis. More likely, the wind sets the water surface in motion and the system responds at the basin free oscillation frequency. A brief analysis of the free oscillation in Missisquoi Bay follows below.

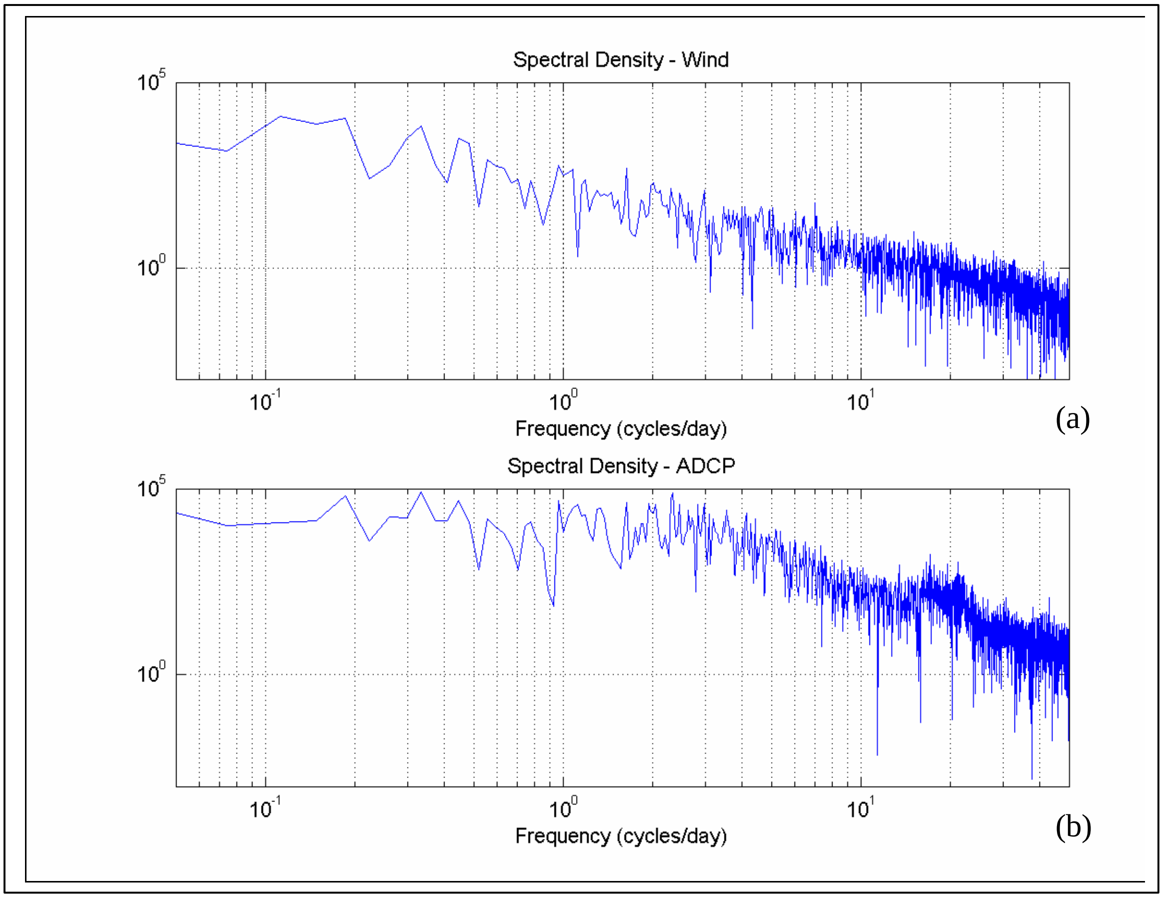

Figure 3 **Power spectral density plot of (a) the North wind component at the Rt. 78 causeway, and (b) the ADCP measured currents at the Rt. 78 causeway opening.**

To further evaluate the observed responses in the elevations and currents, an analytical study was performed to estimate the free surface oscillation periods in Missisquoi Bay, the Northeast Arm and the main lake. The free oscillation in a closed basin is given by Ippen (1966) as:

$$T = \frac{2a}{n\sqrt{gh}}$$

where a = basin longitudinal dimension (m)
n = number of nodes
g = gravity (m/s^2)
h = average basin depth (m)

The average depths were taken from the “Lake Champlain Diagnostic Feasibility Study – Interim Report”, VTDEC/NYSDEC 1992. The basin lengths were estimated using a GIS distance measurement tool. An estimate of the period and frequency for each of the basins is presented in Table 1, for comparison to the power spectral density plots. Calculations were made for the first and second mode response, i.e. with one or two nodes in the surface oscillation.

Table 1 Estimates of the free surface oscillation in a closed basin for three water bodies in Lake Champlain.

Calculations with n=1	a	h	T (sec)	T (min)	T (hrs)	f (1/day)
Missisquoi Bay	13000	2.28	5498	91.6	1.53	15.7
North East Arm	36000	13.6	6233	103.9	1.73	13.9
Lake Champlain	120000	40	12116	201.9	3.37	7.1
Calculations with n=2						
Missisquoi Bay	13000	2.28	2749	45.8	0.76	31.4
North East Arm	36000	13.6	3117	51.9	0.87	27.7
Lake Champlain	120000	40	6058	101.0	1.68	14.3

Comparison of the frequency predictions for Missisquoi Bay and the WSE and ADCP spectral density plots indicates that the major response frequencies in the Bay and for flow through the causeway opening are attributable to the free surface sloshing in Missisquoi in the first and second mode. There does not appear to be any significant response in the spectral density at the main lake period of approximately 4 hrs. Below approximately 10 cycles per day, the signal appears to be essentially aperiodic with no indication of response at any specific frequency.

Additional response in the frequency ranges noted above may also be attributable to the free surface movement in the Northeast Arm as indicated by the results in Table 1. With the inclusion of the Northeast Arm in the model grid, the model was capable of predicting the surface seiche of both Missisquoi Bay and the Northeast Arm.

Comment: Lack of Definition of Model Open Boundary Conditions
Response:
Model open boundaries are critical for successful predictions and in many cases such as with river boundaries or tidal boundaries in coastal applications, the open boundaries are used to drive the model response with flow or water surface elevation variation. In the Missisquoi Bay application there are five river boundaries in the bay, three for the Missisquoi, and one each for the Pike and Rock Rivers. For each of the river boundaries a time series of volume flow rates was applied based on data obtained from the USGS and the Quebec Ministry of Environment and Wildlife. Without additional information, it was assumes that the three branches of the Missisquoi River each carried one third of the total river flow. These boundaries provide a specified flow rate to the model calculations but allow the model to predict the water surface elevation based on the conservation of water mass and momentum through the entire grid.

In order to assure that model predictions in Missisquoi Bay and the causeway area were not influenced inappropriately by the open boundaries it was determined that the entire Northeast Arm should be included in the model grid. This was done for several reasons, the first of which was to remove the open boundaries from the study area. For example, it would be possible to place the southern open boundary along a transect across the Alburg Passage at the northern tip of North Hero Island and along to Hog Island. While this would have been possible, specification of the boundary flow, water surface elevation and phosphorus and sediment concentrations would have been difficult and the results would almost certainly have influenced the flow and concentrations at the causeway.

In addition to removing the open boundaries from the study area, including the Northeast Arm allowed the model to predict the surface seiche that has been observed in the NE Arm as a results of the wind (Myer and Gruendling, 1979). In this way, the model is able to appropriately predict the influence of the NE Arm on the flow through the causeway in addition to the Missisquoi Bay influences.

Third, the three open boundary locations were selected at the connections between the water bodies which formed both natural and man made restrictions for flow interaction between the NE Arm and the main lake. The open boundaries were located at the causeway opening at Pelots Point in Carry Bay, at the causeway opening at Sandy Point at The Gut and at the Sand Bar Bridge causeway opening between the NE Arm and Malletts Bay at the south end of the NE Arm. The openings are between two and four times smaller than the Missisquoi Bay causeway opening.

The boundary condition applied at the three open boundaries was a constant surface elevation condition. This means that water is allowed to flow in or out of the domain but that the water surface elevation remains at a fixed level, which was zero in this case. The constant zero water surface elevation level at the boundaries is relative to the mean lake level datum for the simulation period. The water surface elevation within the model domain and at the river boundaries was free to move either up or down. The fixed water surface elevation boundary condition was considered justifiable as the majority of flow is from the NE Arm into the main body of the lake due to excess river flow into the NE Arm, and that reversals, when they do occur persist for not more than several hours (Myer, 1977). In addition, Myer also states that:

> "The maximum volume of water observed to flow through these openings into the Northeast Arm was approximately one million cubic meters. As this flow from the main basin of the lake first must pass through either Carry Bay or the Gut before entering the main basin of the Northeast Arm, there would be little mixing of the water from the northwestern part of the lake into the Northeast Arm. At the southern part of the Northeast Arm, Outer Malletts Bay appears to serve a similar function of isolating the Northeast Arm from the remainder of the lake."

Finally, referring to the power spectral analyses discussed above it is apparent that the frequencies at which signal variations are observed in the ADCP data do not correspond to forcing from the main lake.

Comment: Poor Correspondence Between Model Predictions and Observed Drogue Tracks

Response:

There were two types of current and transport field studies done for comparison with the model predictions. The first was the ADCP current meter study which was fixed in place at the opening in the Rt.78 causeway and produces what is an Eulerian perspective (flow past a fixed point in space). The second was the drogue study, where discrete objects (the drogues) were placed in the Bay and their spatial displacement monitored over time, which is a Lagrangian perspective (points moving over a fixed grid).

General practice indicates that Lagrangian comparisons are far more difficult and less reliable than Eulerian comparisons. The reasons for this lie in the fact that the drogues are subject to many more local forces than the fixed current meter such as small scale circulation features that would be sub-grid scale and poorly defined in the model predictions. Non-linear theory indicates that small deviations in the initial placement of the moving particle can result in large differences in the final position. The effects are cumulative. This is not the case for the Eulerian current meter comparisons where the small differences in the local circulation would not be cumulative and would be dominated by the large scale water movement patterns.

In the report field study and modeling report (ASA, 1997) the model to data comparison for both the drogue study and ADCP observations was discussed in some detail. Several points should be reconsidered here for comment on the drogue data comparison. In general the model predicted currents match ADCP currents well in terms of large scale patterns and trends but have differences in the smaller time scale variations. This can be attributed to several sources including: the wind used for model forcing was recorded as half hour averages at the Rt. 78 bridge but the ADCP data was recorded at a 5 minute averaging period; the grid cell size, while refined enough to capture the inter-basin scale transport and mixing was not resolved to capture the small scale circulation features.

Detailed comparisons of the model predicted currents and the ADCP data on both October 10th and October 29th, the two drogue study days, show very good agreement except for a brief period in the late morning (see Figures 6.2 and 6.3 repeated below for clarity). Those times unfortunately coincided with the drogue deployment times which clearly and inappropriately influenced the model predicted drogue tracks. It can be seen that the wind is the major driver in the system (above the steady background river flow) but that the ADCP observations occasionally flow inconsistently with the recorded wind. This result may be due to the wind in Northeast Arm (or in Missisquoi bay itself) being different from the wind measured at the bridge and may affect the model predictions to behave differently than the observations.

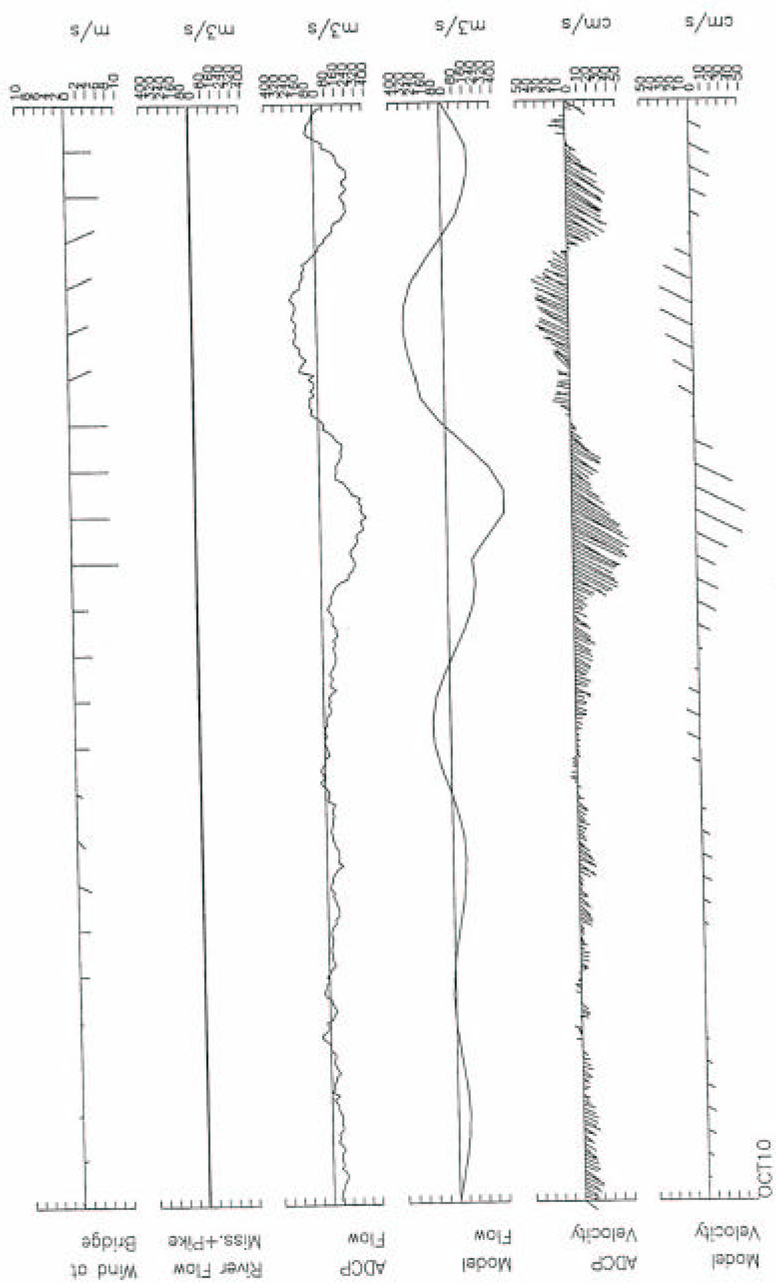

Figure 6.2 Results of the model calibration for October 10, 1996.

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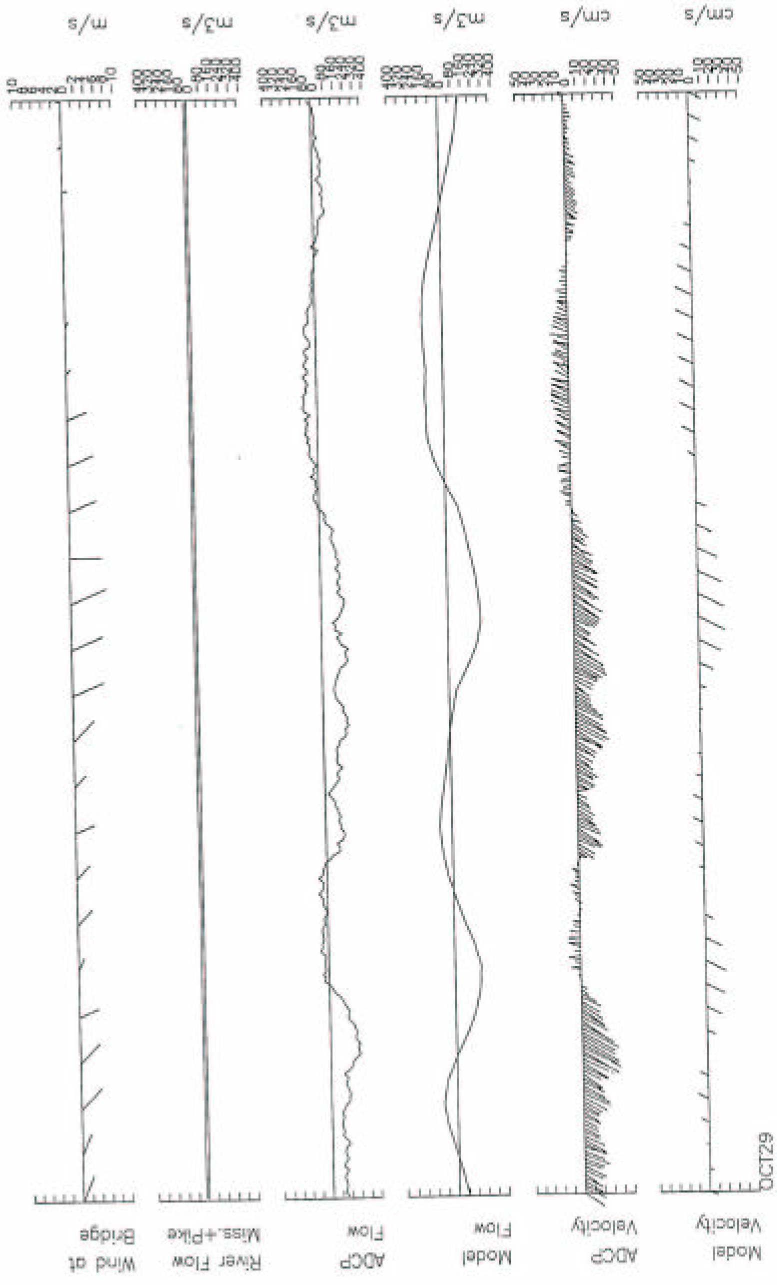

Figure 6.3 Results of the model calibration for October 29, 1996.

Comment: Lack of Consideration of the Effects of Aquatic Macrophytes on Currents
Response:
While it is true that the Missisquoi Bay model application did not explicitly include the effects of macrophytes on the circulation and transport calculations it was determined that relatively little growth was present in the Bay entrance area North and South of the causeway. The flow through the Bay entrance was the primary focus of the study. In addition in his review of the modeling study, Jean-Francois Cantin states that "according to the map of aquatic plants provided by the Quebec Department of the Environment, the impact of the latter on flow in the bay is mostly seen along the shoreline, but remains small on the whole".

In general the effect of the macrophytes would be to slow down the local currents. In calibrating the model the bottom friction was adjusted to better match the model predictions to the observations. The adjustment of the bottom friction to increase the drag would have the same effect as explicitly including the macrophyt drag on the bottom currents. Although a range in the drag coefficient from 0.003 to 0.005 was stated, the 0.003 value selected is double the literature value of 0.0015 for sandy bottom types.

Comment: Insufficient Water Quality Data for Model Calibration
Response:
We believe that there was sufficient water quality data based on the VTDEC and NYSDEC Long Term Water Quality and Biological Monitoring Project for Lake Champlain and the Lake Champlain Diagnostic Feasibility Study, 1992. These studies collected, analyzed and modeled two full years of flow, chlorides (a conservative substance) and phosphorus in all of the inflowing rivers (and the Richelieu outflow), WWTFs and in-situ concentrations, producing a lake wide mass balance for each. In both of the study years the Missisquoi Bay phosphorus levels ranked among the highest in the lake, occasionally superceded by the South Lake area only. With the additional information of the volume inflow and concentrations and therefore the load, a very good understanding of the phosphorus dynamics was possible.

The intent of the phosphorus modeling study was not to do a full and in-depth water quality analysis, but rather it was to assess the effects of the system hydraulics on the phosphorus concentration in the Bay to see if phosphorus was being trapped in the Bay by the causeway. From that perspective the WQ data used was sufficient. For the modeling study under discussion the authors used the actual, recorded river volume flow rates for the three tributaries to the Bay, coupled with the average phosphorus concentration developed in the Diagnostic Feasibility Study, to predict the actual loading for October 1996. During that time period there were several in-situ observations in the Bay which were compared to the model predictions with favorable results. If a full nutrient water quality model study is to be done more data may be necessary.

Comment: Mass Balance Model of Phosphorus
Response:
The first part of the response to this comment was noted in the response above and is reiterated here for clarity. The intent of the phosphorus modeling study was not to do a full and in depth water quality analysis, but rather it was to assess the effects of the system hydraulics on the phosphorus concentration in the Bay to see if phosphorus was being trapped in the Bay by the causeway. From that perspective the WQ data used was sufficient.

At this point the phosphorus cycle in the Bay is not completely known. We do not have measurements of the all of the components in the phosphorus cycle, e.g. nutrient flux from the sediments. For the study however, we approached the problem in the following manner: we elected to perform a flushing study as a proxy for the re-suspended phosphorus load and a transport study for the river born phosphorus in the Bay. For the flushing study the modeling application assumed that a large re-suspension event that produced a uniform phosphorus concentration in the Bay and then monitored the amount of time it would take to complete the removal of this produced concentration with and without the causeway. For the river-borne phosphorus, a long term simulation was performed to monitor the concentration in the Bay over time and the final resulting concentration with and without the causeway.

Finally, as noted above there was sufficient data from the VTDEC and NYSDEC Long Term Water Quality and Biological Monitoring Project for Lake Champlain and the Lake Champlain Diagnostic Feasibility Study, 1992 to perform phosphorus mass balance. These studies collected, analyzed and modeled two full years of flow, chlorides (a conservative substance) and phosphorus in all of the inflowing rivers (and the Richelieu outflow), WWTFs and in-situ concentrations, producing a lake wide mass balance for each.

Comment: From David Borthwick-Leslie
Response:
Mr. Borthwick-Leslie has performed an analysis of the flow, and potential resulting concentrations, for exchange between the main lake, the Northeast Arm and Missisquoi Bay. He states that historical studies indicate that the majority of flow from the Northeast Arm flows to the main lake through the Alburg Passage. It appears that the thrust of his argument is that during high flow events there is not enough cross sectional area in the causeway passage between Carry Bay and the main lake to handle all of the increased inflow. The result is that the excess water from Missisquoi Bay (and associated concentrations) flows into the Northeast Arm temporarily until the flow through the Carry bay passage catches up.

In addition Mr. Borthwick-Leslie performs calculations that estimate the improvement in the flow pattern and water quality in the Northeast Arm that would result from the removal of the Carry Bay causeway as well as the Rt. 78 Bridge causeway. These calculations indicate that because the Carry Bay causeway opening is significantly smaller than the Missisquoi causeway opening, the Carry Bay causeway is the major restriction to water exiting both from Missisquoi Bay and the Northeast Arm. These calculations are in agreement with earlier studies that essentially indicate that the main lake and the Northeast Arm are physically separated enough to be considered separate water bodies, (Myer and Gruendling, 1979).

Authors' Summary

In conclusion we believe the comments provided by the reviewers and Mr. Borthwick-Leslie have been successfully addressed and that the ASA studies conducted on Missisquoi Bay were also successful in attaining their intended goals. It should be reiterated that the concluding comments of the reviewers indicate that none of the technical issues they raised would influence any significant change to the conclusions.

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