YB299A
ENVIRONMENTAL IMPACT ASSESSMENT REPORT
FOR MODIFICATIONS TO THE
PETITCODIAC RIVER CAUSEWAY

Submitted to:
New Brunswick Department of Supply and Services
Fredericton, New Brunswick

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EXECUTIVE SUMMARY

Background

This document is the Environmental Impact Assessment (EIA) Report for the Modifications to the Petitcodiac River Causeway Project. The Petitcodiac River causeway (“causeway”) is a gated dam structure with an installed vertical slot fishway that was built across the Petitcodiac River between the City of Moncton and the Town of Riverview. Figure 1 shows the location of the Petitcodiac River and Figure 2 shows an aerial view of the causeway. Completed in 1968, the causeway was intended to create a second transportation link between the two communities, offer flood protection for farmland between the causeway and the head of tide at Salisbury, and create a freshwater headpond with potential for recreation and as an industrial water source. A bridge would have achieved the transportation objective, but not the other benefits.

As early as 1961, it was recognized by Fisheries and Oceans Canada (“DFO”) that fish passage would be an issue if a causeway was built across the Petitcodiac River. Consequently, DFO required that a fishway be included in the structure. However, the construction of the causeway with the fishway resulted in fish passage issues from the outset. The fishway proved ineffective for all fish species that require passage for life cycle purposes, including the Inner Bay of Fundy Atlantic salmon that is now also protected under the Species at Risk Act because of declining numbers. Subsequent modifications to the fishway and gate management have failed to provide a solution to the fish passage issues. The continual efforts to address fish passage issues have largely failed and thus the facility has not met the intent of the original requirement for a fishway in the structure, and also continues to not meet the requirements of Section 20 of the Fisheries Act.

The history of the causeway was previously reviewed by Eugene Niles, Special Advisor to the Minister of Fisheries and Oceans, in his report of February 9, 2001 (the “Niles Report”; Niles, 2001). The Niles Report concluded that fish passage through the causeway gates and fishway has been problematic and continues to be problematic to this day in spite of numerous changes in operational procedures and modifications to the gates and fishway. The Niles Report recommended four possible options to address the fish passage issue.

Following a variety of separate reports and actions, and based on the recommendations as presented in the Niles Report, it was resolved that an EIA was necessary to evaluate potential Project Options to address the fish passage and other ecosystem issues. The New Brunswick Department of Supply and Services (NBDSS) were tasked with identifying a means to rectify these issues, and a harmonized federal-provincial EIA was established with the issuance of joint Guidelines. In November 2002, NBDSS contracted AMEC Earth and Environmental, a Division of AMEC Americas Ltd (AMEC) to undertake the EIA. AMEC led a Study Team that comprised experts from AMEC (project managers, engineers, biologists, public consultation facilitator) and experts (biologists, engineers, modellers, EIA practitioners, economists and social scientists) from other firms in Canada including: Jacques Whitford; ADI Limited; Canadian Hydraulics Centre; Gemtec Limited; GPI Atlantic (as recommended by the Niles Report); and Gardner
Pinfold Consulting Economists Limited. Many of these experts had previously done work involving the Petitcodiac River, and some had up to 30 years of experience in this regard.

The Purpose of the EIA

The EIA evaluated four Project Options recommended by the Niles Report that were intended to meet the Project Objectives and considered other relevant options identified during the EIA. The Project Objectives were to achieve a long-term solution to fish passage (i.e., achieve compliance with the intent of the original DFO requirement to provide a fishway at the causeway) and other ecosystem issues related to the causeway, including tidal exchange, sediment transport and other physical processes and biophysical functions (e.g., wetlands, populations of flora and fauna, fish habitat).

The principal purpose of the EIA was to evaluate and compare the potential environmental effects of the Project Options that meet the fish passage Project Objective (a long-term solution to fish passage; the unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required for their life cycle), determine if the selected Project Options also meet the other Project Objectives (i.e., ecosystem issues), analyze proposed mitigation and determine significance of the residual environmental effects and compare those to current conditions and the Status Quo (i.e., the current causeway conditions continued into the future). The fish species that were determined to require passage at the causeway were as follows: Atlantic tomcod, rainbow smelt, gaspereau (both alewife and blueback herring), brook trout, American shad, American eel, sea lamprey, Atlantic sturgeon and Atlantic salmon.

The EIA Report

The EIA Report was the result of almost three years of research, consultation, modelling and analyses conducted by the AMEC Earth and Environmental Limited (AMEC) Study Team. The AMEC Study Team wrote the EIA Report on behalf of NBDSS. The EIA Report is intended to fulfill the reporting requirements for an Environmental Impact Assessment Report pursuant to the Clean Environment Act—Environmental Impact Assessment Regulation (EIA Regulation) and is the supporting document for the Screening Report (to be prepared by the Responsible Authorities) under the Canadian Environmental Assessment Act (CEAA). The EIA and EIA Report fulfill the requirements of the Guidelines for an Environmental Impact Assessment – Modifications to the Petitcodiac River Causeway (the “Guidelines”) issued on July 26, 2002 (New Brunswick Department of Environment and Local Government (NBDELG), 2002). The Guidelines reflected the Niles Report and a modelling workshop organized by Environment Canada and DFO in March 2002 to address the issues associated with modelling of the Petitcodiac River and identify the path forward for modelling the Petitcodiac River estuary in order to facilitate the EIA.

The Terms of Reference, prepared by NBDSS on how the EIA would meet the Guidelines, contained details for carrying out three Component Studies. The Component Studies were completed to provide the information necessary to support the EIA Report. The component studies were a Biophysical Component Study (AMEC, 2005a), a Socio-economic Component Study (AMEC, 2005a) and a Hydrodynamic and Sediment Transport Modelling Component Study (AMEC, 2005b).
Scope of the EIA

The conduct of the EIA involved thorough consultation and communication with the public, stakeholders and regulatory authorities and meetings with the Aboriginal Community that was ongoing for the duration of the EIA. Issues not previously identified in the Guidelines were documented and addressed in the EIA Report. Thirteen Valued Environmental Components (VECs) were selected for the EIA, comprising a range of biophysical, socio-cultural and economic aspects of the environment that may be affected by the Status Quo and Project Options. These are as follows:

- Atmospheric Environment;
- Fish and Fish Habitat;
- Terrestrial and Wetland Environments;
- Municipal Services and Infrastructure;
- Road Transportation Network;
- Vessel Traffic and Navigation;
- Land Use and Value;
- Aboriginal Land and Resource Use;
- Tourism;
- Recreation;
- Labour and Economy;
- Heritage and Archaeological Resources; and
- Public Health and Safety.

Existing Conditions

The Petitcodiac River estuary (Figure 1) is unique. The estuary is macro-tidal (i.e., with tides averaging 11 m) with an unparalleled suspended sediment loading typically in the order of up to 30,000 mg/L. The causeway (as shown in Figure 2) is located in the upper portion of the estuary, 20 km from the head of tide. There were very few similar examples found elsewhere in the world where fish passage facilities were incorporated in a facility that is located in a macro-tidal estuary and none display the combination of suspended sediments and macro-tidal conditions. The causeway also experiences temperature extremes from 30°C in the summer to –35°C in the winter. The physical nature of the estuary and the presence of the headpond and gates in the causeway, present challenges for the management of sedimentation and results in the potential for ice jamming and related operational issues. Consequently, a complex Gate Management Plan is in place to ensure safe operation of the facility, and in an effort to ensure improved opportunities for passage of some fish species. As stated previously, the Gate Management Plan has failed to meet the DFO requirement of the original intent of providing a fishway at the causeway.

Evaluation of the Project Options

The Project Options considered were:

- Project Option 1—replacing the fishway;
- Project Option 2—gates open during peak migration;
• Project Option 3—gates open permanently; and
• Project Option 4—replace the causeway with a partial bridge.

The Status Quo is the term recommended by Niles for continuation of the current gate management plan (i.e., no change) and has been considered in this report for comparison to the Project Options. The Status Quo was not considered as a Project Option as it does not and cannot meet the Project Objectives.

The existing fish passage issues were reviewed and found to include a number of impediments to fish passage. These included predation (birds and large fish eating smaller fish near the causeway), difficulties in negotiating the fishway, gate management, dissolved oxygen barriers, a seasonal sediment plug that extends several kilometres downstream of the causeway and upstream of the causeway, and a headpond water level elevation that is lower than highest tide providing insufficient attraction flow for fish.

An exhaustive evaluation of fisheries facilities in New Brunswick, Canada and elsewhere in the world was conducted to identify potential fishway solutions. It was evident that the issues associated with the causeway fish passage facility are difficult to overcome. Technologies that have been applied at other facilities were not applicable to the Petitcodiac River facility. This was mainly due to the unique characteristics of the Petitcodiac River (low and highly variable rate of freshwater flow, high tidal range and high suspended sediment concentrations) and the variety of fish species requiring migration. Examination of the facilities revealed that none examined could provide fish passage, upstream or downstream, for all of the fish species requiring passage at the causeway. It was therefore concluded that a new fishway or further enhancement to the gate management strategy would not be feasible to provide upstream and downstream passage for these fish species. Hence, Project Option 1 (replacing the fishway) would not meet the fish passage Project Objective of providing unimpeded and safe movement of fish upstream or downstream, between aquatic habitats required to complete their life cycle.

Peak fish migration occurs in the spring and fall, with a considerable upstream and downstream migration also occurring in the summer and winter. Opening the gates in the spring and fall only would not provide passage opportunities for all of the identified fish species requiring migration at the causeway and therefore Project Option 2 (gates open during peak migration) would not meet the fish passage Project Objective. Project Option 2 would also be burdened with other issues such as continued sediment accumulation in the headpond, ice-jamming at the gate piers in the winter months, and the summer and winter headpond would be brackish and unsuitable for freshwater fish species.

Project Options 3 (gates open permanently) and 4 (replace the causeway with a partial bridge) would both meet the fish passage Project Objective as they allow free tidal exchange and the movement of fish species that require passage.
Project Description

Design Criteria for the Project Options were developed in addition to the main project objective of safe and unimpeded passage of fish so that these Project Options could meet the other Project Objectives (i.e., ecosystem issues) as well. These criteria included:

- reversing the current infilling trend within the river both upstream and downstream of the causeway;
- the protection of species regulated by SARA or the New Brunswick Endangered Species Act;
- free passage of ice;
- protection of wetland area that provides water quality treatment for the former Moncton Landfill immediately downstream of the causeway and the integrity of the landfill itself; and
- design life of at least 100 years, including consideration of a sea level rise of 88 cm in the next 100 years.

Project Option 3 (gates open permanently) involves the removal of all gates and all but one pier at the location of the existing gates and provides an opening of 68 m wide.

Project Option 4 (replace the causeway with a partial bridge) has been split into the following three separate Project Options that were distinct ways of engineering a partial bridge:

- Project Option 4A involves construction of a 170 m long bridge downstream of the existing gates and the removal of the entire gate and fishway structure to provide an opening of 72 m;
- Project Option 4B involves a new bridge, 280 m long downstream of the existing gates that would afford a range of potential openings from 72 to 225 m; and
- Project Option 4C involves a 315 m long, bridge in the central portion of the causeway, providing a river channel width of 225 m.

Mitigation strategies were built into the design of these Project Options so that the Design Criteria and other Project Objectives can be met. These strategies include erosion and scour protection along critical riverbank locations and the former Moncton Landfill between the causeway and Gunningsville Bridge. Compensation for affected facilities or operations (e.g., Sea Cadet, Tri Community Marina, Town of Riverview public dock) was included.

Precautionary Implementation Strategy

The following precautionary three-staged implementation strategy was developed for each Project Option:

- Stage 1—Design, construction and communication prior to opening the existing gates;
- Stage 2—Open existing gates; and
- Stage 3—Construct the structure required for the preferred Project Option.
Stage 3 involves the following actions for each of the Project Options that meet the fish passage objective:

- for Project Option 3, remove the piers and fish passage facility and replace/construct the bridge deck;
- for Project Option 4A, construct a new bridge downstream of the causeway and remove the piers and fish passage facility;
- for Project Option 4B, construct a new bridge downstream of the causeway and remove the control structure and a portion of the causeway (although this initially may be only removal of the control structure with subsequent removal of a portion of the causeway at a later date); and
- for Project Option 4C, construct cofferdams and a temporary bypass, create an opening in the central portion of the causeway, construct a new bridge and then remove the cofferdams and temporary bypass to permit flow through the causeway. The control structure would be filled in.

This precautionary approach would ensure that the selected Project Option would be implemented successfully and that predictions made in the EIA Report would be verified through monitoring of the evolution of the channel before irreversible decisions could be made for the next stage.

**Description of Anticipated Changes to the River**

Hydrodynamic and sediment transport computer modelling was one tool used to assist in predicting changes to the river. Trend analyses, interviews with people knowledgeable about the river (including government departments and agencies such as DFO) and the expertise of the AMEC Study Team, were also used to assist in describing the future anticipated changes to the River for each of the Project Options that met the fish passage Project Objective. Specifically this was Project Option 3 (gates open permanently) and Project Option 4 (replace the causeway with a partial bridge).

Under the Status Quo, the channel downstream of the causeway would continue to progressively infill. The tidal volume would continue to decrease. Equilibrium would not be anticipated to occur for another 70 years. It was anticipated that tidal elevations in the Moncton area would increase by about 0.2 m due to infilling. Flooding risk under open water conditions would increase under the Status Quo due to infilling both upstream and downstream of the causeway. Current problems with dissolved oxygen downstream of the causeway would continue and likely worsen with the Status Quo. Existing ice jamming and channel narrowing would continue and worsen under the Status Quo.

Project Options 3 and 4 (i.e., 4A, 4B, 4C) would reverse all of these problems identified for the Status Quo. Full tidal exchange would occur up to Salisbury, but the headpond would be lost. The channel would increase in width and depth and the tidal prism would increase, more for Project Option 4 than Project Option 3. Flooding risk would be reduced due to improved conveyance capacity (the amount of water that can move through the river in a given amount of time). Dissolved oxygen problems would be alleviated due to the increased dilution. Sediment
removed from the river as the river widens and deepens will be transported to Shepody and Chignecto Bays, but held in suspension in those bays until ultimately transported into the central portion of Bay of Fundy. Opening the causeway would not result in an alteration of the lobster and scallop beds in Shepody and Chignecto Bays or an alteration of the conditions at Hopewell Rocks.

**Environmental Effects Assessment**

A comprehensive environmental effects assessment was conducted of the Project Options that met the fish passage Project Objective (Project Options 3 and 4) each of the 13 VECs. As noted above, the Status Quo was included for comparison purposes, and the effects assessment was also carried out for the Status Quo. The environmental effects were evaluated for each VEC including the required mitigation. Mitigation of the Status Quo was not described as it was not a Project Option and was provided for comparative purposes only. Table 1 summarizes the results of the environmental effects assessment showing whether or not the potential residual environmental effects were determined to be significant (S), not significant (NS) or positive (P). The Project Options 3, 4A, 4B and 4C did not have different overall conclusions and are therefore presented as one column in the table.

The Status Quo would not meet the Project Objectives and the Status Quo would result in significant negative environmental effects on most VECs, and no overall positive environmental effects on a VEC-by-VEC basis. These significant environmental effects were primarily related directly or indirectly to sedimentation and the loss of the tidal prism and channel conveyance. These significant environmental effects were those that have led to need for the EIA and to a large extent, determined the Project Objectives (i.e., restore fish passage and other ecosystem issues). The Status Quo would have some positive environmental effects (i.e., recreational smallmouth bass fishery and modest vacant land value enhancement adjacent to the headpond, float plane access on the headpond). These tend to lessen the significant negative environmental effects but clearly not to the extent that would render other negative environmental effects not significant, overall.

Overall, the Project Options would result in several positive environmental effects. Most importantly, these Project Options meet the fish passage Project Objective. Fish passage would be restored for the nine species that require passage through the consequent changes to the Petitcodiac River estuary. Other ecosystem issues (e.g., tidal exchange, sediment transport and other physical processes and biophysical functions) and socio-economic issues were similarly addressed. A summary of some of the key issues (i.e., change wetlands and mudflats, change in tourism opportunity, change in property value, change in need for additional sewage treatment) follows.

The Project Options would not result in a substantive interaction between the river and the abandoned City of Moncton Landfill located adjacent to the causeway. The modelling has clearly demonstrated that the new channel (i.e., after implementation of the Project Options) would not erode much of the extensive wetland currently in place between the landfill and the
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S = Significant, NS = Not Significant, P = Positive

river channel. Regardless, as a precautionary measure, it is recommended that erosion protection measures (riprap for all Project Options and sheet piling for Project Options 4B and 4C) be put in place around the landfill to prevent any unanticipated interactions between the river and the landfill from occurring.

The Project Options would not result in substantive environmental effects on lobster or scallop or their habitat. It was concluded that there is no scientific basis for a correlation between the installation of the causeway and the coincidental increase in lobster and scallop populations in
the Shepody and Chignecto Bays. Also, a thorough review of the most recent studies regarding sediment distribution processes in Shepody and Chignecto Bays suggests that most of the sediment that would be released from the Petitcodiac River, with implementation of the Project Options, would be deposited in the Bay of Fundy, and would not accumulate in Shepody or Chignecto Bays.

The Project Options would result in positive environmental effects on wetlands and mudflats. Although the Project Options will cause the overall loss of wetland area, the restoration of estuarine conditions in the area above the causeway will expand the current distribution of provincially significant saltwater marsh, and the increased flushing action downstream of the causeway will enhance saltwater marsh productivity in that area. Similarly, mudflat productivity will be more like what existed in pre-causeway times. Of most importance, the mudshrimp (an important food for migratory birds) requires estuarine or saline conditions. The Project Options will therefore extend the current distribution of mudshrimp to include the mudflats above Dover (the current edge of distribution), including the mudflats above the causeway.

The Project Options would result in positive environmental effects on tourism opportunity along the Petitcodiac River. Most notably, the Project Options would result in the enhancement of the tidal bore. Although it was not considered likely that the tidal bore would attain pre-causeway size, it would be larger and more consistent throughout the year. Implementation of the Project Options may reduce channel infilling near Hopewell Cape, but would not affect the Hopewell Rocks.

The Project Options would also result in adverse environmental effects on recreation opportunity. Alteration of the headpond would, without mitigation, affect the activities of the Tri Community Marina, Town of Riverview public boat launch, the Sea Cadet training facility, float planes and private docks, and would result in the loss of the smallmouth bass and chain pickerel fishery between the causeway and Salisbury. However, the overall environmental effects are anticipated to be positive as opportunity to pursue native fish species such as striped bass, American shad, sea-run brook trout and possibly Atlantic salmon (should this species eventually recover and be removed from the Species at Risk Act) will improve, and the removal of the causeway as an obstruction to navigation and the free tidal exchange in a deeper and wider channel will afford greatly enhanced opportunity for river-based recreation.

The Project Options would result in negative, but not significant, changes in the value of some types of property. Specifically, the Project Options may potentially result in a decrease (-5%) in value of vacant land property immediately adjacent to the headpond (i.e., on the waterfront and above the causeway). The Project Options would not likely result in a significant change in value to developed waterfront property anywhere along the Petitcodiac River.

The Project Options would result in an improved assimilative capacity (the ability of the river to accept wastewater while maintaining acceptable water quality) of the river due to the increased tidal prism and the subsequent improvement to dissolved oxygen levels. As a consequence, the need for additional sewage treatment facilities at Outhouse Point that exists under the Status Quo is greatly reduced, possibly eliminated. However, additional sewage treatment may
be necessary in the future as a result of changes in environmental legislation and increased population. In this case, the Project Options will defer the need for additional sewage treatment facilities at Outhouse Point.

The Project Options would result in some negative environmental effects that would not be significant due to their limited magnitude, extent, duration, frequency and/or reversibility and in consideration of planned mitigation. Key mitigation includes shoreline erosion protection downstream of the causeway, embankment protection at the former Moncton Landfill immediately downstream of the causeway, protection of the riverbank along the Riverview walking trails, restoration and maintenance of agricultural dykes and aboiteaux above the headpond, and compensation for loss of the Tri Community Marina. The Project Options included a comprehensive environmental management strategy that would ensure sound design, construction and operational practices, and an adaptive management approach based on a precautionary implementation strategy and the associated Follow-up Program.

**Effects of the Environment on the Project**

The aspects of the environment that may cause a change in the design or construction of the Project Options and the Status Quo considered in the EIA Report included the following: sediment transport process; tidal prism; weather; flooding; ice; climate change and earthquake activity.

Good engineering planning and design always involves consideration of effects of the environment on a project and the planning and engineering design for the Project Options (3, 4A, 4B and 4C) were no exception. The mitigation (e.g., riprap of erodible shorelines) for potential effects of the environment on the Project were inherent in the planning and engineering design as presented in this EIA Report. In addition, Stage 1 of the Project Options implementation plan would further define the mitigation for construction and operation of the Project Options and monitoring and follow-up, as described in Chapter 12, would further minimize the likelihood of a substantive effect of the environment on the Project Options from occurring.

In consideration of the likely effects of the environment on the Project Options and the proposed mitigation (including monitoring and follow-up), the residual effects of the environment on the Project Options were determined to be not significant.

By contrast, the Status Quo would continue to result in a changing environment due to sedimentation and reduction in tidal exchange. This would in some instances result in an effect of the environment on the Status Quo that would be significant (e.g., increased flooding risk due to decline in channel conveyance, made worse by relative sea level rise and made worse due in part to climate change).

**Cumulative Environmental Effects Assessment**

The assessment of cumulative environmental effects expanded on the environmental effects analysis of the Status Quo and Project Options (3, 4A, 4B and 4C). Once established, the environmental effects of the Status Quo and Project Options must overlap with those of other
past, present and future actions for a cumulative environmental effect to result. The environmental effects assessment and analysis of the effects of the environment on the Status Quo and Project Options very thoroughly established the cumulative environmental effects of past and present actions, including the contribution of the causeway to date. The cumulative environmental effects of the Status Quo and Project Options were evaluated in respect of four main categories of future actions: global, land use, economic and cultural.

Evaluation of these cumulative environmental effects demonstrated that the cumulative environmental effects of past, present and future actions that overlap with those of the Status Quo and Project Options were consistent with those identified in the environmental effects assessment and assessment of the effects of the environment of project. Future actions including other future development projects (e.g., City of Moncton Assomption Boulevard Phase II and Vaughan Harvey Boulevard Extensions) would not contribute in substantive ways to cumulative environmental effects.

Importantly, the Status Quo contributed substantively to cumulative environmental effects that were determined to be significant and negative. These included the persistence of Fish and Fish Habitat issues (i.e., not meeting the fish passage Project Objective), and also:

- sedimentation and ice blocking outfall flapgates and drainage ditches downstream of the causeway;
- increased flooding of roads;
- sedimentation further reduces navigability;
- increased flooding would result in property damage and increased insurance premiums;
- the loss of opportunity for land and resource use for traditional purposes by the Aboriginal Community;
- the loss of a natural estuary and the tidal bore and related tourism opportunity;
- the loss of some recreational fisheries;
- the loss or reduction of some commercial fisheries (e.g., American shad); and
- increased flooding risk and public safety and human health risk due to recreational contact.

By contrast in meeting the Project Objectives, the Project Options would contribute to positive cumulative environmental effects due to changes to the Petitcodiac River estuary that afford the restoration of fish passage and the overall ecosystem benefits (tidal exchange, sediment transport and other physical processes and biophysical functions). Mitigation planned for the Project Options would mitigate potential cumulative environmental effects and no specific mitigation would be required to address cumulative environmental effects beyond those measures.

**Follow-up Program**

A Follow-up Program would be implemented to meet the requirements of both the Guidelines and CEAA, and would be consistent with the implementation strategy for each Project Option.
The overall objective of the Follow-up Program would be to support the successful implementation for the selected Project Option so that it meets the Project Objectives.

In Stage I of the precautionary implementation strategy, the Follow-up Program would focus on the collection of baseline data (if required and not already available) to be used as a benchmark for follow-up of the environmental effects assessment predictions. Data collection would include cross-sections of the upstream channel excavation, tourist surveys in the GMA, and the assembly of catch data for commercial lobster, scallop and eel fisheries.

In Stage II of the precautionary implementation strategy, the Follow-up Program would verify the accuracy of short-term modelling predictions of changes to the river channel, through the seasonal measurement of cross sections along the length of the river. Follow-up would also verify the effectiveness of mitigation measures implemented in Stage I before the gates were opened (i.e., upstream dyke restoration, former Moncton Landfill erosion protection, watermain relocation, embankment and channel bottom protection, and channel excavation upstream of causeway to facilitate initiation of the erosion process). Tourism surveys and commercial fisheries catch data would continue to be collected/assembled throughout Stage II.

In Stage III of the precautionary implementation strategy, the Follow-up Program would verify the effectiveness of mitigation measures and the accuracy of environmental effects assessment and modelling predictions. Follow-up would focus on physical characteristics of the Petitcodiac River estuary as they relate to the following VECs: Fish and Fish Habitat, Terrestrial and Wetland Environment, Municipal Services and Infrastructure, Vessel Traffic and Navigation, Tourism, Labour and Economy, Heritage and Archaeological Resources and Public Health and Safety. In addition, the Follow-up Program would include: collection of sediment and water quality data; air photo interpretation to determine changes in wetland and mudflat areas; evaluation of river-front property market values; continued communication with the Aboriginal Community; collection of river-based tourism, boating and angling survey data; inspection of trails adjacent to the river; continued assembly of commercial fisheries data; evaluation of boater stranding statistics and forest fire fighting resources; and visual inspection of mitigation measures (i.e., watermain relocation, upstream dyke restoration, former Moncton Landfill erosion protection and embankment protection).

The Follow-up Program would focus on an adaptive management approach to verify the conclusions and the effectiveness of mitigation, and in the unlikely event of unanticipated changes to the river or failure of mitigation measures, be used to update the EMP before each construction stage would be implemented.

Economic Considerations

The benefits and costs of the causeway to date, and out into the future with the Status Quo and Project Options (3, 4A, 4B and 4C) that met the Project Objectives were considered. Capital and operating costs were characterized for the Status Quo and Project Options. Other economic considerations associated with the causeway to date (i.e., intangibles or benefits and costs that were difficult to attach “hard costs” to), Status Quo and Project Options were qualitatively and, where feasible, quantitatively analyzed.
On the whole, it was concluded that the costs of the causeway have, from a benefit and cost perspective, not been favorable. This is particularly true when one considers the fact that these negative significant environmental effects would not have occurred if a bridge had been constructed rather than a causeway, although maintenance and possibly enhancement of agricultural dykes and aboiteaux upstream of the causeway would have been required.

The original causeway construction cost between $18,000,000 and $24,000,000 in 2004 dollars. Similar costs would have been expended to build a bridge. The capital and operating cost of the Status Quo going forward from 2005 would be on the surface relatively small for maintenance and operation of the gates, and occasional major repairs (i.e., $666,800 every 15 years). What was not factored into the Status Quo was the undefined but substantial costs associated with elevated flood risk that would result in increased magnitude and frequency of flooding, and/or increased insurance rates (likely in the tens of millions of dollars).

It was estimated that the cost of sewage treatment improvements to address current water quality issues alone would be in the order of $36,400,000. As such, the direct and indirect costs of the Status Quo in future would be well in excess of $36,400,000. However, due to anticipated changes in regulatory requirements for municipal wastewater, it would be possible that at some time in the future improved treatment may be required at the GMSC wastewater treatment facility regardless of the presence or absence of the causeway. If this were to occur, then the direct costs of improvement (estimated at $36,400,000) would not be attributable to the Status Quo, but could at least be deferred to some future time.

The capital and operating cost of the Project Options is summarized in Table 2.

<table>
<thead>
<tr>
<th>Activity</th>
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<tr>
<td>Sub-total Stage 1</td>
<td>$18,430,000</td>
<td>$20,390,000</td>
<td>$20,390,000</td>
<td>$21,610,000</td>
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<tr>
<td>Sub-total Stage 2</td>
<td>$3,120,000</td>
<td>$3,960,000</td>
<td>$5,080,000</td>
<td>$7,000,000</td>
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<tr>
<td>Sub-total Stage 3</td>
<td>$12,530,000</td>
<td>$17,600,000</td>
<td>$29,140,000</td>
<td>$78,660,000</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$34,080,000</td>
<td>$41,950,000</td>
<td>$54,610,000</td>
<td>$107,270,000</td>
</tr>
</tbody>
</table>

*all values in 2004 CDN dollars and include 25% contingency (see Table 12.2.1 for detail)

The costs of Project Options 4B and 4C would likely be fully or almost entirely offset by future avoided costs of the Status Quo when the avoided cost of flood protection, damage, or property insurance were factored in, along with other identified costs. These costs may be further alleviated by the deferred or avoided costs of sewage treatment upgrades.

The Status Quo on the whole has many costs associated with the predicted significant negative environmental effects, but in addition, there could be the consequences of ongoing violation of Section 20 of the *Fisheries Act* and future violation of Section 33 of the *Species At Risk Act* (Atlantic salmon and dwarf wedgemussel) that were not quantified as part of this study, but may result in additional costs (e.g., fines). Conversely, the Project Options in meeting the Project Objectives would overall result in many benefits that on the whole would result in even greater net benefits (e.g., tourism, commercial and recreational fishing and navigation).
From a full cost accounting perspective, notwithstanding regulatory considerations, it would appear that the costs of implementing Project Options, in effect, would be largely nullified, through the benefits that would be accrued (e.g., reduced flood risk, tourism, commercial and recreational fishing and navigation) and the avoided future costs of the Status Quo (e.g., flood protection, damage and insurance).

**Overall Conclusion**

For fish passage to be re-established on the Petitcodiac River for nine important species, the Status Quo and Project Option 1 (replacing the fishway) and Project Option 2 (gates open during peak migration) will not achieve this. Only Project Option 3 (gates open permanently) and Project Option 4 (replace the causeway with a partial bridge) with modifications do.

Project Option 3 would be the least costly to build and operate, but would not have the enhanced benefits (increased sediment erosion and tidal exchange) of Project Option 4(A-C).

Project Option 4A is another way of achieving the same result as Project Option 3, but will have less of an environmental effect on traffic patterns during the construction phase.

Project Option 4B affords a greater degree of flexibility should predicted sediment erosion and increased tidal exchange be found to be less than predicted under Project Options 3 or 4A. Project Option 4B can start with just opening the control structure and, later, widen the causeway beyond the control structure if the tidal exchange needs to be enhanced. If this is not required, then the additional cost of widening the opening can be avoided.

Project Option 4C would be the most costly Project Option and would have inherent construction risks (dredging or cofferdam failure and proximity to the former Moncton Landfill immediately downstream) that would be much greater than the other Project Options.

From a full cost accounting perspective, notwithstanding regulatory considerations, it would appear that the costs of implementing Project Options, in effect, would be largely nullified, through the benefits that would be accrued (e.g., reduced flood risk, tourism, commercial and recreational fishing and navigation) and the avoided future costs of the Status Quo (e.g., flood protection, damage and insurance).
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<td>degrees celsius</td>
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<tr>
<td>cm</td>
<td>centimetre (1/100 of a metre)</td>
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<tr>
<td>dB_A</td>
<td>decibel (A-weighted)</td>
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<td>L_eq</td>
<td>equivalent sound pressure level</td>
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<td>g</td>
<td>gram</td>
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<td>h</td>
<td>hour</td>
</tr>
<tr>
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<td>hectare</td>
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<td>µg/g</td>
<td>micrograms per gram</td>
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<tr>
<td>µg/L</td>
<td>microgram per litre</td>
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<tr>
<td>mg/L</td>
<td>milligram per litre</td>
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<tr>
<td>Mm³</td>
<td>million cubic metres</td>
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<td>most probable number</td>
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<tr>
<td>ng/g</td>
<td>nanogram per gram</td>
</tr>
<tr>
<td>ng/L</td>
<td>nanogram per litre</td>
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<tr>
<td>PM_{2.5}</td>
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</tr>
<tr>
<td>PM_{10}</td>
<td>particulate matter less than 10 µm</td>
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GLOSSARY

Aerobic  Life processes that occur in the presence of oxygen (e.g., respiration or breathing).

Amphidromous  A life style in which most juveniles and adults feed in the estuary or downstream river reaches of their spawning rivers.

Anthropogenic  Refers to changes on the natural environment as a result of man-made actions and processes.

Anadromous  A fish that spends most of its life feeding in the open ocean but that migrates to spawn in fresh water.

Anaerobic  Life processes that occur in the absence of oxygen (e.g., anaerobic decay).

Anoxic  The absence of oxygen.

Assimilative Capacity  The ability to dilute influents or other contaminants.

Brackish  Having a salinity between freshwater (less than 5 mg/L) and saltwater (35 mg/L).

Carbon Sequestration  The uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide, release the oxygen and store the carbon.

Catadromous  Fish that spawns in seawater but feed and spends most of its life in estuarine or fresh water.

Climate  Defined as a description of the regularities and extremes in weather conditions in a particular geographical location over a certain period of time. Usually refers to long-term trends in weather for time periods which may range from months to centuries, or the more widely recognized 30-year timeframe as advocated by the World Meteorological Organization (WMO).

Climate Change  The term climate change is used to refer to changes in the earth’s climate, which can be caused both by natural forces and human activities. Most commonly associated with global warming and the global greenhouse effect which highlight discernable changes to the earth’s climate, i.e. increasing temperatures, due to man-made activities and processes.
Confluence  The location where two watercourses come together to form one watercourse.

Conveyance
(or conveyance capacity)  The ability of a channel (e.g., river or stream) to transfer water from one location to another.

Critical habitat  The habitat that is necessary for the survival or recovery of a Species at Risk and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species under the *Species at Risk Act*.

Decibel, A-weighted (dBA)  Logarithmic unit of sound intensity; 10 times the logarithm of the ratio of the sound intensity to the reference A-weighted scale, which has the same frequency response as the human ear.

Diadromous  Fish species which undertakes spawning migration from ocean to river or vice versa.

e.g.  For example.

Environment  Under CEAA, means the components of the earth and includes:
a) air, water and land, including all layers of the atmosphere;
b) all organic and inorganic matter and living organisms; and
c) the interacting natural systems.

Under the *Clean Environment Act*, "environment" is defined as:
a) air, water, or soil;
b) plant and animal life including human life; and the social, economic, cultural and aesthetic conditions that influence the life of humans or a community as they are related to the matters described in (a) and (b).
Environmental Effect

As per CEAA, an environmental effect means, in respect of a project,
(a) any change that the project may cause in the environment, including any change it may cause to a listed wildlife species, its critical habitat or the residences of individuals of that species, as those terms are defined in the Species at Risk Act,
(b) any effect of any change referred to in paragraph (a) on
   (i) health and socio-economic conditions;
   (ii) physical and cultural heritage;
   (iii) the current use of lands and resources for traditional purposes by Aboriginal persons; or
   (iv) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance; or
(c) any change to the project that may be caused by the environment;
whether any such change or effect occurs within or outside Canada.

Equivalent Sound Pressure Level (Leq)

The equivalent continuous level which is a measure of the energy content of a sound over a time period. It gives a single figure expressing the equivalent of a varying level.

Estuarine

Having physical, chemical and biological properties of an estuary.

Estuary

A body of water that is located between a freshwater body, such as a river, and a saltwater body, such as the ocean. As a result, estuaries have brackish water.

Eutrophic

A body of water that has become enriched in dissolved nutrients evidenced visually be abundant aquatic plant growth.

Eutrophication

The process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Evapotranspiration

The loss of water from land or soil both by evaporation, and by transpiration from the plants growing on the land or soil.

Extinct

No known remaining individuals in existence anywhere in the world.
**Extirpated**  
Locally or regionally extinct, but still in existence elsewhere.

**Fauna**  
Animals.

**Fish**  
Under Section 2 of the *Fisheries Act*, includes fish, shellfish, crustaceans and marine mammals.

**Fish Habitat**  
As defined under the *Fisheries Act*, fish habitat includes the spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

**Fish Passage**  
As defined under the *Fisheries Act*, fish passage relates to the unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required to complete their life cycle.

**Flora**  
Plants.

**Global Warming or Greenhouse Effect**  
The process by which the atmosphere warms the earth. The term *greenhouse effect or global warming* is currently most commonly used to refer to man-made influences on the natural greenhouse effect, including the release of greenhouse gases from human and industrial processes which may result in increasing global temperatures.

**Greenhouse Gases**  
Gaseous components of the atmosphere that contribute to global warming. Greenhouse gases include carbon dioxide, methane, nitrous oxide and water vapour.

**Headpond**  
A body of water created by the construction of a dam or a barrier across a river.

**i.e.,**  
That is/In other words.

**Impoundment**  
Man-made pond.

**Intertidal**  
Estuary zones above the low tide level.

**Invasive Specie**  
A species of plant or animal that is not native to the local environment; and whose introduction to the local environment may lead to negative environmental effects on native species.
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<th>Term</th>
<th>Description</th>
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<tr>
<td>Mesotrophic</td>
<td>Lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.</td>
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<tr>
<td>Meso-eutrophic Range</td>
<td>Nutrient increase, phytoplankton population increase and low water clarity measures.</td>
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<td>Microclimate</td>
<td>The local climate or weather conditions of usually a small site of habitat, such as higher temperatures in urban areas of a city due to heat release and reflection from vehicles, roads and buildings and strong winds channelling through gaps at the base of tall buildings. Variations of the climate within a given area, usually influenced by hills, hollows, structures or proximity to bodies of water.</td>
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<tr>
<td>Milt</td>
<td>The sperm-containing fluid of a male fish.</td>
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<tr>
<td>Mitigation</td>
<td>A measure, plan or strategy for minimizing or preventing an environmental effect.</td>
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<tr>
<td>Olfactory</td>
<td>The human response connected to the sense of smell.</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Micro-organism, i.e. a bacterium, a virus or a parasite, which has the ability to cause disease in other organisms.</td>
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<tr>
<td>Photosynthesis</td>
<td>The process that a plant uses to combine sunlight, water and carbon dioxide to produce oxygen.</td>
</tr>
<tr>
<td>Post-causeway condition</td>
<td>The period after construction of the causeway in 1967-68. This is also referred to as the post-causeway construction condition.</td>
</tr>
<tr>
<td>Pre-causeway condition</td>
<td>Refers to the period prior to the construction and closure of the causeway in 1967-68. This is also referred to as the pre-causeway construction condition.</td>
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<tr>
<td>Project (the Project)</td>
<td>The proposed modifications to the Petitcodiac River causeway between Moncton and Riverview, New Brunswick, initially based on the four options identified in the Niles Report (2001).</td>
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### Project Options
Any and/or all of the four Project Options as outlined in the Niles Report (2001) as well as options identified during the EIA process that include:
- **Option 1**: Replace the fishway
- **Option 2**: Gates open during peak migration
- **Option 3**: Gates permanently open
- **Option 4**: Partial bridge (3 different variations)

### Reservoir
A body of water created by the construction of a dam or a barrier across a river for the purpose of storage.

### Residual Environmental Effect
An environmental effect that remains after mitigation.

### Riparian Zone
The margin of a river or other water body where sufficient soil moisture supports the growth of vegetation that requires a moderate amount of moisture.

### Spatial Boundaries
The topographic area over which environmental effects of the Project are assessed.

### Species at Risk
Species protected by species at risk or endangered species legislation. Specifically, those species listed as Endangered or Regionally Endangered under the *NB Endangered Species Act* and those listed as Extirpated, Endangered, Threatened, or Special Concern by the federal *Species at Risk Act*.

### Species of Conservation Concern
Species that are of concern due to rarity, population decline, sensitivity to habitat disturbance, etc., but that are not protected by federal or provincial legislation.

### Spring Tide
Tide with large amplitude occurring twice a lunar month, near full moon and new moon.

### Status Quo
The current condition/existing causeway remains unchanged (using present criteria for gate operation).

### Sublittoral zone
The zone below the shore area.

### Subtidal Taxa
Estuary zones below the low tide level.

### Taxa
Plural of Taxon.

### Taxon
An assemblage of organisms that share similar characteristics.

### Taxonomic Group
A broader collection of a bigger assemblage of organisms.
Temporal Boundaries
The length of time over which environmental effects of the Project must be assessed in the EIA.

Toxicological
Relating to the nature, effect, detection or treatment of poisons (i.e., toxins) in animal tissue.

Valued Environmental Components
Specific components of the environment that the environmental assessment is focused on because of their intrinsic value, or because they were identified by regulators, legislation, the AMEC Study Team, or during the public consultation process.

Watercourse
Any flowing body of water such as a river, stream, creek or brook.
### LIST OF ACRONYMS

<table>
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<tr>
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<th>Full Form</th>
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<tr>
<td>AC CDC</td>
<td>Atlantic Canada Conservation Data Center</td>
</tr>
<tr>
<td>ACOA</td>
<td>Atlantic Canada Opportunities Agency</td>
</tr>
<tr>
<td>ADI</td>
<td>ADI Limited</td>
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<tr>
<td>AFA</td>
<td>Alma Fishermen’s Association</td>
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<tr>
<td>AMEC</td>
<td>AMEC Earth &amp; Environmental</td>
</tr>
<tr>
<td>APEGNB</td>
<td>Association of Professional Engineers and Geoscientists of New Brunswick</td>
</tr>
<tr>
<td>BC</td>
<td>British Columbia</td>
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<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
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<td>BoFEP</td>
<td>Bay of Fundy Ecosystem Partnership</td>
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<td>CCME</td>
<td>Canadian Council of Ministers of the Environment</td>
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<td>CEAA</td>
<td>Canadian Environmental Assessment Agency</td>
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<td>CHC</td>
<td>Canadian Hydraulic Centre</td>
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<td>Canadian National</td>
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<tr>
<td>CO</td>
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<td>Carbon Dioxide</td>
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<td>COSEWIC</td>
<td>Committee on the Status of Endangered Wildlife in Canada</td>
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<td>CWS</td>
<td>Canadian Wildlife Service</td>
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<td>DO</td>
<td>Dissolved Oxygen</td>
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<td>DFO</td>
<td>Fisheries and Oceans Canada</td>
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<td>Environmental Impact Assessment</td>
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<td>Environmental Impact Assessment Terms of Reference</td>
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<td>EMP</td>
<td>Environmental Management Plan</td>
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<td>Environmental Monitoring Working Group</td>
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<td>Gemtec Limited</td>
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<td>Greater Moncton Area</td>
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<td>GMSC</td>
<td>Greater Moncton Sewerage Commission</td>
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<tr>
<td>GNB</td>
<td>Government of New Brunswick</td>
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<td>HADD</td>
<td>Harmful Alteration Disruption and Destruction</td>
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<td>Lake Petitcodiac Preservation Association</td>
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<td>L&lt;sub&gt;eq&lt;/sub&gt;</td>
<td>Equivalent sound pressure Level</td>
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<td>Level of Service</td>
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<td>Maritimes Marshland Rehabilitation Administration</td>
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<td>Memorandum of Understanding</td>
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<td>MSL</td>
<td>Mean Sea Level</td>
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<td>New Brunswick Department of Agriculture, Fisheries and Forestry</td>
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<td>New Brunswick Department of Environment and Local Government</td>
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1.0 INTRODUCTION

1.1 The Environmental Impact Assessment Process

This document is the report for the Environmental Impact Assessment (EIA) of the Modifications to the Petitcodiac River Causeway Project. The Petitcodiac River causeway (“causeway”) is a gated dam structure with an installed vertical slot fishway that was built across the Petitcodiac River between the City of Moncton and the Town of Riverview. Figures 1.1.1 to 1.1.3 show the Petitcodiac River with the causeway shown on Figure 1.1.3. Completed in 1968, the causeway was intended to create a second transportation link between the two communities, offer flood protection for farmland between the causeway and the head of tide at Salisbury, and create a freshwater headpond with potential for recreation and as an industrial water source. A bridge would have achieved the transportation objective, but not the other benefits.

As early as 1961, it was recognized that fish passage would be an issue if a causeway were built. Consequently, a fishway was included in the facility to meet the requirements of the Fisheries Act. However, the construction of the causeway with the fishway resulted in fish passage issues from the outset. The fishway proved ineffective and subsequent modifications to the fishway and gate management have failed to provide a solution to the fish passage issues. The continual efforts to address fish passage issues have failed and thus the facility does not meet the requirements of the Fisheries Act. The New Brunswick Department of Supply and Services (NBDSS) have been tasked with identifying means to rectify this.

This EIA evaluates four Project Options and other relevant options identified during the EIA that are intended to meet the Project Objectives. The Project Objectives are to achieve a long-term solution to fish passage and other ecosystem issues related to the causeway, including tidal exchange, sediment transport and other physical processes and biophysical functions (e.g., wetlands, populations of flora and fauna, fish habitat).

This EIA evaluates the Project Options against the Project Objective, determines which Project Options can meet the Project objective, and assesses the potential environmental effects of those Project Options that meet the Project Objectives. The EIA also evaluates the existing and potential future environmental effects of the Status Quo (the continuation of current conditions). Although the Status Quo is not one of the four Project Options, it is included in the EIA, along with pre-causeway conditions for comparative purposes. The EIA employs elements of full cost accounting to assist in this comparative analysis.

The Petitcodiac River estuary is unique. The estuary is macro-tidal (i.e., with tides averaging 11 m) with a suspended sediment loading typically in the order of up to 30,000 mg/L. The causeway is located in the middle of the estuary (20 km from the head of tide). There are very few similar examples elsewhere in the world where fish passage facilities are incorporated in the facility at midpoint in a macro-tidal estuary. The causeway also experiences temperature extremes from 30°C in the summer to –35°C in the winter. The physical nature of the estuary and the presence of the headpond and gates in the causeway, present challenges for the management of sedimentation and results in the potential for ice jamming and related
operational issues. Consequently, a complex Gate Management Plan is in place to ensure safe operation of the facility, and in an effort to improve opportunities for passage of some fish species.

1.2 The EIA Report

This EIA Report is the result of almost three years of research, consultation, modelling and analyses conducted by the AMEC Earth and Environmental Limited (AMEC) Study Team. The AMEC Study Team and their roles and primary responsibilities are presented in Table 1.2.1.

<table>
<thead>
<tr>
<th>AMEC Study Team Member</th>
<th>Role/Primary Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMEC Earth &amp; Environmental Limited (AMEC)</td>
<td>Project Management/Biophysical Studies</td>
</tr>
<tr>
<td>Jacques Whitford</td>
<td>EIA Management/Biophysical Studies</td>
</tr>
<tr>
<td>ADI Limited (ADI)</td>
<td>Socio-economic Studies</td>
</tr>
<tr>
<td>Canadian Hydraulics Centre (CHC)</td>
<td>Hydrodynamic and Sediment Transport Modelling</td>
</tr>
<tr>
<td>Gemtec Limited (Gemtec)</td>
<td>River Engineering Analysis and Data Collection to Support Modelling</td>
</tr>
<tr>
<td>GPI Atlantic</td>
<td>Full Cost Accounting</td>
</tr>
<tr>
<td>Gardner Pinfold Consulting Economists Ltd. (Gardner Pinfold)</td>
<td>Full Cost Accounting</td>
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The purpose of this EIA Report is to present the results of the EIA. The purpose of the EIA was to evaluate and compare the potential environmental effects of the Project Options that meet the Project Objectives, analyze proposed mitigation, and determine significance of the residual environmental effects and to compare these to current conditions and the Status Quo. The AMEC Study Team wrote this EIA Report on behalf of the New Brunswick Department of Supply and Services (NBDSS). The EIA Report is intended to fulfill the reporting requirements for an Environmental Impact Assessment Report pursuant to the Clean Environment Act—Environmental Impact Assessment Regulation (EIA Regulation) and is the supporting document for the Screening Report (to be prepared by the Responsible Authorities) under the Canadian Environmental Assessment Act (CEAA). The EIA and EIA Report fulfill the requirements of the Guidelines for an Environmental Impact Assessment – Modifications to the Petitcodiac River Causeway (the “Guidelines”) issued July 26, 2002 (New Brunswick Department of Environment and Local Government (NBDELG), 2002).

Note that the organization of the EIA Report differs from the Guidelines and the EIA Terms of Reference (NBDSS, 2003). This organization reflects the professional judgment of the AMEC Study Team and is based on an improved understanding of the complex nature of the EIA gained over the duration of the process and a desire to present the information in a format that is clear and concise. A concordance table that links the requirements of the Guidelines to the location in the EIA Report is located at the front of this document.

Component studies were completed to provide the information necessary for the EIA and to support completion of the EIA Report. The component studies were a Biophysical Component Study (AMEC 2005a), a Socio-economic Component Study (AMEC 2005a) and a Hydrodynamic and Sediment Transport Modelling Component Study (AMEC 2005b).
summary of the data included in each Component Study is provided in Section 3.3. The EIA Report, the Biophysical and Socio-economic Component Studies, the Modelling Component Study and the Public Consultation Report will all be posted on the EIA website (www.petitcodiac.com).
2.0 BACKGROUND

The history of the causeway was previously reviewed by Eugene Niles, Special Advisor to the Minister of Fisheries and Oceans Canada, in his report of February 9, 2001 (“the Niles Report”) (Niles, 2001). Mr. Niles was formerly Regional Director General for the Gulf Region at Fisheries and Oceans Canada (DFO). He had a mandate to conduct a review of all the issues and existing information concerning the causeway, consult stakeholders, meet with the Aboriginal Community, and seek appropriate expert opinion on a course of action to restore fish passage in relation to the causeway.

Part One of the Niles Report provides a summary of stakeholder consultations and meetings with the Aboriginal Community at Fort Folly First Nation and a synthesis and evaluation of available information on issues, perspectives and areas of consensus and divergence related to the causeway and the Petitcodiac River watershed. Part Two of the report includes the identification of a range of options and recommendations to the Minister of Fisheries and Oceans, as well as provides advice on information gaps, how to address these gaps, and the next steps that should be taken in addressing the issues at the causeway. The Niles Report provides a good summary of the background to the causeway development and the associated evolving issues, and this section uses information from that report. Interested readers can access the Niles Report through the Petitcodiac River Causeway Environmental Impact Assessment website (www.petitcodiac.com) by following the "More Information" link.

2.1 Planning and Development of the Petitcodiac River Causeway

The Niles Report noted the following milestones in the planning and development of the causeway.

- A resolution of the Moncton City Council on January 7, 1960, called on the provincial government to conduct a feasibility study for the construction of a causeway from the City across the Petitcodiac River. This study was conducted by Maritime Marshland Rehabilitation Administration (MMRA, an entity of Canada Department of Agriculture that from 1948 to 1970 worked cooperatively with the Maritime Provinces to maintain and enhance dykes and aboiteaux and reclaimed marshlands). The report, dated March 30, 1961, considered three sites for a causeway, one being the current location of the causeway.
- Correspondence from the Federal Department of Fisheries dated July 3, 1961, advised of the requirement for a fishway in the structure.
- At a meeting on July 30, 1963, with representatives from the City of Moncton Town Planning Commission, a representative from the south side of the Petitcodiac River, representatives from the Provincial Department of Health, Department of Public Works, the New Brunswick Water Authority and the Moncton City Engineer, a decision was made to propose a causeway at the western end of the City where the structure now stands.
- In November 1963, the MMRA was authorized to proceed with the engineering design work. The Provincial Department of Public Works consulted with the Federal
Department of Fisheries, Federal Department of Public Works, Federal Department of Transport, Federal Department of National Health and Welfare, the Federal Water Resources Branch, the Provincial Department of Health and the Provincial Department of Lands and Mines. The project was given approval under the *Navigable Waters Protection Act* (NWPA) on June 3, 1964.

- Because of the perceived benefits to agriculture lands, the MMRA agreed to cost share construction in the amount of $800,000 out of an estimated total cost of $3,000,000. The Provincial Water Authority, in giving their approval, believed the resulting freshwater headpond would provide a source of water for industrial use as well as have the potential for recreational purposes.
- Construction started on February 8, 1966 and was completed on March 10, 1968. Reports indicate that the causeway gates remained open until May 3, 1968. (Butler, R.L. Memo Regional Director General, DFO January 21, 1969 from the Niles Report).

The design of the causeway consisted of an earth filled dam (1.0 km in length) with the upstream water level controlled by five bottom-opening gates. Fish passage was to be achieved by using a vertical slot fishway.

### 2.2 History of Environmental Concerns with Causeway Development

#### 2.2.1 Evolving Issues

The history of environmental concerns associated with the causeway was reviewed in the Niles Report. The following discussion is drawn largely from his thorough review, and the reader is referred to that report for additional information. Much of what is contained in this section is taken directly from the Niles Report.

The causeway was constructed in 1968, and it became evident within a few months that fish passage was problematic. The fishway, based on a design used for Pacific salmon and Pacific trout (e.g., rainbow trout and cutthroat trout) that could operate at a variety of water levels, was ineffective for Atlantic salmon and unsuitable for many other species (e.g., brook trout). Concerns were expressed as early as 1961 about the potential effect of a causeway on fish runs. Within one year of the completion of the causeway, R.L. Butler (a biologist with DFO) was reporting that there was no doubt that the causeway would have a detrimental effect on the commercial and recreational fisheries of the area. He also reported that the estuary was rapidly filling with mud in the vicinity of Moncton, and that the development of mudflats down to Stoney Creek (20.2 km downstream of the causeway) was already changing the driftnet fishery (Butler, 1969 from the Niles Report).

Similar reports from 1976 and 1977 identified the following problems associated with the construction and operation of the causeway and its gates:

- erosion along the banks of the headpond;
- inability to maintain stable headpond levels during the summer;
- sedimentation of the headpond upstream and downstream of the causeway;
- ineffective fish passage;
• ice jamming at the causeway end of the headpond; and
• a number of lesser mechanical problems mainly associated with gate operation and maintenance due to sedimentation.

In 1978, the engineering consulting firm ADI Limited was commissioned by the New Brunswick Department of Transportation (NBDOT) to carry out a study related to the above problems. Their report, released in December 1979 (ADI, 1979 from the Niles Report), considered the following three alternative proposals for operation of the causeway:

• continued operation as is, or the Status Quo (not considered to be a practical option);
• operation without gates (preferred by DFO and New Brunswick Department of Natural Resources (NBDNR)); and
• modifications to the gates to improve their “seal”, and modifications to the fishway and gate operations, including raising the headpond from a normal operating level of approximately 4.6 m to approximately 6.1 m, in order to better attract fish to the fishway (implemented in 1988).

The third option was considered to be the best “compromise” option, and was implemented, although the improvements to fish passage, and to environmental conditions in general, were minor at best, and there were persistent requests from various stakeholders and the Aboriginal Community to open the gates to allow free flow to improve fish passage.

The causeway also resulted in water quality and public health and safety issues related to sewage. Sedimentation of the river downstream of the causeway lead to unacceptable issues associated with raw sewage on the newly formed mudflats and drainage channels where sewage outfalls previously discharged directly to the river. This and water quality issues identified in the river by the Montreal Engineering Company Limited (1979), led to a series of initiatives in the seventies, eighties and early nineties to gather the Greater Moncton Area (GMA) sewage, treat it and discharge it to the river at Outhouse Point (Figure 1.1.3). Currently about 70% of the sewage discharged to the river in the GMA is treated by the facility at Outhouse Point.

In 1988, the provincial government decided to open the gates and allow free tidal flow to help fish migration during the period of April 15 to June 7, and again from September 26 to October 31. This program resulted in substantial sedimentation in the headpond and some increased passage of some species. The gates were re-opened from May 3 to June 15 in 1989, and from May 15 to June 15 in 1990, but only during low tide to prevent sedimentation of the headpond as was experienced in 1988.

In May 1991, a provincial government inter-departmental committee prepared a report entitled “Analysis of Options for the Future of the Petitcodiac River Dam and Causeway” (ADI, 1992 from the Niles Report). This report defined a series of options for the future of the causeway:
• operate the gates to maintain the headpond, and minimize tidal exchange (considered to be the “Status Quo”);
• operate the gates to help fish passage;
• design and implement a new fishway;
• implement a “fish trap and transport” option;
• open the gates (with sub-options of one gate or five gates open);
• replace the causeway with a bridge; or
• separate the river from the headpond.

The Niles Report suggests that the conclusions, and even the underlying methodology and assumptions of the ADI report, were controversial, and that as a result, no consensus was generated. Nevertheless, it was concluded that none of the options had quantifiable benefits that would likely outweigh the associated costs, and that only the Status Quo and the “five gates open” option were worthy of further serious consideration. The Status Quo would maintain the headpond year-round and protect agricultural land, but would not produce significantly improved fish passage. The five gates open option would result in significantly improved fish habitat and tourism opportunities, but would eliminate the headpond, and result in flooding of agricultural land by tidal water.

The next important development was the publication in 1994 of a paper by Dr. Alyre Chiasson, suggesting an operating regime for the gates at the causeway that would “clip” the tides. In effect, this proposal would allow partial or free flow of the river and tides at certain times, but would involve closing of the gates to incoming tides when a certain water level was reached on the upstream side of the causeway. In this way, the flooding of upstream agricultural lands could be avoided. Several variants of this concept were evaluated, and resulted in a Memorandum of Understanding (MOU) between the federal and provincial governments in December 1995. The MOU provided for a series of trial gate opening exercises to be carried out.

The gate opening trials were complicated by legal challenges, and called for an environmental assessment under CEAA, prior to their implementation. A screening level environmental assessment was completed voluntarily by the responsible federal government agencies, but as a result of the delays, the trials did not begin until later than planned, and after the high discharge period for the river in 1998. One source of difficulty was the presence of a large sediment plug above the causeway that interfered with flow. The same experiment was initiated again in 1999, with a pre-trial flushing on April 8, but again the trial conditions could not be maintained due to low freshwater flows, and continued difficulty caused by the sediment plug above the causeway.

2.2.2 Stakeholder Issues and Concerns Reported by Niles

In Part One of the Niles Report, Mr. Niles was able to identify and contact a large number (31) of interested stakeholder groups, including the Aboriginal Community, and was able to meet with and receive input from all but a few of these. He also met and consulted with a number of interested individuals (9) and experts (20). A majority of the stakeholders he consulted with,
including the Aboriginal Community, supported free tidal flow at the causeway, although some preferred the Status Quo, or took no position pending the outcome of his report.

Mr. Niles reported the many and varied issues and concerns identified by stakeholders and the Aboriginal Community. The issues and concerns identified in the Niles Report are briefly summarized here, but interested readers should consult the original document for a full perspective.

The issues identified by stakeholders were numerous and included those outlined in the following list. The list makes no attempt to rank the importance of an issue, and presents varied views on certain subjects.

- The Terms of Reference for the Niles Report were too restrictive to fully capture the issues. The Terms of Reference should have been expanded to include the river, the estuary, and fish habitat restoration as well as fish population restoration.
- The Terms of Reference for the Niles Report were not precise enough.
- There is an urgent need to restore a unique but badly damaged macro-tidal estuary.
- A new ecosystem has developed above the causeway, with new species of fish and wildlife, which would suffer if the causeway were removed.
- There is an urgent need to restore the genetically distinct Inner-Bay of Fundy salmon stock (note, since the Niles Report was issued, the Inner-Bay of Fundy salmon stock has been formally listed as endangered). The stock is in decline throughout the region, and is not declining principally as a result of the causeway.
- There remains a thriving eel fishery in the headpond.
- Smallmouth bass and chain pickerel have been introduced illegally to the Petitcodiac River system above the causeway, and should be eliminated before they cause irreparable harm to native species.
- There is a need to protect and restore other fish species (such as rainbow smelt, gaspereau (alewife, blueback herring), American shad, sea-run brook trout and striped bass) that have suffered decline, or been eliminated from the river system, as a result of the causeway.
- The benefits of smallmouth bass and chain pickerel, which support a thriving recreational fishery (including tournament fishing for smallmouth bass) in the headpond and river may outweigh the benefits of having native fish that are of limited recreational or commercial value.
- Opening the causeway might result in the restoration of the tidal bore, which would restore a tourist attraction and provide other economic benefits.
- Restoring the river to full tidal exchange might result in the flushing of accumulated sediment, and encourage recreational sailing, rafting, or tour boat operation downstream of the causeway, as well as recreational and commercial fishing opportunities.
- The potential economic benefits of the headpond (including marina, sailing school, recreational sailing, sea plane moorings, fishing tournaments, etc.) are just beginning to be realized, and outweigh the benefits of the tidal bore.
- Property owners and residents downstream of the causeway have seen property values impacted due to sediment accumulation at the river front, and loss of beaches where they formerly existed.
- Building activities on both sides of the headpond generate a significant economic benefit to others, through employment and tax revenues.
- There has never been a full cost benefit analysis of these issues. Past studies have indicated the difficulty of doing benefit and cost analysis of many of the factors that are intangible. New analytical techniques, such as full cost accounting, may overcome this difficulty.

The concerns identified by stakeholders and the Aboriginal Community, as outlined in the Niles Report, were also numerous and a summary of the concerns, grouped by theme, is provided below.

**Sewage Treatment** for the communities of Moncton, Riverview and Dieppe is accomplished by a relatively modern, chemically assisted primary treatment facility located at Outhouse Point, which discharges about 18 million gallons of sewage into the Petitcodiac River, daily. During heavy rain events, the capacity of the plant is exceeded, and untreated sewage is discharged. Opening or removal of the gates at the causeway would permit this effluent to be carried by incoming tides into what is now the headpond, where some stakeholders believed it could cause a health hazard. This issue appears to have first been brought forward in the Screening Assessment by the DFO prior to the gate openings of 1998 and 1999, where it was noted that fecal coliform levels in the Petitcodiac River did not pose a major health risk. It was suggested that disinfection of the effluent might be a consideration in a long-term, river restoration plan.

**Water Supply** for the greater Moncton area includes two major supply lines that cross the Petitcodiac River, one under the headpond, and the other in the causeway structure. Major modifications to the causeway, such as construction of a partial bridge, might require relocation of this watermain.

**Infrastructure** that might be affected by alterations to the causeway includes watermains and sewer lines that are buried close to the edge of the river, and might have to be relocated.

**Mosquitoes** could find a tidal marsh, such as might be created in the headpond area if the river was restored to tidal flow, an ideal breeding ground. This would lead to a possible health risk.

**Abandoned Landfill Sites** are located at several points near the riverbanks downstream of the causeway. The landfill of greatest concern is the former City of Moncton Landfill (“former Moncton Landfill”), located on the north bank of the river, immediately downstream of the causeway. This landfill, which ceased operation in 1992, is partially (about 10% of its total area) located on sediment that was deposited after the construction of the causeway. Restoring the river to tidal flow could result in erosion of the accumulated sediments, and potentially affect the landfill. The potential effects of the landfill leachate on the river/headpond/estuary ecosystem have also been identified as a concern. Another landfill is located further downstream on the...
north bank and is located under the Hall Betts Sportsplex outside the boundaries of the former river channel.

Tidal Sediment is regularly accumulated and washed out from the river below the causeway. Since the construction of the causeway, there has been a significant net accumulation in this area. The effect of removing the causeway on the sediment deposits near Moncton, and the effect that the remobilization of this sediment may have on other portions of the river/headpond/estuary ecosystem (including fisheries, fish, migratory birds, species at risk, etc.) were not known at the time of the Niles Report.

Emergency Water Supply is available in the headpond, should it be required for fire fighting (either by municipal or forest fire fighting organizations). The headpond has been used by the Town of Riverview and the City of Moncton during drought periods. The headpond is also used by the Town of Riverview to test fire fighting and rescue apparatus and for training purposes.

2.2.3 Options Identified by Niles

Part Two of the Niles Report contains his analysis of the issues, and a series of options that were gleaned from his review of the issues, and discussions with the various stakeholders, Aboriginal Community and expert groups. Five options were considered to be worthy of continued discussion and consideration. These options are described in this section.

2.2.3.1 Niles Option 1 – Status Quo (continued operation)

This Niles Option involves the continued operation of the causeway gates as they are currently operated in perpetuity and is referred to as the “Status Quo”. Most stakeholders and the Aboriginal Community considered this option to be unacceptable, since it does nothing to resolve the fish passage issues that have existed since the causeway was built. Some stakeholders, however, prefer this option since it maintains the headpond at a nearly constant level year-round.

2.2.3.2 Niles Option 2 – Replacing the Fishway

The existing fishway has experienced persistent difficulties with sediment blockage, in addition to being problematic for many species to navigate. Experts who were consulted generally felt that designing an adjustable fishway suitable for a variety of species and functional in a sediment-laden, macro-tidal river was a challenge, but not necessarily impossible. The question of downstream migration, however, is uncertain, and involves risks to juvenile fish ranging from predation or disorientation in the headpond, to physical damage at the gates or fishway. This option would also fail to address the problem of sediment accumulation upstream and downstream of the causeway.

2.2.3.3 Niles Option 3 – Gates Open During Peak Migration

This option proposes that all the gates remain open during peak migration periods of fish in the spring and fall (April to mid-June and October-November). This and the subsequent options involve a number of risks, which are outlined below.
• Effluent from the sewage treatment plant could be conveyed up into the former headpond area, with potential health risks.
• Leachate and waste material from the landfill downstream of the causeway (former Moncton Landfill located between the causeway and the Gunningsville Bridge) could be conveyed upstream or downstream, particularly if the sediment deposits surrounding the landfill were eroded.
• Downstream habitat, including sensitive shore bird reserves, scallop and lobster habitat could be negatively affected.
• Agricultural lands upstream of the causeway could be flooded.
• Sediments may accumulate in the former headpond.

2.2.3.4 Niles Option 4 – Gates Open Permanently
This option proposes permanent opening of the gates, except for possible ice control during the winter. Risks would be similar to, or greater than for Niles Option 3.

2.2.3.5 Niles Option 5 – Replace the Causeway with a Partial Bridge
This option would replace a portion of the causeway with a bridge (“partial bridge”) and provide year-round unrestricted flow at the causeway, but would involve a wider opening than that provided by opening all five gates. The partial bridge would produce less turbulence than the narrow opening of the gates, and would presumably have the greatest potential for flushing out accumulated sediments from the headpond and below the causeway. Risks would be similar to or greater than for Niles Options 3 and 4.

2.2.4 Niles Report Recommendations
The Niles Report concluded with five recommendations. These recommendations are as follows.

2.2.4.1 Niles Recommendation 1
The Province of New Brunswick or the Government of Canada or both governments acting jointly proceed expeditiously with a full EIA based on Niles Option 5, the construction of a partial bridge in the Petitcodiac River causeway.

2.2.4.2 Niles Recommendation 2
Consideration be given to a review by GPI Atlantic, or by another similar agency to assist in defining and prioritizing the indicators and intangibles using FCA methods.

2.2.4.3 Niles Recommendation 3
Provision be made to include stakeholders including Aboriginal Community participation at the very beginning of and throughout the process. It is essential … for stakeholders including the Aboriginal Community to be consulted fully in defining the scope of the assessment and the methodology of implementation of the EIA. To ensure participation, funding to cover the cost of travel of stakeholders including the Aboriginal Community is considered necessary.
The proponent (NBDSS) proceed expeditiously and in a stepwise fashion, with the implementation of the EIA. It is recommended that dedicated resources be allocated to the Project to ensure timely implementation … the stepwise implementation process suggested is as follows:

- Evaluate and define the risks, cost and benefits of Niles Option 1 to establish a baseline.
- Evaluate and define the risks, cost and benefits of Niles Option 2 and progressively evaluate other options in the same manner.

2.2.4.4 Niles Recommendation 4

Should the evaluation indicate the need to do experimental openings of the gates to model and verify the effect of tidal flow, these openings should be scheduled at a time most likely to enhance fish passage opportunity.

2.2.4.5 Niles Recommendation 5

A mediation or conflict resolution mechanism be in place very early in the process, even before the Terms of Reference are finalized, to assure stakeholders including the Aboriginal Community that the process will be fair, objective, open and impartial.

2.3 2002 Modelling Workshop

Following the Niles Report, a workshop was organized by Environment Canada and DFO in March 2002 to address issues associated with numerical computer modelling of the Petitcodiac River estuary. The goal of the workshop was to identify a path forward for modelling the Petitcodiac River estuary in order to facilitate the conduct of an EIA as per the recommendations of the Niles Report. Participants at the workshop included local, national and international specialists on hydrodynamic and sediment modelling of river, estuarine and marine systems together with researchers and engineers with experience on the Petitcodiac River estuary. The workshop report, includes a number of recommendations by the participants. The participants agreed on the complexity of the estuary due to the nature of the tides, sediments and climate. The output from the workshop “Petitcodiac River/Estuary Modelling Workshop Summary” (Environment Canada, 2002) included a series of recommendations, for example requirements for additional data, that have been incorporated into the approach to this EIA.

2.4 Regulatory Context of EIA

This Project is subject to provincial and federal EIA legislation and the following sub-sections describe the regulatory context for the EIA.

2.4.1 Decision to Proceed with Modifications Project Environmental Impact Assessment

Subsequent to the release of the Niles Report, the NBDSS was identified as the Proponent for this Project to modify the causeway, based on the options identified by Mr. Niles. As noted above, the Project is intended to achieve a long-term solution to fish passage and to consider other ecosystem issues related to the solution and Status Quo, including tidal exchange, sediment transport and other physical processes and biophysical functions (e.g., wetlands, populations of flora and fauna, fish habitat). The EIA is to examine the Niles Options listed
above, including the Status Quo (to be assessed to provide a baseline against which to evaluate the Project Options), and other relevant options that were identified during the EIA.

2.4.2 New Brunswick EIA Regulation

Under the EIA Regulation, NBDSS, as the Proponent, was required to register the Project as an undertaking for EIA review. The proposal, which includes consideration of four Project Options and the Status Quo, was registered on April 30, 2002. On the same day, the Minister of the NBDELG announced that the completion of an EIA was required to assess the nature and significance of the proposal’s potential environmental effects (i.e., both positive and negative).

2.4.3 Federal Regulation

On May 8, 2002, DFO determined that the Project was subject to federal regulatory review under the Fisheries Act and NWPA, and that DFO would be a Responsible Authority under CEAA. As a result, an environmental assessment was required in accordance with CEAA pursuant to Section 5(1)(d), at the screening level, before an authorization and/or approval under either the Fisheries Act or the NWPA may be issued. Transport Canada now administers the NWPA and has not, in this new role, made a decision regarding need for approval under the NWPA. There may be a future requirement to seek approval from Transport Canada pursuant to the NWPA pending the detailed design of the selected Project Options(s). The federal coordination regulatory process, in addition to identifying DFO and Transport Canada as the Responsible Authorities for this Project, has identified Environment Canada and Natural Resources Canada as departments in possession of specialist or expert information or knowledge.

2.4.4 Harmonized Environmental Assessment Process and Guidelines

The provincial and federal governments decided to undertake a harmonized EIA to meet their respective requirements. The NBDELG are coordinating the harmonized EIA. The Minister of NBDELG appointed the Technical Review Committee (TRC) including technical specialists from various government departments and agencies (including both provincial and federal governments) whose jurisdictions may be affected by the proposed undertaking. These agencies include:

- New Brunswick Department of the Environment and Local Government;
- New Brunswick Department of Agriculture, Fisheries and Aquaculture;
- New Brunswick Department of Natural Resources;
- New Brunswick Department of Health and Wellness;
- New Brunswick Department of Transportation;
- New Brunswick Department of Tourism and Parks;
- New Brunswick Culture and Sport Secretariat;
- New Brunswick Emergency Measures Organization;
- New Brunswick Museum;
- Greater Moncton Planning District Commission;
- Beaubassin Planning Commission;
- Royal District Planning Commission;
• Tantramar Planning District Commission;
• Environment Canada;
• Transport Canada (Navigable Waters Protection);
• Natural Resources Canada;
• Fisheries and Oceans Canada;
• Canadian Coast Guard;
• Bedford Institute of Oceanography; and
• Canadian Environmental Assessment Agency.

NBDELG and DFO prepared draft Guidelines that were reviewed by the TRC and released to the public for comment. During the public comment period, NBDELG also had meetings with a variety of stakeholder groups and the Fort Folly First Nation. Based upon the draft Guidelines and the subsequent consultation, NBDELG and DFO prepared the final Guidelines that were issued on July 26, 2002 and provide the basis for this EIA Report. NBDELG, DFO and Transport Canada, are the decision-making authorities under their respective provincial and federal legislation. It is their responsibility to determine the requirements of the EIA.

2.4.4.1 Scope of Project

Table 2.4.1 provides a summary of the Project Options and the Status Quo that are included in the assessment.

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<th>Option No.</th>
<th>Option Name</th>
<th>Option Description</th>
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<tr>
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<td>Status Quo</td>
<td>Causeway remains unchanged (using present criteria for gate operations).</td>
</tr>
<tr>
<td>1</td>
<td>Replacing the fishway</td>
<td>This option proposes replacing the current fishway with one that would accommodate all diadromous species and age classes.</td>
</tr>
<tr>
<td>2</td>
<td>Gates open during peak migration</td>
<td>This option proposes that all the gates remain open during peak migration periods in the spring and fall.</td>
</tr>
<tr>
<td>3</td>
<td>Gates open permanently</td>
<td>This option proposes that the gates remain open permanently.</td>
</tr>
<tr>
<td>4</td>
<td>Replace the causeway with a partial bridge</td>
<td>This option proposes to replace part of the existing causeway with a bridge.</td>
</tr>
</tbody>
</table>

n/a = The Status Quo will be assessed only to provide a baseline condition against which to evaluate the proposed Project Options.

In addition to the Project Options identified in Table 2.4.1, other relevant options that were identified during the EIA must be considered.

The scope of the Project to be assessed pursuant to Section 15(1) of CEAA and the EIA Regulation as described in the Guidelines includes:

• the construction and operation of the Project Options that meet the Project Objectives and the current conditions and Status Quo;
• potentially significant environmental effects that may remain beyond the operating life of the Project Options, including decommissioning, for those Project Options that meet the Project Objectives; and
• potential accidents and malfunctions.

It is noted that decommissioning of Project Options will vary widely in nature from the simple closing of the gates to the complex removal of a bridge, pending the selected Project Option. Closing the gates, or reverting to the previous fish passage facility (decommissioning of Project Options 1, 2 and 3) would not be permissible under the *Fisheries Act*, and are therefore not considered further in this EIA. The partial bridge is considered to be in operation indefinitely (i.e., this would be a permanent transportation link), and the decommissioning is therefore not considered further in this EIA. The future decommissioning (removal) of the partial bridge, should it be required, would be subject to the environmental assessment process in place at that time.

For each Project Option, the scope of the Project to be assessed includes the following Project-related components and activities:

• the history of the causeway, and applicable general information on the construction and operation of (fish passage solutions in) tidal barriers around the world;
• a description of the design proposed, focusing on strategies that have been proven elsewhere;
• any secondary containment systems;
• transportation, handling and storage systems of any hazardous materials, additives and by-products;
• the layout of associated infrastructure for each option (e.g., access/road infrastructure);
• upsets of environmental control equipment from operations, which may change the nature of site runoff, emissions and/or effluent; and
• all health and safety and environmental protection measures, including emergency response plans (e.g., fire prevention/control equipment, spill response, flooding and tidal surge protection measures).

### 2.4.4.2 Scope of Assessment

The scope of the EIA as described in the Guidelines considers the factors outlined in Section 16(1)(a) to (d) of *CEAA*. Pursuant to Section 16(1)(e) of *CEAA* and to satisfy additional requirements under the *EIA Regulation*, the scope of the EIA also considers the following factors:

• the need for the Project;
• alternative means of carrying out the proposed Project (each Project Option) that are technically and economically feasible, and the environmental effects of any such alternative means; and
monitoring and follow-up initiatives regarding environmental effects resulting or potentially resulting from those Project Options that meet the Project Objectives.

The specific information requirements for the EIA are outlined comprehensively in the Guidelines. The location within the EIA Report where these requirements are fulfilled is provided in the concordance table in the front of this EIA Report.
3.0 ENVIRONMENTAL ASSESSMENT METHODS

3.1 General Approach

The Project Objectives are to achieve a long-term solution to fish passage and address other ecosystem issues related to the solution and the Status Quo. To that end, the methodology used in this EIA has been designed to provide a fully transparent and broadly based framework within which to evaluate the effectiveness of Project Options in meeting the stated Project Objectives. Necessarily, the process was flexible, consultative, interactive and always focused on the evaluation of the environmental effects of Project Options in terms of not only their respective potential environmental effects, but also their ability to meet the Project Objectives. The Status Quo is not considered as a means of achieving the Project Objectives, therefore it is assessed along with the Project Options for comparative purposes only.

The EIA approach incorporates standard EIA methods (boundaries, Valued Environmental Components, determination of significance), and considers cumulative environmental effects, the effects of the environment on the Project Options (including the Status Quo), and to address the comparative aspects of this EIA, uses elements of FCA. The EIA has followed four phases:

- Phase 1—Scoping;
- Phase 2—Data Gathering and Analysis;
- Phase 3—Environmental Effects Analysis; and
- Phase 4—EIA Report Preparation.

Figure 3.1.1 shows these phases and the relationship to ongoing public consultation and meetings. Table 3.1.1 shows the 19 steps that were followed through these four phases.

Throughout all of the phases, communication with the Aboriginal Community and an extensive public, stakeholder and regulatory communication and consultation program was conducted. At the conclusion of each phase, there were critical milestone points for moving forward. These milestones were based on the information and outputs/conclusions of the preceding phase. These milestones included confirmatory dialogue with NBDSS, regulators, representatives of the Aboriginal Community, stakeholders and the public as appropriate to ensure that the work to be undertaken in the following Phase was appropriate and reflective of the evolving information and findings of the previous Phase.

At the conclusion of scoping and data collection phases, there were critical milestone points for moving forward with the environmental effects analysis. At the end of scoping, EIA Terms of Reference were developed that outlined the approach proposed to meet the requirements of the Guidelines; providing a roadmap for the conduct of the EIA. At the end of the data collection phase, the AMEC Study Team conducted an initial evaluation of the Project Options against the Project Objectives to determine whether they met the Project Objectives. Those Project Options that met the fish passage Project Objective were carried forward in the detailed EIA (e.g., a detailed Project description was developed for the Project Option and it was included
within the environmental effects analysis). Those Project Options that did not meet the Project Objectives were evaluated in detail at the initial evaluation stage.

### Table 3.1.1 Steps for Each Phase of Work Plan

<table>
<thead>
<tr>
<th>Step Number</th>
<th>Step Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1—Scoping</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Development of EIA Terms of Reference</td>
</tr>
<tr>
<td>1.2</td>
<td>Confirmation of Project Objectives</td>
</tr>
<tr>
<td>1.3</td>
<td>Development of Preliminary Study Descriptions for Project Options and the Status Quo</td>
</tr>
<tr>
<td>1.4</td>
<td>Preliminary Hydrodynamic and Sediment Transport Model Development and Modelling</td>
</tr>
<tr>
<td>1.5</td>
<td>Evaluation of Existing Information and Identification of Data Gaps</td>
</tr>
<tr>
<td>1.6</td>
<td>Establishment of Criteria for Evaluating the Achievement of Project Objectives</td>
</tr>
<tr>
<td>1.7</td>
<td>Development of Component Studies Terms of Reference and Confirmation of Phase 2 Work Plan</td>
</tr>
<tr>
<td>Phase 2—Data Gathering and Analysis</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Component Studies</td>
</tr>
<tr>
<td>2.2</td>
<td>Identification of Additional Data Gaps and Modelling Needs</td>
</tr>
<tr>
<td>2.3</td>
<td>Confirmation of Work Plan for Phase 3</td>
</tr>
<tr>
<td>Phase 3—Environmental Effects Analysis Phase</td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Filling Additional Data Gaps and Modelling</td>
</tr>
<tr>
<td>3.2</td>
<td>Identification of Consequences of Project Options and the Status Quo</td>
</tr>
<tr>
<td>3.3</td>
<td>Evaluation of the Environmental Effects of Project Options and the Status Quo</td>
</tr>
<tr>
<td>3.4</td>
<td>Normalization of Project Options and the Status Quo</td>
</tr>
<tr>
<td>3.5</td>
<td>Comparative Assessment of Project Options and the Status Quo</td>
</tr>
<tr>
<td>3.6</td>
<td>Recommendations and Implementation Plan</td>
</tr>
<tr>
<td>Phase 4—Preparation of EIA Report</td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Preparation of Draft EIA Report</td>
</tr>
<tr>
<td>4.2</td>
<td>Preparation of Final EIA Report</td>
</tr>
<tr>
<td>4.3</td>
<td>Public Meeting(s) (hearings)</td>
</tr>
</tbody>
</table>

The following sections describe the various steps in each of the EIA phases listed in Table 3.1.1, reflecting the organizational reporting format of the balance of this EIA Report. It is important to recognize that many of the tasks within the Project phases were carried out in parallel; the steps were not fully sequential.

### 3.2 Scoping and Consultation

Scoping is the process of determining the scope of the Project and the scope of factors to be assessed for the EIA. For the EIA, scoping began with the study conducted by Eugene Niles, as described in Chapter 2. The Niles Report, and all previous studies included within the Niles Report, led to identification of the Project. Following this, the provincial and federal requirements were determined in a harmonized process as described in Section 2.4.4. To carry out this process, a Technical Review Committee (“TRC”) consisting of provincial and federal regulatory representatives was assembled (Section 2.4.4).
NBDELG issued draft Guidelines for public, stakeholder and Aboriginal Community review and comment, and final Guidelines (Section 2.4.4). In response to the Guidelines, the Final EIA Terms of Reference (TOR) were issued following review by the TRC.

Consultation with the TRC throughout the EIA identified key issues for inclusion in the EIA Report. Discussions included the fish passage objective, wetland significance criteria, decommissioning, how to deal with Status Quo, setting the time frame for the EIA (2005 as baseline against 2025 with trends to 2055 and 2105), and the Table of Contents for the EIA Report. The key issues are described in detail in Chapter 6 of this EIA Report as they relate to the fish passage Project Objective.

Public and stakeholder communication and consultation and Aboriginal Community meetings were held throughout the EIA and included open houses, town hall meetings, workshops, direct communication, the interactive and bilingual website (http://www.petitcodiac.com), stakeholder meetings and public review of draft Guidelines and Terms of Reference. The results of the consultation and communication process were included in the Public Consultation Report (AMEC 2005c) and are summarized in Chapter 4.

3.3 Data Collection

Three separate studies were carried out to address data collection needs in support of the EIA. These Component Studies were organized as the Biophysical Component Study (AMEC 2005a), the Socio-economic Component Study (AMEC 2005a) and the Hydrodynamic and Sediment Transport Modelling Component Study (AMEC 2005b). A summary of each Component Study is provided below.

3.3.1 Biophysical Component Study

The Biophysical Component Study (AMEC 2005a) encompasses relevant aspects of the aquatic, atmospheric and terrestrial environment, including wetlands. Information obtained as part of this study include:

- fish and fish habitat – species composition and relative abundance through drift and trap netting, fyke netting, electrofishing, beach seining, smolt tracking and fishway monitoring;
- benthic invertebrates – roundworms, flatworms, annelids, arthropods and insects;
- marine environment – evaluation of seabed changes;
- water quality – seasonal water profiles, temperature and levels of nutrients, dissolved oxygen, salinity, total suspended solids and total organic carbon;
- sediment quality – PAHs, organochlorine pesticides and other organic analytes and metals;
- atmospheric environment – odour, noise, weather and climate and ambient air quality; and
- terrestrial and wetland habitat – shorebird surveys, wetland classification, plant inventory, wildlife observations and AC CDC database results.
3.3.2 Socio-economic Component Study

The Socio-economic Component Study (AMEC 2005a) included specific information on the following:

- municipal services and infrastructure – water distribution systems, sanitary and storm sewer systems, dykes, aboiteaux and wharves;
- road transportation network – highway network development, network traffic, level of service, accident rates and flood prone highway sections;
- vessel traffic and navigation – commercial marine traffic and recreational boating;
- land use and value – dwelling and land values and current and past land use;
- tourism – important provincial attractions, tourism indicators, tourism trends and opportunities, Petitcodiac River tourism attractions and tourism above the causeway;
- recreation – sport fishing, recreational boating and fishing, bird watching, walking and hiking trails;
- labour and economy – regional employment, population, income, labour force, fisheries, agriculture, tourism;
- heritage and archaeological resources – Pre-contact period, Acadian settlement, other European settlement, historic structures and shipwrecks; and
- public health and safety – vehicular accidents, non-vehicular accidents, groundwater and surface water quality, human disease vectors (i.e., mosquitos), flooding and flood risk and human food resources.

3.3.3 Hydrodynamic and Sediment Transport Modelling Component Study

The Hydrodynamic and Sediment Transport Modelling Component Study (AMEC 2005b) included specific information on the following:

- channel morphology – total water volume and volume of sediment transported;
- tidal regime – maximum and minimum tidal envelopes;
- flooding – maximum water levels, extreme hydrologic events;
- salinity – salinity envelopes; and
- tidal bore.

As appropriate, reference to the Component Studies is provided for data or information presented in Chapter 5 of the EIA Report to assist the reader in locating more detailed or source information from the Component Studies.

Terms of Reference were prepared for each of the Component Studies. The draft Terms of Reference were provided to the TRC and the public for review and comment. Public workshops were held to discuss the draft Terms of Reference. Final Terms of Reference were released and made available on the Petitcodiac River Causeway website.

The biophysical and socio-economic data collection process began by determining what data were needed for conducting the EIA given the requirements of the Guidelines. Once data requirements were determined, the next step was to review existing data and identify “data gaps”, or non-existing data that was determined to be necessary for the EIA. Field surveys and
expert consultation were conducted to gather data. The data were processed and presented in the Component Studies by the AMEC Study Team. The Component Studies were then sent to the TRC for review. Final versions of the Biophysical and Socio-economic Component Studies were released concurrently with this EIA Report.

The Biophysical and Socio-economic Component Studies were formatted to present the pre-causeway (prior to 1967), the post-causeway (1969-2002), existing (2003-2004) and baseline (2005) conditions. Information within this format was arranged by Valued Environmental Components (VECs). VECs were selected and the boundaries for the EIA of each VEC were established (presented in Section 4.7).

The hydrodynamic and sediment transport modelling process began with a review of previous modelling attempts for the Petitcodiac River system. It was determined that the modelling would be accomplished with one-dimensional and two-dimensional models of the Petitcodiac River from Salisbury to Shepody Bay. The models were calibrated and verified using the data collected for the Biophysical and Hydrodynamic and Sediment Transport Component Studies. The results of the computer models were used as a tool, in combination with the trend analysis, interviews and the expertise and knowledge of the AMEC Study Team, in order to identify anticipated changes to the Petitcodiac River, resulting from the Project Options and the Status Quo, out to the year 2025 (Chapter 8). Trend analysis was used to extend the predictions out to the years 2055 and 2105.

3.4 Description of Past, Present and EIA Baseline Environment

In Chapter 5 (Description of Past and Existing Environment), the Component Studies were used to describe the pre-causeway, post-causeway, existing and EIA baseline conditions for each VEC and for the causeway and control structure and physical characteristics of the river. As previously noted, the Component Studies support the EIA Report, and in this regard, Chapter 5 provides an overview of only the key information necessary to support the conclusions of the EIA. The reader is encouraged to refer to the relevant sections of the Component Studies for a more thorough presentation of the available data.

3.5 Determination of the Fish Passage Project Objective

Following completion of the data collection and consultation process, and with an improved understanding of the past, present and existing environment and public, regulatory, stakeholder and Aboriginal Community issues and concerns, the Project Objectives were refined to include a specific fish passage Project Objective discussed in Chapter 6. Chapter 6 provides a review of the requirements of fish species for passage, and a detailed review of existing fish passage issues. The Status Quo and Project Options are reviewed against the fish passage Project Objective.

3.6 Description of the Project Options to be Carried Forward in the EIA

The Project Options that meet the Project Objective are described in Chapter 7. Chapter 7 also provides a description of the potential accidents that were considered in the EIA. Descriptions of the Environmental Management strategies that will be applied to manage potential environmental effects are described in Chapter 7.
3.7 Description of the Anticipated Physical Characteristics of the River

The physical characteristics of the river are described, in Chapter 8, to the year 2025 for both the Status Quo and the Project Options that meet the fish passage Project Objective. The physical characterization is made using the results of the computer modelling and other predictive tools. Trend analyses are used to describe anticipated changes in the river to 2055 and 2105.

3.8 Environmental Effects Analysis

The environmental effects analysis is organized by VEC and is presented in Chapter 9. For each VEC, the characteristics of environmental effects that would be considered significant were defined. The potential environmental effects were analyzed for each VEC by:

- evaluating how changes to the river affect the VEC for the Status Quo and each Project Option to 2025, 2055 and 2105 as compared to the existing conditions;
- determining the mitigation necessary to avoid potentially significant environmental effects on each Project Option;
- determining the significance of potential environmental effects of the Status Quo and each Project Option; and
- comparing the environmental effects of the Status Quo and Project Options.

Potentially significant environmental effects resulting from the Status Quo are not mitigated in the environmental effects analysis as the Status Quo is not a Project Option. However, mitigation measures that would mitigate the environmental effects of the Status Quo are described in Chapter 12 in relation to Economic Considerations.

3.9 Effects of the Environment on the Project

The effects of the environment on the Project Options and the Status Quo are assessed. These include: erosion and deposition; tidal prism; weather; flooding; ice; climate change; and earthquake activity. Adding to the unique nature of this EIA, the effects of the altered future river conditions (e.g., increased tidal prism created by implementation of the Project Options) on the Project Options (e.g., causeway-related structures) is also considered.

3.10 Cumulative Environmental Effects

Regional cumulative environmental effects issues of concern that are affected by the Status Quo or Project Options are identified in Chapter 11. Other projects that have environmental effects that overlap with those of the Status Quo and Project Options are identified. The cumulative environmental effects of the Status Quo and Project Options, in combination with those of other projects were evaluated. Mitigation that will be applied to minimize or manage cumulative environmental effects was summarized and the significance of cumulative environmental effects was considered.
3.11 Economic Considerations

Chapter 12 provides a review of the economic considerations (i.e., benefits and costs) of the causeway to date, and out into the future with the Status Quo and Project Options. FCA is used to characterize benefits and costs of the causeway to date in a qualitative way, and where data allow, quantitatively.

3.12 Follow-up Program

Chapter 13 provides recommendations for the Follow-up Program.
4.0 PUBLIC, STAKEHOLDER, ABORIGINAL COMMUNITY MEETINGS AND REGULATORY CONSULTATION

4.1 General

Public and stakeholder communication and consultation and Aboriginal meetings are essential components of the EIA. The consultation program for this EIA was designed to achieve the following specific objectives:

- to meet the requirements of the *EIA Regulation* and *CEAA* as outlined in the Guidelines (NBDELG, 2002) and EIA Terms of Reference (NBDSS, 2003);
- to ensure that the potentially affected public is engaged in meaningful discussion and is well informed prior to the government's decision, as to the nature and extent of environmental effects attributable to the proposed Status Quo and Project Options (i.e., both positive and negative environmental effects);
- to ensure that the values and concerns of the public are incorporated and adequately addressed in the study; and
- to obtain information (where applicable) from various stakeholders and the Aboriginal Community.

The communication and consultation program consisted of meetings and ongoing liaison with the public, stakeholders, regulatory agencies and the Aboriginal Community, as well as continuous media relations. The Public Consultation Report (AMEC 2005c) provides a detailed overview of the communication and consultation that occurred in support of the EIA.

The consultation consisted of four main activities undertaken through the course of the study. The first component consisted of ongoing contact with the public through the Study Facilitator and NBDSS EIA Manager. The second consisted of specific public events organized and linked with the EIA. The third consisted of three Component Studies that focused on specific study areas. The fourth activity (yet to be completed) will consist of formal consultation to be conducted following the release of the final EIA Report, the Biophysical and Socio-economic Component Studies, the Modelling Component Study and the Public Consultation Report.

Workshops were organized for each of the Component Studies and conducted in April, May and October 2003, respectively, in order to present the proposed tasks to the public, stakeholders and Aboriginal Community and to obtain their feedback on the draft Terms of Reference for the Component Studies.

A technical workshop comprising a discussion of fish passage and fishway technology was held in April 2004. This workshop was held as part of the ongoing consultations on the EIA.

A workshop was held on November 6, 2004 to provide an update on the status of the EIA, to discuss the AMEC Study Team EIA approach, and to present preliminary results of the Hydrodynamic and Sediment Transport Modelling Component Study.
The consultation program was designed to include representative locations within the entire Petitcodiac River watershed, however public interest in the Project was primarily province-wide (but also included national and international interest) and the consultation team answered questions of all interested members of the public, stakeholders and the Aboriginal Community and provided requested information. Public open houses and town hall meeting events were held in various locations within the watershed to allow interested people to attend without travelling long distances.

Public and stakeholder consultation and Aboriginal Community meetings were carried out during the course of the EIA at specific milestones in the process. Several one-on-one consultation meetings and discussions, as well as telephone conversations and written correspondence with individual interested members of the public, stakeholders and Aboriginal Community, were an integral part of the consultation process.

4.2 Regulatory Consultation

The AMEC Study Team established a close working relationship with the TRC as the TRC is responsible for ensuring the EIA is conducted in accordance with Guidelines and provided technical expertise to NBDSS and the AMEC Study Team. Meetings with the TRC were planned and held on a regular basis to provide updates on the study progress and to present findings and seek feedback on Project components at key milestones. A total of 26 meetings were held between February 2003 and August 2005.

Discussion of major EIA components with the TRC continued throughout the EIA. Such components included the design and delivery mechanisms of the public consultation program, the finalization of the EIA Terms of Reference, the Component Studies Terms of Reference and the contents of the Fish Passage and EIA and Modelling Update Workshops.

4.3 Public Consultation

Communication with the public used various tools such as bulletins, TV, radio, news releases, and media outlets as well as a dedicated interactive and bilingual website for the study. The website was maintained and updated by NBDSS on a regular basis to enable all interested parties to be kept up to date on the process, status of the study, and informed of any scheduled consultation initiatives such as public open houses. The website experienced upwards of 100,000 visits per month from late 2003 through early 2004. Consultation initiatives such as open houses and information sessions were initiated early on in the process in order to obtain stakeholder input and feedback. Specific technical workshops were held to obtain input to the Terms of Reference, scoping and VEC identification, cost/benefit analysis and approaches to modelling.

The public and all interested parties were invited to attend a series of meetings held at various locations within the Petitcodiac River watershed for the purpose of introducing the consulting team that will undertake the study, explain the EIA and Terms of Reference, and to receive public feedback. The meetings were held in January 2003 and consisted of an “Open House” format in the late afternoon to early evening and a “Town Hall” format, from early to late evening. All meetings were conducted in a bilingual format and participants represented both
The following items were discussed over the course of the meetings:

- background/history of the Project;
- harmonized EIA;
- explanation of NBDSS EIA Project Manager role and the Study Manager role;
- explanation of role of NBDSS;
- explanation of consultant selection process;
- introduction of the AMEC Study Team;
- overview of corporate and individual members of the AMEC Study Team (roles and responsibilities);
- Project Options and Project Objectives;
- high-level process overview;
- high-level schedule;
- detailed EIA approach (4 phases, normalization, etc.);
- roles of other parties (New Brunswick government, federal government, NBDELG, TRC);
- EIA Terms of Reference;
- Component Studies Terms of Reference;
- process for recommendations and decision-making;
- overview of public, stakeholder consultation and Aboriginal Community meeting process;
- opportunities and format for input;
- opportunities for groups to receive presentations;
- ways to access/receive documents;
- toll-free number;
- interactive and bilingual website; and
- important contacts.

Approximately 250 people attended these meetings.

A series of Open House sessions regarding the EIA for the public, stakeholders and Aboriginal Community took place in September 2003. These Open House sessions were advertised via print, radio and television media and personal invitations were issued by telephone or e-mail to all citizens, stakeholders and Aboriginal Community members on the Project mailing list, as well as two local school districts. All meetings were conducted in a bilingual format and participants represented both official language groups at all venues. The specific objectives of the Open House sessions are provided below:

- to present an update on the progress of the EIA to date;
- to provide an overview of the summer 2003 field data collection program;
- to distribute EIA related documents prepared to date; and
- to discuss concerns, suggestions and issues with the public, stakeholders and Aboriginal Community and to receive their comments.
The Open House format provided an opportunity for attendees to review documentation and posters at their leisure, a continuous slide show was also used to present the activities of some results of the summer 2003 field data collection program, and interim reports and EIA documentation were made available in both official languages.

All participants at the January and September Open Houses were requested to respond to an exit questionnaire designed to determine the appropriateness of the information and receive suggestions regarding future consultation format and content. Follow-up comments were also submitted by several participants and stakeholders who did not have the opportunity to attend the Open House sessions.

Table 4.3.1 presents a list of the consultation events conducted during this EIA. It should be noted that several one-on-one consultation meetings and discussions as well as telephone conversations and written correspondence with individual interested members of the public was an integral part of the consultation process.

<table>
<thead>
<tr>
<th>Date of Event</th>
<th>Stakeholder / Type of Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>January 27-30</td>
<td>Open houses/Town Hall meeting events</td>
</tr>
<tr>
<td></td>
<td>January 27 - Salisbury</td>
</tr>
<tr>
<td></td>
<td>January 28 – Hillsborough</td>
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<td></td>
<td>January 29 – Moncton</td>
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<tr>
<td></td>
<td>January 30 – Memramcook</td>
</tr>
<tr>
<td>February 12</td>
<td>Petitcodiac Riverkeeper meeting</td>
</tr>
<tr>
<td>February 19</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>February 24</td>
<td>Petitcodiac Riverkeeper meeting</td>
</tr>
<tr>
<td>February 26</td>
<td>Pré-den-Haut Fishermen’s</td>
</tr>
<tr>
<td>February 26</td>
<td>Petitcodiac resident meeting</td>
</tr>
<tr>
<td>February 27</td>
<td>Alma Fishermen’s Association</td>
</tr>
<tr>
<td>March 7</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>March 10</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>March 12</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>March 19</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>March 24</td>
<td>LAPPA meeting</td>
</tr>
<tr>
<td>April 3</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>April 7</td>
<td>Moncton Friendship Club</td>
</tr>
<tr>
<td>April 8</td>
<td>LAPPA meeting</td>
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<tr>
<td>April 9</td>
<td>Inner Bay of Fundy Working Group meeting</td>
</tr>
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<td>April 9</td>
<td>APEGNB (Moncton Branch)</td>
</tr>
<tr>
<td>April 26</td>
<td>Biophysical Component Study Workshop</td>
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<tr>
<td>April 28</td>
<td>Village of Memramcook Council presentation</td>
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<tr>
<td>May 5</td>
<td>Technical Review Committee</td>
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<td>May 31</td>
<td>Socio-economic Component Study Workshop</td>
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<td>June 4</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>June 7</td>
<td>CSCE Congress 31st Conference</td>
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<tr>
<td>June 11</td>
<td>Petitcodiac Riverkeeper meeting</td>
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<tr>
<td>June 17</td>
<td>The National Program of Action (NPA) – Government Representatives from DFO</td>
</tr>
<tr>
<td>July 3</td>
<td>Fundy Biosphere Initiative Workshop</td>
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<tr>
<td>July 7</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>July 9</td>
<td>Senior fishers and Petitcodiac residents meeting</td>
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</tbody>
</table>
### Table 4.3.1 Consultation Events

<table>
<thead>
<tr>
<th>Date of Event</th>
<th>Stakeholder / Type of Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 28</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>September 10</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>September 19</td>
<td>Petitcodiac River resident meeting</td>
</tr>
<tr>
<td>September 19</td>
<td>Petitcodiac River fisherman meeting</td>
</tr>
<tr>
<td>September 22-25</td>
<td>Open House Events</td>
</tr>
<tr>
<td></td>
<td>September 22 - Belliveau Village</td>
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<tr>
<td></td>
<td>September 23 - Village of Petitcodiac</td>
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<td></td>
<td>September 24 - Riverside Albert</td>
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<td></td>
<td>September 25 - Riverview</td>
</tr>
<tr>
<td>September 22</td>
<td>Mathieu Martin High School presentation</td>
</tr>
<tr>
<td>September 25</td>
<td>Petitcodiac Riverkeeper meeting</td>
</tr>
<tr>
<td>September 26</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>October 18</td>
<td>Modelling Component Study Workshop</td>
</tr>
<tr>
<td>October 29</td>
<td>Petitcodiac Riverkeeper meeting</td>
</tr>
<tr>
<td>November 4</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>November 11</td>
<td>LAPPA meeting</td>
</tr>
<tr>
<td>December 5</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>December 10</td>
<td>Dorchester Cape Fishermen’s meeting</td>
</tr>
<tr>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>January 16</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>January 19</td>
<td>City of Dieppe Council presentation</td>
</tr>
<tr>
<td>January 22</td>
<td>APEGNB (Fredericton Branch)</td>
</tr>
<tr>
<td>February 4</td>
<td>Lake Petitcodiac Bass Fishing Tournament Organizer meeting and Dorchester Cape Fishermen’s meeting</td>
</tr>
<tr>
<td>February 16</td>
<td>City of Moncton Council presentation</td>
</tr>
<tr>
<td>February 27</td>
<td>Alma Fishermen’s Association</td>
</tr>
<tr>
<td>March 5</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>March 16</td>
<td>UdeM Engineering Faculty presentation</td>
</tr>
<tr>
<td>March 29</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>April 17</td>
<td>Fish Passage Workshop</td>
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<tr>
<td>May 3</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>May 14</td>
<td>Riverview High School presentation</td>
</tr>
<tr>
<td>May 27</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>June 1</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>June 2</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>June 15</td>
<td>LAPPA meeting</td>
</tr>
<tr>
<td>July 8</td>
<td>Alma Fishermen’s Association</td>
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<tr>
<td>July 22</td>
<td>Greater Moncton Sewage Commission presentation</td>
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<tr>
<td>July 22</td>
<td>Petitcodiac Riverkeeper meeting</td>
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<tr>
<td>September 10</td>
<td>Technical Review Committee</td>
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<tr>
<td>September 26</td>
<td>Technical Review Committee</td>
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<tr>
<td>September 27</td>
<td>Technical Review Committee</td>
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<tr>
<td>October 12</td>
<td>Fort Folly First Nation meeting</td>
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<tr>
<td>November 6</td>
<td>EIA Update and Modelling Workshop</td>
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<tr>
<td>November 16</td>
<td>Moncton Naturalists’ Club</td>
</tr>
<tr>
<td>December 16</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>January 5</td>
<td>Moncton Probus Club</td>
</tr>
<tr>
<td>February 22</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>March 15</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>March 15</td>
<td>Greater Moncton Chamber of Commerce Environment Committee Presentation</td>
</tr>
<tr>
<td>March 15</td>
<td>U de M Civil Engineering Students Presentation</td>
</tr>
</tbody>
</table>
Table 4.3.1 Consultation Events

<table>
<thead>
<tr>
<th>Date of Event</th>
<th>Stakeholder / Type of Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 15</td>
<td>CSCE Moncton Presentation</td>
</tr>
<tr>
<td>April 4</td>
<td>Fort Folly First Nation meeting</td>
</tr>
<tr>
<td>April 19</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>May 17</td>
<td>Riverview High School presentation</td>
</tr>
<tr>
<td>June 29</td>
<td>Riverview resident meeting</td>
</tr>
<tr>
<td>July 7</td>
<td>Riverview resident meeting</td>
</tr>
<tr>
<td>July 13</td>
<td>TRC meeting (DFO, DSS, AMEC)</td>
</tr>
<tr>
<td>July 14</td>
<td>Riverview resident meeting</td>
</tr>
<tr>
<td>July 19</td>
<td>TRC meeting (NWPA, Transport Canada, DFO, DSS, DELG, AMEC)</td>
</tr>
<tr>
<td>July 21</td>
<td>Tri Community Marina meeting</td>
</tr>
<tr>
<td>July 22</td>
<td>TRC meeting (NWPA, Transport Canada, DSS, DELG, AMEC)</td>
</tr>
</tbody>
</table>

4.4 Stakeholder Consultation

Stakeholders were identified at the early stage of the Project. Stakeholders were requested to register as interveners in the process. This involved a notice placed in the media requesting that stakeholders apply to NBDSS for formal intervener status. This application would indicate the level of involvement planned/desired and would include information such as: profile of the stakeholder, representation, constituency, number of members/directors, history of past involvement in the causeway, organizational structure, corporate status, etc. This procedure assisted in the identification of groups which have a clear plan to undertake a concerted effort to respond directly to the evidence and information presented in the EIA documents, and to participate effectively in the consultation processes. An initial list of stakeholders was developed through this process and was expanded through the course of the EIA.

4.5 Aboriginal Community Meetings

The Aboriginal Community meetings were initiated by identifying the appropriate Aboriginal Communities and First Nation Associations with interest in the EIA. Only one Aboriginal Community was identified, Fort Folly First Nation. A process was then developed to provide Aboriginal people with an opportunity to become involved in meaningful discussion and the decision-making process.

The overall objective of the Aboriginal Community meetings was to communicate with the Fort Folly First Nation regarding the EIA and identify any current use of land and resources for traditional use by Aboriginal Persons.

The Aboriginal meeting process involved direct contact with the Chief of Fort Folly First Nation to determine the desired method for their participation. Meetings were comprised of presentations by various representatives of the AMEC Study Team and/or the NBDSS and discussions. Interviews were conducted with selected members of Fort Folly First Nation in addition to meetings with Chief and Council, at the Chief’s request and suggestion. Fort Folly First Nation was also invited to all EIA public participation events.
The Study Facilitator maintained close liaison with the Chief of Fort Folly First Nation and requested meetings when major milestones occurred or when Chief and Council desired information and updates on the EIA and results.

4.6 Summary of Issues

Various issues were raised over the course of the consultation process. Feedback received from consultations was constructive and offered an insight to concerns and issues held by the public, stakeholders and Aboriginal Community. The Public Consultation Report (AMEC, 2005c) presents the complete results of the consultation process for this EIA. The majority of the issues that were raised during consultation was also raised in public and other consultation for the Niles Report, and as such is presented in Section 2.2 of this EIA Report. In addition to those issues previously identified in the Niles Report, there were some new issues raised. The new issues pertained to the following three categories:

- EIA components;
- proposed Project Options; and
- commitment of government in the EIA.

These new issues are described in the following sections.

4.6.1 EIA Components

Comments received regarding the EIA components during the consultation and meeting process included recommendations on conducting a thorough study of proposed Project Options and the Status Quo and issues arising from each. Suggestions included the review of similar activities in other locations throughout the world for possible direction (Cardiff, Wales; Fraser River, British Columbia; Grand Falls, Newfoundland and Labrador; and Windsor, Nova Scotia) and past reports and studies conducted on the Petitcodiac River.

Another key issue arising from comments appeared to be centered around information available to the public. Many questions were posed that may be provided to the public for clarification such as identification of stakeholders, EIA findings, thorough descriptions of EIA resources and financial aspects of the EIA.

4.6.2 Proposed Project Options

Issues raised regarding the Project Options centered around how a final decision was to be made and associated costs for each. It was also questioned as to whether a provincial comprehensive EIA would be conducted on each Project Option.

Most comments received from the public regarding the Project Options referred to the elimination of Project Options 1 and 2 (replacing the fishway and keeping gates open during peak fish migration) from the study, and that focus should be placed on the permanent opening of the gates (Project Option 3) or construction of a partial bridge (Project Option 4). Some comments were received about possibly continuing with the Status Quo. Other opinions were expressed as full removal of causeway and aiding or allowing the river to restore itself to a natural state.
4.6.3 Commitment of Government in EIA

Comments were received regarding the commitment of various levels of government and government departments in the EIA. Some comments documented opinions with respect to lack of direction, financial support, and participation in the EIA. Some concerns were raised regarding potential negative effects from federal legal interventions and lack of communication between provincial and federal governments over final decisions.

4.7 Selection of Valued Environmental Components

The selection of VECs was based on the consultation and meeting process as presented in this chapter and the professional judgment of the AMEC Study Team. VECs are selected to outline the best way to organize the EIA to reflect Project-environment interactions and issues and concerns associated with them. Table 4.7.1 presents the list of VECs and the key aspects, issues and factors that were considered for each VEC and also provides the spatial boundaries for the environmental effects analysis (the “Assessment Area”) of each VEC. The table was prepared in full consideration of the Guidelines. Chapter 9 describes the environmental effects of the Status Quo and Project Options on these VECs and includes further details on the rationale for selecting each VEC.

The temporal boundaries for all VECs are from 2005 baseline conditions out to 2025. These boundaries are restricted by the results of the modelling performed for this EIA. Trend analysis was used to anticipate the environmental effects out to 2055 and 2105.
### Table 4.7.1 Valued Environmental Components

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect</th>
<th>Issues and Factors to be Considered</th>
<th>VEC Spatial Boundaries (the “Assessment Area”)</th>
</tr>
</thead>
</table>
| Atmospheric Environment       | Climate           | - Microclimate conditions, including fog and temperature.  
                          |                   | - The contribution to climate change from greenhouse gas emissions and the loss/gain of carbon sinks.           | - Greater Moncton Area and southeastern New Brunswick for characterization of local and regional climate.          |
|                               |                   | - Greater Moncton Area for characterization of microclimate.  
                          |                   | - Southeastern New Brunswick for characterization of climate change and variability.                           |                                                                                                                |
| Air Quality                   |                   | - Emissions of conventional air contaminants from construction activities and wind blown dust from drying mudflats, and the quality of the ambient air including:  
                          |                   | - Particulate matter (PM);  
                          |                   | - Fine particulate matter (PM$_{10}$);  
                          |                   | - Sulphur dioxide (SO$_2$);  
                          |                   | - Nitrogen oxides (NO$_x$);  
                          |                   | - Carbon monoxide (CO).                                                                                       | - Greater Moncton Area for characterization of conventional air contaminant emissions.                     |
|                               |                   |                                                                                                    | - Southern and southeastern New Brunswick for characterization of ambient air quality.                       |
| Sound Quality                 |                   | - Noise (type, intensity and character of sound emissions).                                                                                                  | Greater Moncton Area for the characterization of sound quality.                                             |
| Odour                         |                   | - Odour from exposure of mudflats and decaying wetland vegetation.                                                                                           | Greater Moncton Area and nearby communities in the immediate vicinity of the Petitcodiac River, including the headpond area and existing mudflats downstream of the causeway. |
| Fish and Fish Habitat         | Fish and Fish     | - Marine, estuarine and freshwater components including:  
                          | Habitat Quality     | - Fish species presence;  
                          |                   | - Direct mortality;  
                          |                   | - Fish habitat type;  
                          |                   | - Fish migration impediments;  
                          |                   | - Species at risk; and  
                          |                   | - Freshwater recreational fisheries resources.                                                                 | Village of Salisbury to the mouth of the Petitcodiac River and Shepody and upper Chignecto Bays.         |
Table 4.7.1 Valued Environmental Components

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect</th>
<th>Issues and Factors to be Considered</th>
<th>VEC Spatial Boundaries (the “Assessment Area”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td></td>
<td>• Marine, estuarine and freshwater components including:</td>
<td>• Village of Salisbury to Shepody and Chignecto Bays.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water chemistry, including suspended sediments;</td>
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<tr>
<td></td>
<td></td>
<td>• Bacteria concentrations; and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mixing zone of fresh and saltwater.</td>
<td></td>
</tr>
<tr>
<td>Sediment Quality</td>
<td></td>
<td>• Marine, estuarine and freshwater components including:</td>
<td>• Village of Salisbury to Shepody and Chignecto Bays.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sediment chemistry;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Physical properties; and</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Contamination.</td>
<td></td>
</tr>
<tr>
<td>Benthic Community</td>
<td></td>
<td>• Marine, estuarine and freshwater components including:</td>
<td>• Village of Salisbury to Shepody and Chignecto Bays.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Benthic community composition.</td>
<td></td>
</tr>
<tr>
<td>Commercial Fisheries</td>
<td></td>
<td>• Commercial fisheries resources in Shepody Bay and the Inner Bay of Fundy.</td>
<td>• Village of Salisbury to Shepody and Chignecto Bays.</td>
</tr>
<tr>
<td>Terrestrial and Wetland</td>
<td>Wetlands</td>
<td>• Saltwater marsh area downstream of causeway.</td>
<td>• Village of Salisbury to Shepody Bay. The outer limit for data assembled is Marys Point and Lower Rockport.</td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td>• Freshwater marsh area upstream of causeway.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Contamination of wetlands.</td>
<td></td>
</tr>
<tr>
<td>Wildlife and Vegetation</td>
<td></td>
<td>• Species at risk.</td>
<td>• Village of Salisbury to Shepody Bay. The outer limit for data assembled is Marys Point and Lower Rockport.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Quantity and quality of habitat.</td>
<td></td>
</tr>
<tr>
<td>Birds</td>
<td></td>
<td>• Migratory and non-migratory bird habitat quality and quantity.</td>
<td>• Village of Salisbury to Shepody Bay. The outer limit for data assembled is Marys Point and Lower Rockport.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Avoidance of habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Direct and indirect mortality.</td>
<td></td>
</tr>
<tr>
<td>Mudflat Productivity</td>
<td></td>
<td>• <em>Corophium volutator</em> (mudshrimp) distribution and abundance.</td>
<td>• Village of Salisbury to Shepody Bay.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Importance of mudshrimp to staging shorebirds.</td>
<td></td>
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</tbody>
</table>
### Table 4.7.1 Valued Environmental Components

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect</th>
<th>Issues and Factors to be Considered</th>
<th>VEC Spatial Boundaries (the “Assessment Area”)</th>
</tr>
</thead>
</table>
| Municipal Services and Infrastructure | Services                            | • Services for the municipalities and Local Service Districts located along the banks of the Petitcodiac River, including:  
• Emergency services (fire, police, ambulance);  
• Water distribution system;  
• Sanitary sewer system; and  
• Storm water system.                                                                 | • Village of Salisbury to the Village of Alma.                                                                 |
| Infrastructure                          | Infrastructure components (excluding road transportation network) of the services for the municipalities and Local Service Districts located along the banks of the Petitcodiac River, including:  
• Water supply conduits;  
• Sanitary and storm sewers;  
• Drainage works and culverts;  
• Dykes and aboiteau; and  
• Other infrastructure.                                                                 | • Village of Salisbury to the Village of Alma.                                                                 |
| Road Transportation Network            | Road Transportation Network         | • Traffic patterns.  
• Traffic disruption.  
• Level of Service (LOS).  
• Transportation network infrastructure stability.                                                                 | • All provincial roads that run alongside and/or cross the Petitcodiac River, and alongside the mouths of tributaries of the Petitcodiac River. |
| Vessel Traffic and Navigation         | Vessel Traffic and Navigation      | • Navigational opportunities.  
• Vessel traffic.                                                                 | • Village of Salisbury to Shepody Bay.                                                                 |
| Land Use and Value                    | Land Use                            | • Agricultural.  
• Access to headpond.                                                                 | • The Petitcodiac River basin with focus on both sides of the Petitcodiac River from the Village of Salisbury to the mouth of the river at Shepody Bay. |
### Table 4.7.1 Valued Environmental Components

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect</th>
<th>Issues and Factors to be Considered</th>
<th>VEC Spatial Boundaries (the “Assessment Area”)</th>
</tr>
</thead>
</table>
| Land Value                     | • Property value.  
                                 | • Insurance rates.  
                                 | • Aesthetic value, including view, odour and noise.  
                                 | • Proximity to headpond.  
                                 | • Access to the Petitcodiac River | • The Petitcodiac River basin with focus on both sides of the Petitcodiac River from the Village of Salisbury to the mouth of the river at Shepody Bay. |
| Current Use of Lands and Resources for Traditional Purposes | Current Aboriginal Land and Resource Use | • Identified current uses of land and resources for traditional purposes by Aboriginal Persons. | • The Petitcodiac River including shoreline areas from the Village of Salisbury to the mouth of the Petitcodiac River. |
| Tourism                        | Tourism Opportunities | • Above the causeway.  
                                 | • Below the causeway, including  
                                 | • Tidal bore.  
                                 | • Tourism trends. | • Village of Salisbury to Chignecto Bay, with a focus on the river and its shoreline areas.  
                                 | • The GMA, Westmorland/Albert region and the Province of New Brunswick for assessment of the economic implications of the tourism attractions. |
| Recreation                     | Recreational opportunities | • Recreational fishery.  
                                 | • Boating and kayaking.  
                                 | • Bird watching.  
                                 | • Walking and hiking trails. | • Village of Salisbury to Chignecto Bay. |
| Labour and Economy             | Local and Provincial Economies | • Agriculture.  
                                 | • Commercial fishery.  
                                 | • Population.  
                                 | • Income.  
                                 | • Tourism. | • The urban and rural communities along the river on both sides of the river from the Village of Salisbury to Chignecto Bay.  
                                 | • The Province of NB where specific local region data are not available. |
| Heritage and Archaeological Resources | Heritage and Archaeological Resources | • Loss of heritage and archaeological resources. | • Locations where there are likely to be environmental effects to lands that may contain heritage resources. |
| Public Health and Safety       | Vehicular Accidents | • Accident rates.  
                                 | • Accident types. | • Village of Salisbury to Shepody Bay. |
## Table 4.7.1 Valued Environmental Components

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect</th>
<th>Issues and Factors to be Considered</th>
<th>VEC Spatial Boundaries (the “Assessment Area”)</th>
</tr>
</thead>
</table>
| Non-vehicular Accidents and Unplanned Events | • Boating accidents.  
• Accidents related to mud.  
• Source of water for fire fighting. | Village of Salisbury to Shepody Bay. |
| Groundwater | • Saltwater intrusion. | Village of Salisbury to Shepody Bay. |
| Contaminated Effluents and Distribution of Contaminants | • Sewage contamination. | Village of Salisbury to Shepody Bay. |
| Human Disease Vectors | • Spread of West Nile Virus via mosquitoes. | Village of Salisbury to Shepody Bay. |
| Flooding and Flood Risk | • Channel conveyance.  
• Dykeland.  
• Causeway.  
• Road transportation network. | Village of Salisbury to Shepody Bay. |
| Human Food Resources | • Recreational and commercial fishery.  
• Recreational plant harvesting.  
• Contaminants. | Village of Salisbury to Shepody Bay. |
5.0 DESCRIPTION OF PAST AND EXISTING ENVIRONMENT

In order to provide the information necessary to support the EIA and prepare the EIA Report, the AMEC Study Team prepared Component Studies as described in Section 3.3. The information reported in the Component Studies was a synthesis of available information, additional studies, and modelling conducted by the AMEC Study Team. Refer to Section 3.3 for a summary of the data included in each of the Component Studies.

Section 5.1 provides a description of the existing causeway and control structure. Section 5.2 describes the past and existing physical characteristics of the Petitcodiac River and is derived from the Hydrodynamic and Sediment Transport Modelling Component Study.

Sections 5.3 to 5.15 describe the past and existing environments for each VEC assessed in the EIA, as identified in Table 4.7.1. Sections 5.3 to 5.15 provide a summary of key information from the Biophysical and Socio-economic Component Studies and describes the biophysical and socio-economic environments of the causeway for the following time periods:

- pre-causeway (prior to construction of the causeway in 1967);
- post-causeway (period after construction of the causeway in 1968 to 2002);
- existing conditions (period of data collection in 2002 and 2003); and
- baseline conditions for the EIA (existing conditions extrapolated to 2005).

Figures depicting information from the Component Studies are included within this Chapter where necessary to support the conclusions of the EIA. Additional figures summarizing the results of the Biophysical Component Study are available on the Petitcodiac River website [http://www.petitcodiac.com].

5.1 Causeway and Control Structure

5.1.1 Causeway

The causeway was constructed from 1966-1968 using rock fill. The causeway is 1,036 m long, and the top of the causeway is at elevation 9.5 m (all elevations within this report are referenced to geodetic datum). The top of the causeway is about 18 m wide. The elevation of the marsh, downstream of the causeway, is about 7.2 m, and the mudflats located immediately upstream, on the Moncton side of the river, are at approximately elevation 3.5 m. High tide in the river can reach an elevation of 8.0 m during the fall season (extreme high tide as recorded in 2003), and higher water levels are possible during extreme storm events in the Bay of Fundy, associated with a high tide. Figures 5.1.1 and 5.1.2 show the location of the causeway on aerial photographs. Figure 5.1.3 illustrates the existing infrastructure in the area that is relevant to this EIA.

5.1.2 Control Structure

The control structure is a concrete structure with gates that is located on the Riverview side of the causeway. The structure is founded on relatively weak bedrock consisting of flat lying beds
of sandstone, shale and mudstone. The location of the control structure and fish passage structure are shown on Figure 5.1.3. Figure 5.1.4 illustrates both structures with photographs taken in 2003.

The floor of the structure consists of a 1.2 m thick concrete slab, and the elevation of the top of the slab is -1.52 m. This concrete floor is about 53 m long and extends over the entire width of the structure. The structure was designed to allow flow from the headpond to the estuary, and as a consequence, an energy dissipation basin was built on the downstream side (east side) of the structure. There is no such provision on the upstream side.

The control structure has five gate openings of 8.84 m wide, each. Piers, with a 3.35 m width, separate the gates from one another. With a bottom elevation of -1.52 m and the top of the gates at elevation 4.57 m, the total gate opening height is 6.09 m. This provides for a total gate cross-sectional area of 53.8 m$^2$ per gate, and a total opening area for all five gates of 269 m$^2$.

Slots for stop logs are located at the upstream and the downstream ends of each of the original piers. In addition there is an opening on the Moncton side of the control structure in which the present fish passage facility is located.

In 1997, a new, two-lane bridge was constructed just upstream of the original structure in order to upgrade the crossing to four lanes. The bridge abutment on the Moncton side was placed to the north of the existing fish passage facility.

The fish passage facility is intended primarily to provide upstream passage for Atlantic salmon. The vertical slot fishway has 19 pools, each 3 m long and 2.4 m wide. The drop between pools is 23 cm, and the slots are 30.5 cm wide. The drop between the pools can, however, vary in response to the difference in water surface elevation and can be as much as 40 cm for a headpond elevation of 6.5 m and a downstream water elevation of -1.5 m, or 0 cm when the two water surface elevations are the same. The flow will also reverse in the fishway when the tides are higher than the headpond elevations. The invert elevation of the top pool is +2.6 m and the invert elevation of the lowest pool is -1.5 m. The assumed elevation of the headpond at the time of the fishway's design was +4.6 m, which was the expected normal operating level. It should be noted that the headpond operating level varied between 0 m and in excess of 6 m during its operation. As noted above, the gates are also manipulated to aid in fish passage.

### 5.1.3 Water Supply Line

There is an existing water supply line that crosses the Petitcodiac River upstream of the control structure, as shown in Figure 5.1.3. The pipeline is a reinforced concrete pressure pipe, 750 mm in diameter. The invert elevation of the pipeline varies across the river, and the highest invert elevation is -2.0 m. The top of the pipe was covered with 0.6 m of concrete as scour protection when the line was installed. The line runs to the northeast and joins the causeway just north of the fish passage structure. Here, it crosses eastward through the causeway, and the invert elevations of the pipe on the east side are all 4.2 m. The line joins the City of Moncton water system near the traffic circle at the Moncton end of the causeway.
5.1.4 Sediment Deposit in Headpond

Construction of the causeway, and other actions and consequences of the operation of the causeway have resulted in sedimentation in the headpond between 1968 and 2003 of about 4.9 Mm$^3$. It is known that substantial deposition of sediment (1.3 Mm$^3$) occurred during the construction of the causeway. The gates in the control structure were not fully in place until May 1968 hence, sediment was able to be transported upstream through the control structure between February 1968 and May 1968. This was in addition to sedimentation that occurred during the construction of the causeway itself. At various times since construction, the gates have been held open for several weeks or more. Trial gate openings in 1988 alone resulted in 3.1 Mm$^3$ of sedimentation. It is estimated that approximately 0.2 Mm$^3$ of sediment has been deposited upstream through the fishway. Runoff from the watershed upstream of the headpond has contributed an estimated 0.3 Mm$^3$ between 1968 and 2003. Also, following construction, the gates leaked water from downstream into the headpond at high tide and may have contributed to this overall amount of deposited sediment.

At the time of construction, the causeway was intended to provide flood protection and a transportation link between Riverview and Moncton. A secondary benefit of the project was the creation of the headpond. The headpond was at the outset operated at elevation 4.6 m. Due to operational issues associated with the fishway at this low elevation, the normal operating level within the headpond was raised to 6.1 m. At 4.6 m, without the unanticipated sedimentation, the headpond would have had a total estimated volume of 10.2 Mm$^3$, half of which was lost due to sedimentation. At 6.1 m, the current headpond volume is about 15 Mm$^3$, reduced from its potential volume of 20 Mm$^3$ as a result of sedimentation.

This continued sediment accumulation within the headpond has resulted in a deposit (referred to as a sediment plug) upstream of the causeway, occupying most of the headpond, which extends from the causeway to about 6.5 km upstream. Above that, the former estuary is now effectively a river channel confined by the pre-existing banks. Also, during periods of low river flow, there is a potential for ice jams to occur in the headpond as the ice “hangs up” on the sediment plug. The general location of the sediment plug is shown in Figure 5.1.5. Figure 5.1.5 also shows the thalweg elevation (defined as the lowest elevation in the channel cross section) of the greatly reduced central channel of the former estuary. Sediment deposits in the headpond have resulted in shallow water over most of its area. The mean water depth of the headpond is currently estimated to be 2.5 m, but this estimate is skewed by the narrow central channel that has a typical depth in the order of 6.5 m. Consequently, typical depths over most of the headpond are very shallow and in the order of 1-2 m.

5.2 Physical Characteristics of the Petitcodiac River Estuary

5.2.1 Channel Morphology

The morphology of the Petitcodiac River estuary was described based on field measurements of channel properties taken at several locations along its length from Salisbury to Hopewell Cape. Specific cross section locations were used during previous field surveys and were also used to conduct the field surveys carried out by the AMEC Study Team. The specific locations are
presented in Table 5.2.1 and shown on Figure 5.2.1. An aerial view of the Petitcodiac River taken in 1969 following the construction of the causeway is shown in Figure 5.2.2. The channel properties usually obtained at these locations include: the thalweg elevation (defined as the lowest elevation in the channel cross section); the cross sectional area; and cross sectional width.

Generally, an estuary is characterized by the exchange of water and sediment from the ocean with water and sediment from the land. Over time, the geometry (cross-sectional characteristics) of the estuary tends toward equilibrium notwithstanding seasonal variations and longer term trends in geologic time (e.g., erosion of land, changes in climate and sea level). If substantial changes occur in the supply of sediment or water, whether imposed by nature or by human intervention, the geometry of the estuary adjusts in response to these changes.

The Petitcodiac River estuary is located within the Bay of Fundy which has a tidal range that is considered to be the largest in the world. The concentration of total suspended sediment (TSS) in the water within the estuary is extremely high (up to 30,000 mg/L). In addition, the formation of ice in the estuary affects the amount of water and sediment that is exchanged during the winter period.

Prior to the construction of the causeway in 1968, free tidal exchange took place on the Petitcodiac River where the head of tide reached Salisbury. This free tidal exchange resulted in a fairly stable channel. The stability of the channel in the century before the causeway was built has been demonstrated by comparing historical cross sections. Historical cross sections of pre-causeway conditions were obtained from 1861, surveys conducted by the British Admirality, 1915 surveys obtained during the construction of the Gunningsville Bridge, and 1960 surveys conducted by the MMRA. Comparisons between these cross sections are presented in Figure 5.2.3. Figure 5.2.3(a) provides a comparison between the 1861 cross section and the 1915 cross section located at 2.1 km downstream of the causeway at the Gunningsville Bridge. Figure 5.2.3(b) provides a comparison between the 1861 cross section and the 1960 cross section located at 5.1 km downstream of the causeway. It is noted in Figure 5.2.3(a) that the difference between the 1915 cross section and the 1861 cross section is relatively small when it is recognized that the sections were taken 54 years apart and that there are seasonal variations in cross-sectional area. In a similar manner, the 1960 cross section is relatively close to the 1861 cross section obtained 99 years earlier, Figure 5.2.3(b).

Following the construction of the causeway in 1968, the free tidal exchange within the river system above the causeway was arrested. The volume of the tidal prism above the causeway (volume of water contained during a high tide) was about 28.9 million cubic metres (Mm³) and this volume was removed from the tidal system. The headpond that was created is shallow as a consequence of sedimentation that occurred during construction and subsequently (Section 5.1.4). The headpond is currently a very shallow body of water with typical depths of 1-2 m except in the much-narrowed central channel. That central channel is maintained by higher flows during the spring freshet and other high freshwater flow events where it is necessary to
### Table 5.2.1 Location of Cross Sections Relative to Causeway

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<td>Line 4</td>
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open the gates. In addition, as the causeway was constructed, sediment accumulated on the banks and bottom of the river that further reduced the volume of the tidal prism downstream of the causeway. The reduction in the tidal prism resulted in a lower flushing capacity within the river and caused substantial sediment deposition downstream of the causeway. The channel morphology changed in response to this new depositional environment. This reaction is demonstrated by the observed changes in depth, channel width and channel slope and consequently, the volume of water within the channel. Observations of channel infilling are demonstrated on Figures 5.2.4 (near Dieppe) and 5.2.5 (at Hopewell Cape).

At Hopewell Cape (Figure 5.2.5), some channel infilling occurred prior to the construction of the causeway, where an average deposition of about 1 m took place between 1861 and 1965 (104 years). The average rate of deposition in this period was about 1 cm/year. After construction of the causeway, there was an average deposition of about 2.5 m between 1965 and 1991; and an average deposition of about 1 m between 1991 and 2001. This is equivalent to an average rate of deposition following the construction of the causeway of about 10 cm/year, 10 times larger than before the causeway.

During 2003, regular surveys were carried out by the AMEC Study Team at the Gunningsville Bridge, located 2.1 km downstream of the causeway, with the results after the spring freshet between April and October 2003 presented in Figure 5.2.6. These surveys demonstrate that the bed of the river increased from about elevation -4.0 m to about +4.5 m between April 2003 and October 2003. That is, after the spring freshet, the river bed rose during the periods of low flow in the river and through the gates at the causeway. Figure 5.2.7 shows that in the fall, when there is typically heavy rain fall event, some of the sediment deposits that accumulated in the summer eroded during the high freshwater flow events. During the winter months, there can be some accumulation of sediment that is then eroded during the following spring freshet. If the fall rains were not heavy enough to erode the sediment, then the spring freshet erodes the sediment that accumulated the previous summer, fall and winter.

The AMEC Study Team also conducted monthly surveys during the ice-free period in 2003 at various locations along the Petitcodiac River estuary from the causeway to Hopewell Cape. These surveys provided data to characterize the longitudinal profile of the channel and to evaluate the seasonal changes in the channel geometry along the estuary. The longitudinal profile of a river is based on the thalweg elevation or the mean bed elevation associated with a reference water surface elevation. Figure 5.2.8 shows the longitudinal profile of the Petitcodiac River. The reference elevation was generally taken as the average marsh level along the Petitcodiac River and varied along the length of the river as shown on Figure 5.2.8. At Moncton, the marsh level/reference elevation was 7 m. Various physical features such as the slope of the bed of the channel and the seasonal variations in bed elevation can be interpreted from the longitudinal profiles.

It was determined that most seasonal changes in the longitudinal profile took place between the causeway and Stoney Creek, some 20.2 km downstream of the causeway. Seasonal changes of the bed elevations downstream of Stoney Creek were relatively small. Much of the seasonal changes were associated with seasonal deposits in the upper end of the estuary.
Analysis of the longitudinal profiles indicated that there are considerable changes in channel slopes between pre-causeway and post-causeway conditions. For instance the channel slope between the causeway and a point located at 27.4 km downstream of the causeway in the vicinity of Belliveau Village and Hillsborough increased from $2.1 \times 10^{-4}$ in 1861, to $3.1 \times 10^{-4}$ in November 1991, and reached $3.6 \times 10^{-4}$ by November 2001. This is the result of sediment deposition near the causeway causing an increase in elevation of the bottom at that point relative to sea level.

The width of the channel at the reference elevation (near marsh level) was determined at each cross section along the estuary. The width of the channel is constrained by bedrock outcrops at two sites along the estuary: one is at Dover (20.2 km downstream of the causeway at the confluence of Stoney Creek) and the other at Hopewell Cape (37.3 km downstream of the causeway). The width of the pre-causeway channel is noticeably narrower at these two sites when compared to the general trend of the channel width along the estuary as was demonstrated in Figure 5.2.4.

An analysis of the field observations indicated that the greatest percentage reduction in channel width, at the reference elevations along the estuary after the completion of the causeway, is in the reach between the causeway and the Gunningville Bridge. This analysis has also indicated that the reduction in channel width with reference to the pre-causeway channel width declines in the downstream direction and that the reduction in width is greater than about 20% over the upper 20 km of the estuary, below the causeway.

Cross-sectional areas along the Petitcodiac River estuary below the reference elevation for the surveys of 1861, November 1991 and November 2001 were examined. This examination revealed that the reduction in cross-sectional area between pre-causeway and post-causeway conditions was greater than 40% in the reach extending 20 km downstream of the causeway.

The total water volume within the channel upstream of each section location was computed using the cross-sectional area at each section location and combing this with the length of the river between sections to arrive at a volume. Figure 5.2.9 shows results of these calculations with the volumes summed moving down the river. In other words, Figure 5.2.9 shows the cumulative volume of water within the channel with distance down the channel. For the pre-causeway conditions, the 1861 survey below the causeway location and the 1960 survey above the causeway location before the causeway was constructed were used. For the post-causeway conditions, the surveys of November 1991, November 2001 and April-May 2002 below the causeway location were used to estimate the total water volumes. The cross-sectional areas at each section (and therefore the volumes) were estimated in relation to reference elevations, taken to be the average marsh elevations at various reaches along the estuary as shown on Figure 5.2.8. This is approximately equivalent to the elevation of the low high tide and, therefore, the volume of water in the channel plotted in Figure 5.2.9 is really the volume of water contained in the tidal prism under a low high tide. When the tides are higher than the low high tide, water floods the banks and the volume of water contained in the channel would be higher, but for the purposes of this discussion, we have considered the volume of
water below the marsh land (or below low high tide) as representative of the Petitcodiac River volume.

Table 5.2.2 summarizes the computed total water volume below the reference elevations and upstream of Hopewell Cape that are shown on Figure 5.2.9. The total water volume in the estuary above Hopewell Cape in November 2001 has been reduced by about 40% from that calculated for pre-causeway conditions. This is attributed to the accumulation of sediments within the channel and the reduction of channel depth and width associated with the construction of the causeway.

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Water Volume (Mm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1861$<em>{ds}$  – 1960$</em>{us}$</td>
<td>462</td>
</tr>
<tr>
<td>Nov 1991</td>
<td>295</td>
</tr>
<tr>
<td>Nov 2001</td>
<td>272</td>
</tr>
<tr>
<td>April – May 2002</td>
<td>270</td>
</tr>
</tbody>
</table>

- **a** 1861$_{ds}$ means that the sections downstream (ds) of the causeway were based on the 1861 hydrographic chart.
- **b** 1960$_{us}$ means that the sections upstream (us) of the causeway were based on the six cross sections obtained in June 1960 by MMRA and a 1965 cross section at the location of the causeway.
- **c** Total Water Volume is equal to the base river flow (below low tide) plus the tidal prism.

As noted in Figure 5.2.9 and Table 5.2.2., there has been a reduction of almost 200 Mm$^3$ of water volume since the causeway was constructed, 28.9 Mm$^3$ of which was due to the loss of the tidal prism in the headpond as discussed above, but the remainder is due to infilling along the sides and bottom of the river downstream of the causeway. Between 1991 and 2001, the average rate of deposition has been 2.0 Mm$^3$/yr. This rate of infilling is apparently continuing based on data from 2002 and 2003.

In addition to the infilling on the sides and bottom, some areas of dense and less erodible sediment (referred to as bars) have developed on the riverbed near Moncton that have a substantial influence on the behaviour of the river. The bottom elevation at the bend near Moncton has significantly risen, creating such a bar above elevation zero is causing this reach of the river to act as a constriction or control area.

### 5.2.2 Tidal Regime

The Petitcodiac River estuary is characterized by a high energy environment since it is subject to the highest tides in the world. The tidal regime in the Petitcodiac River estuary is characterized by 14 day tidal cycles where high tides occur twice in every lunar day of 24.8 hours. The tidal cycle in the Bay of Fundy near the mouth of the estuary is essentially sinusoidal in character (the shape of a sine curve). Figure 5.2.10 shows the typical tidal cycle at Hopewell Cape (Canadian Hydrographic Service Tide Table).

Prior to the construction of the causeway, the tidal envelope extended up river to Salisbury (head of tide). At that time, large volumes of tidal water moved freely twice daily in the
Petitcodiac River. As noted above, the volume of the tidal prism below a reference elevation, taken to be the average marsh level, upstream of Hopewell Cape was about 462 Mm$^3$. This has been reduced to about 270 Mm$^3$ and this has substantially modified the characteristic of the tides at Halls Creek as presented in Figure 5.2.11.

Presently, high tides at Moncton range from 4.5 to 8.0 m with a mean high tide of 6.1 m which is slightly lower than pre-causeway conditions.

5.2.3 Flows

The mean monthly flows for the Petitcodiac River at the causeway, prorated from the flows measured at the Water Survey of Canada gauging station located on the Petitcodiac River at Petitcodiac, are presented in Figure 5.2.12. A peak flow of 80 m$^3$/s occurs in April while low flows in the summer months are below 10 m$^3$/s. It should also be noted that mean daily flows of the Petitcodiac River at the causeway have been recorded to be lower than 2 m$^3$/s. It is also likely that, considering water withdrawal at Turtle Creek and evaporation from the headpond, the flow at the causeway would be near zero during extended summer and early fall low flow periods.

5.2.4 Sources and Fate of Sediment in the Petitcodiac River

The sources and fate of the sediment in the Petitcodiac River has always been of interest and a number of studies have been conducted to investigate this. Sediment is transported toward the Petitcodiac River from the Bay of Fundy and Chignecto and Shepody Bays (Figure 1.1.1). The amount of sediment transported from the Bay of Fundy is not well documented, but studies have been able to quantify the sediment that is drawn from the cliffs adjacent to Shepody Bay, Cumberland basin and Chignecto Bay (Figure 1.1.1) as well as scouring of the seabed that comprises sand and silt material. The average cliff erosion rates for Shepody Bay, Cumberland Basin and Chignecto Bay between 1947 and 1975 were 0.19, 0.20 and 0.37, respectively, resulting in about 1.0 Mm$^3$ per year of sediment into Shepody and Chignecto Bays and Cumberland Basin (Hildebrand, et al., 1980 and Amos, et al., 1991). The highest rate of erosion occurs in wave dominated areas such as the western side of Chignecto Bay and the mouths of Shepody Bay and Cumberland Basin (Amos, et al., 1991). Since waves tend to be greater in the spring and fall, these are also the times of year that that the most sediment is eroded from the cliffs.

Scouring and erosion of the seabed in Chignecto and Shepody Bays by the currents supplies approximately 6 Mm$^3$ per year (Amos and Zaitlin, 1985). Another 0.3 Mm$^3$ per year of sediment comes from rivers and streams that are tributaries to the area, especially during the spring break up or freshets (Amos, 1987).

Therefore, based on the sediment volumes noted above, a total of 7.3 Mm$^3$ of sediment is released annually into Chignecto and Shepody Bays and Cumberland Basin (Amos, et al, 1991), of which 1.3 Mm$^3$ is derived from external sources (rivers and eroding cliffs) and the remainder is derived from bed erosion.
This 7.3 Mm$^3$ of sediment is combined with the sediment coming from the Bay of Fundy. Approximately 99% of the sediment is suspended in the water column and transported up the Petitcodiac River, down the Petitcodiac River and out into the rest of the Bay of Fundy beyond Chignecto Bay in suspension.

The general circulation in the Bay of Fundy, west of the mouth of Chignecto Bay is counter clockwise (inward along the eastern margins and seaward along the western margins; Amos, et al., 1991). Water and sediment flows into Chignecto and Shepody Bay during the high tide with sediment that has formed in the water column in Chignecto and Shepody Bays being transported into the Petitcodiac River along the margins of these bays. As the tide recedes and water flows from the Petitcodiac River into Shepody and Chignecto Bays, the water with suspended sediment tends to flow through the central portion of Shepody and Chignecto Bays toward the Bay of Fundy.

Based on the volume of deposits in Chignecto Bay, Amos (1991) indicated that there is very little deposition in Chignecto Bay, with only 1% of the sediment in the form of sand and gravel introduced in Chignecto Bay. It has also been established by Schubel and Carter (1994) that the trapping efficiency of the Chignecto Bay is very small as a result of the reclamation of fringing salt marshes (Amos and Tec, 1989) and high wave activity. Therefore, it is assumed that the sediments that flow out of Chignecto Bay either from the Petitcodiac River or Chignecto and Shepody Bays and the Cumberland Basin are ultimately transported to the Bay of Fundy. The export of this material was verified by direct measurements made by Amos and Asprey (1981) at the mouth of Chignecto Bay.

As noted earlier, the Petitcodiac River is continuing to infill at a rate of 2 Mm$^3$ per year, hence, it is apparent that a portion of the sediment coming from the Bay of Fundy and derived from Chignecto and Shepody Bays and Cumberland Basin that flows up into the river is left behind as accumulation on the river banks and bottom.

It is also of interest to note that the process of sediment transport into and out of the river and out into the Bay of Fundy does not appear to be related to the construction of the causeway in 1967/68. Prior to the causeway construction, there would have been a similar amount of sediment removed from Chignecto and Shepody Bays and Cumberland Basin and held in suspension up into the river and down the river and out into the Bay of Fundy where it was deposited. The construction of the causeway altered the balance of where the sediment was deposited, with a portion deposited in the Petitcodiac River and not finding its way to the middle of the Bay of Fundy. There would still have been erosion of the cliffs and seabed in Chignecto and Shepody Bays and Cumberland Basin since 1967/68 even without the causeway.

### 5.2.5 Seasonal Changes and Sediment Transport

The erosion/deposition cycle in the Petitcodiac River estuary is not consistent throughout the year due to the dynamic contribution of flow to the estuary of the Petitcodiac River. Table 5.2.3 shows the maximum daily flow down the river recorded each year for the water level gauge in the Petitcodiac River in the Village of Petitcodiac, from 1961 to 2000. The table indicates the
date of the flow measurement and the associated season. The maximum flows in the river have occurred in all seasons, however, 2/3 of these maximum flows occurred in the spring, and in every year on record the mean flow in the month of April has exceeded the mean flow for the year. Erosion of the sediment that accumulates in the river occurs during the high flow events. There is always a high scouring flow in the spring, but as indicated by the information in Table 5.2.3, there can be high scouring flows in the summer and fall as well. In the winter, frozen ground conditions can limit the scouring potential. During the times of low flow, the sediment re-accumulates on the sides and bottom of the river.

Based on the river cross section surveys done in 2003, it is apparent that 10 to 20 Mm\(^3\) can be removed from the Petitcodiac River, past Hopewell Cape and into Shepody Bay, during a spring freshet as a “pulse of sediment” (See Appendix A- of the Modelling Component Study Report). There also can be a “pulse” in the fall depending on the intensity of the fall rains. For the purpose of discussion in this report, it has been assumed that about 15 Mm\(^3\) of sediment can be released from the river, past Hopewell Cape in the form of “pulses” during a spring freshet or heavy fall rain.

As noted above, the channel is infilling at a rate of 2 Mm\(^3\) per year. Hence, over the course of a year, there can be about 17 Mm\(^3\) of material deposited on the banks and bottom of the river with 15 Mm\(^3\) mobilized into the Shepody Bay area during the short term events in the spring and fall. The sediment that is deposited in the river during low flow events comes out of suspension when the energy is low and is then re-suspended during the high flow events. The sediment is held in suspension in Shepody and Chignecto Bays and Cumberland Basin with a portion sent to the middle of the Bay of Fundy and then a portion sent back up the river. It is unlikely that the sediment that leaves the Petitcodiac River during the spring and fall pulses accumulates on the bottom of Chignecto and Shepody Bays.

5.2.6 Flooding

Flooding events along the Petitcodiac River have been recorded for many years, well before the construction of the causeway. The Saxby Gale storm surge event on October 4, 1869 is considered as the major historical flood-causing event on the Petitcodiac River system. The Saxby Gale event was associated with heavy rainfalls and high winds resulting in a water elevation of 10.0 m at Moncton. More recently, flooding events have been associated with high precipitation events due to the limited channel conveyance capacity within the main channel resulting from sediment accumulation as well as the substantial sediment deposits at the mouth of tributary channels.

Prior to construction of the causeway, flooding events occurred as a result of high precipitation and in some events were associated with early spring break up and ice jamming. It has been reported that undersized storm sewers have been a major factor contributing to flooding in Moncton and Riverview. In addition to being undersized, many of the City of Moncton’s storm sewers and sanitary sewers are located at elevations below flood levels. This reduces their effectiveness in removing water from the City. For example, the Amirault Street sanitary sewer is at an elevation of 4.5 m and the storm sewer is at an elevation of 6.6 m.
### Table 5.2.3 Maximum Daily Flows in the Petitcodiac River, 1962 to 2000

<table>
<thead>
<tr>
<th>Date</th>
<th>Maximum Daily Flow</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 02, 1962</td>
<td>210</td>
<td>Spring</td>
</tr>
<tr>
<td>May 02, 1963</td>
<td>125</td>
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<tr>
<td>April 16, 1964</td>
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<tr>
<td>March 25, 1966</td>
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<td>May 13, 1967</td>
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<tr>
<td>November 14, 1968</td>
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</tr>
<tr>
<td>April 11, 1969</td>
<td>65</td>
<td>Spring</td>
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<tr>
<td>October 25, 1970</td>
<td>76</td>
<td>Fall</td>
</tr>
<tr>
<td>April 15, 1971</td>
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<td>May 05, 1972</td>
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</tr>
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<td>March 22, 1996</td>
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<tr>
<td>July 05, 1997</td>
<td>69</td>
<td>Summer</td>
</tr>
<tr>
<td>March 10, 1998</td>
<td>118</td>
<td>Spring</td>
</tr>
<tr>
<td>September 24, 1999</td>
<td>120</td>
<td>Fall</td>
</tr>
<tr>
<td>March 29, 2000</td>
<td>63</td>
<td>Spring</td>
</tr>
</tbody>
</table>

Source: Environment Canada, 2000

Following the construction of the causeway, high precipitation events have been the major cause of flooding along the Petitcodiac River. The risk of flooding is also increased when high precipitation events are associated with high tides. Most of the recent flooding in the Moncton area has been related to drainage problems and the inability of tributaries such as Jonathan Creek, Halls Creek, Babineau Creek and the drainage channel from the traffic circle on the
north end of the causeway to effectively convey flood waters. This is a direct result of the accumulation of sediments at the mouth of these tributaries as well as further upstream within these tributaries limiting the cross-sectional flow area and resulting in back up flooding. The risk of flooding has also been increased as a result of the change in land use and the continuing suburban developments, particularly along Jonathan Creek. The frequency and the severity of flooding have increased in the Moncton area since the construction of the causeway. For instance, the flood event in 1999 nearly caused flood waters in the headpond to overtop the causeway structure which has a crest elevation of 9.5 m.

One area that has been subject to frequent flooding is the traffic circle at the end of the causeway structure on the Moncton side. Sediment accumulation at the outlet of the culvert under the traffic circle prevents the free flow of flood waters and results in flooding at the traffic circle. Such frequent flooding events not only affect the flow of traffic at the causeway but also pose a safety risk for motorists. Figure 5.2.13 shows such a frequent flooding event which occurred on August 31, 2004. The causeway traffic circle has a minimum elevation of 8.7 m.

Recent flood events during normal high tide conditions (e.g., not during spring flood conditions or during storm surge events) further suggest that the sediment accumulation in the Petitcodiac River estuary and tributaries is a contributing factor to increased flooding. The flood shown in Figure 5.2.13 at the traffic circle and the Main Street flooding of 1999 are examples of this.

The present Gate Management Plan (Appendix A) of the control structure at the causeway maintains headpond levels at an average elevation between 5.3 and 6.1 m. The plan allows for the manipulation of the headpond levels in order to prevent ice jam flooding along the banks of the headpond. Despite these efforts to prevent ice jam flooding within the headpond, ice jam flooding events still occur within the headpond as shown in Figure 5.2.14 during an ice break up event in February 2003 near Boundary Creek.

5.2.7 Ice Regime

In the reach between the causeway and Dover, the width of the channel at high tide is substantially reduced because of the build up of shorefast ice on the banks as shown in Figure 5.2.15. The tidal mud in the banks of the channel becomes locked in place over the winter period because of the shorefast ice. The source of the sediment in this zone is mainly from the narrowed channel bottom. As a result of the greatly reduced cross-sectional area of the tidal channel in this zone, the volume of the tidal prism above any section in the zone is also greatly reduced.

In the reach between Dover and a point near Belliveau Village, where the bed of the channel corresponds with the elevation of the low water associated with a spring tide, there is limited channel narrowing, however there are often large inter-tidal mud flats. There is evidence of a relatively uniform build up of ice on these mud flats, especially near Gautreau Village. In addition, drift ice can become stranded on these mud flats as the monthly tidal cycle goes from spring to neap.
In the reach between Belliveau Village and Hopewell Cape as well as part way out into Shepody Bay, the inter-tidal flats are covered by water most of the time.

During the winter months, shorefast ice develops on the banks of the Petitcodiac River estuary. The relative portion of the ice-free channel cross section filled with shorefast ice increases as one progresses up the estuary, as described above. The decrease in channel cross-sectional area results in a smaller tidal prism and smaller tidal discharges through a particular cross section. In addition, there is a substantial increase in the resistance to flow in the channel. As a result, the tidal elevations in the upper portion of the estuary should be reduced from that anticipated for the same ice-free tidal elevations at the lower end of the estuary near Hopewell Cape.

During the period December 2002 to March 2003, observations of the top width between the banks of shorefast ice were made by the AMEC Study Team from the downstream sidewalk rail on the Gunningsville Bridge. The measurements were supplemented with ground photographs and high-level aerial images on January 25, 2003 and February 27, 2003, and low-level aerial images on February 26, 2003.

The top widths between the banks for the ice-free section and between the banks of shorefast ice are presented in Table 5.2.4. It is noted that the minimum top width at the location of the Gunningsville Bridge is about 27% of the estimated width between the banks during ice-free periods. It should be noted that the data presented in Table 5.2.4 are based on the field measurements obtained from December, 2002 to March, 2003.

<table>
<thead>
<tr>
<th>Date</th>
<th>Width Between Tops of Banks of Shorefast Ice (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 12, 2002</td>
<td>123</td>
</tr>
<tr>
<td>December 24, 2002</td>
<td>93</td>
</tr>
<tr>
<td>January 01, 2003</td>
<td>87</td>
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<td>January 06, 2003</td>
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<td>82</td>
</tr>
<tr>
<td>February 05, 2003</td>
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</tr>
<tr>
<td>February 07, 2003</td>
<td>65</td>
</tr>
<tr>
<td>February 18, 2003</td>
<td>44</td>
</tr>
<tr>
<td>February 21, 2003</td>
<td>37</td>
</tr>
<tr>
<td>March 21, 2003</td>
<td>33</td>
</tr>
</tbody>
</table>

**Table 5.2.4 Top Widths of the Banks of Shorefast Ice at the Gunningsville Bridge (Winter of 2002-2003)**

5.2.8 Tidal Bore

A tidal bore is defined as a flood tidal wave that advances up a relatively shallow and sloping estuary in the form of a solitary wave with a vertical or near vertical turbulent front. Tidal bores
are natural phenomena, which occur in parts of the world with high amplitude semidiurnal tides. Bartsch-Winkler and Lynch (1988) list sixty seven (67) known tidal bores in rivers and estuaries around the world.

As the incoming tide is forced into a narrowing river mouth, it builds in height until a single wave materializes and moves up the river. The tidal bore is immediately followed by the high waters (flood tide). Most bores occur within about 100 km from the mouth of the estuary; even though the tidal effects may be evident much further inland. They usually reach their maximum height soon after formation, and decay gradually upstream of that point.

The formation of a tidal bore requires that the following conditions be met (Dalton, 1951; Lynch, 1982; Bartsch-Winkler and Lynch, 1988):

- the tide at the mouth of a river must rise rapidly to a high amplitude;
- the river must be shallow with a gradually/gently sloping bottom and a broad, funnel-shaped estuary; and
- the river must become gradually narrow.

The phenomenon is also influenced by factors such as downstream flow rate (the current of the river tends to increase the speed of the bore and to reduce its height), seasons/days (certain tidal bores may only form during the most favourable times of the lunar monthly cycle), and winds.

The form of the tidal bore depends on the ratio of the water depth just downstream and just upstream of the bore or on the ratio of the speed of the bore to the speed of the shallow water waves in front of the bore. For a water depth ratio between 1.0 and 1.4, the tidal bore is undular (non-breaking); above 1.4, all bores break. Most bores change form and decrease in height as they move upstream into shallower water due to increased friction and change in the bottom configuration of the estuary.

The tidal bore in the Petitcodiac River was one of the most renowned tidal bores in the world, prior to the construction of the causeway. Its average height was approximated at 1 m, and the wave front exceeded a height of 1.5 m at Moncton during the largest tides. The tidal bore in the Petitcodiac River estuary is even said to have reached between 2 and 3 m, during the Saxby Gale of 1869. The bore used to form around Dover and continue to approximately 10 km upstream of the Boreview Park at Moncton.

Since the construction of the causeway, the tidal bore has been severely reduced in the Moncton area. The height of the tidal bore in the Petitcodiac River estuary near Moncton varies from just a few centimetres (particularly in conditions of winds blowing from the south and southwest) to approximately 75 cm. The deposition and erosion patterns in the river have resulted in a change in channel configuration that has affected the bore. For example, the width of the river channel has been significantly reduced over the years between Dover and the causeway, altering, amongst other things, the funnel-shape of the estuary. In addition, the bar of less
erodible material located at the bend near Moncton has negatively affected the bore. South of the bend at Moncton, the tidal bore is more pronounced.

5.2.9 1988 Trial Gate Opening

As noted above, in 1988, the gates at the causeway were opened on a trial basis between May 10 and June 7 and between September 26 and October 31, 1988. The first opening was after the spring freshet when all five gates had been left open to release the spring freshet down the river. During the initial opening, about 0.7 Mm$^3$ of sediment was deposited in the headpond and during the second opening, another 1.8 Mm$^3$ of sediment was deposited. During the initial trial, two to three gates were opened continuously and during the second trial, one gate was left open continuously. These openings were not enough to restore full tidal exchange into the headpond and resulted in deposition in areas of low energy away from the main channel. The trial gate opening took place after the spring freshet (when the flows down the river would have been much greater) and resulted in the “pulse” of sediment as discussed above. In addition, the trial gate opening did not result in any erosion of the banks downstream of the causeway as the volume of the tidal prism in the headpond was too small because of the limited gate openings.

5.3 Atmospheric Environment

The Atmospheric Environment is the component of the environment that comprises the layer of air near the earth’s surface to a height of approximately 10 km. The Atmospheric Environment is typically characterized by three key aspects: air quality; climate; and sound quality (noise). Odour is considered as a fourth key aspect in this EIA to address concerns raised during public consultation regarding the potential for increased exposure of mudflats that could result in increased odour.

5.3.1 Climate

The climate in southern and southeastern New Brunswick may be classified as moist continental, with the Bay of Fundy and the Lurcher marine areas of Nova Scotia providing a strong moderating influence on air temperatures over the region in both summer and winter. Summers in these areas are often punctuated with cool weather, whereas the advent of warm moist air from the Atlantic Ocean produces mild spells in the winter. The Fundy coast of New Brunswick receives the greatest amount of annual precipitation in the province (>1,200 mm), with the southeastern New Brunswick region lying in one of two provincial snowbelts. The Bay of Fundy is also among the foggiest areas of the Maritimes, due to advection fog formed when warm moist air from the south in spring and summer is cooled and condensed by the cold waters of the Bay.

The microclimate (see Glossary) in the GMA is influenced primarily by the presence of urban infrastructure, as well as water bodies such as the Petitcodiac River. The microclimate in the GMA is influenced primarily by the presence of urban infrastructure, as well as water bodies such as the Petitcodiac River. Although the characterization of microclimatic conditions would require establishing climate stations in the immediate vicinity of the causeway, in the absence of localized climate data immediately near the causeway, the AMEC Study Team relied on historical published information from the nearest Environment Canada weather stations at
Moncton Airport and the City of Moncton for characterizing the likely microclimatic conditions during the pre-causeway, post-causeway and existing conditions.

Compared with the climate normals from the Moncton Airport (1977-2001), the urban areas of the GMA had higher monthly average daily mean temperatures during spring and summer, and lower monthly average daily mean temperatures during the winter months. The differences in the monthly averages of the daily mean temperatures in spring and summer (approximately 0.8°C) are higher in the post-causeway construction period than those measured for pre-causeway conditions (approximately 0.2°C), with monthly average daily mean temperatures in winter not having changed appreciably between these time periods. This may reflect the influence of the growth of urban infrastructure and population of the GMA during the post-causeway period. Based on an analysis of non-scientific observation and reporting (AMEC, 2005c), the larger Petitcodiac River tidal exchange or prism during pre-causeway conditions was considered to have had a moderating microclimatic influence on the shoreline areas of the GMA. The Petitcodiac River tidal exchange has diminished in size during the post-causeway time period, and based on the information collected (AMEC, 2005c), its moderating microclimatic influence on air temperatures on the river and its shoreline has also been reduced in comparison to pre-causeway conditions.

Since the headpond freezes over during the winter months, a large source of moisture is lost for fog propagation in the GMA, which combined with the diminished tidal exchange may likely have led to a decrease in the number of days with fog during the post-causeway time period when compared with pre-causeway conditions.

In terms of possible global climate change, a regional cooling trend has been observed in the GMA and southeastern New Brunswick where mean temperatures have shown a decrease of approximately 0.2°C from pre-causeway to post-causeway timeframes based on 30-year climate normals (1971-2000), annual average precipitation rates have increased from 1,099 mm to 1,223 mm, and severe weather occurrences have increased in the number of days with thunderstorms from 15 to 19. Recent extreme weather events in the Atlantic Canada region, including the winter storms in the GMA from 2001 to 2003 (CWTP, 2004) and hurricane Juan in Nova Scotia and Prince Edward Island, suggest that extreme weather is becoming more frequent (Environment Canada, 2004a). However, the causes for the increased frequency of extreme weather are presently not understood, and cannot be attributed to or uniquely identified as being triggered by global events such as climate change or global warming.

Due to the lack of available data, greenhouse gas emissions for southeastern New Brunswick could not be characterized for the pre-causeway timeframe. However, based on the lower population, and less developed urban and industrial infrastructure in the GMA during pre-causeway conditions (Atlantic Canada Opportunities Agency (ACOA), 1998), it is reasonable to expect that greenhouse gas emissions during pre-causeway conditions would have been markedly lower than post-causeway and existing levels. In 1996, regional greenhouse gas emissions in southeastern New Brunswick were 3,310,000 metric tonnes Carbon Dioxide (CO₂)-equivalent/year. Estimated levels for 2003 and 2005 are 4,820,000 and 4,920,000 metric tonnes CO₂-equivalent/year, respectively. A number of national, regional and provincial
initiatives were undertaken, during the post-causeway and current timeframes, to reduce greenhouse gas emissions. Particular initiatives include the Kyoto Protocol and the Climate Change Action Plan of the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP).

For the purpose of this EIA, it is reasonably assumed that climate in the GMA during baseline (2005) would be similar to that observed in post-causeway and existing conditions (2004), as global climate does not change at a rate that would be noticeable over 1 year, and there is no anticipated substantive changes to factors affecting microclimate in the Assessment Area.

5.3.2 Air Quality

Pre-causeway conditions for air quality were characterized using a qualitative approach, due to the lack of quantitative data during this time period. Given the less developed urban and industrial infrastructure of the GMA, the lower population and fewer vehicles, it is likely that air contaminant emissions during the pre-causeway construction period would have been similar to or lower than current levels. Similarly, it is likely that ambient air quality in the GMA during the pre-causeway construction period would also have been similar to, or better than, that observed during post-causeway construction conditions.

During the post-causeway construction period (1969-2002), air contaminant emissions of particulate matter (PM) PM$_{10}$ (particulate matter with a diameter of 10 micrometres and smaller), nitrogen oxides (NO$_x$) and carbon monoxide (CO), as reported in national emissions inventories, were on the rise. However, the apparent increase in emissions is likely due to improved emissions estimation techniques, a larger number of facilities reporting emissions data to regulatory agencies, increased source emissions testing and improved monitoring, and other factors. Environment Canada had forecasted provincial sulfur dioxide (SO$_2$) emissions to rise above 1995 levels in 2000, then stabilize at those levels for 2005. Provincial NO$_x$ emissions were forecasted to increase in 2000 from 1995 levels, and rise again slightly in 2005. On a local basis for the GMA, it is reasonable to assume that the emissions of these contaminants would follow the same trends as the provincial emissions.

From the perspective of local ambient air quality, annual average ambient concentrations of CO, NO$_x$ and PM$_{2.5}$ (particulate matter with a diameter of 2.5 micrometres and smaller) in the GMA for the post-causeway and existing conditions were reported by regulatory authorities to be well below the respective regulatory standards, and are likely to remain unchanged for baseline conditions. From the perspective of regional ambient air quality, ground-level ozone was selected as a key contaminant for evaluating long-term trends for ambient air quality on a regional basis. Overall, there does not appear to be any obvious trends in ground-level ozone concentrations regionally from 1995-2002, although the data does tend to suggest a slight tendency towards an increasing trend.

For the purpose of this EIA, it is reasonably assumed that ambient air quality in the GMA during baseline (2005) would be similar to that observed in post-causeway and existing conditions, as there are no anticipated substantive changes to air emissions in the Assessment Area.
5.3.3 Odour

Based on the information obtained, there were few odour issues and sources identified in the GMA during the pre-causeway period. The main source of odour emissions during pre-causeway conditions was identified as the Swift meat packing plant in the downtown Moncton area, which was in operation well before the causeway was built. Although there was no wastewater treatment in the GMA and raw sewage was discharged directly into the Petitcodiac River during this period, there were no odour issues reported in the information collected.

Following the causeway construction, and subsequent reduction in flow and width of the river downstream of the causeway, tidal action was no longer effective as a flushing mechanism, and raw sewage had to flow a greater distance over mudflats from the Moncton side to reach the reduced river channel. This resulted in sewage accumulation on mudflats and their drainage channels. Although odour issues are not discussed in the available reports, it is reasonable to expect that there may have been some localized odour emissions from raw sewage accumulation on the mudflats and the river until the collection of sources was complete between the 1970s and mid 1990s.

The Swift meat packing plant was closed down in the 1970s. However, another facility, Hub Meat Packers, commenced operation around the same time period (ACOA, 1998). Hub Meat Packers also discharged wastewater from slaughtering activities directly into the Petitcodiac River, leading to similar odour issues as with the Swift plant during pre-causeway conditions. Another odour source identified was the former Moncton Landfill located adjacent to and immediately downstream of the causeway, which was in operation from shortly after the causeway was constructed until decommissioning in 1992. There were odour emissions, typical of waste disposal facilities, from the former Moncton Landfill during its operation, which could be detected in the downtown Moncton area. Odour issues were also identified from fish deaths in the river channels during annual gaspereau migration in springtime, which is localized to the riverbank area on the Riverview side. City of Moncton officials are not aware of any official odour complaints reported in the GMA in recent years.

A field odour survey was conducted in June 2004. No perceptible odours were observed at any of the seven odour monitoring sites for both high and low tide events in the Petitcodiac River. According to at least one source, an odour may be detected when one is directly on the Petitcodiac River downstream of the causeway, as during kayaking or fishing (AMEC, 2005c). This odour is reported to be low in intensity and localized to the water’s surface, and may not be detectable to persons on shore or further inland (AMEC, 2005c). These odour emissions were confirmed through personal observations of the Water Quality Field Study team (Jacques Whitford, 2004).

At Outhouse Point, odour emissions were also reported from algal growth or blooms in the headpond area near the causeway gates (GG, 2004; AMEC, 2005c). These odour emissions are reported to be restricted to the causeway area and during periods of high algal growth. The presence of the odours near the causeway gates was also confirmed in field observations of the Water Quality Study team in the summer of 2003 (AMEC, 2005a). In addition, there is usually
one or two weeks during the year when odours are detectable in the downtown Moncton area, particularly during hot and humid weather conditions (Landry, pers. comm.). The exact causes for these odours are not known, but are thought to originate from the river, and are either associated with marshy areas or sewage outfall from the wastewater plant (Landry, pers. comm.).

For the purpose of this EIA, it is reasonably assumed that odour in the GMA during baseline (2005) would be similar to that observed in the existing conditions (2004) as there is no anticipated substantive change in odour producing activities in the Assessment Area.

**5.3.4 Sound Quality**

No published sound quality data were available for the characterization of pre-causeway, post-causeway, and existing conditions.

The population of southeast New Brunswick in the 1960s before the causeway was on the order 105,000, approximately 30% less than the population at the time of the last census in 2001 (CIRRRD, 1996; GNB, 2004). Correspondingly, there were lower levels of vehicle traffic. With a lower level of vehicle traffic, it is expected that ambient sound pressure levels throughout the assessment spatial boundaries were, in general, lower than existing ambient sound pressure levels. It is thought that during the pre-causeway period, traffic was a less dominant sound emission source in the Assessment Area (as defined in Section 4.7) and other sources, such as rail traffic, train whistles, other activities at the rail yards and other human-caused noise sources had a stronger influence on sound quality. The dominant feature affecting the travelling of sound waves (sound propagation) in the Assessment Area is the open area of the Petitcodiac River and the reflective surface of water in the Petitcodiac River. In this regard, pre-causeway sound propagation characteristics for sound emissions travelling across the river was likely to have been similar to the existing characteristics.

At the start of the post-causeway period (immediately following opening of the causeway), the opening of a new route across the Petitcodiac River altered traffic patterns within the GMA. It is assumed that the initial traffic levels in the area of the causeway rapidly increased while traffic levels at the Gunningsville Bridge decreased as motorists redistributed themselves between the two crossing points. Over time, with the increasing population of the GMA, traffic levels also increased gradually and proportionally throughout the GMA. Based on interviews conducted, there did not appear to be a history of sound related complaints in the Assessment Area (Landry, pers. comm.). With the increase in traffic levels and the decrease in rail traffic over the post-causeway period, it is likely that vehicle traffic gradually became the dominant source of noise in the Assessment Area.

Currently, the sound character in the Assessment Area is typical of urban environments where sound emissions are dominated by vehicle traffic. While being highly variable with respect to intensity, traffic sound emissions are generally not impulsive (sudden) or tonal (distinct tone) in nature. Ambient sound pressure levels measured at both sides of the causeway were fairly consistent with an average 24-hour $L_{eq}$ (Equivalent Sound Pressure, see Glossary) range of 58 – 66 dB$_A$. Sound levels measured near the Gunningsville Bridge had a higher variability during
the day, which reflected the sporadic nature of traffic in that area. Ambient sound levels dropped during the nighttime, with a minimum 1-hour equivalent sound pressure level between 49.8 dB$_{A}$ and 57.0 dB$_{A}$, which are comparable to daytime sound levels and may suggests that vehicle traffic during the night is sufficient to influence night time ambient sound levels.

For the purpose of this EIA, it is reasonably assumed that sound in the GMA during baseline (2005) would be similar to that observed in existing conditions (2004), because there has been little change to the sound propagation characteristics and little change to sound emission sources (e.g., traffic).

5.4 Fish and Fish Habitat

This section presents a summary of the findings of the fish, water quality (as it pertains to fish habitat) and sediment quality surveys as reported in the Biophysical Component Study. The biology of commercial and recreational fish important to the EIA is provided in Section 5.4.3 and the current status of those fisheries is presented in Section 5.4.5. Further description regarding the recreational fishery is presented in Section 5.12 (Recreation). Further description on the value of the commercial fishery is presented in Section 5.13 (Labour and Economy VEC). Further description regarding water quality as it affects humans is presented in Section 5.15 (Public Health and Safety VEC).

5.4.1 Field Program

The AMEC Study Team carried out a field program to identify the fish species currently using the Petitcodiac River system. This field program included rainbow smelt spawning observation (late April and early May 2003), drift netting (summer and autumn 2003), smolt monitoring (May 2003), fyke netting (June and July 2003), electrofishing (August 2003), fishway monitoring (June, July, October and November 2003) and beach seining (July, August and September 2003) components. These field programs have attempted to identify all fish species present in the Assessment Area, as defined in Section 4.7, at the time of collection. It is assumed, for the purpose of this EIA, that the baseline fish populations in the Petitcodiac River (2005) will be identical to those observed at the time of the field survey.

The fish species found in the headpond included:

- white sucker (*Catostomus commersoni*);
- common shiner (*Notropis cornutus*);
- brown bullhead (*Ictalurus nebulosis*);
- American eel (*Anguilla rostrata*);
- pearl dace (*Semotilus margarita*);
- gaspereau (collectively alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*));
- blacknose shiner (*Notropis heterolepis*);
- white perch (*Morone americana*);
- rainbow smelt (*Osmerus mordax*);
• 3-spine stickleback (*Gasterosteus aculeatus*); and
• smallmouth bass (*Micropterus dolomieu*).

No chain pickerel (*Esox niger*), brook trout (*Salvelinus fontinalis*) or wild Atlantic salmon (*Salmo salar*) was observed in the headpond.

The fish species found in the fishway included:

• gaspereau;
• American eel;
• Atlantic tomcod;
• sea lamprey;
• white sucker;
• stickleback, various species;
• brown bullhead; and
• American shad (*Alosa sapidissima*).

The fish species found downstream of the causeway included:

• American shad;
• rainbow smelt;
• Atlantic sturgeon (*Acipenser oxyrhynchus*);
• Atlantic silverside (*Menidia menidia*);
• spiny dogfish shark (*Squalus acanthias*);
• juvenile gaspereau;
• Atlantic tomcod (*Microgadus tomcod*);
• flounder, various species;
• striped bass (*Morone saxatilis*);
• 3-spine stickleback; and
• mummichog (*Fundulus heteroclitus*).

Consultation with members of the public who have lived along the Petitcodiac River for a long time and have fished the river for many years identified the following other marine species periodically encountered in the Petitcodiac River estuary:

• Atlantic cod (*Gadus morhua*)
• harbour porpoise (*Phocoena phocoena*);
• Atlantic menhaden (*Brevoortia tyrannus*);
• great white shark (*Carcharodon carcharias*);
• blue shark (*Prionace glauca*);
• porbeagle shark (*Lamna nasus*); and
• thresher shark (*Alopias vulpinus*).
5.4.2 Fish That Require Passage

The following fish species require passage through the Petitcodiac River causeway to complete their life cycle. This list of species was identified through consultation with the regulatory authorities as well as consultation with the public and stakeholders and meetings with the Aboriginal Community. The species were categorized according to their respective migration requirements: catadromous (migrate from fresh to saltwaters to spawn); anadromous (migrate from the sea to freshwater to spawn); and diadromous (migrate between fresh and saltwaters). The species and their associated migration requirements are listed as follows:

- American eel (catadromous);
- American shad (anadromous);
- Atlantic salmon (anadromous);
- Atlantic tomcod (anadromous);
- brook trout (anadromous);
- gaspereau (anadromous);
- rainbow smelt (anadromous);
- sea lamprey (*Petromyzon marinus*) (anadromous); and
- Atlantic sturgeon (anadromous).

The striped bass also migrates into the Petitcodiac River to feed, but is not known to spawn in the river.

5.4.2.1 Pre-causeway Fish (prior to 1967)

Of the above-mentioned species, existing pre-causeway populations were documented for Atlantic salmon. The following estimates are available in the literature for the annual (unless otherwise noted) pre-causeway spawning Atlantic salmon run:

- 2,000-3,000 fish (Fisheries and Oceans Canada, 1968);
- 2,000-3,000 fish (Beaulieu, 1970);
- 2,000-3,000 fish (Dominy, 1970);
- 1,500-3,000 fish (McLeod, 1973);
- 2,000-3,000 fish (Semple, 1975);
- 7,000-9,000 fish with an at-sea survival of 12% (Semple, 1979);
- 5,000 salmon (Ritter, 1991 interpreting Pettigrew’s data);
- at least 5,000 fish (Washburn & Gillis Associates Ltd., 1994); and
- 8,000 to 10,000 fish in 1966 (Elson, referenced by Harvey, 1997).

In support of the above estimates, Pettigrew (1977) estimated that 86,000 smolts are needed to produce 4,000 adult fish.

In reference to the remaining above mentioned species that require passage at the causeway, the following observations are provided regarding their occurrence in the Petitcodiac River.
• American shad - formerly spawned in the main stem of the Petitcodiac River as far upstream as the Village of Petitcodiac, and were known to enter the lower reaches of the major tributaries in the system (Elson, 1961).

• Atlantic tomcod - spawn in freshwater near the head-of-tide, although in the Petitcodiac River system, the species was known to spawn 19 km above the head-of-tide prior to the construction of the causeway (Liem and Scott, 1966).

• Brook trout – abundant resident, non-anadromous brook trout population that would travel to the lower ends of the tidal river following spawning in the fall (Curry et al., 2002).

• Gaspereau – travel far into the Petitcodiac River system and enter from late April through mid-to-late June.

• Rainbow smelt – enter river systems at night to spawn prior to, and immediately after, ice-out. Massive schools of smelt spawned in the Petitcodiac River in late April and early May in the Salisbury area.

• Sea lamprey – move into freshwater following ice leaving the river, and spawn in late May or early June throughout the flowing water reaches of the Petitcodiac River drainage.

• Atlantic sturgeon – abundant occurrence in the Petitcodiac River, however spawning in this system has not been documented.

• Striped bass – often entered the lower river to feed on available food fish such as gaspereau and smelt. Striped bass from 3 to 25 lb in weight were angled and observed in the river in June (members of the Petitcodiac River Sportsmen’s Club, pers. comm.). Bass were taken in gill netting exercises by the Department of Natural Resources in the Petitcodiac River headpond in 1978 (Cronin, 1978).

5.4.2.2 Post-causeway Fish (1969-2002)

Many fish species that inhabited the Petitcodiac River have decreased in abundance, and some species have been eliminated from the river, because of upstream or downstream fish passage difficulties. In contrast, the abundance of other species (e.g., gaspereau) has remained similar to, or increased from pre-causeway conditions because of the habitat created by the headpond. The existence of the headpond has also created opportunities for the proliferation of non-native fish species such as smallmouth bass and chain pickerel.

5.4.2.3 Existing Fish (2003-2004)

The following species identified that require passage at the causeway were observed in the 2003 and 2004 field programs, and are considered representative of baseline (2005) conditions:

• American eel – abundant occurrence;
• Atlantic salmon - some occurrence of juvenile fish;
• Atlantic tomcod - few fish observed, lower than historical numbers;
• gaspereau - observed with adequate passage;
• rainbow smelt – some fish observed, lower than historical numbers;
• sea lamprey – large numbers observed; and
• Atlantic sturgeon – observed downstream of causeway.

Brook trout were not observed during the survey of existing conditions (2003-2004), however, it is reasonably assumed based on regulatory and public consultation and the professional judgment of the AMEC Study Team that brook trout did exist in the Petitcodiac River at the time of the survey.

5.4.3 Other Fish Important to the EIA

As noted above, a number of other fish species exist in the Petitcodiac River system, estuary and nearby marine environments. The following species were considered of particular importance for purposes of the EIA because of their economic value:

• American lobster;
• scallops;
• smallmouth bass; and
• American Shad.

These species are discussed further in Section 5.4.5.3.

5.4.3.1 Fish Species At Risk

Two aquatic Species at Risk are known to occur in the Petitcodiac River. They are the “endangered” Inner Bay of Fundy Atlantic salmon and the dwarf wedgemussel, which has a vital life stage that appears to be dependent on either the existence of the American shad or the Atlantic salmon, where both have been virtually extirpated from the river.

Atlantic salmon have been extirpated from the Petitcodiac River with the exception of juvenile fish that have been introduced from live gene banks where distinct populations of the Inner Bay of Fundy Atlantic salmon have been preserved.

Returning salmon encountered fish passage difficulties due to low DO levels in the summer in the vicinity of the causeway. This restricted them to an autumn upstream migration strategy. They were further delayed by the downstream sediment plug that often grows to heights that completely block high tides from reaching the causeway. This effect was made worse in low water years. Fishways are never 100% successful for any species, including Atlantic salmon.

Emigrating salmon smolts have likely encountered severe mortality during their downstream migration in May. Considering that the Inner Bay of Fundy Salmon stocks have a large percentage of repeat spawners, the difficulties with migration through the causeway during the post-causeway period likely had a substantial effect on the past survival of this species.

The dwarf wedgemussel was prevalent in the Petitcodiac River system at the time of causeway construction, but was completely absent by 1984 and was not seen in subsequent surveys in later years (Hanson and Locke, 2000). Typically, following fertilization in freshwater mussels, an intermediate phase is released by the female mussel into the water column. This attaches
and encysts on the fins and buccal (cheek) cavity of specific fish hosts (Moser, 1993). Following a period of change and development on the fish, small mussels drop off the fish and onto the substrate. A few of the host fish species for the dwarf wedgemussel in rivers in the United States have been identified, but none have ever been present in the Petitcodiac River drainage. Since the mussel’s disappearance occurred coincident with the construction of the Petitcodiac River causeway, it was reasoned that a lack of passage for a diadromous fish species that provided the glochidia host for the mussel caused the extirpation of the mussel species. It is contended that the potential host fish species for the dwarf wedgemussel in the Petitcodiac River are the American shad and the Atlantic salmon (Hanson and Locke, 2000). Although adult salmon have difficulty entering the Petitcodiac River through the causeway, they maintained a viable population into the 1980s and the river has often been stocked with juvenile salmon since causeway construction. Therefore, it is strongly suspected that the American shad, which has been effectively blocked from spawning in the Petitcodiac River since causeway construction, was the major intermediate phase host for the dwarf wedgemussel. Juvenile shad spend their first summer in fresh water and these fish are thought to be the host for the intermediate phase of the mussel (M. Hanson, pers. comm., 2003).

Any program to re-introduce the dwarf wedgemussel to the Petitcodiac River must ensure that the American shad is also re-introduced. The re-introduction of American shad into the Petitcodiac River can be achieved by addressing the fish passage issues and impediments associated with the causeway structure.

**Baseline Fish (2005)**

For the purpose of this EIA, it is reasonably assumed that the fish species during baseline (2005) would be the same as those observed during existing conditions (2003-2004), because there not likely to be substantive change to the fish passage restrictions (e.g., DO levels) or to the river characteristics that affect fish passage (e.g., sediment plug) occurring during the interim time.

**5.4.4 Fish Habitat**

**5.4.4.1 Water Quality**

Water quality data for the Petitcodiac River prior to causeway construction were found to be very limited. Post-causeway construction water quality data for the Petitcodiac River were much more accessible with the NBDELG holding records of a sampling station (Petitcodiac River at old Highway 2, now located at new Trans Canada Highway crossing) consistently monitored since 1971. Data were also available for the area of the causeway and near Salisbury with 30 to 40 sampling events taking place at these locations between 1970 and 1999. A database was also provided by Environment Canada that encompassed the collection of 300 different parameters at 128 stations throughout the entire Petitcodiac River watershed, from 1965 to 2001.

The data collected provided baseline water chemistry, metals, organics, nutrients and coliform bacteria data for the Petitcodiac River above and below the causeway. These data were evaluated in relation to established and site specific guidelines.
Pre-causeway Water Quality (prior to 1967)

As early as 1891, human-caused pollution in the Petitcodiac River as far downstream as the Bay of Fundy was reported from forestry products such as sawdust being washed downstream in freshets (Pratt, 1893; Miles, 1894; and Prince, 1912).

Negative water quality conditions also occurred naturally prior to causeway construction. Wilder (1942) measured high water temperatures in the upper reaches of the Petitcodiac River that were believed to have caused the recorded death of 2,517 American shad in June of 1942. Also in 1942, a lesser number of fish kills occurred for Atlantic salmon smolts, gaspereau, brook trout, American eel, lake chub (*Couesius plumbeus*), creek chub (*Semotilus atromaculatus*) and white sucker.

Another source of pollution occurring prior to causeway construction consisted of sewage discharge from the Villages of Salisbury and Petitcodiac.

Only one sampling event was found for multiple water quality parameters prior to causeway construction, which took place in the upper reaches of the Petitcodiac River at the Trans-Canada Highway crossing with the river near the Village of Petitcodiac in 1966. A total of 23 water quality parameters were measured including dissolved nutrients (phosphate, nitrogen), physical parameters such as pH (a measurement of acidity), alkalinity, apparent colour, conductance, temperature, turbidity and biological oxygen demand, major cations and anions and dissolved metals such as aluminum, copper, iron, manganese and zinc. The documented concentration for the measured parameters did not indicate impaired water quality.

Salinity, temperature, chlorine, specific gravity and sediment concentration were measured along a line between Gautreau Village (located between Dover and Belliveau Village) and the shore opposite Dover in the lower estuary of the Petitcodiac River (Warren, 1946). Salinities were found to be in the order of 29-30 mg/L. Similar salinities were obtained at Gunningsville Bridge and at Gautreau Village. Maximum salinities at Moncton were similar to those documented at Gautreau Wharf, indicating that freshwater influence was negligible at the time of sampling.

Sediment was observed in aerial photographs taken before 1966 in the waters of the Petitcodiac River from Salisbury to the current causeway location in Moncton and beyond. Sediment concentrations from a 1946 document ranged from 132 mg/L at the surface to 220 mg/L at a depth of 7.6 m. The state of the tide, however, is not known at the time of these measurements.

A review of available information suggests that pre-causeway water quality in the Petitcodiac River reflected the land use activities in the watershed before the causeway was constructed.


Numerous sources of water quality data were available for the area upstream of the causeway since its construction in 1968. These data were analyzed in the Biophysical Component Study (AMEC, 2005a) and the key findings are summarized in this section.
Water Quality Index

The water quality of the Petitcodiac River freshwater environment (i.e., upstream of the causeway) was evaluated against the Council of Canadian Ministers of Environment Water Quality Index (CCME WQI), whose indexes range from Poor to Excellent. Based on the datasets obtained, it can be concluded that the quality of freshwater upstream of the causeway has improved since the initial period following causeway construction, however is still considered in the fair to marginal WQI range.

A substantial amount of water quality data have been collected upstream of the causeway since the end of its construction in 1968. Much of this monitoring data has been collected by NBDELG from 1975-1979 as part of their program to monitor watersheds in the Province of New Brunswick (NBDELG, 1980), and by the 1997-1999 Trial Gate Opening Project (Environmental Monitoring Working Group (EMWG), 1998; 1999, 2000). Electronic databases containing these and other water quality data were obtained from NBDELG, PWMG and Environment Canada. Rather than trying to interpret water quality values on a variable-by-variable basis, a WQI was calculated and used to provide a convenient means of summarizing complex water quality data. For this purpose, the National CCME WQI was used (CCME, 2001).

The index produces a value, the CCME WQI value, which is ranked by relating it to one of the following five categories.

- **Excellent** (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
- **Good** (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
- **Fair** (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
- **Marginal** (CCME WQI Value 45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
- **Poor** (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

To be able to compare among sites and to obtain at least four variables sampled at least four times, the Petitcodiac River was divided into three sites or areas. The first site is the “Petitcodiac River Headpond” that spans from the causeway to just below Turtle Creek. The second site is the “Middle Petitcodiac River Section” that spans from the Turtle Creek to Boundary Creek, and the third site is the “Upper Petitcodiac River Section” that spans from Boundary Creek to the upper reaches of the Petitcodiac River.

Overall, the WQI of the Petitcodiac River upstream of the causeway since 1970 is fair to marginal. On a few occasions, the WQI was good in the mid 1990’s for the upper section of the Petitcodiac River and more recently in the headpond. After the causeway was built, the WQI for the upper section of the Petitcodiac River declined in the early 70’s, but then improved gradually as of 1978 until 1998 where it declined again and appears to oscillate in the fair to marginal
range. The WQI for the headpond was categorized as poor in the early 70’s, and appears to have improved since then, oscillating from fair to good to marginal. The WQI is generally fair for the middle section of the Petitcodiac River in the late 1990’s and appears to be more consistent than the upper section of the river or the headpond. It can be concluded that the freshwater quality upstream of the causeway has improved since the initial period after the causeway was built, but still is in the fair to marginal range.

The CCME WQI was not calculated for downstream waters of the causeway in the estuarine or marine environment due to insufficient data and variables for which marine water quality guidelines exist.

**Bacteria**

Montreal Engineering Company Limited (1969) indicated that sewage from the small communities upstream of the causeway, especially Salisbury and Petitcodiac, was noted as a potential problem in the headpond. This report further stated that “unless this potential pollution is controlled at its source, it is possible that during times of low river flows in the summer, stagnation will occur in the headpond which would detract from its recreational value.”

Although fecal coliform and *E. coli* bacteria do not directly affect aquatic life, they are considered indicators of water quality as they imply the degree of contamination by human or animal waste and the potential for transmission of microbial pathogens (illness causing micro-organisms) to aquatic animals that may be associated with these wastes. It is considered an important variable in the assessment of water quality and is considered a key indicator for issues related to sewage, outfalls and tributaries.

Based on a review of the data available, bacteria in the estuarine and marine waters downstream of the causeway are likely to be attached to suspended sediments.

The arrival of the tidal bore increases the concentration of suspended sediments, which is suspected to be a result of re-suspension of riverbed sediments attributed to higher bottom velocities during the passage of the bore. After the bore passes, the bottom water velocities decrease as do the concentration of suspended sediments. Therefore, bacteria counts also increase with the passing of the bore, but then decrease after the bore has passed. The concentration of suspended sediments and bacteria also increases on the ebbing tide, most likely as a result of higher bottom velocities associated with an ebbing tide that lead to re-suspension of bottom sediments. Suspended sediments and bacteria concentrations are elevated downstream of the causeway, to the confluence with the Memramcook River, on a low or ebbing tide. However, on a flooding or high tide, suspended solid and bacteria concentrations are much lower than that for low tide, with a fraction of bacteria counts at low tide conditions (except for when the bore is passing as indicated above). Peaks in bacteria counts were observed at low tide, however did not appear to be related to one outfall or effluent source. These peaks, however, are found in the vicinity of the location of sewage outfalls situated along the bank of the river. This suggests that mixing is not necessarily complete during one tidal cycle, and may require several tide cycles before complete mixing is achieved.
Dissolved Oxygen

DO in the water is a key variable for sustaining aquatic life and a basic necessity essential to the metabolism of all aerobic organisms on Earth. It is an important variable to measure as an indicator for issues related to eutrophication (see Glossary), general biological productivity, and organic effluents in industrial, agricultural and municipal wastes.

Headpond (Freshwater)

The CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2003) recommend that DO concentrations for cold-water animals in freshwater should not decrease below 9.5 mg/L for early life stages of aquatic life and 6.5 mg/L for other life stages of aquatic life. For warm-water animals, DO concentrations should not decrease below 6.0 mg/L for early life stages and 5.5 mg/L for all other life stages. Since the target fish species of most importance and/or sensitivity in the freshwater environment of the Petitcodiac River is the anadromous adult salmon and smolt, which are considered cold-water animals and fall under “other life stages”, the CCME recommended DO guideline of 6.5 mg/L was used as a guideline in this study. This is a conservative DO concentration guideline in freshwater to prevent stress, lethal, or sublethal effects in Atlantic salmon. It is generally accepted that water quality with DO concentrations <5 mg/L will affect Atlantic salmon and may cause death.

Almost 200 DO concentration measurements were taken upstream of the causeway and in the headpond since 1970 in the Petitcodiac River. These measurements were taken during daylight hours and for all seasons. No values were found to be below the freshwater guideline value of 6.5 mg/L. The median and mean DO concentrations for these measurements were both 11.3 mg/L. Only one value on August 19, 2002 taken below Salisbury in the upper Petitcodiac River was relatively low at 6.66 mg/L. The results indicated that the headpond and river upstream of the causeway were well-oxygenated (NBDELG, 1999; Petitcodiac Watershed Monitoring Group (PWMG), 2000). Vertical profiles of DO concentrations revealed normal patterns in the headpond with a general slight decrease near the bottom (NBDELG, 1999). Overall, it can be concluded that DO upstream of the causeway was generally above the guideline value of 6.5 mg/L throughout the year in this freshwater environment. The data did not include DO measurements at night, when use of DO by animals is not offset by the production of oxygen by plants.

Estuary and Marine (Saltwater)

The CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2003) recommend a minimum DO concentration of 8.0 mg/L for marine and estuarine waters (interim guideline). It is an interim guideline because the depression of DO below this recommended value should only occur as a result of natural processes. When ambient DO concentrations are greater than 8.0 mg/L, human activities should not cause DO levels to decrease by more than 10% of the natural concentration expected in the receiving environment at that time (CCME, 2003). The areas with the greatest DO depletion are those with restricted circulation and an abundant supply of organic matter from the accumulation of any combination of natural sources, sewage, food-related industries, agricultural runoff, pulp and paper mills, or other human activities (CCME, 1999). Where effluent was discharged into areas of restricted circulation, low
DO levels were found to be common. Extremely low DO levels were also observed when flushing rates in estuaries were reduced because of low river runoff (CCME, 1999).

Downstream of the causeway, DO concentrations were measured on an incoming tide, starting at low tide, at Gunningsville Bridge on October 1 and 30, 1997 (Anonymous, 1998). DO values ranged from 11.4 to 12.0 mg/L (for both dates) with the incoming tide and decreased to 7.7 to 8.4 mg/L at high tide, indicating good levels of DO. NBDELG (1980) took DO measurements at high and low tide at 15 locations on the Petitcodiac River, from downstream of the causeway gates to Hopewell Cape on August 22, 1978. It is presumed that these are surface DO measurements, as the sampling depth is not provided. At low tide, DO levels were depressed and below 8 mg/L for the entire length of the Petitcodiac River downstream of the causeway gates. Very low DO levels were also measured for approximately 13 km of the Petitcodiac River, from about Outhouse Point down to near Stoney Creek (upriver of Dover) that was <5 mg/L which indicated unacceptable conditions. The DO concentration for this section of the river ranged from 4.4 to 3.4 mg/L, respectively (salinity of 23.9 to 28.5 mg/L, respectively). The DO concentrations immediately downstream of the causeway and at Hopewell Cape for low tide were 5.9 mg/L and 5.5 mg/L, respectively (salinity of 14.0 and 31.0 mg/L, respectively).

At high tide, DO concentrations were also depressed below the guideline of 8 mg/L downstream of the causeway and extending to the mouth of the Petitcodiac River (Hopewell Cape). Very low and unacceptable DO concentrations were measured at the causeway (2.6 mg/L) (salinity of 29.9 mg/L) and at Gunningsville Bridge (4.6 mg/L) (salinity of 31 mg/L). Downstream of this area, DO values increased progressively from 5.4 mg/L at Outhouse Point (salinity of 31.2 mg/L) to 7.4 mg/L at Hopewell Cape (salinity of 31.9 mg/L), all below 8 mg/L. It should be noted that the 1978 survey was conducted before the GMSC constructed a sewage treatment plant at Outhouse Point. Therefore, the data likely do not represent conditions that would have existed following construction of the sewage treatment plant.

It can be concluded that overall, downstream of the causeway and in the estuarine and marine environments of the Petitcodiac River DO concentrations were acceptable and above guideline values in autumn, but not in the summer. In general, DO concentrations in summer (August) were below the recommended guideline of 8 mg/L at both high and low tide. Very low oxygen levels (<5 mg/L) were present at low tide for a 13 km stretch of the Petitcodiac River from Outhouse Point to about Dover. At high tide, very low DO levels were also observed, but more upriver and for a 2 km stretch from the causeway down to about Gunningsville Bridge. The 1978 data indicated that in late summer, a “parcel” of water with unacceptable low (<5 mg/L) DO moved up and down the estuary with the rising and falling tide. This was presumably due to the discharge of untreated sewage (NBDELG, 1980) and the inability to flush this sewage with the tide from the Petitcodiac River into the Bay of Fundy.

Suspended Sediments

A review of available suspended sediment data in the water column suggests that total suspended sediments (TSS) are low in the headpond and increase during spring runoff in April, May, and probably in the fall as a result of precipitation and runoff, reflecting periods of increased gate operation and associated increased flow velocity in the headpond. In the
estuarine and marine environments of the Petitcodiac River, suspended sediments increase with an ebbing tide, and increase even more with a spring tide. Once outside the Petitcodiac River, suspended sediment concentrations decrease rapidly in Shepody Bay and Chignecto Bay.

**Sediment Quality**

Information collected from the limited data sources indicate sediment from the headpond and downstream of the causeway to Gunningsville Bridge are not contaminated to any discernible level of concern for either metals or organic compounds. This is also true for suspended sediments, with the exception of polycyclic aromatic hydrocarbons (PAHs, byproducts of petroleum products) and lead that were observed higher than CCME guideline levels (2,000 ng/g and 35 mg/kg respectively) in a single sample taken during an incoming tide at the causeway in 1997. Mercury that was detected in 1974 as occurring in the headpond, was not detected in 1998. These bottom and suspended sediments are also not considered toxic according to amphipod (small crustaceans) bioassay tests.

Freshwater mussels and clams sampled in 1997 upstream of the causeway in the Village of Petitcodiac were also not considered contaminated with metals, PAHs, or PCBs.

Frequent disturbances in the headpond resulted in a reduction of the stability and maturity of macrophyte (plant life) and benthic (bottom dwelling animals) communities in this area. Three drawdowns of the headpond in 1997, 1998 and 1999 also resulted in dramatic decreases in the abundance and biomass of macrophytes and benthic invertebrates in the headpond.

**Nutrients**

Nutrients were generally low in the Petitcodiac River at the villages of Petitcodiac and Salisbury. In addition, it was observed that phosphorus appeared to be the limiting nutrient in the upper reach of the Petitcodiac River whereas nitrogen was limiting close to the causeway.

With the exception of mercury in water that was sampled in 1974, which was noted to be approximately 10 times the CCME guidelines for the protection of marine and freshwater aquatic life, all toxicity tests for Petitcodiac River water had non-toxic results, including that of the wastewater from the Greater Moncton Sewerage Commission (GMSC) outfall.

**Existing Water Quality (2003-2004)**

**Bacteria**

Trends were observed in the samples collected in 2003 that concluded that upstream of the causeway and as far upstream as Salisbury, fecal coliforms are higher following rain events and generally in autumn. In addition, fecal coliforms are generally higher at the causeway. When the gates are open during low tide, there appears to be an increase in fecal coliforms upstream of the causeway. Downstream of the causeway, coliform counts are much higher at low tide than at high tide throughout the estuary and the marine environment of the Petitcodiac River and as far as Hopewell Cape. On a seasonal trend, summer appears to be the worst time for fecal coliforms downstream of the causeway, as measured at Gunningsville Bridge. Compared
to the Health Canada/CCME Recreational Water Quality Guideline and Aesthetics of 200 fecal coliforms/100 mL, results from samples collected upstream of the causeway in the 2003 and 2004 field programs ranged from none detected to 559 fecal coliforms/100 ml. Samples collected at the causeway showed ranges from 140 to 2000 fecal coliforms/100 ml.

**Dissolved Oxygen**

Dissolved Oxygen (DO) concentrations in the fishway through a tide cycle are generally above the marine water CCME guideline value of 8 mg/L for the months of April to June, indicating good water quality. In July to September, however, the DO levels are severely depressed (<5 mg/L and as low as 1.72 mg/L in July). This suggests that unacceptable conditions occur at the fishway in the summer for fish passage. This is also observed at Gunningsville Bridge and at Halls Creek.

DO levels become depressed rapidly in time and appear to be initiated with the arrival of the tidal bore, remain depressed for the duration of the incoming tide, but then are elevated to an acceptable level with the outgoing tide. The upstream stations at the causeway and Boundary Creek have vertical salinity profiles of 0 mg/L, suggesting no salt intrusion was observed during these surveys. It should be noted, however, that salt water intrusion into the headpond occurs occasionally when the incoming tide level exceeds the headpond level resulting in a reversed flow through the fishway.

Vertical profiles for DO were conducted at: Gunningsville Bridge on May 14, 2003; at Outhouse Point on May 15, 2003; at Dover on June 12 and at Hopewell Cape on June 13, 2003 during a tidal cycle by the Bedford Institute of Oceanography, DFO. DO concentrations in May for both Gunningsville Bridge and Outhouse Point are slightly depressed in the vertical with respect to the marine CCME guideline of 8 mg/L. Further, bottom water at high tide at Gunningsville Bridge reaches critical levels of DO < 5 mg/L. During the ebbing tide, DO is in the range of approximately 5 to 7 mg/L. In June at Dover, DO concentrations are at critical levels and <5 mg/L for the greater part of the ebbing tide, whereas during the flooding tide, the DO range is only slightly better (5 to 6 mg/L). In the same month at Hopewell Cape, DO concentrations are similar and borderline with respect to unacceptable DO concentrations for the ebbing tide.

Vertical profiles of DO were conducted at various locations from Boundary Creek upstream of the causeway, to Hopewell Cape downstream of the causeway in the summer (August 20 – September 3, 2003). It can be noted that except for the upstream causeway profiles (Boundary Creek and causeway), DO concentrations are generally below the recommended guideline for the marine environment (<8 mg/L). At high tide at the Gunningsville Bridge, DO is unacceptable and <5 mg/L for the bottom water. At low tide, DO is critically depressed for the entire water column from the Gunningsville Bridge to Dover, and downstream of the causeway at the fishway entrance when bottom water is considered. This represents a 16 km segment of the Petitcodiac River that may be impaired. The low water, DO vertical profile for Hopewell Cape is also depressed (<6 mg/L). The range of salinity for all stations surveyed downstream of Gunningsville Bridge is in the order of 20 to –30 mg/L. The upstream stations at the causeway and Boundary Creek have vertical profiles of 0 mg/L suggesting that no salt intrusion was observed during these surveys. It should be noted, however, that salt water intrusion into the
headpond occurs occasionally when the incoming tide level exceeds the headpond level resulting in a reversed flow through the fishway.

Single measurements and profiles were also conducted at various stations and for different locations upstream of the causeway to Salisbury, and downstream of the causeway. DO measurements were taken in all seasons of the year. Other than what has been noted above with respect to critically low DO (<5 mg/L) in the estuarine and marine environments, only one site was observed to have very low DO in the freshwater environment. This occurred in the winter of 2004 where a DO of 0.13 mg/L was measured on March 14 in the Petitcodiac River at Turtle Creek and 200 m from shore. A strong smell of sewage was also emanating from this area and drain sewers could be identified on shore. A return visit on March 19 revealed a DO concentration of 5.45 mg/L at the site of the sewer drain, and a DO of 4.85 mg/L 160 m downstream of the drain. DO measurements at other adjacent sites were not below the freshwater DO guideline of 6.5 mg/L.

DO levels at night were measured from the headpond up to Mitton Pool at five stations to determine if oxygen consumption at night by aquatic animals depressed DO concentrations. Sampling was conducted from 4:00 to 5:00 in the morning and in the dark on July 12, 2004. All five stations had DO concentrations above 8 mg/L.

**Nutrients**

The nutrients that would be considered of most concern as a result of the agricultural practices, livestock farming, watershed drainage, urban runoff and effluent discharges into the Petitcodiac River are ammonia, nitrate, total phosphorus and total organic carbon (TOC).

TOC is present in the water as much upstream as downstream of the causeway. It also appears that TOC during the summer is higher in the headpond than downstream of the causeway. In the fall, however, TOC does not seem to vary as much between upstream and downstream locations to the causeway. The spatial trend for TOC in the summer is such that TOC is expected to be higher due to less precipitation and runoff. In the headpond, the TOC level is twice as much as that for downstream locations. Further, TOC at low tide is consistently higher than that for high tide throughout the Petitcodiac River estuary.

Overall, these data show a pronounced “signature” of the contribution of sewage below the causeway, peaking in the vicinity of Gunningsville Bridge, but extending as far as Outhouse Point during the ebbing tide and even as far as Hopewell Cape with respect to phosphorus and nitrate.

**Metals**

Water samples were analyzed for twenty metals. Most of these were undetected or close to detection limits.

The only metal that was detected on several occasions is mercury. Total mercury was not detected upstream of the causeway. Downstream of the causeway it was detected from Gunningsville Bridge to Hopewell Cape, in surface and bottom water samples, at high tide and
low tide. The range of mercury values at Gunningsville Bridge was generally lower (0.04 to 0.17 µg/L) than those for Outhouse Point, Dover and Hopewell Cape (0.17 to 0.30 µg/L). The values for mercury are also above the CCME guideline of 0.016 µg/L to protect aquatic life in marine water, and may be a metal of concern. Mercury readily attaches itself to organic matter and on suspended sediments containing organic matter. The high concentration of suspended sediments in the Petitcodiac River and organic matter from sewage effluent may explain the high levels of mercury.

**Organic Compounds**

Polychlorinated Biphenyls (PCBs), organochlorine pesticides, and extracts for organophosphates and carbamate pesticides were not detected in the water samples collected.

In the chlorinated benzenes, 1,4-dichlorobenzene was the only compound detected. It was detected in the summer at Boundary Creek, the causeway, as well as at Gunningsville Bridge. The concentrations measured in the headpond and downstream are not considered a concern, due to the low concentrations observed.

There were 13 polycyclic aromatic hydrocarbon compounds detected. The only one that was above CCME Guidelines was anthracene. This compound was detected at the causeway in the summer. Bottom waters at Dover contain the highest anthracene, followed by Oouthouse Point. The surface and bottom waters at Hopewell Cape contain traces of anthracene. Downstream of the causeway, the concentration is higher at high tide, and no difference is apparent between gates open or closed. PAHs such as anthracene are prevalent in the human environment due to hydrocarbon use and other anthropogenic sources of pollution.

**Baseline Water Quality (2005)**

For the purpose of this EIA, it is reasonably assumed that the water quality during baseline (2005) would be similar to that observed during existing conditions (2003-2004), because there is not likely to be substantive change to the inputs of contaminants to water quality (e.g., sewage) or to the river characteristics that affect water quality (e.g., the amount of water in the river) occurring during the interim time.

**5.4.4.2 Sediment Quality**

Data collected from the field programs implemented in 2003 and 2004 suggest that sediment from the headpond and downstream of the causeway to Hopewell Cape are apparently not contaminated to any discernible level of concern for either metals or organic compounds. This is also true for suspended sediments, with the exception for one PAH compound that was higher than guideline levels in three samples collected on the flood tide at Gunningsville Bridge. The source of the PAH compound at the Gunningsville Bridge is not known.

Based on 2003 field survey results of the Petitcodiac River headpond, benthic community biomass has remained low since 1999 for sphaerid clams, gastropods and amphipods. However, there appears to be an increase in the biomass of insects such as chironomids, mayflies and trichopterans. The benthic biomass levels at Gunningsville Bridge mid-channel
were relatively low compared with other locations in the tidal portion of the Petitcodiac River and upstream of the causeway.

Benthic biomass was highest during summer and fall seasons when production is expected to be higher due to warmer water and invertebrate reproduction and growth. Little change in biomass was observed between low tide and high tide in winter and spring when the gates to the causeway were closed, however biomass increased with high tide in the fall due to an influx of mysid shrimp.

**Baseline Sediment and Benthic Community (2005)**

For the purpose of this EIA, it is reasonably assumed that the sediment quality and benthic community during baseline (2005) would be similar to that observed during existing conditions (2003-2004), because there is not likely to be substantive change to the water quality or to the physical river characteristics that affect (e.g., the amount of water in the river) occurring during the interim time.

### 5.4.5 Commercial Fisheries

#### 5.4.5.1 Pre-causeway Commercial Fisheries (prior to 1967)

According to landings records, five fish species were commercially fished in the Shepody Bay and lower Petitcodiac River estuary (Statistical Districts 79 and 81) prior to causeway construction. District 79 has Alma as its main port and District 81 includes Wood Harbour and the Petitcodiac River inside of Shepody Bay. The fish species that were commercially fished were:

- gaspereau;
- Atlantic salmon;
- American shad;
- Atlantic sturgeon; and
- American lobster.

#### 5.4.5.2 Post-causeway Commercial Fisheries (1969-2002)

According to landings records, the following species were commercially fished in the Shepody Bay and lower Petitcodiac River estuary (Statistical Districts 79 and 81) following causeway construction:

- gaspereau;
- American shad;
- Atlantic salmon;
- American lobster;
- Atlantic sturgeon; and
- American eel.
It is important to note that the construction of the causeway created opportunities for commercial fisheries to be developed for the American eel that did not previously exist.

Bluefin tuna (*Thunnus thynnus*) was also noted as a commercial species fished, however the landings were considerably lower (total landed approximately 7 tonnes) then the landings for those species listed above.

### 5.4.5.3 Existing Commercial Fisheries (2003-2004)

Various groups contend that commercial fisheries have been affected positively or negatively by the construction of the causeway. The Alma Fishermen’s Association (AFA) contends that the causeway has positively affected their fisheries for lobsters and scallops. It is obvious also that the construction of the causeway and the establishment of the headpond made the smallmouth bass and eel fisheries possible. Conversely, the commercial shad fishery has declined considerably since the construction of the causeway, and the Atlantic salmon has disappeared. It is less clear what implications the causeway had on the brook trout fishery.

**American Eel**

Approximately two tonnes of adult eels are taken from the Petitcodiac River headpond per year. The fishery was conducted in 2004, but not in 2003. The fishery for elvers (very small juvenile eels) that was conducted immediately downstream of the causeway for several years has been discontinued because of poor prices for live elvers.

**American Shad**

There is a shad fishery that is conducted in the lower estuary during the daylight hours around high tide. In 2003, only three fishers participated in the fishery, which has become more of a hobby/subsistence operation.

**Smallmouth Bass**

Smallmouth bass are a freshwater fish that have no tolerance in any life stage for saltwater. Although smallmouth bass is non-indigenous to the Petitcodiac River, they were found in the headpond at the time of the fish survey in 2003. Smallmouth bass prefer clean water with little or no suspended sediment, minimum dissolved oxygen levels of 6 mg/L, cool water and require sandy, gravel, or rocky bottoms for spawning. Habitat varies with size of fish and time of year, however, they are usually associated with rocks, submerged logs, or dense growths of aquatic plants.

**Lobster**

The American lobster goes through early stages of life as a pelagic (free-swimming, off-bottom) organism for a period of time that depends on the water temperature and ranges from a few weeks to several months. It is not until late in the fourth stage of life that a lobster larva descends to the bottom and becomes a resident benthic (bottom dwelling) organism. Juvenile lobsters that settle on the bottom appear to prefer clean (unembedded) substrates, or at least cobble (small rocks) near the surface of the ocean floor between which they can excavate tunnels. They use any interstitial spaces (spaces between rocks for example) that offer cover from predators. Lobsters rely on cover, and are shelter-restricted for several stages.
The trend of increased lobster landings is depicted in Figure 5.4.1 for Lobster Fishing Area (LFA) 36 (extending from just west of Alma along the NB Fundy coast to Maine), Statistical District 50 of LFA 38 (essentially Grand Manan Island in the outer Bay of Fundy), and for LFA 35, which includes the Upper Bay of Fundy east of Alma and the Nova Scotia side of the Bay of Fundy as far as Digby. Figure 5.4.2 depicts lobster landings in the Port of Alma, Statistical District 79 in Lobster Fishing Area 35, and a five-year moving average trend in these landings as well as the landings and landings trend for the port of Wood Point, Statistical District 81 in Cumberland Basin. The commercial fishers from Wood Point largely rely on catches from Shepody Bay and Inner Chignecto Bay (i.e. close to the mouth of the Petitcodiac River). Figure 5.4.3 depicts the landings and trends for the port of Wood Point only. Commercial lobster catches have increased dramatically in the Inner Bay of Fundy, reflecting an increase in the population throughout the Bay of Fundy since the 1980s. This population increase was the result of a major recruitment pulse (one or several dominant year classes entering the fishery) that occurred in the 1990s (Lawton et. al., 2001). In one area of the Chignecto Bay called “the hole” fishers contend that prior to the causeway’s construction and during gate openings, it was difficult to haul traps because of mud infilling the traps to the point where they were ineffective. To put the fishery in context, Alma fishers report that they take approximately 5% of their lobsters from the area in question, and expend 10% of their effort there. It is the first place that the fishers can fish early in the spring.

The presence of the causeway has created a depositional area in the river where fine sediment, possibly eroded from the bottom of outer Shepody Bay and Chignecto Bay and beyond, has been deposited. As noted in Section 5.2.4, the construction of the causeway altered the balance of where sediment was deposited with a portion of it being deposited in the Petitcodiac River estuary after the construction of the causeway rather than in the middle of the Bay of Fundy. There would still have been scouring from the seabed in Chignecto and Shepody bays even without the causeway.

Whereas in the 1970s and 1980s, Chignecto Bay was a rearing area only for large migrating lobsters (Robichaud and Campbell, 1991), it is now also a nursery area for juvenile lobsters (Lawton et. al., 2001). There is a theory that is advanced by several fishers in the area that the construction of the Petitcodiac River Causeway in 1968 has resulted in improved habitat for juvenile lobsters in the upper Bay of Fundy with attendant increases in lobster production. They point to increased landings and increased numbers of juvenile lobsters in the area as evidence of the improvement in habitat. The Petitcodiac River Causeway resulted in a large quantity of sediment being deposited in the Petitcodiac River estuary seaward of the causeway. The theory put forward by the commercial fishers is that because the sediment was and continues to be deposited in the estuary, the bottom substrate in the upper bay became cleaner, with more open spaces available for juvenile lobsters seeking cover (stage four and later). Put in other terms, the theory holds that the lobster population in the Upper Bay was limited by the availability of juvenile habitat. Further, once such habitat became available, the lobster population increased as a consequence of increased juvenile production.

If a population is habitat limited, such as is often the case for some freshwater or marine fish species, when habitat is made available the population increases rapidly. If indeed the lobster
of the Upper Bay of Fundy were habitat limited, one would anticipate an increase in production of lobster shortly following the increase in habitat availability. The largest quantity of material deposited in the Petitcodiac River estuary took place in the years immediately following construction of the causeway. If this material were related to the lobster habitat, and the lobster population habitat limited, there should have been a response in the lobster community as indicated by greater landings within a few years of construction of the causeway. This was not the case for the Upper Bay of Fundy. Lobster landings in the Upper Bay showed no increase until the mid to late 1980’s (Figures 5.4.1 and 5.4.2) – consistent with increases in lobster landings elsewhere in the Bay of Fundy (Figure 5.4.3) and the Gulf of Maine.

The increased number of juvenile lobster found in the Upper Bay would be anticipated given the large increase in lobster numbers in the region as evidenced by the significant increase in landings. It would be unusual for there not to be an increase in numbers of juveniles given a normal population pyramid. Also, other factors such as reduced numbers of predators, could have contributed to the increased number of juveniles.

The causeway was constructed in 1967 and the gates closed in May of 1968. Improved fishing conditions should have resulted in an almost immediate increase in landings. A secondary pulse should have occurred five to seven years later as improved juvenile production resulted in legal-sized lobsters. Instead, after a spike in landings in the ‘80s, the latest big increase in lobsters occurred in the latter half of the ‘90s and early in the current decade. As the closest statistical district to the causeway Wood Point (Stat. District 81) should have shown the most dramatic increase in lobster landings. However, a similar trend in landings as elsewhere in the Bay of Fundy is apparent even at Wood Point. Therefore, it can be concluded that the trend in improved lobster catches that had occurred within the last two decades is unrelated to the presence of the Petitcodiac River causeway.

**Scallops**

These bivalves are suspension feeders and therefore are found in beds located in high-energy environments with sand and or gravel substrates that afford a steady stream of food material. Due to the requirement for a high-energy clean gravel or sand environment, scallop beds can be damaged by heavy levels of sediments or changes in energy in the water column. In the case of scallops, the commercial fishing groups contend that a bottom substrate that is comprised more of sand and gravel as opposed to finer material, and lower TSS levels benefit scallops.

Scallops are taken with drags that are towed along the sea floor. Presently, the line between a fishable population density and a non-commercial biomass appears to be firmly drawn at a right angle across Chignecto Bay from Apple River to New Brunswick. Potentially fishable scallop beds east of this including adjacent to Grindstone Island were not detected in the Trial Gate Opening surveys, and in fact no scallops were taken at all in tows immediately southwest of Grindstone Island itself. Recent surveys indicated that populations of an adequate size for commercial exploitation were to the West of this line (Kenchington, Dempsey and Lundy, 1998).

Generally, scallop catches in Scallop Production Area (SPA) 1, (essentially the entire Bay of Fundy including the Upper Bay minus two small areas around Digby), peaked in 1989 and 1990,
declined during the ‘90s, and has started to increase since the low point in 1997. There are three fleets that fish scallops in Scallop Production Area 1, the Full Bay, the mid-Bay and the Upper Bay fleets. Catch per unit effort (CPUE) data for the 16 Upper Bay licenses that fish only east of Ile Haute, just west of Cape Chignecto, have been available only since 1997 (DFO, 2002). Since then until 2001, the CPUE for the Upper Bay fleet has been similar to that for the Full Bay fleet, which can fish the entire Bay of Fundy and the mid-Bay fleet, which can fish the NB side of the Bay of Fundy

Baseline Fish (2005)

For the purpose of this EIA, it is reasonably assumed that the commercial fish species harvested during baseline (2005) would be the same as those harvested during existing conditions (2003-2004), because there not likely to be substantive change to the habitat (i.e., water quality and sediment quality) used by commercial fish species occurring during the interim time.

5.5 Terrestrial and Wetland Environments

5.5.1 Wetlands

The Biophysical Component Study examined wetlands within the Assessment Area (as described in Section 4.7). There is approximately 33% more wetland area at present then existed pre-causeway. Wetlands were not entirely estuarine prior to causeway construction. Approximately 97 hectares (ha) of freshwater wetlands have been formed in the Assessment Area since construction of the causeway that includes 46 ha of Ducks Unlimited sites. Downstream from the causeway, wetlands are predominantly saltwater high marsh. Approximately 544 ha of saltwater marsh have formed downstream of the causeway since causeway construction; an increase of over 42% due to accretion of sediments caused by the causeway. Based on field observations, wetland areas in the immediate downstream area appear to be still growing at a rate in the order of at least 2-5 metres/year. Vegetation in pre-causeway portions of downstream wetlands is slightly more diverse and appears more vigorous and densely vegetated than “new” wetland areas that have formed since causeway construction. Figure 5.5.1 shows the extent of wetlands in 2003.

The Assessment Area contains approximately 1,723 ha of saltwater marsh, which represents a substantive portion of this type of wetland both regionally and provincially. Substantive areas of former saltwater marsh exist above the causeway as dykelands and riverbank on the outer edges of the dykes, which has remained above the operating level of the Petitcodiac River headpond.

5.5.2 Wildlife and Vegetation

Changes in the general landscape and range of available terrestrial and wetland habitats were relatively minor after construction of the causeway. Development of some vegetated areas for urban expansion has been somewhat offset by the abandonment of numerous agricultural fields, that have been left uncultivated and allowed to revegetate into shrubland and immature forest. Small amounts of relatively and regionally common, freshwater wetland has formed upstream of the causeway and small amounts of salt marsh have been isolated from tidal
influence and have dried and “freshened” into upland meadow. The greatest change in habitat is the dramatic increase in saltwater marsh area downstream of the causeway brought about by causeway construction.

5.5.2.1 Terrestrial Species at Risk and Species of Conservation Concern

For the purpose of the EIA, “Species of Conservation Concern” include species listed by the Atlantic Canada Conservation Data Centre (AC CDC); and/or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

For the purpose of this EIA, “Species at Risk” include only those species that are afforded protection under the federal Species at Risk Act (i.e., listed in Schedule 1), or under the New Brunswick Endangered Species Act (i.e., listed as “Endangered Species” or “Regionally Endangered Species”).

Historical air photos indicate that the terrestrial Species at Risk or Species of Conservation Concern that used the terrestrial or wetland habitats that existed prior to causeway construction were probably very similar to those that exist presently, since there has been no addition or loss of major habitat types in the general landscape. However, the relative abundance of such populations may have changed due to changes in the proportion of various habitats.

The Assessment Area contains a relatively small-to-moderate number of Species at Risk or Species of Conservation Concern records: 169 records of 85 species from 24 sources (AC CDC, 2003). There are 36 records of 26 rare plants, and 2 records of 2 rare mosses. The Assessment Area contains 116 records of 46 rare animals (mammals, amphibians and reptiles), and 15 records of 11 rare insects. Table 5.5.1 summarizes Species at Risk and Species of Conservation Concern known to occur in close proximity to the Assessment Area. Detailed submissions by the Atlantic Canada Conservation Data Centre (AC CDC) are included in the Biophysical Component Study (AMEC 2005a).

Fourteen of these species are ranked by AC CDC as S1. An animal or plant species ranked as S1 is considered extremely rare throughout its range in the province (typically 5 or fewer occurrences or very few remaining individuals), and may be especially vulnerable to extirpation (complete disappearance within a region, though not globally extinct). These include one mammal (Lynx canadensis), one damselfly insect (Enallagma carunculatum), five vascular plant species (Draba arabisans, Dryas integrifolia, Pseudognaphalium obtusifolium, Salix myrtillifolia, Solidago multiradiata), two moss species (Aloina rigida, Pleuridium subulatum) and five bird species. Three of these species are ranked by COSEWIC as Special Concern: short-eared owl (Asio flammeus), monarch butterfly (Danaus plexippus) and wood turtle (Glyptemys insculpta). Two species are ranked by COSEWIC as Threatened: Peregrine Falcon (Falco peregrinus) and Least Bittern (Ixobrychus exilis). The Canada Lynx is designated as Regionally Endangered under the NB Endangered Species Act.
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Species of Conservation Concern

During field surveys in 2003, three plant Species of Conservation Concern were identified as follows:

- *Distichlis spicata* (salt grass);
- *Rumex maritimus* (golden dock); and
- *Triglochin gaspensis* (Gaspe peninsula arrow grass).

Golden dock was observed in the near field both up and downstream on eroded river banks and disturbed fields. A known concentration of golden dock was identified between the old Gunningsville Bridge and Jonathan Creek. Gaspe peninsula arrow grass was identified at only one location in the far field downstream at Mountville, in the “low marsh” margin of a panne (i.e., a permanent pond in a saltmarsh). Salt grass was also identified at only one location in the far field downstream at Gautreau Village near the mouth of Downing Creek at the high marsh/low marsh boundary.

It was identified at the Biophysical Workshop (April 26, 2003) that Wood Turtles and/or Snapping Turtles have been known to lay eggs in the Turtle Creek area. Wood Turtles have also been identified by the AC CDC as occurring in watersheds throughout the Assessment Area and are known to use both high and low elevations. No sign of wood turtles or snapping turtles was observed during field surveys by the AMEC Study Team. A photo of a snapping turtle found within the Petitcodiac River watershed was provided by the Fort Folly First Nation.

Species at Risk

There were no plant or wildlife Species at Risk observed during the surveys.

5.5.2.2 Invasive Species

The invasive plant species Purple Loosestrife (*Lythrum salicaria*) was observed in 5 of the 34 wetlands that were field visited (AMEC 2005a). It occurs both upstream and downstream of the causeway in freshwater wetlands or in the fresh or brackish margins of saltwater wetlands. Elephant Grass (*Phragmites australis*), also known as Common Reed occurs in many old dyked areas and may have been introduced by the Acadians as a thatching material (NSM, 1996). An alien race of Common Reed (presumably the European *Phragmites australis* (Cav.) Trin. ssp. *australis*) has been rapidly spreading along roadsides and invading and dominating wetlands in parts of southern Ontario and Quebec since the early 1990s (Schueler 2000a, b, Robichaud &
5.5.2.3 Other Terrestrial Species of Interest

Samphire greens (Salicornia europaea) (called "tétines de souris" by local Acadians) and goose tongue (called "passe-pierre" by local Acadians) were identified during public consultation as a traditional food source. These species were observed in small numbers throughout the area downstream of the causeway. The main concern expressed was that there has been an apparent decline in the abundance of these species in the Petitcodiac River since construction of the causeway. These species are more frequently associated with low marsh habitat and it seems likely that it was not more abundant in the Assessment Area in the recent past. Salicornia europaea forms the major vegetation of more northerly coastal wetlands in Atlantic Canada (EC, 1988).

Some concern was raised during the public consultation program for effects of the Project on muskrat populations in the Assessment Area. Muskrat populations were surveyed in the Greater Moncton Area in 1995 through 1997 as part of the mosquito control program. Muskrat populations have been identified in Moncton, Riverview, Dieppe and surrounding areas. In 1997, 113 huts were identified, the majority of which were located in the Dover Ducks Unlimited impoundment. Muskrat populations were found to fluctuate from year to year by almost 20%, in response to availability of food and population densities (MWG, 1998).

5.5.3 Migratory Birds

Bird species using the Petitcodiac River before causeway construction were predicted based on the habitat present, as determined from 1962-63 aerial photographs. Waterfowl species that may have nested within or at the fringe of the salt marsh habitat include Mallard (Anas platyrhynchos), American Black Duck (Anas rubripes), Green-winged Teal (Anas crecca) and American Wigeon (Anas americana). Canada Geese (Branta canadensis) would likely have been present during migration and other migratory bird species that would likely have bred in the pre-causeway salt marshes include Nelson’s Sharp-tailed Sparrow (Ammodramus nelsoni), Savannah Sparrow (Passerculus sandwichensis), Bank Swallow (Riparia riparia) and Belted Kingfisher (Ceryle alcyon). It is also likely that American Crow (Corvus brachyrhyncos) would have used the former mudflats for feeding and Common Mergansers (Mergus merganser) may have been attracted to the river channel during migration. Species currently using the mudflats just below the causeway would likely have been present where similar habitat existed upstream of the causeway prior to construction. In particular, shorebirds would have likely used the mudflats during fall migration.

In 2003, approximately 92 species made some use of the open water, freshwater wetland and/or upland habitat (shown in Figure 5.5.1) immediately adjacent to the headpond as breeding, feeding, resting, or migratory habitat. The most numerous bird species encountered during surveys were Mallards, gulls (Herring (Larus argentatus) and Great Black-backed gulls (Larus marinus), predominantly) and Canada Geese; there are a number of Bank Swallow colonies along the eroding banks of the headpond. Other species present in the headpond area...
during the breeding season but not typically reported in the Assessment Area immediately below the causeway include Common Loon (*Gavia immer*), Northern Pintail (*Anas acuta*), Wood Duck (*Aix sponsa*), Pied-billed Grebe (*Podilymbus podiceps*) and Ring-necked Duck.

**Species of Conservation Concern**

Marsh species including American Coot, Common Moorhen and Virginia Rail have been recorded not only in Bell Marsh, but in other marshes in Riverside-Albert, Hillsborough and Gray Brook Marsh. Virginia Rail was also detected in a salt marsh near Fox Creek in late August. Green Heron (*Butorides striatus*) has historically been recorded in the vicinity of Lower Coverdale near the headpond. This area is a popular birding area, however, Green Heron has not been reported more recently. Red-breasted Mergansers (*Mergus serrator*) are more likely to be observed in the Assessment Area during migration or following breeding, as the largest numbers in the Maritimes are found on coastal islands and sandbars and probable breeding records for this species within the Assessment Area are limited to Riverside-Albert area and Weldon (Erskine, 1992). Ruddy Duck, an accidental breeder in New Brunswick, has been confirmed as breeding in Bell Marsh (NatureNB Archives 2004). Gadwall (*Anas strepera*) was recorded by CWS during headpond surveys near the Village of Salisbury sewage lagoon, and has been noted by birdwatchers in Bell Marsh (NatureNB Archives, 2004). Red-necked Grebe are more typically reported in Shepody Bay during migration, however there were a few reports in the headpond during the volunteer-based surveys and headpond surveys by CWS.

Several of the species have been recorded at only a few locations in the Assessment Area. These records are located at the downstream portion of the river, associated with nearby freshwater marshes or other habitat likely to have limited interaction with the Project Options. These include Least Bittern (*Ixobrychus exilis*) (Germantown Marsh), Sedge (*Cistothorus platensis*) and Marsh (*Cistothorus palustris*) wrens (*Riverside-Albert*) and Black Tern (*Chlidonias niger*) (Grindstone Island). Piping Plover (*Charadrius melodus*) is only noted from Waterside, likely outside of the influence of the Project options, given the critical habitat and the distance from the causeway.

The Short-eared Owl is listed as Special Concern in NB by COSEWIC (COSEWIC, 2004). The Short-eared Owl is known to breed in wet meadows and marshes and coastal bogs and grasslands. Their abundance in the region may be limited to the abundance of their main prey species, meadow vole. In 1994/95 five Short-eared Owls were sighted using the Outhouse Point Marsh ESA area, probably feeding on voles (NTNB, 1995). Since these sightings Short-eared Owl are regularly reported from marsh areas neighbouring Shepody Bay and its feeder rivers, such as Taylor Village and Dorchester Marsh on the Memramcook River, as well as marshes in the vicinity of Outhouse Point (NatureNB Archives, 2004).

Nelson’s Sharp-tailed Sparrow, although ranked as S3 (uncommon throughout its range in the province) by AC CDC (see Appendix W of AMEC 2005a for explanation of S rankings), is considered Secure by NBDNR. This species is present in most of the salt marshes assessed as part of the volunteer-based surveys of bird communities in coastal wetlands. They are taking advantage of the creation of new wetland in parts of the Petitcodiac River as sediment accumulates and the flats become vegetated over time. Surveys in the vicinity of Gunningsville
bridge have suggested that Nelson’s Sharp-tailed Sparrow is tolerant of some level of disturbance close to breeding habitat.

Migratory shorebird species with relatively few records or low numbers resulting in S1 (extremely rare throughout its range in the province) to S3 rankings or considered sensitive include Red Knot (Calidris canutus), American Golden-Plover (Pluvialis dominica), Sanderling, Baird's Sandpiper (Calidris bairdii) and Hudsonian Godwit (Limosa haemastica). Most of these species have been reported associated with the important migratory staging areas in Shepody Bay, however sightings of some species do occur upstream of Dover and within the headpond (e.g., Black-bellied Plover was reported from the Jones’ Farm by CWS headpond surveys and Dieppe Marsh/Bridgedale by volunteers.). There have been some records of Wilson’s Phalarope (Phalaropus tricolor) breeding in fertile ponds in southern New Brunswick (Erskine, 1992), however the only AC CDC record of breeding is in a sewage lagoon in Dorchester.

**Species at Risk**

American Peregrine Falcon populations are apparently recovering in the Bay of Fundy, with successful breeding recorded in recent years, including near Johnson Mills where shorebird banding was conducted in 2003. Adult and juvenile peregrines, among other raptors, were recorded chasing shorebirds at Johnson Mills during banding efforts. In 1998, 7 pairs of Peregrine Falcons nested successfully in the Bay of Fundy (Hicklin 2003). Three nests reported in the Assessment Area in 1999 were at Owl’s Head, Grindstone Island and Edgett’s Landing (AC CDC 2004). Breeding habitat of peregrines (cliff ledges) are not at risk from the Project Options. The potential interaction of the Project Options with peregrines is indirect, limited to the effects on the prey (mudshrimp) of its prey (shorebirds). The NB Endangered Species Act designates the bald eagle (Haliaeetus leucocephalus) as regionally endangered. Bald Eagle nests are known from the Assessment Area both upstream and downstream of the causeway, however will not be influenced by the Project. Eagles tend to nest in large trees near water, and feed on fish and dead bodies of other species (Erskine, 1992). They feed in both estuarine and freshwater habitats in the Assessment Area.

There are several provincially designated Environmentally Significant Areas (ESAs) within the Assessment Area, that have been designated as an ESA primarily due to the presence of migratory birds: Allison Station Eagle Nest; Coverdale Marsh; Outhouse Point; Lower Coverdale Island; Big Cape; Dorchester Marsh; Hopewell Rocks; Grindstone Island; Shepody Bay Ramsar/Western Hemispheric Shorebird Reserve Network (WHSRN) Site; and Shepody National Wildlife Area/Marys Point Ramsar Site. In addition, there are three Ducks Unlimited Sites within the Assessment Area including: Wilson Marsh (Bell Marsh), Turtle Creek and Dover Marsh.

5.5.4 Mudflat Productivity

The major mudflats in Shepody Bay prior to causeway construction include: Calhoun Flats; Daniels Flats; New Horton Flats; and Grande Anse. The mudshrimp (Corophium volutator) is a small tube-dwelling shrimp that builds u-shaped burrows in the sediment surface of mudflats. These are an extremely important food source for a multitude of migratory bird species, fish and other animals.
While the distribution of the mudflat in Shepody Bay has not changed substantially since 1965, tidal currents, sedimentation processes and, consequently, the biological nature of the mudflat has changed considerably since the introduction of causeways and dams on the Bay of Fundy estuaries, including the Petitcodiac River. Within the Petitcodiac River just downstream of the causeway, the channel was largely filled in with sediment following construction. As a result, the area of mudflats initially increased within the river channel. Subsequently, much of the created mudflats became vegetated and thereafter became wetlands. The remaining narrow bands of mudflats along the Petitcodiac River are considered less important as feeding habitat for migrating shorebirds because they comprise a relatively small area compared with the much larger mudflats within Shepody Bay, and are exposed for a shorter period of time in the tidal cycle (Hicklin, pers. comm.).

It is believed that mudshrimp populations collapsed in the mid-1990s. Some scientists have speculated that this apparent collapse may have been related to the causeway or other tidal barrier structures within the drainage area (Shepherd et al., 1995; Hicklin, pers. comm., Bay of Fundy Ecosystem Partnership (BoFEP), 1999). However, not all scientists agree with this, arguing that Shepody Bay is a very dynamic environment in terms of sediment movement, and the contribution of the periodic flushing of sediment from the Petitcodiac River may be less important than other factors that contribute to suspended sediments in the water column, such as cliff line erosion, seabed reworking and river input (Amos and Tee, 1989; Amos, 1987).

Recent benthic sampling in the Petitcodiac River provides the first documentation of mudshrimp distribution on tidal flats in the river. Mudshrimp were abundant at the mouth of the river (Hopewell), less abundant mid-way upriver towards the causeway (Dover), and were not found to be present in or near Outhouse Point.

5.6 Municipal Services and Infrastructure

The existing causeway and control structure are both considered as municipal infrastructure. A description of the causeway and gated control structure are provided in Section 5.1, and are not addressed further here.

5.6.1 Water Distribution Systems - Greater Moncton Area

The installation of watermains in the City of Moncton began in the downtown area in the late 1890s. Prior to 1968, the City of Moncton, the then Town of Dieppe and three villages on the south shore of the river (Riverview Heights, Gunningville and Bridgedale), were supplied with water from the City of Moncton’s Turtle Creek Reservoir supply. In 1963-1964, a water transmission line was constructed across the Petitcodiac River in a tunnel under the river, 1.8 km west of the causeway. The Village of Lewisville had its own system provided by wells and properties in St. Anselme and Chartersville were on well supplies.

In 1973 (post-causeway construction), the boundaries of Moncton and Dieppe were expanded and the Town of Riverview was incorporated; the Turtle Creek Reservoir became the water supply source for the three communities with the extension of the distribution system to all three communities. Well systems in the former villages were abandoned and each municipality
expanded and upgraded their distribution system. Water storage reservoirs, pumping stations and transmission lines were added as the area expanded and in 1999, a 110 million L/d water treatment plant was completed at Turtle Creek to improve the water quality. In 1995, a 750 mm water transmission line was installed 20 m east of the causeway and parallel to the roadway as a second supply line across the mudflats, as discussed in Section 5.13.

5.6.2 Sanitary Sewer System - Greater Moncton Area

The installation of the first sanitary sewer systems began in the late 1890s. Untreated wastewater in the GMA was discharged directly into the Petitcodiac River and its contributing streams by area municipalities. Twice daily, the tidal action of the river flushed the wastewater, as the tide passed by the municipalities to Salisbury 21 km to the west. The receding tide cycle carried the flow out to the Bay of Fundy. The river had the capacity to effectively disperse the wastewater.

However, the construction of the causeway resulted in the narrowing and relocation of the river channel. Sediment deposits formed in the former river channel, which separated the outfalls from the new river channel. The flows from the outfalls created a network of swales and drainage channels that meandered to the river channel. Sediments were deposited in these swales, which created a potential health hazard to people who walked on the newly created mudflats. Odours occurred from a build up of untreated sewage and the areas became unsightly.

In response to this condition, several trunk sewers and related pumping stations were constructed in the 1970s to collect the wastewater and discharge it directly into the Petitcodiac River at 58 outfall locations. In 1983, the Greater Moncton Sewage Commission (GMSC) was created and between 1984 and 1994, the GMSC designed and built a wastewater collection and a chemically assisted primary treatment system to serve the three area municipalities. A 30 km collector sewer system, complete with 29 overflow structures, was completed along the riverbank to collect wastewater from the three separate municipal systems. At strategic points in the collection system, an overflow pipe was installed from the GMSC collector sewer to the edge of the river or creek. Steel flapgates were installed at the end of the overflow pipes at headwall structures built at the edge of the river and/or creeks. They are hinged at the top and sloped so as to remain closed under normal conditions and prevent river water from entering the system during high tides. When the collector system surcharges during major storm events, the flapgates are forced open to provide relief to the system. The sewer outfall discharges into the primary zone of the river below the bend.

5.6.3 Storm Sewer System - Greater Moncton Area

Pre-causeway construction, in the older parts of the municipalities the drainage systems were constructed as combined sewers (combined storm and sanitary sewers). Prior to the 1960s, the three GMA municipalities used ditches in many areas to transmit storm water. Prior to the installation of curb and gutter systems, these ditches were connected to existing combined sewers (sanitary and storm sewer contained in a single pipe), storm sewers or new storm water sewers.
Currently in the City of Dieppe, the GMSC Virginia Street Storm Water Pumping Station is located at the bend in the river. The station is constructed at the rear of the dyke and the twin outfalls are protected with armourstone. The City of Moncton has storm water systems discharging into the Petitcodiac River, creeks and streams in the area. Problems exist with the storm sewer system due to factors such as sedimentation.

5.6.4 Dykes and Aboiteaux

Acadian settlers constructed the first dykes in southeast New Brunswick over 300 years ago. Farmers built dykes to protect marshland from the tides in the Bay of Fundy. Early settlers also used the aboiteaux, which was a wooden tunnel built into the dyke with a hinged door inside. The door would swing open to let the freshwater from the marsh drain to the river but close to keep the salty river water out. This protected marshland and provided the farmers with farmland.

Prior to the construction of the causeway, there were 20 marsh bodies along the Petitcodiac River. Downstream of the future causeway, there were 10 provincial marsh bodies, which protected 957 ha of land. They contained a total of approximately 22 km of dyke with 21 aboiteau structures (Robichaud, pers. comm.). Above the proposed causeway location, there were 10 marsh bodies protected by a 4.6 km dyke system with 30 aboiteaux, which comprised an area of 703 ha. Of this, 186 ha were used for crop land and 250 ha for pasture by area farmers, the rest was left uncultivated (Robichaud, pers. comm.).

Since 1968, the Provincial Department of Agriculture, Fisheries and Aquaculture have been responsible for maintaining the New Brunswick dykeland infrastructure. This infrastructure protects over 15,000 ha of land from the Bay of Fundy tides. Along with providing farmers with land for agricultural purposes, this protected dykeland also protects real estate, highways, parks, municipal sewage lagoons and other public infrastructure.

Since construction of the causeway, the number of marsh bodies and total dyke lengths has not changed. However, above the causeway, most of the dyke structures have been either destroyed or have fallen into disrepair, since protection from flooding upstream by saltwater has been provided by the causeway.

5.6.5 Wharves

Prior to the construction of the causeway, there were 12 wharves in operation along the Petitcodiac River from Moncton to Alma. However, with the construction of the causeway and the subsequent narrowing of the downriver channel due to the continued sediment deposition and channel infilling, shipping declined rapidly and the wharves were used less often for freight transportation. This was largely due to navigation issues but there were other unrelated changes in the shipping industry that led to the decline. Some barging remained until the early 1980’s to transport oil and gas to the wharf in the Halls Creek area of Dieppe. Also, as major industries closed, such as the gypsum plant at Hillsborough in 1980 (Jonah, pers. comm.), use of the wharves diminished. Today, there are three active wharves at Alma, Dorchester Cape and Belliveau Village. Generally, only the Belliveau Village wharf is used to facilitate boating activity in the estuary, primarily for recreational fishing by licensed commercial fishermen. The
Alma and Dorchester Cape wharves are not located within the Petitcodiac River estuary, but rather are located downstream of Hopewell Cape.

### 5.6.6 Other Infrastructure

The City of Moncton has developed a timber boardwalk supported on steel piles from Halls Creek up to the rear of the Landing at the Bend strip mall at the edge of the present river channel. A two-storey building with a viewing deck was also constructed. A new section was completed in 2004 in front of Boreview Park. The Château Moncton Hotel was constructed on piles to the rear of this boardwalk. No shoreline protection was installed along the riverbank for the hotel project and the boardwalk. Old concrete slabs and fill material had been placed in the area over the years. As well, old timber cribwork from loading docks constructed for shipping up to the 1960s remains under some sections of the present boardwalk.

In 1948, the City opened an incinerator at the end of Foundry Street that was closed in 1969/70. A landfill site was created between Bridge Street and Foundry Street South of Waterloo Street, which was in operation from 1969 to 1974. This material is now below the Hal Betts Sportsplex fields (Landry, pers. comm.).

In the early 1970’s, the City of Moncton developed a landfill site on tidal marsh on the north side of the Petitcodiac River immediately downstream of the causeway, west of Jonathan Creek and south of the Canadian National (CN) yards (former Moncton Landfill). This was an unconfined landfill that operated from 1971 to 1992, when it was decommissioned just as the present Westmorland Albert Solids Waste Commission Facility was brought on-line. Approximately 30% of the landfill footprint is built over sediment that was deposited after installation of the causeway.

Adjacent to the causeway an overhead utility pole line carries Aliant telephone lines (Miller, pers. comm.) and a Rogers fibre optic cable (Boudreau, pers. comm.) from Moncton to Riverview. There are no power lines in the immediate vicinity of the Petitcodiac River (MacKenzie, pers. comm). Also there are currently no gas pipelines along the shore or crossing the river (Walker, pers. comm.), however a future gas pipeline crossing from Moncton to Riverview is planned. At the Gunningsville Bridge there are NB Power cables and fibre optic cables for Aliant and Rogers Cable. These will be abandoned when the new Petitcodiac River Bridge is completed in the fall of 2005.

### 5.7 Road Transportation Network

#### 5.7.1 Highway Network Development

Although many of the provincial roads date back to the 1800’s and early 1900’s, it was during the 1950’s to the 1970’s that most of the present road network was built, or reconstructed, to design standards appropriate to today’s automobile and truck travel demands. As noted above, the decision by the Province to construct a causeway over the Petitcodiac River was announced in February 1964 (Moncton Transcript, 1965). The causeway would connect the City of Moncton to the suburban communities of Riverview Heights, Bridgedale and Gunningsville that now comprise the Town of Riverview. Previous discussions and public demands for a second
crossing of the Petitcodiac River had extended back into the 1950s. While there were numerous other non-transportation reasons at the time for selecting a causeway over a bridge, including flood protection upstream, the need for a second crossing was apparently driven by the increasing traffic congestion at the Gunningsville Bridge.

The rural road network within the Assessment Area (as described in Section 4.7) prior to construction of the causeway was essentially the same as it is today. Similarly, most of the provincial highway network within the urban GMA existed prior to construction of the causeway. Figure 5.7.1 shows the locations of the provincial highways. The main exceptions are the causeway link of Route 114, completed in 1968, and Wheeler Boulevard (Route 15), which was completed in the 1980’s. A new Petitcodiac River Bridge, just upstream of the Gunningsville Bridge, is presently under construction and is due for completion in 2005. Additional transportation linkages at either end of the new Bridge are planned. In Moncton, Vaughan Harvey Boulevard will be extended to meet up with the north entrance to the new Petitcodiac River Bridge, and Assomption Boulevard would be extended from Westmorland Street to intersect with the Vaughan Harvey Boulevard extension. Plans to begin construction of these network connections in Moncton are in place for 2005 and are expected to be completed in time for the completion of the new Petitcodiac River Bridge. In Riverview, the new Petitcodiac River Bridge will initially connect to Route 114. However, plans are in place to extend a new road in Riverview across Route 114 at grade to the south and west to connect to Findlay Boulevard, south of Whitepine Road. This work is presently scheduled to begin in 2005 and be completed in 2007.

5.7.2 Network Traffic

Traffic volume trends since the mid-1970’s show that traffic on urban routes has grown substantially throughout the GMA, with the exception of more remote segments, and traffic volumes on the causeway has increased by more than 10,000 vehicles per day, while traffic volumes on the Gunningsville Bridge have remained virtually the same. Rural segments of the provincial routes along the Petitcodiac River have experienced very modest, if any, traffic growth over the past two and a half decades and traffic volumes are much higher in the GMA than outlying rural areas. At present, 42,000 vehicles cross the river within the GMA each day on the two river crossings (68% on the causeway and 32% on the Gunningsville Bridge). It is predicted that there will be a much more balanced flow of cross-river traffic between the new bridge and the causeway.

5.7.3 Level of Service

Level of Service (LOS) is the measure of traffic operating conditions during peak traffic periods. LOS is based on prevailing traffic conditions, roadway geometrics and traffic control measures on urban streets and rural highways. Six levels of service are designated by the letters A to F to define traffic flow conditions. LOS A represents the best operating conditions and LOS F the worst. Corrective action is required at LOS D and below.

Rural highway and urban arterial levels of service are measured by intervals of specific volume-to-capacity ratios (V/C) and densities. In urban areas, intersections and other traffic control measures present more of an influence on traffic conditions during peak periods. Intervals of
average stop time delay at intersections are categorized to measure levels of service on urban streets. Table 5.7.1 presents the LOS criteria for urban area signalized and two-way stop controlled (TWSC) intersections, as measured and categorized in terms of seconds of delay.

<table>
<thead>
<tr>
<th>LOS</th>
<th>Signalized Intersections Control Delay (seconds per vehicle)</th>
<th>LOS Description</th>
<th>Two Way Stop Controlled (TWSC) Intersections Control Delay (seconds per vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Less than 10.0</td>
<td>Very low delay; most vehicles do not stop (Excellent)</td>
<td>Less than 10.0</td>
</tr>
<tr>
<td>B</td>
<td>Between 10.0 and 20.0</td>
<td>Higher delay; more vehicles stop (Very Good)</td>
<td>Between 10.0 and 15.0</td>
</tr>
<tr>
<td>C</td>
<td>Between 20.0 and 35.0</td>
<td>Higher level of congestion; number of vehicles stopping is significant, although many still pass through intersection without stopping (Good)</td>
<td>Between 15.0 and 25.0</td>
</tr>
<tr>
<td>D</td>
<td>Between 35.0 and 55.0</td>
<td>Congestion becomes noticeable; vehicles must sometimes wait through more than one red light; many vehicles stop (Satisfactory)</td>
<td>Between 25.0 and 35.0</td>
</tr>
<tr>
<td>E</td>
<td>Between 55.0 and 80.0</td>
<td>Vehicles must often wait through more than one red light; considered by many agencies to be the limit of acceptable delay.</td>
<td>Between 35.0 and 50.0</td>
</tr>
<tr>
<td>F</td>
<td>Greater than 80.0</td>
<td>This level is considered to be unacceptable to most drivers; occurs when arrival flow rates exceed the capacity of the intersection (Unacceptable)</td>
<td>Greater than 50.0</td>
</tr>
</tbody>
</table>


Note: The LOS descriptions are specific to signalized intersections and their approaches, but provide a general indication of conditions at stop sign controlled intersections as well.

Figure 5.7.2 shows the level of service for the provincial highways. Most of the highways within the Transportation Network Assessment Area are within the limits of acceptable LOS, with the following three exceptions:

- Route 114 - Petitcodiac River causeway is presently operating at LOS F during the evening peak conditions. The diversion of traffic to the new Petitcodiac River Bridge in 2005 will improve the LOS of the causeway.
- Route 196 - Gunningsville Bridge is presently operating at LOS E. It is a substandard very narrow two-lane bridge and will be replaced by a new four-lane Petitcodiac River Bridge in 2005.
- Route 114 in Riverview between the causeway and the Gunningsville Bridge is presently operating at LOS E. Upon completion of the "ring road" connection in 2007 between the new bridge and Findlay Boulevard, south of Whitepine Road, traffic will be diverted from this section, which will improve its LOS.
At this time all three of the LOS traffic flow deficiencies along the provincial highway route segments noted above are related to river crossing traffic. The levels of service will be improved in each case upon completion of the new Petitcodiac River Bridge and the new connecting roads in Moncton and Riverview.

5.7.4 Accident Rates

The highest traffic accident levels are generally experienced in the urban area of the GMA. The two highest accident rates have occurred along Route 106 in the Downtown Moncton area (Main Street between Vaughan Harvey Boulevard and the Halls Creek Traffic Circle) and in Dieppe (Champlain Street from the Halls Creek Traffic Circle to Acadie Avenue). The separation of traffic from the new Bridge between Vaughan Harvey Boulevard and Assomption Boulevard will reduce traffic within the commercial/pedestrian area of Downtown Moncton, and thereby reduce the vehicle accidents on this segment of Main Street (Route 106). In addition, a new north-south arterial by-pass in Dieppe, which by 2008 will extend from the Dover Road intersection of Route 106 at Amirault Street to Dieppe Boulevard at Champlain Street, will reduce traffic and accidents along the Champlain Street segment of Route 106.

5.7.5 Flood Prone Highway Sections

There are segments of the existing provincial highway network that experience flooding during certain conditions (e.g., precipitation events overlapping high tide made worse by a constricted river channel due to sediment infilling). This overall process is described in Section 5.2. Sections of the road network within the GMA that are 8 m elevation, or lower, and are potentially vulnerable to flooding, or may have experienced flooding over or alongside part of the street include: Causeway Traffic Circle; Downtown Moncton, Foundry Street to Halls Creek Circle; Traffic Circle Route 15, Superstore and Champlain Mall area; Botsford Street near Wheeler Boulevard (Halls Creek, Humphrey Creek); east of Archibald Street, north of Wheeler at Université de Moncton sports field; west of Morton Avenue, north of Wheeler Boulevard, marsh area by Crowley Farm Road; Champlain Street Route 132 at Babineau Creek; Acadie Avenue/Amirault Street at Babineau Creek; and Amirault Street and Margarite Street at Fox Creek.

5.8 Vessel Traffic and Navigation

5.8.1 Commercial Marine Traffic

The Petitcodiac River, at one time, supported commercial marine traffic as well as shipbuilding at a number of locations including Moncton and Salisbury. Some of Moncton’s first settlers arrived by ship as early as the 18th century. Marine transportation served as the major supply route for goods arriving from Europe and other North American centres. As the rail and road systems developed through the 19th and 20th centuries, the Moncton area became less reliant on marine transportation. At the time of the causeway construction, the only commercial marine traffic in the Moncton area was the delivery of petroleum products from Saint John to the Irving Oil tank farm located in Dieppe near Halls Creek. The Irving petroleum barging operation began around 1960 and continued until the early 1980’s when Irving switched its entire river barging operations to truck transportation. There has been some commercial marine traffic to and from
Dorchester Cape during the post-causeway period. However, dredging efforts were unable to maintain sufficient depth at the wharf.

There are currently a number of commercial fishing vessels that may operate within the Assessment Area. Although the number of vessels is not fixed, they service approximately 25 scallop licenses, 3 American shad licenses, 1 eel license (in the headpond) and approximately 100 lobster licenses. Only a portion of these vessels may actively fish within the Assessment Area during any given year/season, and most operate within the marine environment (i.e., Shepody and Chignecto Bays). Licensed commercial fishermen based in Belliveau Village continue to fish for recreational purposes in the Petitcodiac River estuary. This activity is greatly constrained by the extensive sedimentation at Belliveau Village and upstream that has occurred since the construction of the causeway.

5.8.2 Recreational Boating

There are no data available regarding recreational boating on the Petitcodiac River in the pre-causeway period. However, there would have been recreational boating associated with recreational fishing throughout the Assessment Area. The pre-causeway period was before the major growth in recreation boating, including powerboats, sailboats, personal watercraft, windsurfing and kayaking.

Currently, the Bay of Fundy is a popular recreational boating area. A wide range of recreational boats operate in Shepody Bay, including power and sailboats, as well as kayaks and canoes. Commercial sea kayaking and canoeing operations are located in St. Martins, Alma, Cape Enrage and Hopewell Rocks (Tourism New Brunswick, 2003) and there is only one wharf at Belliveau Village remaining in the estuarine portion of the Assessment Area. There is some recreational boating below the causeway, which is mostly limited to kayaking and canoeing. Generally, powerboats only operate below the Stoney Creek confluence (approximately 20.2 km below the causeway) due to low water conditions at low tide (Cormier, pers. comm.).

The headpond up to Salisbury supports a range of recreational boating activities but these are constrained by the shallow water of the headpond. The Tri Community Marina in Riverview is owned by its members and provides docking facilities for 22 boats (17 power boats and 5 sailboats in 2005). It has been in operation for six years. In 2005 there is a waiting list of 14 boat owners. The adjacent public launching facilities are operated by the Tri Community Marina for the Town of Riverview. The public launch is used by other recreational boaters, including hunters that proceed up the Petitcodiac River during the fall bird hunting season. On weekends in the summer up to 80-100 people can use the facility, and the Tri-Community Marina hosts sailboat races, weather permitting. Headpond boating activities include cruising, sailing, kayaking, water skiing, fishing and hunting using small, shallow-draft boats. There is an annual bass fishing tournament hosted by the Tri Community Marina that serves local area participants. Other recreational boating activities, including powerboat racing and dragonboat racing, have taken place on the headpond. The last power boat race occurred in 2001 and the last dragonboat race in 2003 (Cormier, pers. comm.). Other passive recreational boating activities on the headpond include windsurfing, canoeing and kayaking. Kayak rentals are promoted from the public launch in summer. The headpond area also supports the sea cadet sailing program,
operating since 1975. The cadets have their own facility where they house 15 small, shallow-draft sailboats. Recently, the sea cadet program was moved from the public launch area to a new facility constructed next to the Riverview tennis courts, also on the headpond.

5.9 Land Use and Value

5.9.1 Land Use

By all indications, there was a clear pattern of land use growth established in the Assessment Area (as described in Section 4.7) prior to the construction of the causeway across the Petitcodiac River. This pattern included the concentration of industrial and commercial development in the urban areas of the City of Moncton, while the communities of Dieppe, Riverview, Coverdale and Salisbury were transforming into suburban communities as the general availability and use of the automobile increased in the 1950’s and 60’s. In addition, forestry and agricultural activities continued in the rural areas. Dykelands have been important for agricultural purposes since early Acadian settlers installed the first dyke and aboiteaux systems. This fertile agricultural system was one of the primary reasons that the region experienced development. More information on dykelands is provided in Section 5.6.4. By the early 1960s the area had experienced substantial growth and according to the 1966 Census, the population of the City of Moncton had reached 45,847 and the population of the Town of Dieppe was 3,847. The Town of Riverview was yet to be created.

The City of Moncton, the City of Dieppe and the Town of Riverview have their own master plan and zoning by-laws that have been approved by the Province; and therefore, they have responsibility for their own land use planning issues. The Greater Moncton Planning Commission administers land use planning and management for the largest part of the area, which includes the western portions of Albert and Westmorland Counties. The Beaubassin Planning Commission administers land use planning and management for the Dieppe area (outside the City of Dieppe). Land use planning and management for the Dorchester-Memramcook area is administered by the Tantramar Planning Commission. As a result of good land use planning and management, the communities in the Assessment Area appear to have grown in an orderly fashion.

Current land use within the Assessment Area includes activities that are discussed in the Vessel Traffic and Navigation VEC (e.g., recreational boating), the Tourism VEC (e.g., bird watching) and the Recreation VEC (e.g., float planes).

5.9.2 Land Value

The median value of the 3,488 occupied dwellings located in Albert County rose from $6,829 in 1961 to $13,921 in 1971. During the same time period, the median value of the 22,568 occupied dwellings located in Westmorland County rose from $7,500 to $11,774. In the City of Moncton, the median value of the 11,605 occupied dwellings rose from $11,129 in 1961 to $16,299 in 1971. When the median values are converted to current dollars, these residential property values still increased between 1961 and 1971, however, it is noted that the amount of increase between 1961 and 1971 was substantially higher in Albert County at 53% than it was in Westmorland County at 19%. It is possible that this increase is due, in part, to the growth of
the suburban area of Riverview following the opening of the causeway in 1968. It could not be discerned from the available data if the presence of the Petitcodiac River had any effect on the value of property located in close proximity to the river prior to the construction of the causeway.

There has been substantial growth in the property tax base between 1968, when the causeway was opened, and 2004. Adjusting the 1968 total tax base to current dollars, it appears that there has been about a threefold increase in the property tax base during the intervening time period. The number of occupied dwellings located in the Assessment Area increased between 1996 and 2001, however, it appears that the amount of increase in the communities of Riverview, Dieppe, Moncton and Salisbury did not keep pace with inflation. Since the 2003 Census, it appears that values have continued to increase in at least portions of the Assessment Area. The value of property other than residential dwellings has also appeared to increase steadily during recent years.

The value of woodland located within the Assessment Area rose substantially during the 1990s. However, values of this class of property appear to have remained steady in recent years. Similarly, the value of farmland located in the Assessment Area does not appear to have changed substantially in recent years. Therefore, in all general categories of property located within the Assessment Area, it appears that values have continued to increase up until the present. However, it is recognized that this level of increase may not have kept pace with inflation in certain sub-sectors of the market.

In an effort to determine if the presence of the Petitcodiac River has had any effect on the value of property located in close proximity to the river, sales data from the Assessment Area were collected and analyzed. A total of 5,594 transactions were gathered from a provincial database compiled by Service New Brunswick (SNB). 1,504 of the transactions involved the sale of vacant land of varying type and parcel size. The balance of transactions involved the sale of properties that were improved with some type of building(s), such as residential dwellings, farm structures, commercial office complexes, industrial facilities, etc. All of the transactions that occurred between the beginning of 1998 and the end of 2003 were located in the Assessment Area.

In order to establish a baseline for comparison, the sales data were sorted to identify “pairs” of sales. The criteria for the pairing was that one of the sales would be located on the Petitcodiac River, either above or below the causeway, while the other sale would be a non-waterfront property. In an effort to isolate the influence that a waterfront location might have in a particular transaction, every attempt was made to find “pairs” of sales that were highly similar in other respects. Given the existing pattern of growth, this exercise was generally easier to conduct in the urban/suburban neighbourhoods located in close proximity to the causeway. Conversely, due to a lack of a similar development, the exercise became increasingly more difficult in the rural areas both above and below the causeway.

In order to select “pairs” of sales for use in this analysis, the 5,594 transactions that were compiled by SNB were sorted by location, property type, size and date of sale. The transactions were then subdivided into various neighbourhoods or sub-districts. The sales in
each of these neighbourhoods or sub-districts were then examined in an effort to discover any patterns or clusters of transactions.

After examining all the sales involving vacant land, it was concluded that there was only a very limited amount of data relating to non-residential land. Therefore, only sales involving individual residential lots were selected for the pairing analysis. These sales, which were located either in interior subdivisions of along public roads in the Assessment Area, ranged in price from a low of less than $10,000 to a high in excess of $60,000. In selecting the “pairs” of sales of vacant land, consideration was given to location, size and other physical characteristics such as shape and topography. A total of seven “pairs” of sales were analyzed.

Similar to the sorting of the sales involving vacant land, an examination of all of the sales involving improved property (a total of five “pairs”) did not reveal a significant amount of meaningful data involving non-residential property. Therefore, only sales involving single-family dwellings were selected for the pairing analysis. These sales, which were generally located in interior subdivisions along or in close proximity to the river, ranged in price from a low of less than $100,000 to a high in excess of $250,000. In selecting the “pairs” of sales of improved property, consideration was given to the location of the dwelling, size of the lot, size of the dwelling and the age/class of the dwelling.

After identifying and analyzing the seven “pairs” of sales that involved vacant land it was concluded that the enhancement of a waterfront location may have a positive influence on the value of certain vacant residential lots located above the causeway (from Moncton to Salisbury). However, the available evidence does not support a similar conclusion for vacant lots located below the causeway (from Moncton to Shepody Bay). After taking into consideration differences in value as the result of changing market conditions over time and varied physical characteristics, an enhancement in the order of 10% is indicated for comparable lots above the causeway. However, an enhancement in the order of 5% or less is indicated for comparable lots below the causeway.

An analysis of the five “pairs” of sales that involved improved residential property did not reveal any evidence to support a conclusion that there is any measurable difference in value as a result of the presence of the Petitcodiac River (above or below the causeway). However, as there is a myriad of factors that can influence the prospective purchaser of an improved residential property, it is extremely difficult to isolate the influence that the presence of the Petitcodiac River may or may not have as a solitary factor.

In summary, the Petitcodiac River does not appear to have a measurable influence on the value of all categories of real property located in the Assessment Area, except for vacant residential lots above the causeway. However, it is logical to surmise that if all other factors are equal, the fact that a property is located on the Petitcodiac River could result in a positive, but perhaps nominal, influence on its value.
5.10 Past and Present Use of Land and Resources for Traditional Purposes by Aboriginal Persons

Although it is anticipated that there has been an Aboriginal presence in the Petitcodiac River area since the retreat of the glaciers over 10,000 years ago, this section will discuss the use of the lands and resources as it has been documented in the living memory of the First Nation community at Fort Folly, near the mouth of the Petitcodiac River.

Based on communication with members of the Fort Folly First Nation, the activities which members of the local Aboriginal Community have partaken in are mainly fishing and gathering, and, to a lesser extent, hunting. In addition, the Petitcodiac River was used by member of Fort Folly as a means of transportation up to the time of the construction of the causeway (Figure 5.10.1). These activities have significantly declined or been stopped altogether since the construction of the causeway due, according to the information sources (M. Knockwood, pers. comm.), to the negative environmental effects on the resources used as a result of the causeway.

Hunting activities are documented for such species as moose, deer and bear as well as a series of smaller, fur-bearing animals with bird/water fowl species being sought as well. These activities as described as having taken place within the land between the Memramcook and Petitcodiac Rivers, the current location of the Fort Folly First Nation community. Hunting also took place in the wetland areas along various shoreline locations in the headwaters of the Petitcodiac River, where although not specifically listed, it is presumed that various waterfowl species were the prime objective.

Hunting activities have also been described as taking place much further to the west, in the Caledonia Mountains, and in the lands above the Salisbury area although these areas are, for the most part, outside of the zone of influence of the Project.

The main forms of land and resource use in the zone of influence of the Project have been fishing and gathering. Fishing activities in the Petitcodiac River include such species as tomcod, brook trout, shad, dogfish, sturgeon and Atlantic salmon. Most of this activity was undertaken for personal use (i.e., food) and some recreational fishing. There is also record of members of the Fort Folly First Nation guiding both on the river for such species as salmon and sea trout, as well as on land for moose, deer, bear and duck (J. Knockwood, pers. comm.). Fishing in the Petitcodiac River has reportedly declined since the construction of the causeway, with shad and Atlantic salmon harvesting stopping altogether, due to the decline in the fish stocks using the river. Currently some brook trout fishing still takes place in the Petitcodiac River. Lobster fishing boats, which fish in the Shepody Bay/Bay of Fundy area are launched from Parrsboro, although this area and activity are outside of the zone of influence of the Project. The freshwater headpond, created by the construction of the causeway, has resulted in the presence of various freshwater species, such as smallmouth bass however, there is no record of these species being exploited by members of Fort Folly First Nation.
Gathering typically refers to collecting various plant species and is reported to have taken place and continues to take place in the wetland areas along the shorelines of the Petitcodiac River, although reportedly at a reduced level. Species reported as being traditionally gathered include fiddleheads, cattails, sweet grass, Labrador tea, e’psemosi, cedar, pearly everlasting, various edible grasses and many others. This activity would be seasonal and would vary from species to species, depending upon the appropriate gathering time for each. These species are gathered for food, crafts and medicinal use. Some species, such as various edible plants and sweet grass are no longer available in their traditional locations and are sought further down river. The newly developed mudflats along the Petitcodiac River are not used for gathering activities. Timber was also harvested along the Petitcodiac River before the construction of the causeway.

There is no recorded use of the causeway headpond area by members of the Aboriginal Community. Overall traditional use of the Petitcodiac River and its shoreline areas has reportedly declined since the construction of the causeway, due to the decline in the presence and availability of the species sought.

5.11 Tourism

The GMA has historically served as a service centre for the tourism and visitor industry within the Assessment Area (as described in Section 4.7). It has and continues to serve as a transportation hub for both passengers and freight. Tourism literature in the late 1960’s identify local and area attractions, such as the high tides of the Petitcodiac River (e.g., the Tidal Bore), Shediac Beach (Parlee Beach Provincial Park), Magnetic Hill, Fundy National Park and Hopewell Rocks, as the major natural attractions of the area. Other visitor attractions include the parks, museums, bird watching, shopping, restaurants, game farm and golfing. The 1969 Atlantic Development Board reported that in 1966, the Steeves Mountain Provincial Park received about 16,700 visitors and 6,000 campers. Parlee Beach Provincial Park had 227,500 visitors and 20,300 campers that year. Magnetic Hill had 36,000 visitors in 1966.

The Fundy tides and the tidal bore were promoted by both Greater Moncton and the provincial government. There are no data identifying the number of visitors that viewed the tidal bore or specifically came to the GMA to experience the tidal bore or Petitcodiac River tides. However, it is common knowledge that the tidal bore had been an attraction. During the public consultation process, local residents pointed out that it was common to centre family activities on sighting the bore, especially when being visited by out-of-town family and friends.

Tourism is a major industry in New Brunswick and the GMA. Total tourism expenditures in the Province reached $1.1 billion in 2003. This economic sector is estimated to be responsible for 31,000 person years of employment generating $272 million in tax revenues. The Province had 1.9 million non-resident visitors in 2003 (Province of New Brunswick, 2004). Three of the 29 provincial “must see and do” attractions listed by the New Brunswick Official Travel Guide are related to the Inner Bay of Fundy: Hopewell Rocks; Fundy National Park; and Cape Enrage. It is estimated that total provincial tourism expenditures in 2002 were $1.2 billion and Moncton accounted for over 28% of this total (New Brunswick Tourism and Parks, 2004).
importance of the GMA and surrounding area would be even greater in terms of the provincial tourism sector.

New Brunswick Tourism and Parks (NBTAP) recently released the results of its assessment of the development opportunities within the tourism sector and identified three categories of experience that should be the priorities for the New Brunswick tourism industry: coastal, natural wonders and heritage and culture (NBTAP, 2004). The Petitcodiac River and Bay of Fundy clearly offer or have the potential to offer such experiences as wildlife viewing and bird watching, boat tours, lighthouses, covered bridges, beach access, canoeing, kayaking and fishing. During the public consultation process there was a report of occasional float plane use of the headpond by tourists.

5.12 Recreation

Recreation in the Assessment Area prior to causeway construction included recreational fishing and bird watching. The Petitcodiac River pre-causeway recreational fishery principally included Atlantic salmon, rainbow smelt and American shad (Blakney, pers. comm.). Other species included brook trout, Atlantic sturgeon, American eel and Atlantic tomcod. The most popular bird watching areas during the pre-causeway period included Marys Point and Memramcook River, primarily focusing on shore birds unique to mudflat areas.

Recreational fish in New Brunswick include Atlantic salmon, various types of trout and smallmouth bass. Other fish, such as American shad are not defined as recreational fish. The current recreational fishing in the Petitcodiac River system is focused on smallmouth bass, chain pickerel (both non-indigenous) and brook trout above the causeway and tomcod and striped bass in the lower Petitcodiac River estuary. There is an annual smallmouth bass fishing tournament in the headpond. There are other “non-sport” species of fish involved in the recreational fishing, such as American shad below the causeway. A recreational Atlantic salmon fishery existed below the causeway for a number of years after the causeway was completed (Blakney, pers. comm.).

Current bird watching is a year round activity and is popular with residents and visitors. The GMA provides numerous opportunities for bird watching including the Petitcodiac River and its watershed. The Moncton Naturalists’ Club is an active supporter of this activity and published a guide to Birding in the Moncton Area (Moncton Naturalists Club, 1996).

All three communities (Moncton, Riverview and Dieppe) have constructed walking paths along the Petitcodiac River below the causeway. In addition to the trails along the river, there are also trails along Fox Creek, Jonathan Creek, Halls Creek and Mill Creek. The Trans-Canada Trail also uses both shores of the Petitcodiac River. The trail extends to the West on to Hillsborough and Fundy National Park and to the east towards Sackville, Nova Scotia and Prince Edward Island (Merlin, 2003).
Other summer recreational activities that take place in the headpond include:

- recreational boating and a marina located on the Riverview side;
- hydroplane racing;
- swimming;
- a dragon-boat regatta;
- float plane access;
- sailboat racing; and
- kayaking.

Other winter recreational activities that take place on the headpond include:

- cross-country skiing;
- snowmobiling;
- skating; and
- dog-sledding.

Other recreational activities that take place below the causeway include:

- recreational boating (including canoeing and kayaking);
- tour boats; and
- harbour porpoise/seals viewing.

5.13 Labour and Economy

The GMA economy in the 1950’s and 60’s was dominated by such employers as CN Railway and other transportation and distribution companies. In the 1950’s, CN Railway was directly or indirectly responsible for employing approximately 25% of the Greater Moncton labour force (Enterprise Greater Moncton, 2003). By 1971 (post-causeway construction), the major industries, in terms of employment, were service industries along with retail and wholesale businesses, transportation, communications and manufacturing. Resource industries, including farming, fishing, forestry and mining, accounted for less than 1% of the employment.

The pre-causeway period was characterized by a decline in farming in Albert and Westmorland counties. Construction of the causeway has provided protection for agricultural land, which supports a range of agricultural operations including crop production and livestock operations.

The pre-causeway period supported an active commercial fishery in the Petitcodiac River and the Bay of Fundy. Lobster was the dominant species accounting for 75% of the value of commercial landings. Other commercial fisheries were Atlantic salmon, American shad and gaspereau. Currently, the Assessment Area (as described in Section 4.7) includes an active commercial fishery, primarily focused on lobster and scallops. In addition there are other commercial fishing activities, including American eels and American shad. The largest
concentration of fishery related employment within the Assessment Area is in the Alma, Harvey Parish and Hopewell Parish areas (Statistics Canada, 2001).

The Moncton Census Agglomeration (MCA) population represents over 98% of the population within the Assessment Area (117,727 in 2001). The MCA is among the fastest growing areas in New Brunswick. It experienced a population growth of 3.7% between 1996 and 2001 compared to the provincial population which decreased 1.2% over the same period. Approximately 58% of the MCA population had earned income in 2001 versus 53% for the provincial population. Over 37,000 persons, or 32% of the MCA population worked full time versus 26% of the provincial population. Average earnings for the MCA are slightly higher than the provincial average, but earnings for full time workers were almost the same as the provincial average. The MCA has a substantially higher participation rate and employment rate than the Province. This has led to a lower unemployment rate (2001) of 8.1% versus 12.5% for the Province. The service sector (business and other services) is the largest sector for the MCA, employing 27,400 people and accounting for 42% of total employment. Other major MCA industries are wholesale and retail, health and education and manufacturing and construction. Agriculture and other resource based industries account for only 1.5% of total employment. This industry sector includes agriculture, fishing, forestry and mining. The MCA has a relatively small resource based industry compared to the Province. Resource based industries account for 7.5% of the provincial employment. The principal occupations for the MCA labour force include sales and service occupations (27% of total labour force), business, finance and administration occupations (22.5%) and trades, transport and equipment operators (13.5%).

5.14 Heritage and Archaeological Resources

As noted in Section 5.10, it is likely that the Petitcodiac River has been the site of human activity for close to 10,000 years. As one of the largest waterways in southeast New Brunswick, it would have been a major focal point for transportation and travel, in addition to providing an excellent location for settlement, both temporary and permanent by all peoples living in the area. During the Pre-contact period, the indigenous groups living in the areas that would become New Brunswick and Nova Scotia, the Mik’maq and Maliseet, would have used this river for transport and resource and food procurement. The shorelines of the river would have been their habitation sites and the start of portage routes from this river to many of the other waterways in the area (Ganong, 1899; Larracey, 1995). To date, however, no comprehensive archaeological survey or testing of the Petitcodiac River shoreline has been conducted. Therefore, the quantity and quality of pre-contact archaeological sites from this timeframe has not been studied.

With the arrival of European populations in the Petitcodiac River area, it appears that the dispersal of settlements of Aboriginal people became more limited to the areas at Beaumont and around Dorchester (Kristmanson, 1994). Historical evidence (Ganong, 1899) suggests that a sizeable Aboriginal campground may have existed at the bend in the Petitcodiac River, near Halls Creek. This site was eventually settled by European inhabitants, and became the City of Moncton, displacing the Aboriginal population.

The earliest record of Acadian settlement in the area of the Petitcodiac River is from 1698, by an individual named Pierre Thibodeau. The Acadian population grew along the Petitcodiac
River, founding settlements at Fox Creek, Moncton, Hillsborough and Coverdale, amongst others. They cleared and farmed the land along the banks of the river, and successfully reclaimed the marshlands along the Petitcodiac River shorelines through the use of earthen dykes and wooden aboiteaux. Many fragments of these wooden structures still exist along the current river shorelines.

The first non-Acadian permanent settlement on the Petitcodiac River began with the arrival, on June 3, 1766, of Pennsylvanian German immigrant families to “The Bend”, at Moncton. These families spread out into Moncton and Hillsborough, and created farming communities, and these areas were later the source of successful retail and shipbuilding industries. In the 1770s, the second wave of European settlers arrived in the area from England, Scotland and Ireland. After the American Revolution of 1776, a number of people that had chosen to remain loyal to the King of England left the former Colonies of New England and also settled in the area. It was during this period that much of the settlement began to expand away from the shoreline areas of the river, with the riverbank being used more for industry and shipping ports.

By the mid 1800s, the area where the downtown portion of the present City of Moncton is located had become an established seaport and trading post whose primary trade was the export of lumber hewn in local forests to various markets in Europe. The seaport’s secondary trade was the import of manufactured goods for the local residents along the river and the “back” settlements, such as Scotch Settlement and Irishtown. In the 18th and 19th centuries, shipbuilding became a lively industry along the Petitcodiac River, and an 1863 map of the area shows three large shipyards located in Moncton, west of Halls Creek, and a substantial number of wharves. There is also documentary evidence suggesting that at least two shipyards were located at “The Bend”.

In the 1970’s and 80’s, a historic (pre-1914) standing building survey and mapping project was conducted by the Province of New Brunswick to establish an inventory of historic buildings in New Brunswick, as part of a larger inventory of historic buildings in Canada. According to this mapping, there are more than 10 buildings pre-dating 1914 located within 1 km of the banks of the Petitcodiac River, from Gunningsville to Hopewell Cape.

According to Parks Canada, there are 13 recorded shipwrecks in the Petitcodiac River. These ships were constructed between 1846 and 1901, some at shipbuilding facilities along the river itself, and the last recorded wreck sank in 1929. Many of these wrecks sank in the river near Dover and Moncton. This number does not, however, likely reflect the true number of shipwrecks for this waterway, as this information is dependent upon archival information, and is incomplete. As the Petitcodiac River was a thriving center for shipbuilding in the 18th/19th century, it is probable that many other ships were scuttled or sank of their own accord in and around the shipyards. Additionally, the large tidal flats and the large tidal currents and bore (particularly near the mouth of the Petitcodiac River) regularly threatened the safety of ships in the area.

It is highly probable that a substantial number of unrecorded and/or unidentified archaeological sites still remain along the Petitcodiac River after the construction of the causeway. However,
the ongoing process of urban renewal, and the continuing growth of the towns and cities along the Petitcodiac River may have covered or otherwise affected some Aboriginal Communities and historic period archaeological sites. The construction of the causeway did not cause any known erosion of the Petitcodiac River shoreline below the causeway itself, and therefore no causeway induced changes to archaeological and heritage resources are anticipated for the post-causeway period. The current headpond water levels are similar to the pre-causeway high tide water levels. Therefore, the presence of the causeway has not likely had any negative environmental effects on unknown archaeological sites in the headpond area due to flooding.

The only known locations of archaeological or heritage features that occur within the confines of the Petitcodiac riverbanks (e.g., within the wetlands or mudflats) are the wooden aboiteaux and dyke structures of the Acadians. There are also shipwrecks within this area, however, the locations of these wrecks are not known.

5.15 Public Health and Safety

5.15.1 Vehicular Accidents

There were little data available on vehicular accident rates for pre-causeway conditions.

Currently, the highest traffic accident levels have been experienced in the urban area of the GMA. The LOS on the causeway and Gunningsville Bridge is Level F and E, respectively (see Section 5.7.3), leading to the current construction of a new bridge adjacent to the Gunningsville Bridge that will come into service in 2005. Although not the highest in the Assessment Area, accident occurrences on the causeway and Gunningsville Bridge are relatively high. There were no fatal accidents on either the causeway or the Gunningsville Bridge from 2001 to 2003. Property Damage and Personal Injury vehicle accident rates on the causeway were 57.0 and 43.4 accidents per 100 million vehicle kilometers (Acc/100MVK), and on the Gunningsville Bridge, 86.2 and 49.7 Acc/100MVK, respectively.

5.15.2 Non-vehicular Accidents

There are no available records or any available data on non-vehicular accidents or incidents in or near the Petitcodiac River before the construction of the causeway.

Only non-scientific information could be obtained regarding non-vehicular incidents or accidents in or near the Petitcodiac River post-causeway construction. One source indicated that boating accidents and other non-vehicular accidents are not known for the headpond and a gate operator was unaware of any gate operation incidents or accidents within the last 14 years (Colepit, pers. comm.). Apparently, every 2 or 3 years there have been near-death incidences involving people getting stuck in the mud downstream of the causeway. There was a mud-related accident near Halls Creek on July, 14 1986; a sailor from France got his boat stuck in the mud, as he was unaware that the river was not navigable (Times Transcript, July 14, 1986).

5.15.3 Groundwater

In 1960 and 1961, fifty-eight groundwater samples from fractured bedrock in the Moncton map-area were analyzed for chemical composition (Carr, 1968). Although one well exhibited sodium
and chloride levels above the CCME (2002) Drinking Water Quality Guidelines (200 mg/L and 250 mg/L respectively), the high levels of sodium and chloride were likely attributable to the chemistry of the rock formation in the area. In addition, 12 boreholes were drilled within the GMA to determine the intersection of saltwater within the bedrock. Carr (1968) reported that saltwater intersections were observed at depths ranging from 76 to 520 m.

A hydro-geochemical (groundwater chemistry) survey of southeastern New Brunswick was conducted in 1992 and 1993 and published by the Geological Survey of Canada (Boyle et al., 1994). Groundwater samples were generally collected from the kitchen taps of residential water supplies. Results of this survey indicated sodium levels within the survey area varying from 1 to 1,666 mg/L. The results also indicate that sodium levels observed in wells located along the Petitcodiac River varied considerably. It is interesting to note from these results that higher sodium levels were observed along the Petitcodiac River upstream of the causeway. However, these levels were all below the Canadian Drinking Water Quality Guidelines, with the exception of small areas near Coverdale and Salisbury.

Boyle et al. (1994) also reported chloride levels ranging from 1 to 2,664 mg/L. It is noted from their results that chloride levels in wells located along the Petitcodiac River upstream and downstream of the causeway exhibited similar trends to those of sodium levels. Although most of the wells had chloride levels below the Canadian Drinking Water Quality Guidelines, a few wells upstream of the causeway, near Coverdale and Salisbury, reported levels above the Guidelines and consistent with the sodium observations. It is also interesting to note that sodium and chloride levels in wells in close proximity to the Petitcodiac River downstream of the causeway were well below the Canadian Drinking Water Quality Guidelines. These results may reflect:

- the presence of marine sediments within the largely continental carboniferous clastic sediments of the region;
- the occurrence of salt deposits;
- areas within the saltwater-groundwater interface; or
- the effects of postglacial marine incursions.

5.15.4 Surface Water Resources

The Petitcodiac River received sewage and wastewater for decades pre-dating the construction of the causeway. More detailed information regarding the pre-causeway sewage infrastructure and water quality is provided in Section 5.4 (Fish and Fish Habitat VEC) and Section 5.6 (Municipal Services and Infrastructure VEC).

Due to the disposal of sewage, urban and agricultural runoff and sedimentation caused by the construction of the causeway in 1968, the Petitcodiac River and headpond have experienced high levels of pollution and been subject to serious stress (GMSC, 1999). Between 1984 and 1994 the GMSC designed and built a wastewater collection and treatment system to serve the three area municipalities. The outfall from this treatment facility is situated downstream of Outhouse Point on the south shore and the effluent from the treatment is discharged to the
Petitcodiac River (see Municipal Services and Infrastructure VEC Section 5.6 for more detailed information).

5.15.4.1 Bacteria Upstream of the Causeway

Fecal coliform and *E. coli* bacteria do not directly affect aquatic life, but are indicators of water quality as they imply the degree of contamination by human or animal waste and the potential for transmission of microbial pathogens to aquatic animals that may be associated with these wastes. It is an important key variable to assess and as a key indicator for issues related to sewage, outfalls and tributaries.

NBDELG (1976) measured fecal coliforms in the headpond along the Riverview side upstream of the causeway. More than 50% of the area studied on August 24, 1976 had fecal coliform counts in excess of the recommended level for body contact use (200 counts/100 mL). The source of this contamination was found to be mainly surface runoff of untreated waste from local residential dwellings, and not coming from upriver or from downstream of the causeway. Extreme high values (69,000/100 mL) occurring at one station east of Riverview Heights in particular was traced to a nearby overflowing storm sewer. On another occasion, NBDELG (1999) measured fecal coliforms and *E. coli* in 1997 and 1998 along transects in the headpond during the summer and fall for the Trial Gate Opening Project. They observed that *E. coli* was higher in 1998 than 1997 and indicated that this increase could be a result of normal annual variations. NBDELG (1999) also observed a pattern of upstream to downstream increase in both fecal coliform and *E. coli* counts, but which was not as evident in 1998. In addition, fecal coliforms and *E. coli* exhibited a rising trend through summer and into the fall of 1997, but declined in the fall of 1998. It is suspected that the observed variations may have been due to the fluctuating nature of bacteria populations, the presence of local sources, sampling error, or lab error.

5.15.4.2 Bacteria Downstream of the Causeway

Hydro-com (2000) conducted a cross section survey of the Petitcodiac River downstream of the causeway at Gunningsville Bridge for water quality, including bacteria (*E. coli and Enterococcus*), at high tide and low tide on November 24, 1999. However, it should be noted that infilling within the river channel is near its peak during November, and that the tidal prism would therefore be near its lowest volume. This would result in the discharge from sewage treatment facilities comprising a greater percentage of the total river water volume below the causeway. It is not know if the gates were open or closed during the survey to assess potential effects of upstream flow through the gates on downstream water quality. In their study, Hydro-com also incorporated water quality data collected by NBDELG and Environment Canada from samples taken at the causeway and along stations of the Petitcodiac River down to the confluence with the Memramcook River. The data was collected on October 28, 1999 at high tide and low tide with the use of a helicopter. Cross-sectional sampling beneath Gunningsville Bridge revealed overall well-mixed water quality parameters (DO, temperature, pH, Total Dissolved Solids (TDS), specific conductance, turbidity) both vertically and horizontally. Average values calculated for the cross section revealed a drastic increase in the bacteria count (both *E. coli and Enterococcus*) immediately following the passage of the tidal bore, and a less severe increase at approximately 15:00 hrs when the tide started to ebb. Further, TSS and total
phosphorus concentrations also closely followed this trend. There was also an increase in the chemical oxygen demand during high tide conditions. TOC, however, decreased during high tide conditions. These results suggest the high correlation between the bacteria counts and TSS levels may indicate that the sediment on the channel bed of the Petitcodiac River is a substantial source of water quality “contaminants”. The mobile nature of the channel bed is also suggested as a sink of sorbed water quality parameters on the basis that phosphorus, a highly sorbed chemical, is closely correlated to the TSS levels, while nitrogen, a highly mobile chemical, does not appear to be correlated to TSS levels.

It was noted that at low tide conditions, six peaks in the Enterococcus counts were observed at various locations along the Petitcodiac River. These peaks were located immediately downstream of the causeway, and at 7 km, 15 km, 28 km, and 35 km downstream of the causeway. There was no joining trend to these peaks because they did not follow each other and were interspersed by a sampled location containing substantially reduced bacteria counts. In addition, the bacteria counts downstream as far as 35 km and at the mouth of the Petitcodiac River had Enterococcus counts that exceeded 2,000/100 mL and were similar to counts at the causeway (the acceptable CCME Canadian Recreational Water Quality Guidelines and Aesthetics for Enterococcus is equal to or below 35/100 mL). The other peaks had similar trends and concentrations and it was suggested that the downstream peaks are associated with separate effluent sources (Hydro-Com, 2000). The trends and peaks for TSS and total phosphorous concentrations were found to also follow closely that of Enterococcus, but not total nitrogen or nitrates-nitrites except for a localized nitrate-nitrite peak approximately 7 km downstream of the causeway.

Under high tide conditions, a single peak in Enterococcus counts was observed at approximately 2 to 4 km downstream of the causeway. Peaks that were observed during low tide conditions at approximately 15 and 22 km downstream of the causeway were not present during high tide conditions. The bacteria count of the Enterococci peak at high tide was 300/100 mL, and 1/6th less than the bacteria count during low tide conditions. This trend was again followed closely by both the TSS and total phosphorus concentrations. There was a gradual decrease in TOC concentration from approximately 8.5 mg/L near the causeway to approximately 2.5 mg/L about 22 km downstream of the causeway. During low tide, TOC was also 8.5 mg/L near the causeway to approximately 4.5 mg/L near the confluence with the Memramcook River. Localized peaks were observed for both total nitrogen and nitrate-nitrite concentrations at approximately 4 km downstream of the causeway. It is possible that the limited area of influence for the nitrate-nitrite peaks is related to the state of the tide and location of the GMSC’s outfall.

Cammen and Walker (1982) investigated the distribution of suspended bacteria (free-living bacteria and attached bacteria to suspended sediments) in the Bay of Fundy on DFO research vessels in the spring, summer and fall of 1979. They sampled at a total of 22 stations throughout the Bay at the surface, mid-water and bottom. All bacteria in the water samples were preserved and then counted. They noted that free-living bacteria dominated the lower Bay of Fundy in all seasons, whereas the attached bacteria were more important in the upper reaches of the Bay of Fundy (Shepody Bay, Chignecto Bay and Cumberland Basin).
attached bacteria in the upper reaches of the Bay accounted for up to 94% of the total bacteria. Further, both the abundance and proportion of attached bacteria were strongly correlated with the concentration of TSS. This study tends to support and confirm the findings of Hydro-Com (2000) that, in general, higher bacterial counts would be expected with higher TSS in the water.

The above investigations suggest that bacteria in the estuarine and marine waters downstream of the causeway are likely to be mostly attached bacteria to suspended sediments, the concentration of which is highly correlated to the concentration of suspended sediments. Total phosphorus also appears to be correlated with suspended sediment concentrations, but not total nitrogen or nitrates-nitrites. The arrival of the tidal bore increases the concentration of suspended sediments, which most probably is a result of re-suspension of riverbed sediments attributed to higher bottom velocities during the passage of the bore. After the bore passes, the bottom water velocities decrease and so do the concentration of suspended sediments. Therefore, bacteria counts also increase with the passing of the bore, but then decrease after the bore has passed as was observed by Hydro-Com (2000). The concentration of suspended sediments and bacteria increases on the ebbing tide as well, and most likely as a result of also higher bottom velocities associated with an ebbing tide that lead to resuspension of bottom sediments. The spatial trend for the Petitcodiac River downstream of the causeway to the confluence with the Memramcook River also revealed that on a low or ebbing tide, suspended sediment and bacteria concentrations are elevated and highly correlated. However, on a flooding or high tide, suspended sediment and bacteria concentrations are much less than that for low tide, and about 1/6th that of bacteria counts at low tide conditions (except for when the bore is passing as indicated above). Peaks in bacteria counts were observed at low tide that did not all appear to be correlated to one outfall or effluent source. These peaks, however, are found in the vicinity of the location of sewage outfalls situated along the bank of the river. This suggests that mixing is not necessarily complete during one tidal cycle, and may require several tide cycles before complete mixing is achieved.

5.15.4.3 Other Surface Water Resource Use

A recent forest fire near Riverview in the summer of 2004 identified the use of the headpond as a proximal location for water bombers and helicopters to obtain water, although this is an infrequent source for water. Previous to this incident, the headpond has been used on occasion by the Town of Riverview Fire and Rescue to train for fire fighting and rescue services and as an emergency fire fighting water source during draught conditions for the Town of Riverview and the City of Moncton. However, there are no designated water bodies in the Province for refilling water bombers. There are two acceptable water sources near the headpond, the Bay of Fundy and Shediac Bay. Furthermore, chemical fire retardants, such as foam, are generally more effective and are often used instead of water.

5.15.5 Human Disease Vectors

Research did not identify any information on human disease vectors pre-dating the causeway.

In 1998 and 2000, a study revealed that the marsh-type areas in the Petitcodiac River provide perfect conditions for mosquito reproduction, as the waters are stagnant, providing good habitat (EMWG, 1998). Above average larvae densities were encountered during a 1999 monitoring
program within the Outhouse Point Marsh in Riverview and the marsh within the outlying areas in St. Anselme. Larvicide spray programs have been in place since 1997 within the Tri-Communities to attempt to control larva densities.

West Nile Virus is spread by the Culex mosquito species, which have fed off the blood of infected birds. The Culex mosquito species can reproduce in salt marshes, but prefers freshwater marshes (Rutgers University Mosquito Homepage, http://www.rci.rutgers.edu/~insects/sp11a.htm). Monitoring of a selected bird species, namely the red-winged blackbird, revealed little change and general stability in the bird population.

In August 2004, mosquito pool surveillance data indicated zero confirmed positive mosquito pools in New Brunswick (Health Canada, 2004). In 2004, there were zero clinical cases for humans reported in New Brunswick (Health Canada, 2004). According to the New Brunswick Health and Wellness internet site (www1.gnb.ca/0600/west_nile_public/humans-e.asp), the first case of West Nile virus infection in a human in New Brunswick was detected in November 2003, however the subject in this case was determined to have contacted the disease outside of New Brunswick; and no person has tested positive for West Nile virus infection in New Brunswick in 2005.

According to the New Brunswick Health and Wellness internet site (www1.gnb.ca/0600/west_nile_public/deadbirds-e.asp?year=2003) West Nile virus was first detected in New Brunswick in a crow on July 16, 2003; and a total of 6 dead birds tested positive for West Nile virus in New Brunswick in 2003.

No bird has tested positive for West Nile virus in New Brunswick in 2004 or 2005.

5.15.6 Flooding and Flood Risk

Prior to construction of the causeway, some areas proximal to the river or its tributaries in the Assessment Area were prone to occasional flooding during higher than normal or storm tides, or resulted in failure of the dyke infrastructure. Pre-causeway conditions were such that the tidal flow was less restricted than the post-causeway or current conditions. The channel was 800 m wide with an average tidal range of 6 or 7 m at Moncton. The river had a large flow and tidal exchange.

The construction of the causeway resulted in the gradual but definite narrowing of the river channel, reducing its conveyance capacity. The main channel is currently approximately 200 m wide. The tidal flushing does not keep the main channel open as compared to the pre-causeway condition, and all adjacent creeks have narrowed and marshlands have filled in (Touchie, 1994). The dykelands below the causeway are prone to flooding during extreme tides or as a result of infrastructure malfunction, which has been made worse since causeway construction due to the narrowing of the main channel and tributary channels. There are potential flooding problems associated with the operation of the gates in the causeway, as a result of sediment build up against the gates in periods when they are not operated, and by the potential for estuarine and river ice to accumulate and result in an ice jam at or in the vicinity of
the gates. Additional information regarding existing flooding events is presented in Section 5.2.6.

5.15.7 Human Food Resources

The Petitcodiac River fostered a commercial and recreational fishery during the historic period, and fish were no doubt an important food source for Aboriginal people prior to the arrival of European settlers. The Petitcodiac River was productive, hosting many migratory species including but not limited to Atlantic salmon, smelt, striped bass, sea-run brook trout, gaspereau and shad. Catches declined over the past century but Atlantic salmon and shad fisheries were actively pursued in the pre-causeway period. Although no data were available on the harvesting or level of contamination of plants in the GMA, recreational plant harvesting of samphire greens and goose tongue greens were very common in the Petitcodiac River area (AMEC, 2005c).

In the post-causeway construction period, the river experienced many alterations and consequently has been unable to support the species richness characteristic of pre-causeway conditions. Chapter 6 provides a detailed evaluation of the existing fish passage conditions at the causeway. The fishway did not allow species including smelts, gaspereau and shad to pass and as a result no shad or smelts would be found downstream again and the smelt fishery was terminated (Harvey, 1997). Tomcod also suffered, although currently there is a subsistence/recreational fishery in the lower Petitcodiac River estuary in the summer and fall (DFO, 2000). Salmon were able to navigate the fishway though with great difficulty. Throughout the 1970s, the majority of migratory fish stocks declined annually with a result of no returns in many cases. Poor angling landings reflected diminished populations (Harvey, 1997). Only 60 salmon were landed in 1970, which fell to 17 in 1975.

While some plant harvesting for goose tongue and samphire greens still occurs in August in the Memramcook Valley and Hopewell, it has been completely eliminated in the headpond area. The decline over the years is not attributed to the construction of the causeway, but rather due to changes in lifestyle and the passing of older resource harvesting traditions.

There are no available data on contamination of fish or harvested plants in the Petitcodiac River area.
6.0 EVALUATION OF EXISTING FISH PASSAGE CONDITIONS AND THE STATUS QUO AND PROJECT OPTIONS IN ACHIEVING THE FISH PASSAGE PROJECT OBJECTIVE

This chapter provides an evaluation of the existing fish passage conditions and an evaluation of the Status Quo and Project Options in achieving the Project Objectives. The Project Objectives are a direct derivation of that suggested in the Niles Report. The EIA Guidelines established that the modifications to the causeway, in keeping with the conclusions of the Niles Report, are intended to achieve “a long-term solution to fish passage and other ecosystem issues”. For the purpose of this EIA, the specific fish passage Project Objective was therefore defined (in consultation with regulatory authorities) as the “unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required to complete their life cycle”. Other ecosystem issues are addressed in Chapters 7, 9, 10 and 11, as applicable.

As mentioned in Section 3.5, the specific fish passage Project Objective was selected for the evaluation of the Project Options and the Status Quo. The fish passage Project Objective was determined to be the primary Project Objective because any selected Project Option must meet with the requirements of the *Fisheries Act* that have not been met since the installation of the causeway. Therefore, if a Project Option cannot restore unimpeded fish passage, then that Project Option will not be considered further in the EIA process.

In order to support the evaluation, an overview of the nine fish species that require passage at the causeway and some of their relevant biological characteristics are first provided.

6.1 Requirements of Fish Species for Passage

The fish species requiring passage at the causeway were initially identified through review of literature and consultation as identified in Section 5.4.2. This initial list was augmented through field investigations for the Biophysical Component Study as described in Section 5.4. Additional species that require fish passage but were not observed at the time of the fish field survey were identified in the early stage of this EIA through discussions with the regulatory agencies, consultation with the public and stakeholders and meetings with the Aboriginal Community. The completed list of species requiring migration past the causeway was presented to the public, stakeholders and the Aboriginal Community at the Biophysical Component Study workshop held on April 26, 2003 and at the Fish Passage Workshop held on April 17, 2004 and has been available on the website (www.petitcodiac.com) since that time. The species requiring migration past the causeway for life cycle purposes were determined to be:

- American eel (catadromous);
- American shad (anadromous);
- Atlantic salmon (anadromous);
- Atlantic tomcod (anadromous);
- brook trout (anadromous);
- gaspereau (both alewife and blueback herring) (anadromous);
- rainbow smelt (anadromous);
• sea lamprey (*Petromyzon marinus*) (anadromous); and
• Atlantic sturgeon (anadromous).

DFO, the Responsible Authority, has confirmed these species in respect of the fish passage Project Objective.

It should be noted that brook trout, although not observed at the time of the field survey, are known to use the Petitcodiac River and its tributaries for spawning purposes and are, therefore, included in the list of fish species that require fish passage.

Atlantic sturgeon is also included in the list of species requiring migration. Atlantic sturgeon spawns in freshwater. It was reported that a dead gravid (full of eggs) female Atlantic sturgeon was found in the headpond in 2001, within 100 m upstream of the causeway. It is assumed that this sturgeon migrated through the opened gates and not the fishway as the sturgeon itself was wider in girth than the fishway notch width. Also, many adult Atlantic sturgeon were captured downstream of the causeway during the netting exercise conducted as part of the field program. Atlantic sturgeon typically return to their native streams to spawn. Atlantic sturgeon have a very low rate of wandering for spawning purposes to streams other than those where they themselves were spawned. Their presence in the Petitcodiac River estuary suggests a strong likelihood of a spawning population. Atlantic sturgeon live to be older than 60 years, and possibly more than 100 years (Scott et al., 1973). Some of the sturgeon in the Petitcodiac River estuary probably developed in the headwaters of the Petitcodiac River prior to the causeway construction, others may have gained access to the headwaters in 1988 when the gates were opened between April and June. Other sturgeon may have come from the Saint John River. Based on this, there is sufficient evidence that sturgeon require passage at the causeway.

The striped bass was not included, as there was no evidence found indicating that this species spawned in the Petitcodiac River prior to or since the causeway construction. They are known to have made feeding forays into the river in the spring, but the alternative feeding opportunities for this fish species were considered adequate to preclude any negative effects on the bass population. However, striped bass have not been observed in the Petitcodiac River in several years (AMEC, 2005a). If present, striped bass will be protected by measures taken to assure passage of the other nine key species.

The species listed above were selected since they require habitat in both freshwater and saltwater to complete their life cycle and, therefore, they require appropriate fish passage at the causeway. The biology of these species has evolved so that they can take advantage of particular attributes of each habitat type in order to complete their life cycle. These fish species are termed anadromous and catadromous. Anadromous fish are those that spawn in freshwater and feed and grow predominantly in saltwater. Catadromous species spawn in saltwater and feed and grow predominantly in freshwater. All of the species listed above are anadromous except for the American eel, which is catadromous.

A unique feature of these species is that at various stages of their life cycle they can tolerate living in the freshwater or saltwater environments. When these fish undergo the physiological
changes necessary to permit survival in their new environment and are ready to migrate between the freshwater and saltwater environments, they have a very narrow window in time during which they can tolerate the movement from one to the other. Therefore, it is critical that the windows for migration be synchronized with migratory behaviours in order to ensure their survival. For example, Atlantic salmon smoltify (become physiologically capable of living in full-strength saltwater and are referred to as “smolts”) at about 10°C in rivers when they are ready to migrate to saltwater. This occurs when they are approximately 15 cm in length (2 or 3 years old). Their physiological capability to tolerate saltwater is of limited duration after which the smolts will not be able to survive in saltwater.

As noted in Section 5.4.3.1, some of these anadromous fish species serve as the intermediate host for life stages of rare or endangered species. In the Petitcodiac River system, it is strongly suspected that juveniles of the American shad serve as a host for the dwarf wedgemussel (Hanson et al., 2000), while juvenile Atlantic salmon serve as the intermediate host for the pearl mussel (Hanson et al., 1998). The absence of these fish species in the Petitcodiac River results in the absence of the dependent mussel species as well.

Fish migration is governed by several factors including time of day, length of day, season of the year, freshwater signal, water quality, water temperature, water velocity, flow direction, tide levels and the location of fish in the water column. Some fish such as Atlantic sturgeon characteristically move along the bottom, while others such as American shad and gaspereau swim at mid-depth or near the surface. Synchronization between these factors is very important for successful fish migration. Achieving such synchronization in the Petitcodiac River system is complicated by the wide variety of migratory requirements associated with the nine fish species requiring migration at the causeway. The migratory behaviour of these fish species vary greatly in relation to their spawning age, their migration patterns during the day and their time of spawning. Species requiring upstream migration at the causeway move at different times during the day and spawn during most months of the year. Figure 6.1.1 presents a fish migration chart indicating the migration times for the fish species requiring migration past the causeway. It is evident that upstream and downstream migration by the identified fish species occurs at all times during the year.

The variation in size of these fish species adds another challenge in relation to fish passage at the causeway structure. For upstream migration, the size of fish varies from 5 cm (elver eel) to greater than 180 cm (Atlantic sturgeon). For downstream migration, the size of fish varies from less than 1 cm (rainbow smelt larvae) to greater than 180 cm (Atlantic sturgeon).

The swimming ability of these fish species and, therefore, their speed of travel and their ability to withstand currents can be directly related to their size (large fish are stronger swimmers). Due to the vast difference between the sizes of the species requiring migration at the causeway, considerable difference between their swimming abilities is evident. Such large difference in swimming abilities complicates the design of an appropriate fish passage facility. The swimming abilities of the identified fish species are shown in Table 6.1.1. Sustained speed is defined as the speed that the fish can maintain almost indefinitely; while burst speed is defined as the speed that can be maintained for 5-10 seconds, to capture prey, escape predators, leap falls.
In summary, the fish species requiring migration at the causeway use both freshwater and saltwater; they travel up and down rivers; and they have different characteristics and needs. The varying characteristics and migratory behaviour of these fish species adds to the complexity of designing a fish passage facility to accommodate the needs of the nine species requiring migration at the causeway. It is important, as mentioned earlier, that all the factors governing fish migration be synchronized for the successful survival of these species.

**Table 6.1.1 Swimming Abilities of Fish Species that Require Fish Passage**

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Sustained Speed (m/s)</th>
<th>Burst Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult</td>
<td>Juvenile</td>
</tr>
<tr>
<td>Tomcod</td>
<td>0.35</td>
<td>1.25</td>
</tr>
<tr>
<td>Rainbow smelt</td>
<td>0.30</td>
<td>1.00</td>
</tr>
<tr>
<td>Gaspereau</td>
<td>0.6</td>
<td>0.15</td>
</tr>
<tr>
<td>Brook trout</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>American shad</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>American eel</td>
<td>1.5</td>
<td>0.15</td>
</tr>
<tr>
<td>Sea lamprey</td>
<td>2.0</td>
<td>0.25</td>
</tr>
<tr>
<td>Atlantic sturgeon</td>
<td>5.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Atlantic salmon</td>
<td>1.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>


### 6.2 Existing Conditions

#### 6.2.1 Description of Existing Causeway

Fish passage is a course for fish to move between and within habitat types; while a fish passage facility is a man-made structure to provide access for fish past a barrier. This distinction is necessary since fish passage implies a very broad and all encompassing system of which a fish passage facility is a component. There are a number of fish passage facility issues and challenges associated with the movement of fish through a facility. It should be noted again that the fish passage Project Objective is to provide for unimpeded and safe movement upstream and downstream of fish between aquatic habitats required to complete their life cycle. The fish passage facility at the causeway consists of two components: the fishway and the gate structure and its associated Gate Management Plan (available at www.petitcodiac.com).

The following subsections describe the fish passage facility (fishway and gate structure) and the issues associated with the fish passage facility and the overall fish passage along the Petitcodiac River.

#### 6.2.1.1 The Fishway

The existing fishway, that was intended primarily to provide upstream passage for Atlantic salmon and brook trout, has 19 pools, each 3 m long and 2.4 m wide. The drop between pools is 23 cm, and the slots are 30.5 cm wide. The drop between the pools can, however, vary in response to the difference in water surface elevation and can be as much as 40 cm for a headpond elevation of 6.5 m and a downstream water elevation of -1.5 m, or 0 cm when the two
water surface elevations are the same. The flow will also reverse in the fishway when the tides are higher than the headpond elevations. The invert elevation of the top pool is +2.6 m and the invert elevation of the lowest pool is -1.5 m. The assumed elevation of the headpond at the time of the fishway's design was +4.6 m, which was the expected normal operating level. It should be noted that the headpond operating level varied between 0 m and in excess of 6 m during its operation.

Further, due to sediment accumulation at the tail end of the plunge pool downstream of the causeway, the water elevation almost always exceeded 0.0 m. This condition decreased the water surface slope within the fishway and decreased the velocity of water and hence the flow in the downstream direction in this facility. This negatively affected fish passage. In an attempt to improve conditions, the headpond elevation was raised and operated at approximately 6.1 m in 1983.

In 1983, two additional problems at the fishway were addressed (Semple, 1983). One was that the gates leaked, and it became difficult to maintain the level of the headpond. The leakage was so severe that it distracted fish from the fishway and negatively affected the success of upstream fish passage. The leakage also occurred at high tides in the reverse direction, and significant quantities of sediment were introduced into the headpond. Sediment was also imported to the headpond at high tides in reverse flow through the fishway. The sediment deposited upstream of the causeway gates became an impediment to upstream fish passage for fish that had already passed through the fishway. Generally, adult salmon passing through the fishway would rest in the brackish water pooled between the upstream sediment plug and the gates. These fish were often flushed downstream during the next gate opening. To combat these faults, the actions described below were undertaken in the fall of 1983 (Semple, 1983).

- The walls of the fishway entrance pool (vertical slot baffle) were raised to an elevation of 8.3 m from 4.9 m. The tide could no longer overtop the fishway walls upstream of the causeway exit baffle, and reverse flow was reduced. This also caused flow to be concentrated in the vertical slot during normal (downstream) fishway flow when the tide exceeded 4.9 m.
- The fishway containment wall on the exit (upstream) end and the baffle heights of the last six pools were increased from 7.0 m to 8.1 m to contain the back-flowing tide.
- The gate slots were sealed to greatly reduce the leakage through the gate openings under all tidal conditions.
- To provide attraction water and provide an alternate means of upstream Atlantic salmon and brook trout passage, Gate 5 adjacent to the fishway was also modified. A stoplog slot was constructed on the downstream side of the gate slot. Stoplogs could be inserted into this slot. The stop log had two fish passage ports extending through it that allowed water to flow from the headpond and create a surface water attraction flow of approximately 14 m³/second (Semple, 1983). When the headpond was higher than the tidal elevation in the river, Gate 5 was completely opened and the flow from the fish passage ports provided attraction flow and an alternative entrance to the system for salmon. When the headpond was lower than the tide, all of the gates were closed.
including Gate 5. The stop log ports also provided an alternative exit for downstream migrating fish.

The use of this special stoplog structure was discontinued after 1998 because the use of the stoplogs rapidly lowered the headpond and reduced the water availability required for flushing the sediments accumulated in the headpond. It also caused a decrease in the discharge through the fishway. The fishway itself became increasingly plugged with sediments, which was displaced to the headpond during reverse tidal flow events, contributing to the upstream sediment plug (the sediment accumulation upstream of the gate structure). Since the structure was primarily intended to provide fish passage for Pacific salmon and Pacific trout, and there were very few salmon returning to the Petitcodiac River, it was also concluded that the stop log structure was not meeting its objective.

Although the vertical slot fishway design allowed the facility to operate despite variable water levels on the upstream (outlet) end and the downstream (inlet) end, the Petitcodiac River fishway had several inherent setbacks with respect to the species that are to be passed as discussed in Section 6.2.2.

Despite the improvements made in 1983 as well as intense juvenile stocking of the system, salmon counts within the system averaged only 163 fish per year from 1984 to 1989. The average was 386 fish from 1968 to 1972 indicating that the fishway renovations did not improve its performance.

It has also been documented that the decline in the recreational and commercial Atlantic salmon fisheries within the Petitcodiac River was coincident with the construction of the causeway. Recreational Atlantic salmon fishery catches have been documented for the Petitcodiac River, the Big Salmon River and the Stewiacke River and are presented in Figure 6.2.1.

As can be interpreted from Figure 6.2.1, the Atlantic salmon recreational fishery catch fell sharply after 1968 following the construction of the causeway. On the other hand, Atlantic salmon recreational fishery catches on the Big Salmon and the Stewiacke Rivers continued to remain healthy despite some annual fluctuations.

Commercial Atlantic salmon catches in the Petitcodiac River exhibited similar trends where the catch took a sharp decline after 1968, following the construction of the causeway, as depicted in Figure 6.2.2.

6.2.1.2 The Gate Structure

The gates at the causeway control structure are operated to achieve the following objectives:

- maintain the headpond level at the normal operating level of 6.1 m;
- manage the mud accumulation upstream and downstream of the gate structure;
- manage ice accumulation within the headpond;
- control open water flooding within the headpond;
• prevent saltwater intrusion into the headpond; and
• provide for fish passage at the causeway.

As noted in this list, the gates are operated to achieve several objectives as well as fish passage. It should also be emphasized that the primary objective of the gate structure is to maintain the headpond level. A summary of the fish passage elements of the Gate Management Plan (DFO and NBDOT, 2004) is outlined below.

Rainbow Smelt

• Migrate upstream in Mid-April to end of May.
• As a minimum, one gate is opened at night at least four hours before high tide if sufficient river discharge is available to maintain normal headpond elevation.
• When maximum high tide is the same as the headpond level, gates are left open for another four hours.
• Fishway open and operating.
• If gates open for longer than five hours to discharge water and prevent flooding in the headpond, the extra time will occur before high tide to prevent smelt flushing.

Gaspereau and American Shad

• Migrate upstream in Mid-May and June.
• Fishway remains open after the end of the smelt upstream migration.
• As a minimum, if there is sufficient water, one gate is opened during the daytime hours four hours before maximum high tide.
• Headpond level is maintained as close as possible to 6.1 m during large high tide (>6.3 m).
• Headpond level is maintained as close as possible to maximum high tide level during medium high tides (5.5 to 6.3 m).
• Headpond level is lowered as much as possible to the expected maximum high tide elevation during neap tides (<5.5 m).
• On the rising tide, the gate(s) is closed when the tide level gets to be at the same elevation as the headpond.

Atlantic Salmon Smolts

• Migrate downstream in Mid-May to end of June.
• A number of gates, as required, are opened at night on a receding tide only.
• The gates are opened in such a way to promote rapid drawdown “flushing” of the headpond.
• The headpond is allowed to fluctuate between elevation 6.1 and 4.5 m.
• During low freshwater flow, gates will not open on daily basis. Gates are opened every second or third day.
Summer Period

- July through to late September or early October, the fishway is closed to maintain headpond level.
- Gates operated for mud and headpond level management.

Juvenile Gaspereau

- Migrate downstream from mid-July to end of August.
- July 21 to August 31, gates are opened at night for at least 2 hours on a receding tide when tide is at the same elevation as that of the headpond.
- Mud flushing during this period is not allowed.

Adult Atlantic Salmon

- Migrate from first fall rains to mid-December.
- As a minimum, one gate is opened during the daytime four hours before high tide.
- Headpond level is maintained as close as possible to 6.1 m during large high tide (>6.3 m).
- Headpond level is maintained as close as possible to maximum high tide level during medium high tides (5.5 to 6.3 m).
- Headpond level is lowered as much as possible to the expected maximum high tide elevation during neap tides (<5.5 m).
- On the rising tide, the gate(s) is closed when the tide level gets to be at the same elevation as the headpond.

Atlantic Tomcod

- Fishway open from early October until February 15, and then closed until end of March.

The effectiveness of the gate operation is related to the timing conflict between migrating fish. For instance, Atlantic salmon smolts would be migrating downstream while shad and gaspereau are trying to migrate upstream. There is also a timing conflict between smelt and gaspereau migrations; where smelt migrate at night and gaspereau migrate during the day. These migrating timing requirements would necessitate gate operation on a continuous basis. However, there is typically not enough freshwater flow within the Petitcodiac River to satisfy such requirements.

6.2.2 Other Existing Fish Passage Issues

The AMEC Study Team has identified the existing issues associated with the migration of the identified fish species requiring migration past the causeway. These issues were categorized in relation to the headpond habitat, the fish passage facility (the combined fishway and gate operation) and the estuary downstream of the causeway, as outlined below.
6.2.2.1  **Headpond Habitat**

**Delayed Downstream Migration**

Migration delays were observed in the headpond during the Atlantic salmon smolt tagging program carried out during the field program, as noted in Section 5.4. Also, during the field program, juvenile gaspereau were observed in the headpond during October, when those fish should already have migrated to the estuary well before that date. It is anticipated that these migration delays, associated with the gate management strategy, would also be experienced by other fish species trying to migrate downstream following spawning. For example, tomcod need to migrate to the saltwater very quickly after they spawn. Therefore, a delay in migration would negatively affect that species of fish.

**Headpond Sediment Plug**

This sediment plug of approximately 6 km in length exists upstream of the causeway structure. This sediment accumulation was caused by the various gate opening experiments and continues to grow from the sediment introduced through the fishway.

Sediment accumulation upstream of the causeway further reduces the effectiveness of the gate operation in relation to fish passage because the fish that successfully migrate upstream tend to stay in the deep water near the gates. Therefore, during the next gate opening, these fish are flushed out and returned downstream of the gates.

**Predation**

Predation by American eels within the headpond could result from the delayed downstream migration of juvenile shad, gaspereau and salmon at the causeway structure. This was observed in the case of gaspereau. During the Atlantic salmon smolt migration study, six of the 16 tagged smolts that entered the headpond disappeared in the vicinity of the causeway. It is strongly suspected that these fish were consumed by predator birds.

**Poor Food supply**

It has been documented by DFO (Aube et al., 1998; Aube and Locke, 2000) that the headpond is dominated by rotifers, which are small opportunistic rapidly reproducing zooplankton of low nutritional value to juvenile fish. Larger cladocerans and copepods provide better food for juvenile fish, but have lower reproductive rates. When zooplankton numbers are knocked back by saltwater intrusion, water level drawdowns, rapid headpond flushing in the spring and high turbidity, cladocerans and copepod numbers are slower to rebound than are rotifers which do not provide satisfactory nutritional value.

6.2.2.2  **Fish Passage Facility – Upstream Migration**

**Fish Passage at Various Tide Levels**

The fishway does not allow upstream passage of fish under all tide conditions. As the tide rises, and the lowermost fishway pool drowns out, fish cannot find the entrance to the fishway. Low freshwater flow resulting in low velocity at the exit of the fishway compounds this problem at lower tide levels.
Dissolved Oxygen Deficiencies

DO concentrations below the recommended CCME Guideline were observed in the fishway and for a considerable distance downstream of the causeway in the summer.

High Suspended Sediment in the Fishway

As stated above, there is always a high concentration of suspended sediments and an accumulation of sediments within the fishway. This is occurring as a result of the backwater effect within the fishway at high tides. Sediment accumulation within the fishway contributes to the reduction of its efficiency.

High Velocity within the Fishway

Water velocity within the fishway is high with respect to several species (e.g., rainbow smelt) and sizes of fish.

For upstream fish passage through the gates, moderate velocity is only attained at lower head differential when the tide elevation approaches the headpond level. In other words, as the tide rises, the velocity in the fishway decreases. This provides for only a small window of opportunity for the fish to migrate under the gates and into the headpond.

Narrow Vertical Slot

The vertical slots are too narrow for the migration of American shad that require a slot width of at least 40 cm and Atlantic sturgeon that need a width of at least 75 cm.

Light Levels within the Fishway

There is considerable variation in light levels within the fishway caused by shading from the road overhead. The variability of light within the fishway is problematic for some of the migrating fish species, particularly the American shad. These light variations are further affected by the high suspended sediments within the fishway affecting the ability for light to penetrate the water column.

6.2.2.3 Fish Passage Facility – Downstream Migration

Gate Opening

Most of the downstream migration occurs through the gate structure. The gates are not open at all times; they are opened according to the Gate Management Plan (Appendix A) as described in Section 6.2.1.2. The gates may also remain closed for several days in response to low flow conditions. For these reasons, migrating fish must be at the gate structure at the right time to be able to take advantage of the gate opening. Fieldwork conducted by the AMEC Study Team has demonstrated that the system is not effective for downstream migration, particularly in the case of Atlantic salmon smolts.

It should also be noted that the lack of freshwater flow controls the number of hours during which the gates could remain open. Further, gate openings can force the fish away from the fishway and, therefore, deter the fish from using the fishway, because high water velocity
associated with gate openings can reach as high as 11 m/s. This is well in excess of the swimming abilities of all of the fish species requiring migration at the causeway.

**Bottom Gate Opening**

Gate opening at the Petitcodiac River control structure is achieved by lifting the gates up thereby releasing the water from the bottom. This approach may work for some fish species such as the bottom dwelling American eels and sea lamprey, but does not work well for others such as the Atlantic salmon smolts that travel near the surface of the water column (Thorpe, 1988).

### 6.2.2.4 Estuary

**Seasonal Sediment Plug**

As mentioned earlier, sediment accumulation (increase in bottom elevation) downstream and in the vicinity of the causeway can vary over a range of 4 m during the summer months. This sediment accumulation causes delay for the migrating fish in reaching the fishway; and in some instances, denies the fish from reaching the fishway. Downstream migrating juvenile gaspereau have also been observed to be flushed out onto this mud in early September.

Access to the fishway itself is not only restricted by the lack of freshwater flow, where the fishway is actually closed for extended periods during low flow conditions, but also by the accumulated sediments downstream of the causeway. The bottom elevation of the channel about 0.9 km downstream of the causeway varies between less than –1 m in May to greater than 3 m in August as shown in Figure 6.2.3.

Such large accumulation of sediment could prevent autumn migrating fish such as Atlantic salmon from reaching the fishway. Further, the lack of attraction flow coupled with such sediment accumulation make it difficult for the migrating fish to find the fishway.

**Low Dissolved Oxygen**

Late in the summer, low DO concentrations (Section 5.4.4.1) were observed downstream of the causeway over the entire water column with the exception of the top 1 m from the surface. Such conditions would force the fish to the top of the water column leaving them vulnerable for predators such as cormorants and sea gulls. The low DO concentration within the 13 km stretch from Outhouse Point to Dover would cause mortality among early migrating juvenile gaspereau and shad. It would also deter summer migrating Atlantic salmon adults from approaching the causeway to enter the river.

### 6.2.2.5 Summary of Fish Passage Issues and Existing Fish Passage Conditions

Nine fish species have been identified that require fish passage to meet the fish passage Project Objective. These nine species all have a range of migration times, migration behaviour and swimming capabilities. The existing fishway and gates and the associated Gate Management Plan were developed with a view to improving passage of these species. The ineffectiveness of those measures were identified in the Niles Report and led to the fish
passage Project Objective for this EIA to provide unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required to complete their life cycle.

A review of the many challenges and issues illustrates why fish passage is currently not being effectively achieved. These are summarized in Figure 6.2.4. In the headpond, fish are experiencing delayed downstream migration, low DO, the presence of a sediment plug that reduces the effectiveness of gate operation, conditions that increase predation and poor feeding conditions. At the fish passage facility, upstream migration is confounded by the fact that the fishway does not pass fish under all tide conditions, there are DO deficiencies, high suspended sediment, high velocities at times, inadequate attraction flow at other times, narrow vertical slots and low light levels. Downstream migration is achieved primarily through gate openings, but the gates are not open at all times. Gate openings affect upstream migration due to very high velocity and bottom opening characteristics. The estuary has low DO levels and a seasonal sediment plug downstream of the gates that affect upstream migration. Combined, these factors have resulted in ineffective migration of some species that require passage and prevention of the migration of others, and have led to the requirements to undertake this EIA.

6.3 Status Quo

The Status Quo refers to the continued operation of the control structure, including the existing Gate Management Plan and the existing fishway (from 2005 to 2025). From the conclusions of the existing fish passage conditions presented in Section 6.2.2.5, it can be concluded that the continuation of the existing structure and associated practices into the future (the Status Quo) would not provide an acceptable fish passage solution for passage of the nine fish species requiring migration at the causeway except for possibly sea lamprey and/or American eels. Further support for this conclusion is provided in: Section 8.3 (channel morphology) and Section 9.2 (Fish and Fish Habitat VEC – environmental effects analysis).

6.4 Project Option 1 – Replacing the Fishway

6.4.1 Description of Project Option 1

Project Option 1, as recommended in the Niles Report and as stated in the EIA Guidelines is “Replacing the Fishway”. Project Option 1 involves replacing the fishway with another fish passage facility, or recommending major modifications to the existing fishway in order to meet the fish passage Project Objective. As discussed in Section 6.1, fish passage is a course for fish to move between and within habitat types, including a fish passage facility that provides access to fish past a barrier. Fish passage facilities are generally designed to facilitate the movement of fish in either the upstream or the downstream directions of an obstruction in order to complete their life cycle. Often, both upstream and downstream facilities are required. Therefore, the biology and the migration behaviour of the fish species described in Section 6.1 play a major role in the design of these facilities. Upstream fish passage facilities normally provide areas of low water velocity, areas of high water velocity and require a constant freshwater supply to provide for an attraction flow. Attraction freshwater flow is a key factor that leads migrating fish to the fish passage facility. The maintenance of downstream flow at an acceptable speed is the key to the successful performance of a downstream facility.
It is generally recognized that fish passage facilities should not cause more than three days delay in fish migration in order to maintain a healthy population of fish species (Katopodis, 1992). Such facilities should generally also achieve for at least 80% success in upstream migration and a 100% success in downstream migration.

A number of concepts have been considered for Project Option 1, but no technology or combination of technologies could be applied to the unique conditions of the Petitcodiac River to satisfy the fish passage Project Objective. The AMEC Study Team drew on their extensive experience, consulted with other experts in the field, reviewed literature from around the world, and examined other fish passage facilities in Canada, the United States (US) and Wales. The following subsections describe the other fish passage facilities that were examined and presents how the different technologies might be applied to the various issues identified in Section 6.2 with the challenges associated with them.

6.4.2 Other Fish Passage Facilities

As noted above, the AMEC Study Team examined fish passage facilities in New Brunswick, elsewhere in Canada, the United States and Wales in order to identify appropriate technologies and procedures that could be implemented at the causeway to facilitate the upstream and downstream passage of the fish species requiring migration past the causeway.

The fish passage facilities reviewed in New Brunswick included those installed at the Mactaquac Dam, Beechwood Dam, Tobique, St. Croix, Woodlands, Vanceboro and Magaguadavic. At the Mactaquac facility, the upstream fish passage consists of a fish collection system, where the fish are lifted up and transported by trucks upstream. A fish lift is also used at Beechwood, where the fish are lifted up and released into the Beechwood headpond. The Tobique fish passage facility consists of a pool-and-weir fishway. At the St. Croix facility, a Denil fishway is used (non pool system with baffles and relatively steep). A Denil fishway is also used at Woodlands, while a vertical slot fishway is used at Vanceboro. On the Magaguadavic River, a pool-and-weir fishway system is used as the fish passage facility. These facilities have been designed to facilitate upstream passage of only Atlantic salmon and in incidental cases, gaspereau. It should also be noted that these facilities, with the exception of the Magaguadavic facility (where occasionally the bottom pools are drowned out at high tide), are constructed well above the head of tide, unlike the situation at the causeway.

Other fish passage facilities in Canada, the United States and in Wales examined by the AMEC Study Team during the course of this EIA included:

- Grand Falls facility on the Exploits River in Newfoundland;
- Richelieu River facility in Quebec;
- Hell's Gate system on the Fraser River in British Columbia (BC);
- Turner's Falls facilities in Massachusetts;
- Saco River in Maine; and
- the fish passage facility in Cardiff, Wales.
The Grand Falls facility consists of a vertical slot fishway designed primarily for the passage of Atlantic salmon. Until about fifteen years ago, there was also an associated trucking operation since the fishway only went about half way up to a collection area from where the fish were trucked further up the river. Since then, the fishway has been extended thus eliminating the need for trucking. There is no tidal influence at the Grand Falls facility.

At the Richelieu River in Quebec, the facility consists of a single vertical slot with 16 pools, and a very low drop between the pools, Figure 6.4.1. The facility is designed for lake sturgeon, river redhorse, copper redhorse, American shad and American eel. Abundant freshwater flow is available to operate the facility. The AMEC Study Team was interested in the success of this facility in the passage of lake sturgeon (a smaller fish than the Atlantic sturgeon found in the Petitcodiac River). It was reported that it passed between three and five sturgeon per year up through that system.

The Hell’s Gate facility in BC consists of a double, vertical slot fishway with an orifice at the bottom, designed primarily to pass Pacific salmon species (e.g., coho and sockeye salmon) and steelhead (sea-run rainbow trout) upstream past a natural barrier. Again, no tidal influence is experienced at this facility.

Members of the AMEC Study Team visited the Conte Fish Research Centre in Turner’s Falls, Massachusetts, where research on upstream and downstream fish passage is conducted. Turner’s Falls research centre is equipped with a full-scale testing flume in which research is conducted for studying the hydraulics and the hydrodynamics of full-scale fish passage systems. Leading researchers at this facility have been studying the passage of sturgeon. One of the experiments at the facility included a vertical slot, spiral fishway with which they have had considerable success in the passage of short-nosed sturgeon (a much smaller fish than the Atlantic sturgeon found in the Petitcodiac River). It should be noted that the water velocity in this type of fishway could become fairly high exceeding the swimming abilities of other fish species such as those requiring migration at the causeway.

Members of the AMEC Study Team also visited the Cataract Dam facility on the Saco River in Maine. This facility consists of a crowder system, a collection gallery and a fish lift. The crowder system is used to "crowd" the fish into the fish lift. The crowder system consists of a bar rack that slides on rails at the downstream end of the fish lift. There is a small tide in the range of 0.3 to 0.6 m associated with this system. This fish passage system is used for shad, gaspereau and salmon. Such a facility does not pass smelt primarily because there is no smelt run on the river, but also because of potential problems with bar spacing on the crowder system.

As noted above, these facilities are largely above the head of tide. The only fish passage facility in an estuary with substantial tides was located in Cardiff, Wales.

A member of the AMEC Study Team visited this facility in Wales that is physically located in an area similar to the location of the causeway. A report on a site visit to this facility is included in Appendix B. The fish passage facility is associated with a barrage (a dam and causeway-like structure) constructed within the tidal range of the Severn estuary, downstream of the
confluence of the River Taff and the River Ely, Figure 6.4.2. The Cardiff fish passage facility allows adult Atlantic salmon, sea-run brown trout and occasionally juvenile eels, to move from the ocean into the Cardiff headpond, which is a freshwater headpond created by the barrage in the former estuary. The goal of the visit was to understand the approach to fish passage that is used in Cardiff to determine if any of the information could assist in the development of a solution for a fish passage facility at the causeway.

The lower portion of the fish pass at the Cardiff headpond barrage consists of a pool-and-weir fishway. Flows in the pool-and-weir portion of the fish pass are maintained at 2.5 m$^3$/s whenever the estuary level is below Bay level. Leaf gates are also incorporated in the fish pass to maintain a water velocity of 1.5 to 2 m/s at the fishway entrance. The leaf gate is a gate structure consisting of several leaves that are used to provide for overflow conditions.

At the top end of the pool-and-weir fishway, there are 2 steep-pass (Denil) fishways. One is used to pass fish when the headpond level is higher than that of the estuary. The other is used when the tide is higher than the level of the Bay with pumped flow used to attract salmon and trout up the fishway to a false weir behind which there is a drop into the headpond. When the headpond is higher than the estuary, a separate pipe provides water by gravity flow to the lower pools of the pool-and-weir fishway. This augments the discharge from the entrance slots, without increasing flow down the pool and weir system, and attracts fish into the fish pass. When the tidal elevation is higher than the headpond water surface elevation, water is pumped from the headpond to supply this attraction flow.

There are five sluice gates installed in the barrage, designed to close during high tides to prevent saltwater from entering the headpond, and to maintain a preferred water level in the headpond. The gates can be operated as overflow or underflow structures. The normal mode of operation is overflow that minimizes turbulence in the approaches to the fish passage facility. The water discharged through the fish passage facility and the adjacent sluice gate enters a series of stilling basins in order to control water velocity, keeping them compatible with the swimming abilities of migrating fish.

The main similarities between the Cardiff barrage and the Petitcodiac River Causeway facilities include:

- both are located in an estuary;
- the Cardiff barrage is located along the Severn estuary (tidal range of up to 14 m) while the causeway is located within the Petitcodiac River estuary of the Bay of Fundy (tidal range of up to 17 m);
- the Cardiff barrage has created an upstream headpond similar to that on the Petitcodiac River headpond; and
- the elevation of the highest tides is higher than the elevation of the upstream headpond at both facilities.
Differences between the facilities include:

- the Cardiff barrage fish passage facility is designed to pass only Atlantic salmon and sea-run brown trout, both salmonids (other species rarely, if ever, pass through the facility) while the fish passage Project Objective of this EIA requires fish passage for nine diverse fish species;
- the DO levels in the Cardiff headpond is maintained at 5 mg/L or greater through the entire water column in the headpond by means of artificial aeration;
- the normal suspended sediment concentration in the Severn estuary, in the vicinity of the barrage, is approximately 1,200 mg/L which, although high, is much lower than the 30,000 mg/L observed in the Petitcodiac River estuary;
- the downstream channel is dredged every six months and the dredged material in each dredging event, approximately 70,000 to 80,000 m³, is dumped in the Severn estuary approximately 4 km seaward from the Cardiff barrage; and
- the combined freshwater discharge from the Taff and Ely Rivers is greater than that of the Petitcodiac River, and more importantly, the flows are more evenly distributed throughout the year due to a more temperate climate.

The Cardiff Bay Development Corporation stocks between 50,000 and 60,000 hatchery smolts annually in the river upstream of this barrage order to compensate for the negative environmental effects of the barrage on salmon migration. The facility was designed to pass 1,000 salmon annually upstream, which it has not achieved thus far. There is also concern about the effect of the system on the downstream migration and survival of post-spawned Atlantic salmon and sea-run brown trout (kelt). Seven kelt were tracked using a tagging system after they spawned in 2000. Only one was detected in the marine environment after the period of downstream kelt migration. If downstream post-spawning migration is a problem, it would have serious consequences in the case of Atlantic salmon and brown trout in which repeat spawners provide a significant portion of the egg deposition.

The AMEC Study Team has carefully examined all of these facilities, and considered potential technologies to determine measures that could possibly address the fish passage issues associated with the existing fish passage facility at the Petitcodiac River causeway. The outcome of this examination is summarized below.

6.4.2.1 Headpond Habitat

Delayed Downstream Migration

Trap and transport is a possible technology to facilitate the downstream movement of fish without the delay caused by the causeway structure. Such technology has been applied in Western Canada and the US, particularly on the Columbia River salmonid populations. However, the use of this technology requires sufficient freshwater flow to attract the fish to the trapping device, whether it is a fence or other collection mechanism. Such sufficient freshwater flows are only available in April and May in the Petitcodiac River system. Further, there is associated mortality during the transport process.
Low Dissolved Oxygen

Artificial aeration is a possible technology to combat the oxygen deficiencies within the headpond, as being done in Cardiff Bay in Wales. However, the challenge in using artificial aeration in the Petitcodiac River situation is related to the extremely high-level of suspended sediments. As the situation is today, there exists a 6 km long sediment plug upstream of the causeway structure. Therefore, artificial aeration would not probably succeed in the headpond since the system would likely be buried under the constant accumulation of sediments and would have challenging operational conditions in winter due to ice.

Headpond Sediment Plug

Annual dredging of the sediment plug could be conducted. However, the dredging and disposal of a 6 km long sediment plug every year could be a challenge.

6.4.2.2 Fish Passage Facility – Upstream Migration

Fish Passage at Various Tide Levels

High velocity issues can be addressed by using overflow leaf gates at the entrance to the fishway such as is being used at the Tobique fishway in New Brunswick and at the Cardiff barrage fish passage facility in Wales. The lack of attraction flow can be addressed by pumping as being done at the Cardiff barrage. However, the lack of freshwater flow and the requirement to maintain the headpond level would restrict the ability to pump at the causeway. Further, the operation of a leaf gate system in the winter for Atlantic tomcod and in a river with such high concentration of suspended sediment would be prohibitive. Reliance on an overflow leaf gate would require the fishway to be shut down during periods when the tide level exceeds that of the headpond.

Dissolved Oxygen Deficiencies

Aeration could also be used to address the oxygen deficiencies, however, the high suspended sediments within the fishway coupled with continuous re-suspension of bottom sediment would cause any aeration system to get buried in the mud and would render it impossible to maintain.

High Suspended Sediment in the Fishway

A leaf telescoping overflow gate at the downstream end of the fishway would aid in preventing reverse flow of sediment-laden estuary water into the fishway. However, it is anticipated that sediment accumulation downstream of such a gate would occur very quickly. The removal of such sediment accumulation would be problematic since flows through the fishway are insufficient to provide for the flushing of the sediments.

High Velocity Within the Fishway

The use of a leaf gate could address and control velocity within the fishway. However, one has to realize that reducing the velocity within the fishway would result in further accumulation of sediment in the fishway. A pool-and-weir fishway system with laterally sloping overflow weirs, to create low velocity areas, may be more appropriate for rainbow smelt. However, without an overflow gate at the exit, sediment deposition and back flooding by the tides would negate its effectiveness and practicality.
Narrow Vertical Slot

Here again, a leaf gate system, possibly coupled with a fish lift, could result in successful upstream migration of American shad. For such a system to work properly, attraction flow would be required. Further, sediment accumulation and winter operation of such a system would be a challenge as well.

Light Levels Within the Fishway

A lighting system could be used to address this issue. However, the high suspended sediments characterizing the Petitcodiac River system would impede the effectiveness of any lighting system.

6.4.2.3 Fish Passage Facility – Downstream Migration

Gate Opening

The gate structure could be modified to become a top opening gate, but this would not provide for mud flushing, one of the necessary functions of the gate structure. As noted in section 6.4.2.1, the most effective approach to ensure successful downstream migration of Atlantic salmon smolt would entail a trap and transport system or the operation of a top opening gate structure. Again, in order to trap fish into a collection facility, reasonable amounts of attraction flow would be required. Freshwater flows within the Petitcodiac River system are not sufficient to operate such a trap and transport system. This is most dramatic during the summer when the mean monthly flow in the Petitcodiac River is typically below 10 m$^3$/second with recorded minimum flows as low as 2 m$^3$/second. It is also likely that, considering water withdrawal at Turtle Creek and evaporation from the headpond, the flow at the causeway would be near zero during extended summer and early fall low flow periods. The result would be a channel that is too shallow for effectively trapping fish during this critical period for gaspereau and American shad migration. Further, operating such a system during high spring flows would be impractical.

Bottom Gate Opening

As noted above, the gate structure could be modified to top opening, but it would not be effective for mud flushing. Again, mud management at the control structure is a key component in operating the gates.

6.4.2.4 Estuary

Seasonal Sediment Plug

Flushing and/or dredging are possible technologies to deal with the accumulated sediments. Flushing is being exercised through the Gate Management Plan; however, the fundamental lack of freshwater flow makes such flushing largely ineffective. Dredging could be undertaken, however, the disposal of the dredge material may be prohibitive due to the large amount of material to be dredged. Also, the dredging operation would have to be carried out on an annual basis.
Lower Dissolved Oxygen

An overflow stop-log structure can be used to introduce some aeration of the holding pool downstream of the causeway. This process, however, would negate the mud flushing exercise being undertaken through the Gate Management Plan and would render the plan ineffective. It would also result in lowering the headpond level due to the lack of freshwater supply.

6.4.3 Evaluation of Project Option 1 Against the Fish Passage Project Objective

As mentioned earlier in Section 6.4.2, the examination of other fish passage facilities was conducted to determine if there were similar situations to those experienced in the Petitcodiac River system that accomplished successful upstream and downstream migration of several anadromous fish species. The AMEC Study Team reviewed literature associated with other fish passage facilities around the world, consulted with a number of fish passage experts, and examined fish passage facilities in Canada, the US and Wales. Three fish passage facilities were identified that operate in estuaries or that came under tidal influence. Two of the facilities examined were located at the head of estuaries, where the tidal fluctuations are very small by the time the tides reached the facilities, and at no time did the tidal level exceed that of the water surface elevation upstream of the fishway. None of the facilities examined were capable of passing all of the fish species requiring passage at the causeway.

It is evident from the discussion in Section 6.4.2 that the issues associated with the Petitcodiac River fish passage facility are each difficult to overcome. Technologies that have been applied at other facilities are not applicable to the Petitcodiac River facility. This is mainly due to the unique characteristics of the Petitcodiac River (highly variable low rate of freshwater flow, high tidal range and high suspended sediment concentrations) and the variety of fish species requiring migration past the causeway. Examination of other facilities revealed that none of the facilities examined could provide passage, both upstream and downstream, for all of the fish species requiring passage at the causeway. Further, on the basis of the characteristics of the Petitcodiac River, neither the number of fish species requiring migration at the causeway and their varying migratory behaviour nor a combination of technologies could provide for upstream and downstream passage of the nine fish species requiring fish passage. It is, therefore, concluded that a new fishway or further enhancement to the gate management strategy is not feasible to provide upstream and downstream passage for these fish species. Hence, Project Option 1 does not meet the fish passage Project Objective of providing unimpeded and safe movement of fish, upstream or downstream, between aquatic habitats required to complete their life cycle.

6.5 Project Option 2 – Gates Open During Peak Migration

6.5.1 Description of Project Option 2

Project Option 2, as recommended in the Niles Report and as stated in the EIA Guidelines is “Gates open during peak migration”. This Project Option intended that all the gates remain open during peak migration periods in the spring and in the fall, as described in the Niles Report.
This is not simply a modification to the Gate Management Plan (presented in Section 6.2.1.2) but would have the gates fully open during peak migration allowing for free tidal exchange upstream of causeway.

6.5.2 Evaluation of Project Option 2 Against the Fish Passage Project Objective

As presented in Section 6.1 and demonstrated in Figure 6.1.1, one or more of the fish species requiring migration at the causeway migrate at all months of the year. It is evident in Figure 6.1.1 that considerable upstream and downstream migration is also occurring in the summer and winter. Therefore, opening the gates in the spring and fall only would not provide passage opportunities for all of the identified fish species requiring migration at the causeway. Should the gates be open year round, then, Project Option 2 would, in fact, become Project Option 3.

Therefore, it is concluded that Project Option 2, with gates open in the spring and fall, will not meet the fish passage Project Objective of providing unimpeded and safe movement of fish, upstream or downstream, between aquatic habitats required to complete their life cycle.

Further, there are other issues that would be associated with Project Option 2, including:

- continued sediment accumulation in the headpond during the gate opening periods;
- ice-jamming due to the relatively small channel width between piers (Section 7.1); and
- the headpond created in the summer and winter months (when the gates are closed) will be characterized as brackish habitat and would be rendered unsuitable for freshwater species.

6.6 Project Option 3 – Gates Open Permanently

Project Option 3, as recommended in the Niles Report and as stated in the EIA Guidelines is “Gates open permanently”. This Project Option means that the five gates remain open year round to free tidal flow.

Opening the gates permanently and allowing free tidal flow at the causeway structure would provide for upstream and downstream fish passage opportunities for all fish species requiring migration at the causeway. Therefore, Project Option 3 would meet the fish passage Project Objective and address all of the fish passage issues presented above. However, this Project Option requires some modification as discussed in Section 7.1.

6.7 Project Option 4 – Replace the Causeway with a Partial Bridge

Project Option 4, as recommended in the Niles Report and as stated in the EIA Guidelines is “Replace the causeway with a partial bridge”. This Project Option means removing a portion of the causeway and constructing a bridge structure over the opening. Under this Project Option, according to Niles, the existing control structure would be buried in rock, but as described in the next section, there are variations of Project Option 4 that do involve removal of the control structure rather than filling in with rock.
Removing a portion of the causeway and constructing a bridge structure allowing free tidal flow at the causeway would provide for upstream and downstream fish passage opportunities for all fish species requiring migration at the causeway. Therefore, Project Option 4 would meet the fish passage Project Objective and address all of the fish passage issues presented above.

There are alternative means of carrying out the construction of a partial bridge structure at the causeway location. These alternatives are discussed in detail in Section 7.2.

6.8 Other Options

During consultation with the public and stakeholders and meetings with the Aboriginal Community, other options were proposed that were evaluated by the AMEC Study Team. One option that was proposed was to completely remove the causeway from shore to shore and replace with a full bridge (as opposed to a “partial bridge”). From a fish passage perspective, removal of the complete causeway was not required and there would be no added benefit as compared to Project Option 4 that was already being considered. In addition, this option would require significant modifications to the former Moncton Landfill located between Jonathan Creek and the causeway. Other options were considered for providing fish passage and maintaining a headpond that included a proposal to construct a bypass channel and a proposal to construct a weir across the Petitcodiac River.

The bypass channel would be difficult to construct and would require a fish passage facility to preserve the headpond that would have the same challenges as described above for Project Option 1. If the headpond was not preserved, then this would become the same as Project Options 3 or 4, with tidal exchange upstream and downstream of the causeway. But, such a channel would likely be narrower than the existing control structure and have a less direct course, thus resulting in infilling and a smaller tidal prism, such that the channel would not be as effective as Project Options 3 or 4.

A weir could be a wall built of concrete or some other materials across the river that would allow water on the high tide to flow over the weir and travel upstream of the causeway and, when the tide recedes, the water level upstream of the causeway would not drop below the top of the weir, thus sustaining a portion of the headpond.

The primary purpose of the weir would be to retain some resemblance of a headpond that could be used in the same manner as it currently is (i.e., recreational water craft, sailing, canoeing, etc.) while also meeting the fish passage Project Objective. For the body of water upstream of the weir to bear any similarity to the existing headpond, the elevation of the lowermost portion of the weir would have to be about 4 or 5 m. Currently, the water level in the headpond is operated between elevation 4.5 and 6 m during the summer for recreation activities. That is, the weir would have to be designed so that the water level in the body of water contained by the weir during the summer months did not drop below elevation 4 m.

Under this condition, there will be infilling in the area upstream of the weir over time, likely to about elevation 4 m. A main channel would be created, similar to what is predicted for the Project Options and mudflats at about elevation 7 m would develop on either side of the main
channel (see Section 8). The resulting “headpond” would be a small portion of the existing headpond and the level of the headpond would fluctuate with the tide.

The volume of the tidal prism upstream of the weir will be substantially reduced relative to the volume that could be achieved through Project Options 3 and 4. The body of water ponded behind the weir will not be suitable for recreation or support of a sport fishery as is currently done and the goals associated with retaining the headpond will not be achieved. The sediment plug downstream of the causeway might be reduced, but would probably still be an issue with respect to fish passage because of the reduced tidal prism. The limited tidal prism could also result in continued infilling of the river downstream of the causeway. Such a weir would also present an impediment to navigation along the length of the river.

A variation of the weir option was also considered that involved constructing a variable elevation structure that could be lowered to elevation -1.5 m (the same elevation as the concrete sill in the existing control structure) during the winter months and raised to elevation 4 or 5 m in the summer months to create the headpond. The mudflats described above would still form, the headpond would not be substantial, and the volume of the tidal prism would be reduced relative to Project Options 3 and 4. This variation would still not meet the goal of retaining a headpond that could be used as it currently is and, at the same time, prevent navigation of other vessels along the length of the river, as can be achieved by Project Options 3 and 4.

To construct a weir (with or without variable elevation control) the causeway would be breached and a bridge constructed similar to Project Option 4C. The weir would be integrated within the remaining causeway structure. As with Project Option 4C, construction would commence with cofferdams built on the upstream and downstream side of the causeway, a bypass road created for traffic around the construction area, causeway material excavated down to the native sediment and bedrock, the weir constructed, the bridge constructed (similar to the bridge in Project Option 4C), the new fish passage facility construction, the cofferdams breached, and the existing control structure decommissioned. The costs for this option would be substantially more than Project Option 4C.

With respect to fish passage, the weir would act as an impediment to fish passage and a separate fish passage facility would be required for those times of the year that the weir is above elevation -1.5 m. Such a facility would suffer from many of the same challenges as discussed in Section 6 and would not be technically viable.

It was concluded that a weir option was not feasible for the following reasons:

- a headpond could not be retained to support recreational boating in the same manner as the current use;
- the weir would present an obstacle to navigation;
- the weir cannot meet the fish passage objective even with a separate fish passage facility; and
- the costs of this option would be much more than the options that do meet the Project Objective of fish passage.
7.0 PROJECT DESCRIPTION AND IMPLEMENTATION STRATEGY

This chapter describes Project Options 3 and 4 that meet the fish passage Project Objective and presents a strategy for their implementation, estimated costs and time frame. It also discusses areas that should be addressed if the Status Quo continues.

In order to address the fish passage and ecosystem Project Objectives, the following Project Options Design Criteria were developed to minimize the magnitude and extent of potential environmental effects:

- the Project Option must provide for the unimpeded and safe movement of fish, upstream or downstream, between aquatic habitats required to complete their life cycle;
- the Project Option should reverse the current infilling trend thereby improving water quality and reducing flooding potential;
- the Project Option should not result in a non-permitted prohibition of *Species at Risk Act* (SARA) or a violation of the New Brunswick *Endangered Species Act*;
- the Project Option should allow for the free passage of ice so that the causeway does not have the potential to become a location of ice-jamming;
- the Project Option should ensure that the wetland area that provides water quality treatment for leachate from the former Moncton Landfill is not sufficiently reduced to compromise its performance;
- the Project Option should include means to reduce flooding at the traffic circle at the north end of the causeway that occurs due to poor drainage into the river;
- the Project Option should protect the integrity of the former Moncton Landfill between the causeway and Jonathan Creek, the water service line and other infrastructure; and
- the Project Option should have a design life of at least 100 years, and include consideration of a rise in sea level of at least 88 cm (IPCC, 2001) in the next 100 years.

The project descriptions provided in this chapter were developed to meet these Project Options Design Criteria.

7.1 Project Option 3

As noted in Section 6.6, Project Option 3 as recommended by Niles involved opening the gates permanently. However, this option required modification to account for the potential for ice jamming in the winter months.

Based on historical knowledge of ice behaviour within the Petitcodiac River estuary and supported by observations obtained during the spring of 2003, it is estimated that the largest piece of shorefast ice that may be entrained into the flow could be in the order of 8 m x 3 m x 3 m. Such a large piece of shorefast ice would most likely be broken into smaller sizes within a short time after it is entrained into the flow. Based on available data and ice observations, it is assumed that the required open channel width necessary at the control structure should be 24 m to pass three pieces of ice of the size mentioned above. Further, during the winter, the
width of the current channel a short distance downstream of the control structure is significantly reduced due to ice growth.

The existing causeway control structure consists of five gates with open channel widths of 8.84 m each (minimum open channel width), separated from one another by four piers that have a width of 3.35 m each. The total channel opening width is 44.2 m (5 gates x 8.84 m).

The proposed modification to Project Option 3 is to remove all of the existing piers except the middle one, remove the fish passage facility, strengthen the remaining pier, construct a new pier cap and construct a new bridge deck. This would effectively provide for two channels with open channel widths of 33 m and 35 m, for a total open channel width of 68 m. This will provide an opening area of 646 m² between the sill elevation of -1.5 m and the high water at +8 m. This compares to the current opening area of 269 m². Figures 7.1.1 to 7.1.3 show the layout of Project Option 3. The bridge deck will be raised from elevation 9.5 m to 12.0 m.

In general, the implementation of Project Option 3 involves opening the existing gates during open water season to allow for full tidal exchange upstream of the causeway as soon as possible while preparations are made for construction of the Project Option (e.g., removal of the piers and replacement of the bridge deck). Design work, consultation programs, and other activities are required to support the gate opening and the construction of Project Option 3. As a result, the implementation of Project Option 3 would proceed in stages as follows:

- Stage 1 – Design, public communication, construction approvals and construction of improvements and modifications prior to opening the existing gates;
- Stage 2 – Open existing gates during open water season; and
- Stage 3 – Remove piers and fish passage facility and replace bridge deck.

The following sections describe these stages, which form the strategy for implementing this Project Option.

### 7.1.1 Project Option 3 – Stage 1

Stage 1 involves a number of activities that need to be carried out prior to opening the gates to allow flow during ice-free periods (open water). Major activities are presented below.

- A channel will be excavated through the sediment plug located 0 to 6 km upstream of the causeway to assist in establishing the desired channel evolution. The channel will have a base width of 10 m at elevation 0 m. The means of excavation and disposal location of excavated material will be identified and the necessary environmental approvals obtained.
- The water supply pipeline upstream of the control structure will be affected when the gates are opened to two way flow and will need to be moved further below the river channel bottom elevation. The invert of the water supply pipeline must be lowered to elevation -6 m from its current elevation of -2 m.
- The approach of the channel to the control structure from the estuary side during flood tide is relatively straight and, as a result, the flow can readily pass through the structure.
However, for the case of flow during ebb tide and during the melt period (i.e., high freshwater flow downstream), the flow on the upstream side approaches the control structure at an angle and is not well aligned with the current structure as shown on Figure 7.1.1. This could result in scouring along the south (Riverview) riverbank. Riprap has been placed in this area in the past, and it will be necessary to place additional material prior to gate opening to protect the linear park and trail along the river in that area.

- Bank protection will be placed on the Moncton side of the channel from Gunningsville Bridge to Halls Creek.
- An assessment of the potential for local scour at the upstream end of the control structure’s concrete slab will be undertaken and, if necessary, measures implemented to prevent scour.
- An examination of all sewer and drainage outfalls along the river that could be affected by the Project Option will be undertaken and measures developed and implemented as required to ensure their continued operation.
- To prevent erosion of the former Moncton Landfill due to storm surges, the toe (the base of the landfill) will be protected with riprap.
- To reduce the degree of flooding at the traffic circle, the drainage channel on the east side of the causeway will be improved with a protection dyke and outlet works. Also, drainage from the storm sewer system that flows east along Salisbury Road toward the causeway will be diverted into the headpond.
- Upstream dykes and aboiteaux will be repaired/restored to prevent saltwater inundation (flooding) of land (e.g., agricultural lands, Ducks Unlimited sites).
- A compensation plan will be developed for loss of the Tri Community Marina, the Sea Cadets facility, the Town of Riverview public dock and other recreational facilities.
- A detailed gate opening strategy for Stage 2 will be developed in conjunction with NBDOT and DFO.
- The Environmental Management Plan (EMP), including the supporting plans and procedures (e.g., Environmental Protection Plan (EPP), Follow-up Program), will be developed (discussed further in Section 7.5).
- All necessary construction approvals will be obtained.
- The design of Project Option 3 will be advanced.

It is important to note that the designs provided in this EIA Report are at a conceptual level. The designs were advanced to a level sufficient to support order of magnitude cost estimating. The fundamental design principles have been established and about 20 to 30% of the engineering has been completed. The remainder of the design process will involve the following elements:

- **Feasibility Level Engineering** – where the design concept will be fully confirmed from both a technical and financial standpoint. At this level, about 60 to 70% of the engineering is completed, and the construction costs can be estimated to within -10 to +25% of expected final cost. Engineering analyses are well advanced at this level, however, refinements to the analyses will typically be required based on detailed design considerations.
• **Detailed Design Engineering** – where all analyses and evaluations will be completed accounting for detailed design information. Engineering is completed to nearly 100% (except for possible field adjustments during construction). The construction costs can be estimated to ±10% of expected final cost.

• **Construction Drawings and Specifications** – these are prepared suitable for a contractor to construct the required elements.

In Stage 1, detailed designs and construction drawings and specifications will be required for the items that are necessary before the gates are opened. The design of Project Option 3 should be advanced to a feasibility level during Stage 1 and prior to the gate opening to confirm the costing and construction plan to ensure that Stage 1 is integrated effectively with subsequent stages.

An integral part of Stage 1 will be a communication program that will advise the public, stakeholders and Aboriginal Community of the Project Option and how the implementation of the overall Project would be carried out including contingency plans.

**7.1.2 Project Option 3 – Stage 2**

After Stage 1 is completed, the existing gates will be opened commencing with the spring runoff as they are now, but will be left open until the fall. The gates will be fully closed in the late fall to avoid potential problems with ice jamming during the winter months.

During the Stage 2 gate openings, monitoring will be conducted as part of the Follow-up Program described in Chapter 13. The results of the monitoring will be used to update the EMP (Section 7.5) and the design of the Project Option as applicable. If necessary during this stage, the gates could be closed to allow for mitigative measures, such as installation of additional erosion protection. Detailed construction drawings and specifications for Stage 3 would be developed.

**7.1.3 Stage 3 – Remove Piers and Fish Passage Facility and Replace Bridge Deck**

The existing control structure will be removed including the deck, girders, piers and fishway. The floor slab, retaining walls and the middle pier from the original control structure will remain in place. It is expected this solid waste will meet the NBDELG definition of Construction and Demolition debris, and thus, can be disposed at an approved site. It would also be possible to dispose the material at the Westmorland-Albert Solid Waste Corporation landfill on Berry Mills Road, Moncton. If the material meets the NBDELG Clean Fill Guidelines, then it will be used as clean fill to the extent possible. The new bridge will have 4 lanes and a sidewalk as shown on Figures 7.1.1 to 7.1.3, the same as the current bridge at the control structure.

The proposed demolition method will not require unproven techniques. The fishway will be removed such that it does not affect the integrity of the remaining structure.

Construction will be sequenced to allow 2 lanes of traffic to continue. The upstream structure will be reconstructed first, followed on completion with the downstream structure. Due to the elevation differential of about 2.5 m between the existing causeway surface and the
reconstructed structures, a temporary retaining wall will be required. The retaining wall will be placed along the existing approach lanes and eastern (downstream) half of the existing bridge structure to maintain 2 lanes of traffic during construction. The overpass structure and the approach and ramps south of Coverdale Road will not be affected.

7.1.3.1 Bridge Deck Elevation

The bridge deck elevation has been based on a design river level elevation of 8.5 m and an allowance of 1 m freeboard between the water level and the bottom of the girders to account for ice flows and sea level rise associated with predicted climate change (0.88 m in 100 years). The girder thickness is expected to be about 2.5 m, such that the bridge deck elevation will be about 12 m. It is noted that the current elevation of the causeway is 9.5 m. These elevations will be confirmed during the Feasibility Level design phase as discussed in Section 7.1.1.

The depths of the pier cap and girders would be greater than the existing ones, and the approach roadways from each end of the bridge would to be raised to provide an acceptable approach to the new structure. On the Riverview side it is expected that the bridge deck elevation of 12 m will be retained from the new bridge to the existing Findlay Boulevard and Coverdale Road (Route 114) interchange ramps.

7.1.3.2 Ice Passage

As noted in Section 7.1, a key design criterion of the Project Options is to allow for free passage of ice in both the upstream and the downstream directions, a concern especially during the spring break-up of ice above the causeway. Currently, once the water level reaches an elevation of +4.57 m at the causeway, movement of floating ice is restricted by the concrete bulkheads located above the top gate openings in the control structure. During the winter months, the width of the current river channel, a short distance downstream of the control structure, is substantially reduced due to ice growth on the riverbanks.

For Project Option 3, the clear distance between the mid-pier and each end of the bridge will be of the order of 34 m as discussed in Section 7.1. Such an opening width is expected to allow for unrestricted ice movement within the river.

7.1.3.3 Traffic

Traffic will continue over the causeway crossing between Moncton and Riverview during the construction period. It is expected that the new bridge, downstream at Gunningville, will be in operation by the time of the proposed construction, but it does not appear to be feasible to divert all traffic over that structure without a decline in the level of service. Traffic will be confined to 2 lanes during the construction of the Project Option 3.

7.1.4 Schedule and Costs

Stage 1 would require approximately one to two years to complete, with Stage 2 starting the next spring after Stage 1 is completed. Stage 2 should extend for at least two full seasons before proceeding with Stage 3 (actual construction of the Project Option). Stage 3 would take 2 years to complete. Therefore, the total estimated time to completion of Project Option 3 is 5 to 6 years.
The estimated costs for Project Option 3 are shown in Table 7.1.1. Note that the costs associated with activities prior to opening the gates are about 50% of the total cost of Project Option 3. Costs for engineering included in this table are related to the designs and preparation of the construction packages noted above and also obtaining the necessary approvals to proceed with construction.

### Table 7.1.1 Capital and Operating Costs of Project Option 3

<table>
<thead>
<tr>
<th>Activity for Implementation of Project Option 3</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
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<td><strong>Stage 1</strong></td>
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</tr>
<tr>
<td>Upstream channel excavation</td>
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<tr>
<td>Upstream channel engineering</td>
<td>$370,000</td>
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<tr>
<td>Upstream shoreline and dyke protection</td>
<td>$2,250,000</td>
</tr>
<tr>
<td>Channel bottom protection</td>
<td>$400,000</td>
</tr>
<tr>
<td>Embankment protection-Halls Creek</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Embankment protection-Château Moncton Hotel and west</td>
<td>$2,500,000</td>
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<tr>
<td>Protection at former Moncton Landfill</td>
<td>$1,250,000</td>
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<tr>
<td>Compensation for Loss of Tri Community Marina and other recreational facilities</td>
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<tr>
<td>Watermain relocation</td>
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<tr>
<td>Improvements of drainage and reduction of flood frequency at traffic circle</td>
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<tr>
<td>Operation</td>
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<tr>
<td>Baseline environmental monitoring</td>
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<tr>
<td>Design engineering</td>
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<tr>
<td><strong>Sub total Stage 1</strong></td>
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<td><strong>Stage 2</strong></td>
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<tr>
<td>Operation</td>
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<tr>
<td>Design engineering</td>
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<tr>
<td>Environmental monitoring</td>
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<td><strong>Sub total Stage 2</strong></td>
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<tr>
<td><strong>Stage 3</strong></td>
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</tr>
<tr>
<td>Rehabilitate bridge</td>
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<td>Remove existing control structure and fishway</td>
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<td>New bridge approaches</td>
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<tr>
<td><strong>Total Cost for Project Option 3</strong></td>
<td>$34,080,000</td>
</tr>
</tbody>
</table>

*all values in 2004 dollars
**all numbers have a built in 25% contingency*
7.2 Project Option 4

The following three alternative means for carrying out Project Option 4 have been developed.

- **Project Option 4A** – Construct a new, 170 m long bridge structure downstream of the existing gates and remove the entire gate structure and fish passage facility as shown in Figure 7.2.1. This will provide an opening width of about 72 m.

- **Project Option 4B** – Construct a new bridge 280 m long downstream of the existing gates as shown in Figure 7.2.2. The 280 m bridge would accommodate the potential widening of the channel in the future. Initially, the channel could be opened to 72 m, like in Option 4A. Pending monitoring results, the channel could be widened to a width of up to 225 m at elevation 8.0 m (high tide level).

- **Project Option 4C** – Construct a new, 315 m long, bridge structure in the central portion of the causeway and fill in the existing control structure as shown in Figure 7.2.3. The bridge will be constructed at a 30° angle to the river channel. The river channel width at elevation 8.0 m (high tide level) will be 225 m, the same as Project Option 4B. However, due to the angle of the bridge, the length of river water traversed by the bridge at elevation 8.0 m will be 260 m.

**7.2.1 Project Option 4A**

**7.2.1.1 Project Option 4A – Stages 1 and 2**

Project Option 4A consists of construction of a new bridge structure just downstream of the control structure and across the existing channel as shown on Figures 7.2.1 and 7.2.4. The existing control structure will be left in place. This Project Option would also be implemented in stages as for Project Option 3.

Stage 1 (activities prior to opening gates) and Stage 2 (open existing gates) for this Project Option would be the same as for Project Option 3, except that the water supply pipeline may have to be modified further in Stage 1. For Project Option 4A, in addition to lowering the waterline immediately upstream of the control structure, it will also need to be lowered further north to a point where the approach road from the new bridge would join the causeway.

**7.2.1.2 Project Option 4A – Stage 3**

**Construction**

The bridge would be built parallel to the existing causeway and would not result in major disruptions of traffic across the causeway (Figures 7.2.1 and 7.2.4). This is the primary advantage of option 4A over 3. Also, management of the gates during the construction period will be simplified. The bridge length will be in the order of 170 m to avoid posing a constriction on the current channel geometry immediately downstream of the causeway and tie in properly with the traffic interchange on the Riverview side of the causeway. An earth and rock fill embankment will be constructed from the existing causeway to the north end of the bridge and will form the bridge approach on the Moncton side. Only minor reconstruction will be required to join the new bridge approach to the traffic interchange in Riverview. The bridge will be
constructed on a skewed angle to allow connection to the existing Findlay Boulevard approach and ramps north of the Coverdale Road (Rte 114) overpass to geometric standards. The centerline of the new bridge will be located approximately 50 m downstream from the existing bridge. This will avoid the need to reconstruct the interchange overpass structure and the approach and connecting ramps south of Coverdale Road. The 50 m distance could be reduced during the design stage.

On the Riverview end of the new bridge, Findlay Boulevard and the interchange ramps between the bridge and Coverdale Road will be realigned and reconstructed. In addition, the approach and ramps will be regraded vertically to connect to the new bridge abutment, approximately 3 m above the elevation of the existing causeway structure. These alignment changes can be achieved within the relatively short distance (approximately 150 m) between the bridge and the overpass structure without requiring any modifications to the Coverdale Road overpass or interchange ramps located south of the overpass.

From the Moncton side abutment of the new bridge, approximately 425 m of new roadway will be constructed to align the bridge with the existing causeway. No changes to the traffic circle will be undertaken.

Once the bridge and approaches have been completed and open to traffic, the gate superstructure, gates, fish passage, bridge deck and piers will be removed from the control structure. This can be done without interacting with the traffic on the new bridge. The concrete abutments and floor slab of the control structure will remain in place after construction. This will be the narrowest point of the channel at 72 m.

The new bridge deck elevation will be 12.5 m, allowing 1 m freeboard. It is 0.5 m higher than Project Option 3 because of the longer spans and thicker girders (3 m versus 2.5 m). Ice passage would be addressed by keeping the bridge piers about 55 m apart. There would be a minor disruption of traffic (1 lane for a few days) during the joining of the bridge approaches to the causeway and the interchange connections in Riverview.

7.2.1.3 Schedule and Costs

As with Project Option 3, Stage 1 would require approximately one to two years to complete, with Stage 2 starting the next spring after Stage 1 is completed. Stage 2 should extend for at least two full seasons before proceeding with Stage 3 (construction). Stage 3 would take 2 to 4 years to construct. Therefore, the total estimated time to completion of Project Option 4A is 5 to 8 years. The estimated costs for Project Option 4A are shown in Table 7.2.1.

7.2.2 Project Option 4B

7.2.2.1 Project Option 4B – Stages 1, 2 and 3

This Project Option is similar to Project Option 4A, with a longer bridge (280 m versus 170 m). Figures 7.2.2 and 7.2.4 show this Project Option. The implementation of this Project Option
### Table 7.2.1 Capital and Operating Costs of Project Option 4A

<table>
<thead>
<tr>
<th>Activity for Implementation of Project Option 4A</th>
<th>Cost</th>
</tr>
</thead>
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<td><strong>Stage 1</strong></td>
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<td>Upstream channel excavation</td>
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<td>Upstream channel engineering</td>
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<td>Upstream shoreline and dyke protection</td>
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<td>Channel bottom protection</td>
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<td>Embankment protection-Halls Creek</td>
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<td>Embankment protection-Château Moncton Hotel and west</td>
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<td>Protection at former Moncton Landfill</td>
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<td>Compensation for Loss of Tri Community Marina and other recreational facilities</td>
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<td>Watermain relocation</td>
<td>$3,120,000</td>
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<td>Improvements of drainage and reduction of flood frequency at traffic circle</td>
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<tr>
<td>Operation</td>
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<td><strong>Sub total Stage 2</strong></td>
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<tr>
<td>Remove existing piers</td>
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</tr>
<tr>
<td>Construct new approaches</td>
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<tr>
<td><strong>Total Cost for Project Option 4A</strong></td>
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</table>

*all values in 2004 dollars
**all numbers have a built in 25% contingency

would proceed in the same manner as the other Project Options (i.e., Stages 1, 2 and 3). In this instance, the causeway embankment, fill and native material upstream and downstream of the causeway would be excavated. This excavation along the causeway would extend about 150 m north of the existing control structure. Natural sediment deposits downstream of the causeway would erode in response to the tidal flux.

Stage 1 (activities prior to opening gates) and Stage 2 (open existing gates) for this Project Option would be the same as for Project Option 4A. Stage 3 would be the same as Project Option 4A with the addition of excavation of the control structure, including lowering the sill elevation and excavation of a portion of the causeway.
It is important to note that this option can proceed in phases, beginning with removal of the control structure such as for Project Option 4A. Depending on results of monitoring programs, the opening of the causeway can then be tripled to up to 225 m without interfering with traffic on the bridge.

### 7.2.2.2 Schedule and Costs

As with Project Option 3 and 4A, Stage 1 would require approximately one to two years to complete, with Stage 2 starting the next spring after Stage 1 is completed. Stage 2 should extend for at least two full seasons before proceeding with Stage 3 (actual construction of the Project Option). Stage 3 would take 2 to 4 years to construct. Therefore, the total estimated time to complete Project Option 4B is 5 to 8 years.

The estimated costs for Project Option 4B are shown in Table 7.2.2. If this option was sequenced such that the bridge was built, but the complete opening was not established, then this would reduce the initial cost by $3 million.

### 7.2.3 Project Option 4C

#### 7.2.3.1 Project Option 4C – Stages 1 and 2

Figure 7.2.3 shows the bridge structure for Project Option 4C. The total span for the completed bridge will be approximately 315 m. The bridge will have four traffic lanes and a sidewalk. The control structure will not form part of the completed bridge crossing, but will be left in place to control flows during the construction period. The gates would continue to be operated as per Stage 2 of Project Option 3 until the new bridge is completed. At that time, the control structure will be buried while the crossing over the control structure is kept in service. Figure 7.2.3 shows the location of the proposed bridge and the new river channel upstream and downstream of the causeway.

The implementation of Project Option 4C would proceed following the three stages as described for Project Option 3.

Stage 1 (activities prior to opening gates) and Stage 2 (open existing gates) for Project Option 4C would be the same as for Project Option 4B, except that the water supply pipeline would be modified further in Stage 1. In addition to lowering the water supply pipe at the control structure, as noted above for Project Option 3, the pipeline will need to be lowered at the location of the Project Option 4C bridge to elevation -6 m.

#### 7.2.3.2 Project Option 4C – Stage 3

**Construction**

The first phase of construction will be to construct a temporary 2-lane roadway bypass on the downstream side of, and parallel to, the existing causeway. The top of the bypass embankment will be at elevation +8 m, or possibly higher, and this embankment will be designed to act as a cofferdam.
### Table 7.2.2 Capital and Operating Costs of Project Option 4B

<table>
<thead>
<tr>
<th>Activity for Implementation of Project Option 4B</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
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<tr>
<td>Upstream channel excavation</td>
<td>$3,700,000</td>
</tr>
<tr>
<td>Upstream channel engineering</td>
<td>$370,000</td>
</tr>
<tr>
<td>Upstream shoreline and dyke protection</td>
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<tr>
<td>Channel bottom protection</td>
<td>$400,000</td>
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<tr>
<td>Embankment protection-Halls Creek</td>
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<tr>
<td>Embankment protection-Château Moncton Hotel and west</td>
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<tr>
<td>Protection at former Moncton Landfill</td>
<td>$1,250,000</td>
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<tr>
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<td>Watermain relocation</td>
<td>$3,120,000</td>
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<td>Improvements of drainage and reduction of flood frequency at traffic circle</td>
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<td>Operation</td>
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<td>Baseline environmental monitoring</td>
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<td>Design engineering</td>
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</tr>
<tr>
<td><strong>Sub total Stage 1</strong></td>
<td><strong>$20,390,000</strong></td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Design engineering</td>
<td>$3,580,000</td>
</tr>
<tr>
<td>Environmental monitoring</td>
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</tr>
<tr>
<td><strong>Sub total Stage 2</strong></td>
<td><strong>$5,080,000</strong></td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td></td>
</tr>
<tr>
<td>Construct new bridge</td>
<td>$19,000,000</td>
</tr>
<tr>
<td>Remove existing piers</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>Construct new approaches</td>
<td>$1,900,000</td>
</tr>
<tr>
<td>Remove remainder of control structure</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Remove causeway and land to the west</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>Engineering</td>
<td>$2,590,000</td>
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<tr>
<td>Environmental monitoring for 5 years</td>
<td>$500,000</td>
</tr>
<tr>
<td>Operation for 3 years</td>
<td>$150,000</td>
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<tr>
<td><strong>Sub total Stage 3</strong></td>
<td><strong>$29,140,000</strong></td>
</tr>
<tr>
<td><strong>Total Cost for Project Option 4B</strong></td>
<td><strong>$54,610,000</strong></td>
</tr>
</tbody>
</table>

*all values in 2004 dollars
**all numbers have a built in 25% contingency

A second cofferdam will be constructed upstream so that excavation of rock fill from below the bridge area can be carried out in dry conditions, although some pumping is anticipated. Excavated rock material from the causeway will be stockpiled for future use in filling the existing channel at the control structure. Excess, or unusable excavated material will be transported to an approved storage and/or disposal site for future use or disposal.

The cofferdams will consist of containment earth dykes or sheet piles and will prevent tidal water and associated sediment deposition from entering the excavation until flow is permitted to take place below the new bridge structure. At that time, the cofferdams would be removed.
Figure 7.2.3 shows the configuration of the bridge. Initially, channels will be excavated and/or dredged and the action of the river will be used to erode the sediments to the ultimate geometry at the bridge. These channels will be excavated upstream and downstream of the new bridge location. Downstream, it is anticipated that a 100 m wide (base width) channel will be excavated to elevation 0 m by widening the river, shifting the north bank of the river further north. The elevation of the marsh downstream of the causeway is approximately elevation +7 m. The length of the excavation will be in the order of 1,000 m (producing approximately 900,000 m$^3$ of dredge material). Upstream, a channel would have to be created to connect to the channel that is established during Stage 1 and would form further during Stage 2. This will also be 100 m wide and 1,000 m in length with a base elevation of 0 m (producing approximately 400,000 m$^3$ of dredge material). The ground surface in the headpond, immediately west of the proposed bridge, is about elevation +3.5 m.

The total quantity of sediment from the excavated channels to be removed is in the order of 1,300,000 m$^3$. It is proposed to place the sediment along the north riverbank upstream of the causeway. A containment berm would be constructed to contain the dredge spoils. The exterior slope of the berm would be protected from the river flow erosion with riprap. The excavation of the sediment could possibly be carried out during winter months working from the frozen marsh surface using excavators. Considering the quantities involved, the excavation could extend over a two-year period.

Once the bridge structure is operational and the river channel excavations are completed, the downstream bypass embankment cofferdam and the upstream cofferdam will be breached to allow flow below the new bridge. Flow will take place though the new channel, and it is assumed that the channel will widen to a maximum of 225 m, at high tide level. This width will be controlled by riprap protection at the bridge abutments.

As part of Stage 3, additional erosion protection measures would be installed in front of the former Moncton Landfill along the alignment shown on Figure 7.2.3. This would consist of anchored steel sheet piling. The location of the sheet piles would be established beyond the expected limit of erosion of the north bank of the river, and would not be relied on as the primary means of erosion protection to the landfill. It is expected that the channel would develop such that the north bank does not shift to the sheet piling. Also, leachate from the landfill would have to be collected and handled instead of discharging into the river as it currently does. It is expected that the landfill leachate could be collected and directed into the City of Moncton sanitary sewer system.

Construction of the steel sheet pile wall will also proceed concurrently with the bridge and excavation operations. The steel sheet pile wall will be 1000 m long with 14 m deep steel sheets, tied back to additional piles installed into the river sediments north of the steel sheet pile wall.

The last phase of the construction will consist of closing the gates and the area between the piers upstream and downstream of the gates will be filled with rock fill. The fishway will also be filled. The filling operation will be designed so that the fill acts as a dam after completion.
superstructure would then be removed. Alternatively, a new bridge deck could be built at the control structure similar to Project Option 3, but this was not included in Project Option 4C at this time.

**New Bridge Deck Elevation**

As for Project Option 3, the bridge deck elevation has been based on a design river level elevation of 8.5 m. Since the bridge spans are longer for Project Option 4C than for Project Option 3 (55 m versus 34 m), the depth from the bottom of the girders to the top of the bridge would be approximately 3 m. With an allowance of 1 m freeboard between the water level and the bottom of the girders, the bridge deck elevation will be about 12.5 m.

**Relocation of Pipeline**

As noted above, the water supply pipeline would have to be lowered to elevation -6 m.

**Ice Passage**

The overall river opening will be about 225 m, and the distance between individual bridge piers would be of the order of 55 m. Project Option 4C allows for the free passage of ice in both directions.

**7.2.3.3 Schedule and Costs**

As with Project Option 3, Stage 1 would require approximately one to two years to complete, with Stage 2 starting the next spring after Stage 1 is completed. Stage 2 should extend for at least two full seasons before proceeding with Stage 3 (actual construction of the Project Option). Stage 3 would take 2 to 6 years to construct. Therefore, the total estimated time to complete Project Option 4C is 5 to 10 years.

The estimated costs for Project Option 4C are shown in Table 7.2.3. A supporting summary table is in Section 12.2.

**7.3 Status Quo**

Under the Status Quo, the following erosion protection measures should be put in place within a few years:

- North (Moncton side) of the river at the location of the old landfill near Gunningsville Bridge.
- North (Moncton side) of the river adjacent to Château Moncton Hotel.
- At the toe of the former Moncton Landfill between the causeway and Jonathan Creek.

The measures to improve drainage at the traffic circle and reduce flood risk should be undertaken as well.

In addition, a detailed flood risk assessment should be undertaken and a flood protection plan developed.
Table 7.2.3  Capital and Operating Costs of Project Option 4C

<table>
<thead>
<tr>
<th>Activity for Implementation of Project Option 4C</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td></td>
</tr>
<tr>
<td>Upstream channel excavation</td>
<td>$3,700,000</td>
</tr>
<tr>
<td>Upstream channel engineering</td>
<td>$370,000</td>
</tr>
<tr>
<td>Upstream shoreline and dyke protection</td>
<td>$2,250,000</td>
</tr>
<tr>
<td>Channel bottom protection</td>
<td>$400,000</td>
</tr>
<tr>
<td>Embankment protection-Halls Creek</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Embankment protection-Château Moncton Hotel and west</td>
<td>$2,500,000</td>
</tr>
<tr>
<td>Protection at former Moncton Landfill</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Compensation for Loss of Tri Community Marina and other recreational facilities</td>
<td>$500,000</td>
</tr>
<tr>
<td>Watermain relocation</td>
<td>$4,100,000</td>
</tr>
<tr>
<td>Improvements of drainage and reduction of flood frequency at traffic circle</td>
<td>$1,200,000</td>
</tr>
<tr>
<td>Operation</td>
<td>$150,000</td>
</tr>
<tr>
<td>Baseline environmental monitoring</td>
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</tr>
<tr>
<td>Design engineering</td>
<td>$2,940,000</td>
</tr>
<tr>
<td><strong>Sub total Stage 1</strong></td>
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<tr>
<td><strong>Stage 2</strong></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Design engineering</td>
<td>$5,500,000</td>
</tr>
<tr>
<td>Environmental monitoring</td>
<td>$500,000</td>
</tr>
<tr>
<td><strong>Sub total Stage 2</strong></td>
<td>$7,000,000</td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td></td>
</tr>
<tr>
<td>Construct new bridge</td>
<td>$24,000,000</td>
</tr>
<tr>
<td>Construct detour and new bridge approaches</td>
<td>$2,100,000</td>
</tr>
<tr>
<td>Bury existing structure</td>
<td>$500,000</td>
</tr>
<tr>
<td>Dredge channel both upstream and downstream of new bridge</td>
<td>$35,000,000</td>
</tr>
<tr>
<td>Install anchored steel sheet pile wall as erosion protection for former Moncton Landfill</td>
<td>$9,000,000</td>
</tr>
<tr>
<td>Collection of landfill leachate and pumping to the City of Moncton sanitary sewer system</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Engineering costs for dredging program</td>
<td>$2,500,000</td>
</tr>
<tr>
<td>Engineering</td>
<td>$3,910,000</td>
</tr>
<tr>
<td>Environmental monitoring for 5 years</td>
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</tr>
<tr>
<td>Operation for 3 years</td>
<td>$150,000</td>
</tr>
<tr>
<td><strong>Sub total Stage 3</strong></td>
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</tr>
<tr>
<td><strong>Total Cost for Project Option 4C</strong></td>
<td>$107,270,000</td>
</tr>
</tbody>
</table>

*all values in 2004 dollars
**all numbers have a built in 25% contingency

The cost for these items is estimated to be about $8,300,000. This cost would be substantially larger under the Status Quo where mitigative measures against flooding to protect urban developments as well as the civil infrastructures would be required. A detailed flood risk assessment would be absolutely necessary to identify the magnitude of flooding under the
Status Quo, to provide the basis for developing a flood protection plan and to quantify the costs required for mitigation. Annual operation and maintenance of the control structure and the causeway will still be required and all five gates will require a retrofit within the next 15 years.

7.4 Accidents and Malfunctions

This section presents the accident and malfunction scenarios that may occur as a result of implementation of the Project Options, and describes those that are considered for the environmental effects assessment (Chapter 9). Note that the term “Project Options” hereafter includes Project Options 3, 4A, 4B and 4C; specific mention of a Project Option (e.g., Project Option 4B) is given when warranted. Accidents and malfunctions are not considered for the environmental effects assessment of the Status Quo as it is not a Project Option.

All necessary precautions will be taken to prevent the occurrence of accident and malfunction events that may occur throughout all phases of the Project Options and to minimize any environmental effects should they occur. As noted in Section 7.5, the EMP will include Emergency Response and Contingency Plans to address these situations. Construction and operation will follow the EMP developed for the Project Option and the relevant regulations, guidelines and accepted industry procedures prescribed therein.

The Project Options will result in substantive quantities of sediment being suspended and transported in the river by erosional processes. Therefore, unexpected and small-scale failure of standard erosion and sediment control measures during construction will not cause a measurable increase to the TSS levels in the Petitcodiac River, and are not specifically mentioned further in this EIA. However, unplanned large-scale erosional events, particularly associated with bank failure, are possible.

The Public Health and Safety VEC (Section 5.15 and Section 9.13) includes an analysis of the following accidents that could occur as a result of Project Option implementation:

- vehicular accidents;
- non-vehicular accidents (including boats); and
- groundwater and surface water contamination.

The Heritage and Archaeological Resource VEC (Section 9.12) includes an analysis of the potential for accidental or unplanned disturbance of heritage or archaeological resources.

Therefore, these accidents are not considered within other VECs, except where hazardous material spills could affect plants or animals and their habitat indirectly using surface water or groundwater as a pathway.

Given the implementation of the EMP, the unique nature of the Petitcodiac River, and the accidents assessed specifically as part of other VECs, the residual accidents and malfunctions with the greatest potential for significant environmental effects include:
• hazardous material spill;
• former Moncton Landfill protection failure;
• unplanned erosion (beyond the pre-causeway river channel); and
• agricultural or wetland dyke failure.

It is difficult to predict the precise nature, severity and likelihood of these events. However, the Modelling Component Study and the supporting modelling studies (e.g., the Trend Analysis) provide a level of confidence in making mid-term (20 year) to long-term (50 to 100 year) predictions for accident likelihood that is not typically available during the environmental assessment process. To better understand the severity of an accident or malfunction, the geographic extent, duration and magnitude of the reasonable worst case was considered.

7.4.1 Hazardous Material Spill

Spills of petroleum, oils, or lubricants (POLs) may occur during construction during refuelling of machinery or through breaks in hydraulic lines. These spills are usually highly localized and easily cleaned up by on-site crews using standard equipment. In the unlikely event of a large spill; soil, groundwater and surface water contamination may occur, potentially negatively affecting the quality of groundwater, fish and fish habitat and wetland habitat, thus resulting in the ingestion/uptake of contaminants by wildlife. Depending on the nature of the spill, it could also potentially affect residential, commercial, agricultural and other land uses.

POLs and other hazardous materials will be handled in accordance with applicable regulations (e.g., the Petroleum Product Storage and Handling Regulation). Procedures will be outlined in the EPP for construction (Section 7.5). Construction equipment will be frequently inspected to detect possible fuel and hydraulic system leaks. Any leaks will be repaired immediately. Refuelling and equipment maintenance will be conducted away from residential and known cultural or heritage properties, and not within 30 m of a wetland or watercourse.

The Emergency Response and Contingency Plan (Section 7.5) will address response procedures for Project Option-related hazardous material spills. This will ensure that in the unlikely event of a hazardous material spill, appropriate measures, materials and training are in place to minimize the potential environmental effects.

Vehicle-related spills during construction are considered where traffic flow has been disrupted or impeded as a result of construction activities.

Vehicle-related spills during operation (e.g., oil tanker accident on the causeway), will not be more likely to occur as a result of implementation of a Project Option. In other words, there is no incremental increase to vehicle accident likeliness in operation of a Project Option compared to that of the Status Quo. Existing emergency response measures (e.g., fire departments, NBDELG) are in place for these types of “public” events. Therefore, these types of accidents are not considered further in the EIA.
7.4.2 Former Moncton Landfill Protection Failure

The results of the hydrodynamic and sediment transport modelling of the river (AMEC, 2005b) indicate that the Project Options will not affect (e.g., erode) the former Moncton Landfill. However, due to the nature of the potential environmental effects of erosion of the landfill, the Project Description includes a precautionary approach to protect the landfill.

The Project Option descriptions have incorporated measures for protecting the former Moncton Landfill integrity as mitigation to prevent the landfill from being affected by a river environment with increased energy and full tidal exchange. The landfill protection will be designed to withstand the 1 in 100 year high water event. It is anticipated that riprap around the toe of the landfill will be adequate for protection due to these flooding related events. Nonetheless, given the unique nature of the Petitcodiac River and the somewhat unpredictable nature of weather systems (e.g., an extreme high return period storm could occur during the next 100 years), the possibility exists for failure of landfill protection. Such an event could result in the movement of waste material or the leaching or erosion of toxic substances with potential negative environmental effects on fish and fish habitat, thus resulting in the ingestion/uptake of contaminants by wildlife and the public. Erosion due to channel expansion and increasing tidal flux may affect the size of wetland in front of the landfill. As a contingency, erosion protection measures such as sheet piles would be implemented where monitoring shows a need for in Project Options 3, 4A and 4B to minimize channel erosion towards the landfill. For Project Option 4C, this is included as mitigation due to expected channel erosion. A long-term inspection program will be developed as a part of the Follow-up Program (Chapter 13) to ensure landfill protection measures are effective. Remedial action (including maintenance) will be taken when required.

7.4.3 Unplanned Erosion

As noted above, a number of erosion control measures will be placed in high consequence areas as a part of Stage 1 for Project Options 3 and 4 (e.g., bank protection on Moncton side, approach to control structure) and monitored and remediated during Stage 2 and Stage 3. There is a possibility that channel erosion may occur outside the pre-causeway channel. The Follow-up Program (Chapter 13) outlines a plan to monitor channel evolution and such unplanned erosion. Where identified, mitigation measures would be implemented to control such unplanned erosion.

7.4.4 Agricultural or Wetland Dyke Failure

Upstream of the causeway, dykes and aboiteaux protecting agricultural lands will be restored/repaired as mitigation for the selected Project Option. Prior to any repair or upgrading of dykes or aboiteaux, a detailed plan will be developed in consultation with the appropriate regulatory agencies, landowners and Ducks Unlimited. For reasons similar to those presented for Former Moncton Landfill Protection Failure and Unplanned Erosion, the possibility exists for these structures to be eroded by unplanned channel erosion or migration outside of the pre-causeway channel, leading to flooding of these lands by saltwater. This could result in the immediate destruction of existing crops and the short-term rendering of the soil as unsuitable for crop growing due to high levels of salt. Similarly, failure of the dykes protecting the Ducks
Unlimited wetland sites could result in damage to freshwater wetland vegetation from saltwater intrusion.

During Stage 1 of the Project Option, the dykes and aboiteaux will be repaired as required. The Emergency Response and Contingency Plan (Section 7.5) will account for a catastrophic unplanned erosion due to unplanned river channel erosion. Remedial action will be taken as prescribed and necessary in the event of unplanned erosion by the river channel outside of the pre-causeway channel.

### 7.5 Environmental Management

An EMP will be developed for the selected Project Option. The purpose of the EMP is to provide protection of the environment for the life of the Project Option by:

- ensuring compliance with the commitments as set forth in the EIA Report;
- ensuring compliance with environmental legislation, regulations and conditions of approval;
- ensuring that the environmental effects of accidents and malfunctions, should they occur, are minimized; and
- outlining a Follow-up Program to verify the accuracy of environmental effects predictions in the EIA and determine the effectiveness of mitigation recommended in the EIA Report (Chapter 13).

The EMP will include an EPP, Standard Operating Procedures (SOPs), an Emergency Response and Contingency Plan, and a Follow-up Program for the full life of the Project Option. The EMP will also define and identify roles and responsibilities, accountability and reporting procedures.

The EMP will be developed during Stage 1 of the Project Option and initiated during Stage 2. During gate openings (Stage 2), previously identified sensitive areas (e.g., the river embankment near the Château Moncton Hotel) will be monitored, and the results may be used to iteratively update the EMP (e.g., identify specific types of erosion control measures for specific locations). The EMP and its supporting documents and procedures will be submitted to the Director of Project Assessment Branch at NBDELG and other regulatory authorities for review and approval prior to the initiation of Stage 3 of the Project Option.

### 7.5.1 Environmental Protection Plan

The EPP is a vital common reference document for implementing environmental protection measures and providing environmental protection procedures. The EPP will be designed to ensure that the construction and operation-related commitments of the EIA and other regulatory permits (e.g., Watercourse and Wetland Alteration Permit, Harmful Alteration Disruption or Destruction (HADD) and Disposal at Sea Permit, if required) are followed. The EPP will use the EIA Report and supporting documents to identify environmentally sensitive areas and concerns and recommended mitigation measures. The EPP will contain SOPs and the Emergency Response and Contingency Plan.
The purpose of each SOP is to provide a description of the best practice mitigation measures to be used during construction and operation. SOPs will provide instructions or steps to be followed to complete the required tasks in an efficient and consistent manner that meets the commitments set forth in the EIA and other regulatory permits. At a minimum, the EPP will include SOPs for the construction and operation activities listed below.

7.5.1.1 Construction SOPs

- Erosion and sediment control.
- Supply, storage and disposal of materials (e.g., asphalt, aggregates, dredge material).
- Storage, handling and transfer of fuels and other hazardous materials.
- Dust and noise control.
- Equipment idling reduction measures.
- Archaeological and heritage resource monitoring.

7.5.1.2 Operation SOPs

- Bridge and causeway maintenance.
- Summer maintenance (e.g., sign and guardrail maintenance).
- Winter maintenance (e.g., snow removal and salting).
- Former Moncton Landfill protection and other erosion protection monitoring.

The purpose of the Emergency Response and Contingency Plan is to ensure safe, quick and effective response to unexpected and emergency situations (i.e., accidents and malfunctions). Specifically, plans will be provided for responding to:

- hazardous material spills;
- former Moncton Landfill protection failure;
- the need for additional landfill protection measures (e.g. sheet piles) for Project Options 3, 4A, and 4B;
- unplanned erosion;
- agricultural or wetland dyke failure (during construction);
- vehicular accidents (during construction);
- non-vehicular accidents;
- disturbance of archaeological or heritage resources; and
- groundwater and surface water contamination.

The Emergency Response and Contingency Plan will be for the life of the Project Option, except as noted above. Agricultural and wetland dykes and aboiteaux will be restored and stabilized as part of the construction phase. During operation, the owners of these dykes and aboiteaux will be expected to maintain and repair these features. The Emergency Response and Contingency Plan for vehicular accidents will only pertain to those accidents that occur as a result of traffic disruption or impediment during construction.
8.0 DESCRIPTION OF THE ANTICIPATED PHYSICAL CHARACTERISTICS OF THE RIVER UNDER THE STATUS QUO AND PROJECT OPTIONS

8.1 General Approach

This chapter provides a description of the anticipated physical characteristics of the Petitcodiac River in response to the Status Quo and the Project Options. The characteristics were based on the experience of the AMEC Study Team with the Petitcodiac River system, interviews with people familiar with the history and evolution of the river, analyses of patterns and trends that the river has experienced over time and a projection of those trends into the future, and empirical relationships, river engineering and hydraulics formulations.

In addition, a series of detailed computer models were developed to represent the geometry of the river and the characteristics of the water and sediment in the river and could simulate the behaviour and evolution of the river before and after the causeway was constructed. The models were then used to assist with the predictions of the physical characteristics of the river associated with the Status Quo and Project Options. Generally, the available data and experience were used to predict the physical characteristics of the river under the Status Quo and the Project Options and the computer models were used to support and further refine the predictions. Further details regarding the computer models are presented in the Modelling Component Study (AMEC, 2005b).

Collectively, the range of approaches that were used to predict the physical characteristics of the river (from experience to the computer models) is referred to as “predictive tools for defining the river’s characteristics.” These tools are discussed further below:

- **Experience of the AMEC Study Team with the Petitcodiac River System:** Several members of the AMEC Study Team have been involved with studies on the Petitcodiac River system for more than 10 years, some for more than 30 years. The studies have been related to the hydrodynamic and sediment transport issues in the river, examining the river since construction of the causeway including the trial gate opening in 1988 and subsequent modifications to the gate operations.

- **Interviews with people familiar with the history and evolution of the Petitcodiac River:** During the data collection phase of the EIA, a number of interviews were held with interested parties about the river dealing with a broad range of issues, from wildlife and aboriginal challenges to the physical characteristics of the river (e.g., infilling, ice jams, winter conditions, flooding, gate operation, changes during construction of the causeway, etc.). Representatives from DFO, NBDELG and Environment Canada provided very useful information in these interviews. This information has been very valuable in supplementing the AMEC Study Team’s understanding of the river system.

- **Analyses of patterns and trends of the Petitcodiac River:** The data collection phase of the study accumulated a wealth of historical and current (2003) data related to the physical characteristics of the river. This included characteristics such as cross sections, river bed elevations, velocity, salinity, water levels, ice patterns, flooding...
conditions and water quality. The data were analyzed for patterns and trends that could be indicative of the future behaviour of the river (i.e., trend analyses) under the Status Quo and Project Options.

- **Empirical relationships, river engineering and hydraulics formulations:** The data, patterns and trends discussed above were analyzed with proven river engineering equations that are based on empirical relationships and theoretical formulations. This understanding supported the extrapolation of the patterns and trends into the future to permit predictions of the physical characteristics of the river.

- **Computer modelling:** The computer modelling process started with preliminary models that were used to further develop our understanding of the basic processes active within the Petitcodiac River. The modelling was then advanced to a more detailed level and was calibrated against observed characteristics. The hydrodynamic portion of the model was first developed and tested and then the sediment transport models were superimposed on the hydrodynamic model to predict the infilling and erosion of the river and the changes that could be expected under the Status Quo and the Project Options. This approach follows the recommendations of the organizing committee for the “Petitcodiac River/Estuary Modelling Workshop that was held in Moncton, New Brunswick, in March 2002” and previous work done by Amos (1984).

In this EIA report, these predictive tools are sometimes collectively referred to as modelling as well.

### 8.2 EIA Requirements of the Predictive Tools for Defining the River Characteristics

Section 4 of this report, particularly Table 4.7.1, listed the VECs for this study and Section 5 provided background information on them. Some of the VECs required a description of the anticipated physical characteristics of the river to assist with the environmental effects assessment (described in Section 9). Other VECs that do not require predictions of the physical characteristics of the river would include labour and economy and road and transportation network, for examples. However, the level of detail, methodology and required resolution (confidence interval) varied for the different key issues (ecosystem and other) depending on the effects that were being considered. Table 8.2.1 lists the key issues that required a description of the physical characteristics of the river. For each key issue, the physical characteristic of interest and a threshold value above (or below) which further analyses or mitigation may be required are identified in Table 8.2.1.

It is important to note that in the early stages of this EIA (during the data collection phase and in the initial phases of the modelling), the need for a number of precautionary mitigative strategies to address potential areas of concern was evident. Certain key issues such as erosion and flooding upstream of the causeway will be mitigated by engineering works. These are described below and have already been included in the Project descriptions outlined in Section 7.
For Project Options 3 and 4A, 4B and 4C

- Repairing the dykes and aboiteaux in the headpond.
- Placing erosion protection on the south (Riverview side) of the Petitcodiac River along the existing water line below the gates for an estimated length of 2 km.
- Placing erosion protection on the north (Moncton side) of the river at the location of the old dump near Gunningsville Bridge (now partially under the Sportsplex).
- Placing erosion protection on the north (Moncton side) of the river adjacent to Château Moncton Hotel.
- Modifying the water line that passes beside and beneath the causeway.
- Improving the drainage from the traffic circle and reducing the flood frequency.

For Project Options 3 and 4A

- Protecting the south (Riverview side) of the Petitcodiac River near the gate structure (for Project Options 3 and 4A).
- Protecting the toe of the former Moncton Landfill between the causeway and Jonathan Creek from storm surges with erosion protection.

For Option 4C

- Installing erosion protection measures on the north (Moncton side) of the river in front of the former Moncton Landfill to protect the sediments beneath the former Moncton Landfill from eroding.
- Collecting leachate from the landfill and discharging into the City of Moncton sanitary sewer system for treatment.

If the Status Quo continues, the following measures should be implemented:

- Placing erosion protection on the north (Moncton side) of the river at the location of the old dump near Gunningsville Bridge (now partially under the Sportsplex).
- Placing erosion protection on the north (Moncton side) of the river adjacent to Château Moncton Hotel.
- Protecting the toe of the former Moncton Landfill between the causeway and Jonathan Creek from storm surges with erosion protection.
- Improving the drainage from the traffic circle and reducing the flood frequency.

The modelling assumed that these measures were in place and did not attempt to predict, for example, the amount of erosion that could occur at Château Moncton Hotel if no erosion protection was in place. From the data that were collected on river behaviour and observations at that location, it was apparent that this area could be affected by erosion under Project Options 3 and 4 and the Status Quo and riprap was, therefore, included in the Project Description for these options from the beginning.
In consideration of the mitigative strategies that were incorporated into the Project Descriptions for the Project Options and the Status Quo, Table 8.2.1 contains those items that require predictions of the physical characteristics of the river to support the environmental effects assessment of key issues in Section 9 (environmental effects assessment). Table 8.2.1 includes a number of considerations regarding the key issues. For each issue, Table 8.2.1 presents the physical characteristic of interest, the threshold limit beyond which more detailed analyses and possibly additional mitigation would be required, the resolution required in the analyses to support the environmental effects assessment, and the tools that were used to achieve the required resolution. The resolution (e.g., accuracy) was based on the requirements of the environmental effects assessment described in Section 9.

The following sections describe the predicted physical characteristics of the river associated with the Status Quo and Project Options. These sections summarize the work that was done as part of the Modelling Component Study and the reader is referred to the Modelling Component Study Report (AMEC 2005b) for details.

8.3 Channel Volume over the Long Term

In predicting the physical characteristics of the river, one of the most important parameters that govern the behaviour of the river is the channel volume (or water volume). Section 5.2.1 presented the volume of the channel under the current conditions and before the causeway was constructed. As noted in that section, the total volume of the main channel (i.e., of water below the low high tide) upstream of Hopewell Cape was approximately 462 Mm$^3$ before the causeway was constructed and was about 270 Mm$^3$ in 2002 (with some seasonal variation). This section addresses the predicted channel volume under the Status Quo and Project Options.

8.3.1 Status Quo

In order to predict the anticipated channel volume under the Status Quo, an evaluation of the volume curves for pre-causeway and post-causeway conditions was undertaken to describe post-causeway trends. The accumulated total water volume curves within the estuary were discussed in Section 5.2.1 and presented on Figure 5.2.9. As noted there, the total volume of water in the estuary was decreased by at least 28.9 Mm$^3$ after construction of the causeway due to the removal of the tidal prism upstream of the causeway and probably more due to infilling that occurred during construction of the causeway.

The Petitcodiac River Causeway has become the head of the tide for the estuary now and the estuary is responding and adjusting to this new condition. Effectively, the head of tide has moved downstream from Salisbury to the causeway. Based on this, Figure 8.3.1 presents the pre-causeway total volume curve (as presented in Figure 5.2.9) translated 21.1 km downstream to the location of the causeway. By November 2001, the cumulative volume curve approaches the translated curve for a distance of about 20 km downstream of the causeway (Figure 8.3.1). It is likely that the translated curve in Figure 8.3.1 will be the lower limit which the volume curves will approach if the causeway remains as the head of tide (i.e., under the Status Quo). Based on the analysis of the data presented in this figure, it is anticipated that deposition could occur downstream as far as Hopewell Cape for some time in the future.
### Table 8.2.1 Key Issues that Require Prediction of Physical Characteristics of the Petitcodiac River

<table>
<thead>
<tr>
<th>Key Issue</th>
<th>Physical Characteristic of Interest</th>
<th>Threshold Limit</th>
<th>Resolution Accuracy Required of Physical Characteristic to Support Environmental Effects Assessment</th>
<th>Predictive Tools Used to Define the Physical Characteristic</th>
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</thead>
<tbody>
<tr>
<td>Fish passage</td>
<td>Connection between freshwater and salt water.</td>
<td>Currently, there are times of the year when the bed of the Petitcodiac River is higher than the low high tide and salt water does not reach the causeway. Also, freshwater is not released from the control structure, thus the freshwater and salt water do not meet. Under Project Options 3 and 4, it is essential that the freshwater and saltwater connect to support fish passage. The head of tide should reach Salisbury Bridge to permit the transfer of fish from salt water to fresh water and vice versa. This requirement will not be met under the Status Quo. In terms of a threshold limit, the elevation of the riverbed should be less than the average water level in the area upstream of the causeway. This is because fish will travel up the river on the flood tide and out of the river on the ebbing tide, above the average water level.</td>
<td>Location of head of tide within 5 km.</td>
<td>Review of available cross section data and mechanisms for deposition and erosion of the banks, projection of the cross-sectional area based on river engineering formulas and computer modelling.</td>
</tr>
<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
<td>Threshold Limit</td>
<td>Resolution Accuracy Required of Physical Characteristic to Support Environmental Effects Assessment</td>
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<tr>
<td>Volume of tidal prism upstream of the causeway</td>
<td>Prior to 1967, the tidal prism volume upstream of the causeway was 28 Mm$^3$. When the 5 gates are opened as part of Stage I for Project Options 3 or 4, the tidal prism in the headpond is expected to be more than 15 Mm$^3$. However, from a fish passage perspective, as long as a channel is sustained that can allow target fish species to reach the freshwater of the Petitcodiac River, then the fish passage objective can be met. For the purpose of the EIA, it was judged that if the tidal prism is predicted to be less than 10 Mm$^3$ for the Project Options, then other analyses would be required to determine if the tidal prism is sufficient to meet the other criteria noted above. This requirement will not be met by the Status Quo.</td>
<td>+/- 20%</td>
<td>Review of available volume information in the headpond, river engineering formular and computer modelling.</td>
<td></td>
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<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
<td>Threshold Limit</td>
<td>Resolution Accuracy Required of Physical Characteristic to Support Environmental Effects Assessment</td>
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<tr>
<td>Vessel Traffic and Navigation</td>
<td>Depth of water</td>
<td>At a minimum, sufficient water would be available for a small boat to pass unobstructed along the length of the Petitcodiac River under Project Options 3 and 4 at low high tide. This can take place now except at the causeway obstruction itself and under low high tide conditions between the causeway and the Gunningsville bridge where the river thalweg following extended low flow conditions is higher than the low high tide. The situation under Project Options 3 and 4 would not be worse than it is now. Of particular interest is the shad fishery at Belliveau Village that has been negatively affected by the continued infilling of the river channel. To reverse this pattern, the infilling of the river at Belliveau Village should be arrested or reversed. This is similar to the fish passage threshold requirements noted above and, therefore, if the threshold values for fish passage are met, then the conditions for vessel traffic and navigation will be met as well.</td>
<td>Same as for fish passage issues.</td>
<td>Same as for fish passage issues.</td>
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<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
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<tr>
<td>Possible erosion of the former Moncton Landfill (from Jonathan Creek to the causeway)</td>
<td>Location of north (left bank) that could be affected by erosion.</td>
<td>Currently, the minimum width of the mudflat between the toe of the former Moncton Landfill and the north bank of the river is 400 m. If the predicted erosion of the north bank is more than 50 m under the Project Options or Status Quo, then additional analyses may be required to determine if erosion protection measures are required. If the predicted erosion is more than 100 m, then additional erosion protection measures should be put in place.</td>
<td>+/- 25 m horizontal</td>
<td>Review of available cross section data, observations made during gate opening trial, and mechanisms for erosion of the river bank. Supported by computer modelling.</td>
</tr>
<tr>
<td>Possible contamination from the landfill.</td>
<td>Width of mudflat in front of landfill to attenuate water quality in leachate from the landfill.</td>
<td>As noted above, the minimum width of mudflat in front of the former Moncton Landfill is 400 m. This area serves to attenuate the water quality of the leachate from the landfill and should not be reduced by more than 25 m. If a Project Option or the Status Quo results in reducing the width of mudflat by more than 25 m, then a more detailed analysis of the water quality and potential requirements for alternate treatment schemes would be required. If more than 50 m of the mudflat is lost, then an alternate treatment system should be included.</td>
<td>+/- 25 m horizontal</td>
<td>Same as above.</td>
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<tr>
<td>Key Issue</td>
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<tr>
<td>Flooding: Causeway structure</td>
<td>Water level in the Petitcodiac River at the causeway and potential for overtopping.</td>
<td>Overtopping the causeway could lead to a potential for loss of life and damage of the road surface on top of the causeway and the structure itself. A depth of water in excess of 0.5 m would result in a serious risk to a person in a vehicle and damages to the causeway (more than elevation 10 m). If this level is exceeded under the Project Options or the Status Quo, then a detailed hydraulic analysis would be required to determine extent of the damage and mitigation measures, if necessary.</td>
<td>+/- 0.2 m vertical</td>
<td>Review of previous flooding records and observations with support from predictions from computer modelling.</td>
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<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
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<tr>
<td>Flooding: Traffic circle at north end of causeway</td>
<td>Water level in the Petitcodiac River at the traffic circle related to flooding.</td>
<td>Flooding of the traffic circle is an inconvenience, but can also be a public safety concern. The traffic circle is at elevation 9.0 m. If the water over the traffic circle is more than 0.5 m deep, then there could be a risk to public safety. Therefore, the threshold value at this location is set at 9.5 m. Flooding of the traffic circle now occurs due to surface water accumulating from the local drainage area. This is made worse by plugging of the drainage system from the traffic circle due to infilling of the river downstream of the causeway. This flooding will be dealt with partially by the drainage improvements noted above but further efforts are required on this matter. From the perspective of the Project Options and the Status Quo for the Petitcodiac River causeway, the predictions focus on the river elevation and the possible impact on the traffic circle.</td>
<td>+/- 0.2 m vertical</td>
<td>Same as above.</td>
</tr>
<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
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<td>Resolution Accuracy Required of Physical Characteristic to Support Environmental Effects Assessment</td>
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<tr>
<td>Flooding: Downstream of causeway</td>
<td>Water level in the Petitcodiac River downstream of the causeway. This is represented by water levels at Halls Creek and Champlain Place Mall.</td>
<td>The parking lot at Champlain Place Mall is at elevation 8.0 m. If the water level under the Project Options or Status Quo is more than elevation 8.5 m, then there could be damage to property and a risk to public safety. If the predicted water level is more than elevation 8.5 m, then a detailed flood risk assessment should be undertaken to better define the flood risk and identify mitigative measures. It is important to note that flooding downstream of the causeway can also occur at Fox Creek, Babineau Creek and Jonathan Creek, but for the purpose of this assessment of flood risk, Halls Creek was considered in this analysis.</td>
<td>+/- 0.2 m vertical</td>
<td>Same as above.</td>
</tr>
<tr>
<td>Key Issue</td>
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<tr>
<td>Lobster and scallop fishery</td>
<td>Volume of sediment discharged from the river on annual basis.</td>
<td>Currently, about 15 Mm$^3$ of sediment is transported into Shepody and Chignecto Bays (i.e., downstream of Hopewell Cape), largely as &quot;pulses&quot; during the spring freshet and fall rain events with 17 Mm$^3$ of sediment redeposited again each year during the low flow periods (i.e., summer and winter). Approximately 2 Mm$^3$ of this redeposited sediment remains in the Petitcodiac River between Hopewell Cape and the causeway. As discussed in Section 5, the lobster and scallop fishery have not been negatively affected by these &quot;pulses&quot; of sediment discharge from the river as it is likely that the sediment is carried further into the Bay of Fundy. This is expected to continue under the Status Quo. As a result, for the Project Options, if the modelling predicts that on an annual basis, the volume of sediment transported to Shepody and Chignecto Bays is less than 10 Mm$^3$, then no negative environmental effect would be anticipated for the lobster and scallop fisheries.</td>
<td>+/- 2 Mm$^3$/year</td>
<td>Trend analysis supported by computer modelling.</td>
</tr>
<tr>
<td>Key Issue</td>
<td>Physical Characteristic of Interest</td>
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<tr>
<td>Wetlands</td>
<td>Area of wetland (fresh and salt water).</td>
<td>The area of wetland after implementation of the Project Options is to be greater than the area of wetland (combined fresh and salt water) that existed in 1967. This requirement is satisfied for the Status Quo.</td>
<td>+/- 30%</td>
<td>Computer models used to predict water levels at the wetland locations combined with experience related to wetland development.</td>
</tr>
<tr>
<td>Mudflat Productivity (Wildlife and Vegetation, Birds)</td>
<td>Energy of the ebb tide.</td>
<td>For the mudflats along the Petitcodiac River and in Shepody Bay to not be negatively affected by the Project Options or Status Quo, the deposition on the surface of the mudflats should be no greater than is currently occurring. This can be achieved by ensuring that the energy associated with the ebb tide (i.e., flow) is equal to or greater than the current energy.</td>
<td>The prediction will be limited to whether the ebb tide energy will decrease or increase and a resolution on this value is not required.</td>
<td>Consideration of the tidal prism volume.</td>
</tr>
<tr>
<td>Recreation Associated with Tidal Bore</td>
<td>Height of the tidal bore.</td>
<td>The height of the tidal bore prior to the causeway construction was 1 to 1.5 m and has been diminished to less than 0.75 m by construction of the causeway. If the Project Options increase the height of the tidal bore (a slight increase was predicted through modelling), then there may be additional recreation activities on the river. If the height of the tidal bore is not increased appreciably by the Project Options, then there could be a loss of this opportunity, but no mitigation measures would be implemented. The tidal bore will not increase under the Status Quo.</td>
<td>+/- 0.20 m</td>
<td>Previous and current observations and computer models.</td>
</tr>
</tbody>
</table>
When the estuary has achieved a state that is more or less in equilibrium, consistent with the translated volume curve in Figure 8.3.1, it can be estimated that the total volume upstream of Hopewell Cape will be about 135 Mm$^3$, that is about 135 Mm$^3$ less than in November 2001. If the average rate of deposition is taken to be 2.0 Mm$^3$/yr after 2001 (the average rate of infilling between 1991 and 2001), then the estuary should approach a relatively constant cross-sectional geometry after about 70 years under the Status Quo. It is anticipated that most of this reduction in total volume will occur in the lower 20 km of the estuary between Dover and Hopewell Cape.

The volume change will occur by a rising of the bed and a narrowing of the channel. Examination of the data indicates that, in the long-term, the bed elevation in the lowermost portion of the estuary will rise and the depth below the reference elevation will be about 78%, on average, of that in November 2001.

The width of the channel at equilibrium will also tend to become narrower at sections at which bedrock outcrops are not currently confining the channel. For sections at the lower end of the estuary that are not laterally constrained, it is anticipated that the ice-free width of the channel will be reduced to about 68%, on average, of that in November 2001.

In summary, based on regime type computations for stable channels, at equilibrium in about 70 years, the depth will be about 78% and the width will be about 68% of that in November 2001. Consequently the estimated area of the cross section below marsh level will be about 53%, on average, of that in November 2001. These are all average values over the length of the river.

Predictions of the changes in water volume in the estuary were developed using the computer model with Figure 8.3.2 showing the results in the main channel upstream of Hopewell Cape. The projections began in 2005 (the baseline condition). Under the Status Quo, the volume of water is expected to decrease by about 45 Mm$^3$ over 20 years. This decrease is expected to occur at a steady rate. Figures 8.3.3 and 8.3.4 show similar results for near Dover and Mill Creek, respectively. The annual average rate of channel infilling is estimated to be about 0.5 Mm$^3$/year at Mill Creek, 1.0 Mm$^3$/year at Dover and 3.0 Mm$^3$/year at Hopewell Cape. It is noted in Figures 8.3.2 to 8.3.4 that the estuary continues to change beyond 2025 which is consistent with the projections discussed above where equilibrium of the channel will require another 50 years after 2025.

In the headpond, sedimentation due to reversing flow through the fishway and the contribution of sediment upstream of the headpond will continue. Between 1968 and 2003, it is estimated that 0.5 Mm$^3$ of sedimentation within the headpond can be attributed to these processes. Under the Status Quo, this sedimentation will continue and would result in an estimated 0.25 Mm$^3$ of sedimentation by 2025 based on the estimated infilling rate attributable to these processes since causeway construction. By 2105, it is anticipated that the headpond would reduce in volume by about 1.25 Mm$^3$, a reduction in the current headpond volume in the order of 12.5%. Ultimately over the longer term, these processes will continue into the future and may lead to the effective loss of the headpond.
8.3.2 Project Options

Figures 8.3.2, 8.3.3 and 8.3.4 also show the predicted change in volume of water in the main channel for the Project Options. Under Project Options 3/4A, the volume of the main channel upstream of Hopewell Cape will initially increase by about 15 Mm$^3$ by virtue of opening the causeway and developing the tidal prism above the causeway. Recall that the tidal prism above the causeway was 28.9 Mm$^3$ before the causeway was constructed. It is anticipated that this volume will be restored to only about 15 Mm$^3$ under Project Options 3/4A. This is for the following reasons:

- The channel will be narrower and there will be infilling of the low energy environment on the north side of the headpond.
- Head losses will occur across the control structure that will result in an upstream elevation less than the downstream elevation, thus further reducing the volume of the tidal prism.

Over the subsequent 20 years after opening the causeway, the overall tidal prism volume will increase by an additional 35 Mm$^3$, with most of the change occurring in the first 10 years.

Under Project Options 4B/4C, the overall tidal prism volume will initially increase by 23 Mm$^3$ due primarily to the tidal prism above the causeway and then increase by another 77 Mm$^3$ over the next 20 years. Note that prior to the causeway construction, the tidal prism was 28 Mm$^3$ upstream of the causeway, but it is not expected that this volume will be achieved through Project Options 4B/4C because of infilling that has occurred in the headpond since construction of the causeway.

Figures 8.3.2, 8.3.3 and 8.3.4 also show the change in volume that would be required to return to the conditions prior to the causeway construction (in 1966) and indicates that even with the wider opening in the causeway associated with Project Options 4B/4C, the volume will not return to the pre-causeway conditions. This is because the volume of the tidal prism upstream of the causeway location will be less than that prior to the causeway construction.

As can be seen from Figures 8.3.3 and 8.3.4, the channel will more closely approach the pre-causeway conditions in the lower portion of the estuary as compared to the upper portion of the Petitcodiac River estuary.

As noted in Section 5.2.4, this sediment will likely end up in the middle of the Bay of Fundy, and not in Shepody or Chignecto Bays.

There will also be more energy in the tidal system, with the ebb tide having at least the same amount of energy as under the current conditions.

As noted in Table 8.2.1, to support fish passage, the tidal prism under Project Options 3 or 4 should be more than 10 Mm$^3$ to sustain a channel above and below the causeway. This requirement will be met by the volumes indicated above. The prediction of the tidal prism
volumes is expected to be accurate within +/-20%, the resolution requirement for this issue. This will also support and sustain a channel adequate for vessel traffic and navigation. At low tide, a channel with sufficient water for small vessels will be available under all Project Options to the head of tide above the current headpond. At high tide, water in the current headpond area will be typically in the order of 1.0 m deeper than currently.

8.4 Channel Bank Locations Over the Long Term

Figures 8.4.1, 8.4.2 and 8.4.3 present predicted plan views for the channel under Project Options 3/4A and 4B/4C after 20 years. The Status Quo after 20 years is also shown for comparison. These figures provide a comparison of the top width of the channel at elevation +4.5 m geodetic elevation. It should be noted that the average marsh elevation in the river reaches presented in these figures is about 7 m and elevation 4.5 m was considered representative to depict the relative locations of the sides of the main channel of the river. In the Lower Estuary (Figure 8.4.1), the river bank location is not expected to change substantially over a 20 year period for the Project Options, although some narrowing is expected under the Status Quo condition. Looking out to 2055 and 2105, there will be additional narrowing the channel under the Status Quo and some widening under the Project Options.

Near Dieppe (Figure 8.4.2), the river is expected to widen under the Project Options, particularly on the south bank around Outhouse Point and near Dover. The river will be wider under Project Options 4B/4C than Options 3/4A because of the larger tidal prism above the causeway and wider opening. The Status Quo will result in continued narrowing of the river.

Between Riverview and Moncton, the location of the channel banks will not change much under Project Option 3/4A and the Status Quo, except around Outhouse Point as discussed above. Under Project Option 4C, the north bank of the river will shift 200 m north, closer to the former Moncton Landfill between the causeway and Jonathan Creek, thus erosion protection measures and an alternate system for treating the landfill leachate will be required prior to activating the opening. Under Project Option 4B, the north bank of the river will shift up to 50 m and erosion control measures and an alternative means of treating the landfill leachate may be required as well, but considered unlikely at this time. The sequenced implementation of Project Option 4B will provide better guidance on this requirement. The accuracy of these predictions is within the resolution requirements indicated in Table 8.2.1.

8.5 Evolution of the River

As noted above, the river will continue to infill under the Status Quo. Under Project Options 3 and 4, the river will widen and deepen. This section further describes the anticipated evolution of the river under the Project Options. As noted in Section 7, Stage 1 is associated with implementing the Project Option involves preparatory works (i.e. repair of the dykes and aboiteaux in the headpond and install erosion protection measures), Stage 2 involves opening all five of the gates during the open water period and allowing for full tidal exchange until freeze-up when the gates area closed again, and Stage 3 will involve constructing the preferred bridge structure.
During Stage 2, all five of the gates will initially be opened in the spring, with sufficient water being directed down the Petitcodiac River to remove the silt plug that forms in the river immediately downstream of the causeway to beyond the Gunningsville Bridge. After the spring freshet subsides, rather than closing the gates as is currently done, the gates would be left open and free tidal exchange will be permitted past the gates into the headpond until freeze-up late in the year. This will change the freshwater environment in the headpond to a salt water/brackish environment. The channel that currently exists in the headpond will be deepened immediately upstream of the causeway, but also narrowed as sediment accumulates in areas of low flow and on the banks of the channel, causing new mudflats to form and the channel to establish a new geometry in response to the gate opening.

It is important to note that during the trial gate opening in 1988 (Section 5.2.9), there was a net accumulation of sediment in the headpond as sediment was deposited in the low energy areas, but also not all of the gates were opened and the full benefit of the tidal exchange was not achieved. With the 5 gates open, deposition is expected as well, but a channel will become established.

Further upstream, the channel will return to its configuration before the causeway was constructed with a narrow main channel. Mudflats will be adjacent to the main channel that will submerged during high tide. During times of low flow in the Petitcodiac River, in the summer and fall, sediment will deposit in the main channel, establishing a silt plug in a new location further upstream of the current location. Summer and fall rain events will erode the silt plug as they currently do and transport the sediment downstream, where it will be resuspended and brought back upstream on the flood tide and redeposited.

During Stage 2, some changes will occur rapidly (e.g., within a few years) such as formation of new mudflats and the start of converting freshwater marsh to saltwater marsh. During Stage 3, if Project Options 3/4A are implemented, then the river evolution will continue on the path started during Stage 2 and, over time, the river will tend to widen and deepen downstream of the causeway and the overall volume of the river increased.

Under Project Option 4B, the course of the river would be altered somewhat at the causeway by increasing the width of the opening at the south end of the causeway, but the general pattern of river evolution would continue. Under Project Option 4C, the course of the river at the causeway would be shifted to the north, close to the original channel prior to the causeway, resulting in erosion of wetland in front of the former Moncton Landfill (between the causeway and Gunningsville Bridge) and erosion of sediment that was deposited in the headpond during Stage 2.

8.6 Sediment Transport Downstream During High Flow Events

During spring freshet and heavy rain fall events, sediment that accumulates in the river is transported down the river in the form of “pulses”. As noted in Section 5.2.5, a substantial volume of material can be transported downstream with about 15 Mm³ of sediment passing Hopewell Cape into Shepody and Chignecto Bays and Cumberland Basin and ultimately the Bay of Fundy during these “pulses”. Much of this material comes from the silt plug that currently
develops downstream of the causeway. The loss of material is offset by other sediment that is transported into the river during low flow events that accumulates on the sides and bottom of the river resulting in a net infilling and an overall narrowing of the river. This pattern is expected to continue under the Status Quo.

Under the Project Options, during Stage 2 and beyond, the increased energy in the river system associated with opening the causeway will tend to reduce the volume of silt that will accumulate in the silt plug that will now form upstream of the causeway, relative to the current conditions and Status Quo. The volume that can accumulate in the silt plug will be further constrained by the relatively narrow width of the river at that location. Therefore, during a spring freshet or heavy fall rain, when there is a substantial flow down the river, the volume of sediment that would be available for transport down the river would expected to be less than the volume of silt contained in the silt plug that will form under the Status Quo (i.e., less than 10 to 15 Mm³).

Moreover, as the silt plug shifts upstream of the causeway from its current location, the amount of sediment that can be transported past Hopewell Cape during the spring freshet and heavy fall rains would also expected to be less than could occur under the Status Quo. Hence, it is likely that the volume of sediment that can be released as “pulses” past Hopewell Cape during high flow events would be less than 10 Mm³ as per Table 8.2.1 with respect to the lobster and scallop fishery.

8.7 Tidal Regime

Another key parameter that influences the behaviour of the Petitcodiac River and the resulting physical characteristics is the tidal range and patterns, also referred to as the tidal regime. The computer models were used to predict the tidal regime over the next 20 years, using the 2005 conditions as a baseline.

For comparison purposes, the water levels associated with high and low tides over a 14-day tidal cycle before the causeway was constructed were predicted and shown in Figure 8.7.1. The maximum water level is based on a high tide level of 6.8 m at Hopewell Cape and rises upstream as a result of contributions from tributaries such as Turtle Creek and the Petitcodiac River. The minimum water level is based on a low tide level of -6.5 m at Hopewell Cape and intersects the river bottom upstream of Dover. The water level above that is a function of the flow down the river.

8.7.1 Status Quo

The predicted water levels under the high and low tides and the average water level for the Status Quo condition after 20 years (i.e., 2025) are shown in Figure 8.7.2. Under the Status Quo, there will be a slight increase of about 0.2 m in the water elevations under a high tide in the Moncton area, the result of continued infilling within the channel below the causeway.

Upstream of the causeway, the water level is controlled by the gates and is not affected by the tidal range.
8.7.2 Project Options

The predicted tidal envelopes for Project Options 3/4A and 4B/4C are shown in Figures 8.7.3 and 8.5.4, respectively. The water level under the high tide in 2025 extends to Salisbury under Project Options 3/4A and 4B/4C. The predicted tidal elevations shown in Figures 8.7.3 and 8.5.4 are lower than the pre-causeway tidal elevations shown in Figure 8.7.1 in the upper portion of the estuary above the location of the causeway. Tidal elevations associated with Project Options 3/4A and 4B/4C in the upper portion of the estuary are between 7 and 7.5 m, while pre-causeway tidal levels varied from 7 to 8 m. This can be explained by the reduction in cross-sectional area of the channel in the middle portion of the estuary between Mill Creek and the location of the causeway. However, the results show that the tide level can reach the same general area (near Salisbury Bridge) as before the causeway was built.

Project Option 4B/4C, provides for a slightly higher tidal envelope in the upper portions of the estuary than Project Option 3/4A, but still lower than the pre-causeway water level by about 1.0 m.

The marsh levels in the upper portion of the estuary range between 7 and 8 m and the tidal level predicted under Project Option 3/4A is between 6 and 7 m and under Project Option 4B/4C, is between 6.5 and 7.0 m, lower than some of the wetlands that currently exist.

Figures 8.7.3 and 8.7.4 also show that the predicted average tidal levels are well above the channel bed level. As noted in Table 8.2.1, a key requirement for fish passage is that the freshwater and salt water connect. A silt plug will form in the main channel upstream of the causeway, but the normal flow of the Petitcodiac River will cut a channel through the silt plug and the average water level shown in Figures 8.7.3 and 8.7.4 is expected to be above the base of the channel, thus achieving the required connection between freshwater and salt water.

As noted above, the predicted water levels for the tides indicate that the head of tide will reach the same location as before the causeway was constructed. To further support this, models were run to predict the salinity in the river with the results presented in Figures 8.7.5 and 8.7.6. Initially, the salinity levels for the Petitcodiac River without the causeway were predicted as shown in Figure 8.7.5, then a prediction was made for the 20 year condition for Project Option 3/4A as this is the narrowest opening, Figure 8.7.6. The salinity predictions were similar, indicating that the head of tide would, in fact, be re-established near Salisbury Bridge.

8.8 Flooding

8.8.1 Status Quo

As presented in Section 8.3, infilling within the Petitcodiac River estuary will continue under the Status Quo and beyond 2025, likely to about 2075. As a result of the continued infilling within the main channel and its tributaries, the frequency and magnitude of flooding during open water conditions in the Moncton area will increase under the Status Quo.
Extreme hydrologic events were simulated during the modelling exercise. These events included a high rainfall event in the fall that actually occurred in September 1999. The flow during this event was 432 m$^3$/s. The simulations also included an extreme fall rainfall event in conjunction with a storm passage (high winds from the Bay of Fundy and rise in Mean Sea Level (MSL). Figures 8.8.1 and 8.8.2 show the results of the modelling for these events and indicate that there is a risk of flooding upstream of the causeway under the Status Quo (the predicted water levels are above the marsh levels).

For the high rainfall event in the fall with a storm and high winds, flooding of the marshland above the causeway is expected, and the water level predicted at Turtle Creek is expected to be above the causeway crest, but less than 0.1 m higher, indicating that overtopping of the causeway is possible, but that there would not be substantial damage (as per Table 8.2.1). The traffic circle would also be flooded under this event, to an elevation of more than 9.5 m and there could be a risk to public safety, more so than just an inconvenience.

A 100-year flood flow event (950 m$^3$/s ) occurring in conjunction with a storm passage (high winds from the Bay of Fundy and rise in MSL) was also simulated. Under this event, the causeway will be overtopped, possibly to above elevation 10.0 m, which could damage the causeway. This scenario would require a more detailed hydraulic analysis to determine the extent of damage and the risk to public safety at the traffic circle.

Downstream of the causeway, a high rainfall event with a storm and high winds, Figure 8.8.3, will result in flooding of the Champlain Place parking lot.

It should be emphasized here that the 2003 channel bathymetry was used in the simulation of the extreme hydrologic events. It has been observed that the bed of the channel could be higher than that observed in 2003. For example, the bed elevation in 2001 was approximately 3.0 m higher than that in 2003. Under such conditions, it is anticipated that flood levels could be higher (about 0.5 to 1.0 m) than those shown in Figures 8.8.1 and 8.8.2.

Hence, under the Status Quo, flooding upstream and downstream of the causeway, at the traffic circle, and overtopping of the causeway due to the nature of the river channel is a distinct possibility. This is in addition to the flooding that does and can occur in the areas adjacent to the river that cannot drain to the river because of impeded drainage. Measures including enhancing the drainage from the traffic circle and diverting storm water from the traffic circle have been identified above that will reduce the frequency of this flooding.

As noted in Section 7, a detailed flood risk assessment should be undertaken if the Status Quo continues for more than a few years.

8.8.2 Project Options

Project Options 3/4A and 4B/4C will result in a reduction in flooding risk in the long-term. The reduction of deposition associated with the Project Options at the culvert under the traffic circle on the Moncton end of the causeway will likely reduce the frequent flooding experienced at that
location since the drainage channel will become shorter, wider and deeper. As noted in Section 7, other measures may also be constructed to further reduce this risk.

Modelling was done for the fall events described above and the Project Options with the results shown on Figures 8.8.1 and 8.8.2. The 2003 bathymetry was used and only Project Option 3/4A was considered in these analyses as the water levels under Project Option 4B/4C would be expected to be lower as the opening in the causeway is bigger.

For Project Option 3/4A, the maximum water level upstream of the causeway is predicted to be lower; 6.8 m as compared to 9 m under the Status Quo, because the restriction from the gates will be removed and overtopping the causeway is not likely.

Downstream of the causeway, tributaries that are presently extended on post-causeway deposits, such as Jonathan Creek, Halls Creek and Babineau Creek, will be shortened due to the increased width of the main channel. These tributaries will also be deepened due to the decreased deposition, with related increased width. The computer models were not run assuming the projected bathymetry under the Project Options, but it is likely that the widening and deepening of the river will reduce the flood risk downstream of the causeway as well.

The level of risk associated with flooding downstream of the causeway can be better quantified through a detailed flood risk assessment, but depends on the option that is chosen and will not change the conclusion that the flood risk under the Project Options will be less than under the Status Quo.

8.9 Ice Regime

The pattern, location, extent, and nature of the ice that forms along the Petitcodiac River in the winter months are referred to as the ice regime.

8.9.1 Status Quo

Under the Status Quo, the ice regime will be similar to existing conditions. However, the winter tidal prism will tend to be less than current conditions due to the continued narrowing of the channel and rising bed in the mid and lower portions of the estuary. Also, ice jamming of tributaries would likely be worse due to shallower, narrower and longer channels, especially downstream of Dover.

8.9.2 Project Options

Under Project Options 3/4A and 4B/4C, the headpond would become estuarine. As such, the current behaviour of ice in the estuary would occur in the new estuary above the causeway as well. It is expected that under Project Option 3/4A, the winter channel should not narrow as much in the Dover to causeway area as it will under the Status Quo. Above the causeway, the ice cover would be replaced with an open channel bounded by shorefast ice. Due to the presence of sea ice, the risk of ice jamming between the causeway and Turtle Creek may increase. However, between Turtle Creek and Salisbury, the risk of ice jamming would be reduced.
Under Project Option 4B/4C, the conditions would be similar but the channel should be wider at any particular point as compared to Project Option 3/4A.

In terms of ice jamming in the main channel associated with Option 3/4A, it is expected that there will be a higher probability of jamming in the portion of the channel between the causeway and Turtle Creek. However, the risk of ice jamming in the upper portion of the estuary from about Boundary Creek to Salisbury is expected to be less than at present since the ice sheet in the headpond will no longer cause river ice to accumulate. Ice jams do occur in the channel upstream of Salisbury as documented by Hudson Engineering Ltd (1998).

Although the ice-free tributary channels below the causeway should become larger, it is likely that they will be as clogged with ice near where the tributaries enter the river as they were before the change. Above the causeway, the blockage of tributaries is expected to be increased somewhat because the elevation of the shorefast ice in the channel will be in the order of 7 m rather than the elevation of about 5.3 m in the present headpond.

For Option 4B/4C, the winter regime will be most like that for the pre-causeway situation. The ice cover on the headpond will no longer be present and the winter channel will narrow in the reach from the causeway to Turtle Creek, but the winter channel will not narrow as much in this reach as for Option 3/4A. During the winter, the segment of the estuary from Turtle Creek to Salisbury will be much like the estuary from about Fox Creek to the causeway under the existing conditions.

The ice-free tributary channels in the reach from the causeway to Dover should be larger than under the present situation. Although the tributary channels will be larger, it is unlikely that the conveyance will be greatly increased because drift ice will continue to be floated into the tributary channels. It is anticipated that the danger from flooding upstream of tributaries will continue to be a problem during the middle of the winter when the tributaries are almost clogged with ice. This will be particularly so for Halls Creek.

**8.10 Tidal Bore**

As noted in Section 5.2.9, the tidal bore at Moncton before the causeway was built was typically one metre in height and on occasion exceeded 1.5 m height. Since the causeway was constructed, the bore has diminished to less than 0.75 m at Moncton.

For the Project Options, computer models were used to predict the height of the tidal bore. Assuming a representative tidal range of -6.5m/+6.3m at Cape Enrage and that the bar of less erodible material (Section 5.2.1) at the bend near Moncton (between Mill Creek and the Gunningsville Bridge) is reduced over 20 years, then the tidal bore is expected to increase, but will never be fully restored. Under Project Option 4B/4C, the tidal bore height is expected to be about half that of the pre-causeway scenario. Under Project Option 3/4A, the height of the tidal bore is expected to be only one-third or less. It is apparent that the geometry of the river near Moncton and Dover has a strong influence on the behaviour of the river and the tidal bore.
More detailed information regarding how the tidal bore occurs in the Petitcodiac River, and how hydrodynamic and sediment transport modelling was used to better understand the tidal bore for the purposes of this EIA Report, is presented in the Modelling Component Study (AMEC, 2005b).

8.11 Wetlands

The computer modelling was used to estimate the wetland area of the Status Quo and Project Options above and below the causeway in the year 2025. Details on the methodology are provided in the Modelling Component Study Report (AMEC, 2005b). Essentially, it was assumed that wetlands would form in areas that are flooded 15% of the time. It was judged that this approach could have an error of +/- 25%, but for the purpose of the EIA, this approach was considered adequate. Table 8.11.1 shows the results of the wetland analyses and modelling for the pre-causeway and baseline conditions and the predictions for the Status Quo and Project Options.

From Table 8.11.1, it is clearly demonstrated that both freshwater and saltwater wetlands along the Petitcodiac River had increased substantially following installation of the Petitcodiac River Causeway. Based on the modelling and the trends derived from examining historical information, it is likely that the wetland area will continue to increase at a modest rate under the Status Quo.

For the Project Options, Table 8.11.1 indicates that there will be a loss of 60 ha (probably between 50 and 100 ha due to the margin of error associated with the analyses) of freshwater wetland by 2025 as compared to the 2005 baseline conditions. This loss will occur upstream of the causeway, where freshwater wetlands created by the causeway will be replaced with saltwater wetlands, except for those that exist within protected Ducks Unlimited sites (approximately 20 ha upstream of causeway and 26 ha downstream in 2001). These Ducks Unlimited sites are located in former dykelands that will be repaired and maintained as freshwater wetlands as mitigation for the Project Options.

Downstream of the causeway, Project Options 3/4A will result in an estimated loss of about 300 ha (possibly 200 to 400 ha) of saltwater wetland area by 2025 as compared to the 2005 baseline conditions. This would occur as accumulated sediments in the river are flushed out and the width of the river increases. However, the wetlands that will be lost had been initially created as a result of increased sedimentation caused by construction of the causeway. Total estimated saltwater wetland area downstream of the causeway in 2025 (1,300 ha) will likely be more than the pre-causeway conditions as the width of the river will still be less than that before the causeway was constructed. As noted in Table 8.2.1, the key criteria with respect to wetlands is that the area of wetland after implementation of the Project Options should be greater than the area of wetland (combined fresh and salt water) that existed in 1967. This is met by Project Option 3/4A.
### Table 8.11.1 Predicted Wetland Areas Under the Status Quo and Project Options

<table>
<thead>
<tr>
<th>Condition</th>
<th>Freshwater Wetland (ha)</th>
<th>Saltwater Wetland (ha)</th>
<th>Total Wetland Area (ha)</th>
<th>Difference in Freshwater Wetland Area Compared to Pre-causeway (ha)</th>
<th>Difference in Saltwater Wetland Area Compared to Pre-causeway (ha)</th>
<th>Difference in Total Wetland Area Compared to Pre-causeway (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-causeway</td>
<td>110</td>
<td>1,200</td>
<td>1,310</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Baseline conditions (2005)</td>
<td>260</td>
<td>1,600</td>
<td>1,860</td>
<td>150</td>
<td>400</td>
<td>550</td>
</tr>
<tr>
<td>Predicted conditions in 2025 for Project Option 3/4A</td>
<td>170</td>
<td>1,300</td>
<td>1,470</td>
<td>60 (-90 relative to baseline)</td>
<td>100 (-300 relative to baseline)</td>
<td>160 (-390 relative to baseline)</td>
</tr>
<tr>
<td>Predicted conditions in 2025 for Project Option 4B/4C</td>
<td>170</td>
<td>1,200</td>
<td>1,370</td>
<td>60 (-90 relative to baseline)</td>
<td>0 (-400 relative to baseline)</td>
<td>60 (-490 relative to baseline)</td>
</tr>
</tbody>
</table>

Note: Values are based on hydrodynamic and sediment transport modelling and are included for the purpose of trend indication only. Actual values may vary considerably (e.g., +/- 25%) and will be verified through Follow-up Program. See first paragraph of Section 8.11 for a description of the method used to generate these values.

For Project Options 4B/4C, there will be a greater loss of saltwater wetland area, by about 100 ha, and it is expected that after 20 years, the area of salt water wetland under Project Options 4B/4C will be similar to pre-causeway conditions. However, there will be more freshwater wetland than pre-causeway and the condition noted above (i.e., total wetland area after the Project Options should be greater than the pre-causeway condition) will be met.

Immediately downstream of the causeway, on the north bank in front of the former Moncton Landfill, there is expected to be a negligible loss of wetland under Project Options 3/4A, but under Project Options 4B/4C, there is expected to be a greater loss as shown on Figures 7.2.2 and 7.2.3. This could affect the capacity of the wetland that currently exists to treat leachate from the landfill and will require the installation of an alternative treatment system under Project Option 4C and may require such a system under Project Option 4B.

### 8.12 Projections to 2055 and 2105

The discussion in the previous subsections largely dealt with the conditions over the next 20 years (e.g., 2025). Beyond 2025, the river will continue to evolve in the patterns noted above, with the Status Quo continuing to cause infilling until about 2075 and the Project Options tending to achieve an equilibrium. A major change over this time will be an expected sea level

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rise of 88 cm as discussed in Section 7. This will lead to more energy into the river system that could result in greater erosion than has been predicted, but even under Project Options 4B/4C, the pre-causeway conditions will not be achieved. Flooding of the Moncton area could become problematic under this sea level rise.

8.13 Adequacy of Predictions

Table 8.2.1 listed the key issues that require predictions of the physical characteristics of the Petitcodiac River with associated threshold limits and resolution requirements. Comments on these issues and the results of the predictions have been provided in the preceding sections. Based on the results and predictions noted above, the accuracy of the predictions falls within the resolution requirements outlined in Table 8.2.1 and, therefore, the predictions that have been made are considered satisfactory for the purpose of the effects assessment in Section 9.

In terms of the threshold values, all of the predictions are within the threshold values that have been specified in Table 8.2.1 except for the location of the north bank of the river in front of the former Moncton Landfill between the causeway and Gunningsville Bridge where, under Project Options 4B and 4C, the north bank of the river will shift more than 50 m north and, therefore, erosion protection measures are an alternate means for treating the landfill leachate will be required.
9.0 ENVIRONMENTAL EFFECTS ANALYSIS

This section describes the environmental effects analysis for the Project Options (that meet the fish passage Project Objective) and the Status Quo. Note that the term “Project Options” includes Project Options 3, 4A, 4B and 4C; specific mention of a Project Option (e.g., Project Option 4B) is given when warranted.

9.1 Atmospheric Environment

The Atmospheric Environment is the component of the environment that comprises the layer of air near the earth’s surface to a height of approximately 10 km. The Atmospheric Environment may be characterized by three key aspects: climate; air quality; and sound quality (noise). To meet the Guidelines and to address issues raised during the consultation process, odour is also assessed as a fourth key aspect.

9.1.1 Rationale for Selection of VEC

The Atmospheric Environment has been selected as a VEC because of its importance to the health and well being of humans, wildlife, vegetation and other animals. The Atmospheric Environment is an important pathway for the transport of air contaminants (including noise), which can result in a transfer of environmental effects to freshwater, terrestrial and human environments.

9.1.1.1 Climate

Climate is generally defined as a description of the regularities and extremes in observed weather conditions in a particular geographical location over an extended period of time. Climate refers to long-term trends in observed weather conditions, both normals (averages) and extremes, measured over time periods ranging from months to centuries. The climate and weather trends may be applicable to large geographic regions such as cities and countries, and to smaller areas within a particular city or town may also experience their own distinct climatic conditions (generally referred to as “microclimate”).

Climate and weather may be influenced by a variety of factors, which include terrain, the presence of water bodies, urban infrastructure and other anthropogenic (man-made) factors. In recent times, the phenomenon of climate change has gained importance, where the global climate is thought to have undergone measurable changes as a result of increased greenhouse gas concentrations in the atmosphere.

9.1.1.2 Air Quality

Air quality is a broad term that generally refers to the properties and characteristics of the air in the lower atmosphere in a given geographic area. Air quality is typically characterized by knowledge of air contaminant emissions from local sources, and also by the existing ground-level concentrations of air contaminants in the outdoor air (termed “ambient air quality”).

The air quality in a particular region may be influenced by local sources of emissions, as well as sources in other regions or countries. Air contaminants emitted in a geographic area can be transported by prevailing winds to influence the air quality of a distant region. Much of New
Brunswick’s air pollution, with some local exceptions, is considered by regulatory agencies as being transboundary in origin (i.e., emitted from sources beyond its provincial borders).

**9.1.1.3 Odour**

Odour is the characteristic of a substance that makes it perceptible to the human sense of smell. It is the sensation that results when olfactory (relating to the sense of smell) receptors in the human nose are stimulated by chemical species in the air. Odour can be pleasant or unpleasant and is generally characterized in terms of its quality (character) and strength (intensity). The human response to odour depends on the quality, strength and frequency of occurrence. The combination of these properties may be related to the annoyance that results from the odour.

The process of odour detection, perception and evaluation is complex. Odour is a subjective parameter and cannot easily be measured directly by conventional techniques. It is most often assessed by personal perception. Prolonged exposure to an odour can result in people becoming desensitized such that they can no longer detect the odour, even though the odour is consistently present in the air.

Ambient odours in a particular area can be influenced by a variety of factors, including the odour emission rate at the source, the surrounding land topography (e.g., mountains, hills, valley, or flat), the amount and type of vegetation nearby, as well as atmospheric conditions such as wind direction and wind speed.

**9.1.1.4 Sound Quality**

Sound quality generally refers to the type (e.g., waves against a shoreline), intensity (related to how loud the sound is at a specific location) and character (including tone, duration and extent) of sound in the outdoor environment. Sound emissions can be defined from a physics standpoint as a physical disturbance that creates waves in a medium such as air or water, or from a human perspective as the sensation produced by the ear when it experiences small pressure variations.

Sound quality is quantitatively characterized in terms of the intensity and character of sound emissions. The intensity of sound emissions or ambient (background) sound pressure levels is characterized using a logarithmic A-weighted decibel (dB$_A$) scale, since the human ear does not respond to sound on a linear scale. For example, intensity must increase by ten times for the human ear to perceive a doubling of loudness. Another way of thinking of this is that it would take ten people playing violins to double the volume produced by one violin. Noise is typically defined as unwanted sound, and since different receptors respond differently to different sound levels, the perception of noise tends to be subjective. Sound quality can be influenced by a variety of natural and human-made factors, including sounds associated with wind and wind movement through vegetation, waves in water colliding against shorelines, sounds produced by birds and other animals, as well as from sound emissions from stationary and mobile sources. Physical changes in the characteristics of the environment (such as a change in land cover or the removal of trees) may also affect the sound transmission (ability of sound to move from the
source to a receptor) or attenuation (from factors that restrict sound travel) characteristics of the environment, thereby influencing sound quality in a specific area.

### 9.1.2 Boundaries

The spatial boundaries for the assessment of the Atmospheric Environment (the “Assessment Area”) are broadly comprised of the GMA and Southeastern New Brunswick as applicable (Table 4.7.1).

Specifically, with the exception of climate, the spatial boundaries for all key aspects of the Atmospheric Environment are defined as the Greater Moncton Area (including the municipalities of Moncton, Riverview, Dieppe and surrounding neighbouring communities) for the characterization of the potential environmental effects of the Status Quo and Project Options on air quality, sound quality and odour.

Given that changes in climatic conditions tend to occur on a regional, national and global scale, the spatial boundaries for the assessment of potential environmental effects of the Status Quo and Project Options on climate are defined as Southern New Brunswick, including of the Counties of Charlotte, Saint John, Kings, Westmorland and Albert.

The temporal boundaries for the assessment of the Atmospheric Environment are the same as defined in Section 4.7.

### 9.1.3 Threshold for Determination of Significance

#### 9.1.3.1 Climate

Climate variability and climate change are global issues, and the effects of human activities on climate are difficult to assess on a localized scale. Climate science has not sufficiently advanced to a point where a clear cause and effect relationship can be established between global climate change and local changes to the environment, or even with emissions of greenhouse gases on a local, provincial, or national scale.

While it is acknowledged that the global climate may currently be undergoing measurable changes, and that emissions of greenhouse gases are thought to be a significant contributor to this global climate change, a cause and effect relationship between climate change and the Status Quo or Project Options would be difficult to establish. Some localized variations to microclimate in specific areas in the immediate vicinity of the Petitcodiac River may result from the Status Quo or Project Options, but these changes would not be distinguishable, with some certainty, on a regional or even provincial or national scale, due to the relatively limited scale of the Status Quo or Project Options in the global context.

In this light, and in the absence of specific regulatory guidance on carbon dioxide (CO₂) emissions or climate change, a **significant negative residual environmental effect** on climate is one that results in a substantive increase to provincial releases of greenhouse gases (i.e., >1% of total provincial CO₂ emissions), or a substantial loss in carbon sinks (i.e., >1% of carbon sinks) in Southern New Brunswick. These are conservatively set thresholds, as climate
variability and climate change is a global phenomenon to which New Brunswick is, relatively speaking, a very small contributor in the context of national and global emissions. Carbon sinks are areas where carbon is removed from the CO₂ in the atmosphere and is concentrated in a non-gaseous form such as occurs in wetland plants, and more substantively in forests; the breakdown of organic matter by biological organisms (e.g., bacteria); and the raising of livestock. It is believed that carbon sinks are essential to help limit climate change caused by excess CO₂ in the atmosphere.

9.1.3.2 Air Quality

A significant negative residual environmental effect (see Glossary) on air quality is one that degrades the quality of the air to such an extent that the emissions of the air contaminants of concern lead to an exceedance of the ambient air quality standards, as defined in the New Brunswick Air Quality Regulation – Clean Air Act. For the purposes of this assessment, the air contaminants of concern are defined as particulate matter (PM), fine particulate matter (PM₁₀), sulphur dioxide (SO₂), nitrogen oxides (NOₓ) and carbon monoxide (CO). These regulatory standards have been established to be conservatively protective of air quality, human health and the environment.

9.1.3.3 Odour

A significant negative residual environmental effect on odour is one that results in a noticeable change in the character, intensity, or frequency of odours in the Assessment Area, such that the resulting odours would frequently (i.e., >10% of the time on an annual basis) and substantially interfere with the normal conduct of business, or the normal enjoyment of the use of properties by a group of people (e.g., residents of a subdivision adjacent to the source), as defined in Section 6(2) of the New Brunswick Clean Air Act.

9.1.3.4 Sound Quality

A significant negative residual environmental effect on sound quality is one that creates a “nuisance” at the nearest residential property boundary, by causing a frequent exceedance (i.e., more than 10% of the time on an annual basis) of the noise guideline level, on a sustained and permanent basis, at the nearest noise sensitive area (NSA). In the absence of official regulatory guidelines in New Brunswick for acceptable ambient sound pressure levels, the current New Brunswick Department of Transportation (NBDOT) threshold value of 65 dBₐ measured as a 24-hour Lₑq (used for highway construction projects) will be used as the noise guideline level (ADI, 2003).

In areas where the baseline (2005) ambient sound pressure levels already exceed the NBDOT noise guideline level, a significant negative residual environmental effect on sound quality is one that creates a “nuisance” at the nearest residential property boundary by frequently causing a substantive increase in ambient sound pressure levels (i.e., >10 dBₐ above background), measured as a 24-hour Lₑq.
9.1.4 Evaluation of Potential Environmental Effects

9.1.4.1 Climate

Status Quo

Other than natural climate variations that may occur in the Assessment Area, as well as the potential environmental effects of global climate changes on the local and regional climate in the Assessment Area, no measurable change on Climate is expected from the Status Quo. There are no features of the Status Quo that would result in substantive changes to greenhouse gas emissions, regional climate, or microclimate in the Assessment Area.

Detailed information on pre-causeway and post-causeway construction climate conditions was presented in the Biophysical Component Study (AMEC, 2005a). Climate statistics at the Moncton Airport over a 30-year period from 1941 to 1970 were reviewed to establish pre-causeway construction conditions, and data for the period of 1971 to 2000 were reviewed to establish post-causeway construction conditions. As evidenced by these data, while some variations (likely natural) in certain climate parameters were observed to occur on a regional scale, the magnitude of these variations was small, or not measurable, in most cases. Since these long-term climatic conditions did not measurably change from the pre-causeway to post-causeway construction periods, although it is difficult to predict, it is not expected that they would be significantly altered solely as a result of the Status Quo by 2025.

On a more localized scale, it is possible that some microclimatic (see Glossary) environmental effects could be observed as a result of the Status Quo, particularly with respect to ambient temperatures, fog, winds and precipitation. However, as evidenced by a comparison of the climate records for pre-causeway and post-causeway conditions, the magnitude of any changes that may have occurred to most weather parameters over these time periods was very small or barely measurable. Although the observations were tabulated for the Moncton Airport, these are not expected to be appreciably different at the current causeway location. Average winter temperatures of approximately -8°C were observed for both time periods at the Moncton Airport, and average summer temperatures ranged approximately 17-20°C. The predominant wind direction was southwesterly in both 30-year time periods, with mean wind speeds having decreased slightly in the post-causeway construction period as compared to pre-causeway conditions (on average, from 18.7 km/h to 16.6 km/h on an annual basis). Urban temperatures in the GMA for the post-causeway construction period increased slightly from pre-causeway levels, which may reflect the growth of urban infrastructure and population in the area over the post-causeway period.

The average number of days with fog in the GMA, however, decreased from the pre-causeway to post-causeway time period from 66 days per year with fog, to 52 days per year. The diminished Petitcodiac River tidal bore during post-causeway conditions was also reported, through information (based on or consisting of reports or observations of usually unscientific observers), to have a less pronounced moderating effect on microclimate conditions than during pre-causeway conditions, and may also have contributed to the lower number of days with fog
in the GMA. Based on 30-year climate normal data, there has also been an increase in extreme weather events, including thunderstorm activity, over these periods; however, this may be statistically insignificant and could be attributed to natural variations. Precipitation also increased slightly between pre-causeway and post-causeway time periods from 1,099 mm per year to 1,143 mm per year, which is not likely to be directly attributable to the construction of the causeway but rather as a result of other factors (see Section 11.3.1.1).

Greenhouse gas emissions in southeastern New Brunswick were projected by Natural Resources Canada to increase at an average rate of 1.1% per year between the post-causeway and 2005 baseline time periods (NRCan, 1999), which may be reflective of the increasing population and urban infrastructure in the region. Although difficult to predict, with the expected increased use of renewable energy sources in the future, and with other measures that are expected to be implemented provincially and nationally to control greenhouse gases as a result of the Kyoto Protocol, greenhouse gas emissions may well decrease by 2025, for the Status Quo.

In short, apart from some very modest changes in some local weather variables observed from the pre-causeway construction period to the post-causeway construction period, there is no evidence to suggest that they may be attributable to the construction of the causeway itself. As a result, building on the past experience from the pre-causeway to post-causeway construction time periods, there is no reason to suggest that the Status Quo may directly result in any significant changes to climate.

Overall, it is difficult to predict what changes to climate would be expected to occur in the GMA by 2025 under the Status Quo. However, it can be stated with some certainty that, whatever changes to climate do occur would more than likely be the result of other factors (e.g., global climate change), and by far outweigh any issues that may arise directly as a result of the Status Quo. In summary, the potential negative environmental effects of the Status Quo on climate, in consideration of the residual environmental effects significance rating criteria, are predicted to be not significant.

**Project Options**

The potential environmental effects on climate are similar for all Project Options. Therefore, the potential environmental effects of construction and operation on climate of all Project Options, and associated mitigation, are discussed together in this section.

During construction of the Project Options, no measurable changes to climate are expected to occur on a local or regional scale. Any changes in local, regional, or global climate that may occur as a result of the Project Options would likely occur over an extended period of time (i.e., over a period of several years to several decades), and would likely not be distinguishable over the limited time period during which construction is expected to take place. As a result, the potential environmental effects of the Project Options on climate during construction will not be discussed further in this assessment.
During operation of the Project Options, some physical changes to the local landscape will occur which have the potential to alter weather patterns (particularly on a localized or microclimatic scale), and consequently climate. Project Options will result in the replacement of the current headpond with a narrow river channel upstream of the current location of the causeway, which will re-establish the free-flow of tidal waters twice-daily upstream of the current causeway location. However, any small-scale changes in the characteristics of the Petitcodiac River channel that may occur downstream of the current causeway location are unlikely to be significant, nor measurable as compared to currently, from a climatological (relating to weather) or microclimatic standpoint, and will not be considered further. The assessment will therefore focus on the potential environmental effects on climate upstream of the current causeway location.

Measurable regional or global climate change as a result of the operation of the Project Options is not anticipated.

From the perspective of microclimate, the tidal waters moving upstream of the current causeway location are expected to contain more sediment than the water currently contained in the headpond. These “muddy” waters are expected to have a lower albedo (i.e., a lesser ability to reflect sunlight) than the surrounding ground surface, as well as in comparison to the water contained in the headpond from the post-causeway construction to the 2005 baseline period. Changing the albedo of the waters could affect the environment’s ability to reflect or absorb solar radiation (i.e., sunlight) reaching the ground surface, which in turn may affect local weather parameters such as temperature and winds on a microclimatic scale. However, since there were no measurable changes observed in most weather variables from the pre-causeway to post-causeway construction periods, the potential changes in microclimate resulting from the albedo of the waters upstream of the causeway, following the implementation of the Project Options, are expected to be not significant.

The headpond currently consists of freshwater and freezes over during winter, upon implementation of the Project Options, the free-flowing waters upstream of the current causeway location will likely consist of saltwater (or mixed saltwater/freshwater) and thus are not expected to freeze during winter, or if freezing occurs, it is not expected to be frequent. The tidal waters, originating from the Bay of Fundy, are also expected to be slightly “warmer” during winter, and slightly “cooler” during summer, than the water contained in the headpond during 2005 baseline conditions, which could lead to local changes in ambient temperature and potentially changes in surface turbulence (i.e., winds). However, from a microclimatic standpoint, since there were no measurable changes observed in most weather variables from the pre-causeway to post-causeway construction periods, the potential changes in microclimate from the changed water temperatures upstream of the causeway upon implementation of the Project Options are expected to be not significant.

The influx of tidal waters twice daily upstream of the current causeway location could result in the presence of fog, either from regional air masses over the Bay of Fundy and carried up-river with the tidal bore (known as “marine advection fog”), or as a result of physical changes to microclimatic conditions. There are no features of the Project Options that would result in
changes to the current atmospheric processes over the Bay of Fundy that lead to the formation of marine advection fog, and thus there are no expected changes to regional air masses from the Project Options that would result in increased or decreased incidence of fog carried up-river from the Bay of Fundy.

With respect to local fog generation, the physics of fog formation require that a combination of weather conditions be present in order to create fog. In simplistic terms, fog is formed when the combination of ambient air temperature, relative humidity, barometric pressure, atmospheric stability, and wind, “collide” at the dew point and result in condensation of water vapour in the air to form fog. Due to the more stable air masses and generally lower wind speeds that occur at night as a result of natural daily variations in temperature and winds, the combination of conditions that lead to fog formation would be more likely to occur during the night and early morning than during the rest of the day.

As evidenced by the information presented in the Biophysical Component Study (AMEC, 2005a), the average number of days with fog in the GMA decreased from the pre-causeway to the post-causeway time period from 66 to 52 days per year with fog occurring for at least 1 hour. The diminished Petitcodiac River tidal bore during post-causeway conditions was also reported to have a less pronounced moderating environmental effect on riverine microclimate conditions than during pre-causeway conditions, and may also have contributed to the lower number of days with fog in the GMA. This was supported by non-scientific observations by some stakeholders who indicated that fog could sometimes be observed as being “carried along” with the tidal bore, prior to the construction of the causeway.

In summary, historical information would tend to indicate that there may be a potential for an increased incidence of fog (an anticipated increase of approximately 14 days per year) in the GMA following the implementation of the Project Options, which may create potential concerns with regard to transportation (e.g., traffic interruptions) as well as public safety (e.g., increased potential for traffic accidents). However, the GMA already experiences fog on average 52 days per year, and any fog that forms as a result of the operation of the Project Options would likely be localized, intermittent (coming and going at intervals) and of short duration (e.g., a few hours). Therefore, the potential environmental effects of fog as a result of the operation of the Project Options are expected to be not significant.

From the perspective of the operation of the Project Options on the loss or enhancement of carbon sinks, the loss of wetlands and other vegetation, which serve as a carbon sink to absorb carbon dioxide in the atmosphere, is not expected to cause any significant negative environmental effects to climate. Although some wetland and related vegetation may be lost as a result of the Project Options, these losses will be relatively small on a regional scale. Many of the existing wetlands did not exist prior to the construction of the causeway, and it is expected that some of these wetlands may be enhanced, and other wetlands could well be created, as a result of the Project Options. This is explained in more detail in Section 9.3.4.1.

As discussed in Chapter 9, it is expected that the Project Options will result in increased deposition of sediment along the river channel, such that some surface area that currently exists
as wetland will likely become mudflat during the operation of the Project Options (AMEC, 2005b). As presented in Table 8.9.1, the hydrodynamic modelling results were used to estimate the loss of wetland area from the implementation of the Project Options at approximately 390 ha of baseline wetland area for Project Options 3/4A, and -490 ha of baseline wetland area for Project Options 4B/4C. Although data for the entire Assessment Area (i.e., Southern New Brunswick including Charlotte, St. John, Kings, Westmorland and Albert counties) are not readily available, the NBDNR reports that there are currently approximately 549,700 ha of forested areas in Westmorland and Albert counties. Since forest land tends to be a more productive carbon sink than wetland, as measured by its relative ability to remove ambient CO₂, this represents a conservative value for comparison. Therefore, in comparison to the current forested areas in these areas, the loss of wetlands near the Petitcodiac River as a result of the implementation of the Project Options represents the loss of less than 0.07% of carbon sinks on a regional basis for Project Option 3 and Project Option 4A, and less than 0.09% of carbon sinks on a regional basis from Project Options 4B/4C. For the entire Assessment Area, this would represent an even smaller fraction of available carbon sinks in the region. Therefore, it is not expected that the Project Options will result in significant losses in carbon sinks in the Assessment Area, and to an even lesser extent as measured on a regional or global scale.

In summary, while there may be some localized changes that occur to the microclimate in the immediate vicinity of the Petitcodiac River following implementation of the selected Project Option, the potential negative environmental effects of the Project Options on climate in consideration of the residual environmental effects significance rating criteria are predicted to be not significant on local, regional, provincial, national and global scales.

Comparative Assessment

The potential negative environmental effects of the Status Quo and Project Options on climate in consideration of the residual environmental effects significance rating criteria are predicted to be not significant on local, regional, provincial, national and global scales. From a climate perspective, although there may be some nominal changes on a localized scale from the Project Options, these changes are not expected to be measurably or substantially different than 2005 baseline conditions.

Although it is known that climate has not changed measurably from the pre-causeway to post-causeway construction periods, there is considerable uncertainty with regard to the potential effects of natural climate variations or global climate change on climate occurring in the region or globally, and potentially affecting climate in the Assessment Area. However, any changes that do occur to climate in the Assessment Area would likely be the result of other factors (e.g., global climate change), and by far outweigh any issues that may arise directly as a result of the Status Quo or the Project Options.

9.1.4.2 Air Quality

Status Quo

Based on the information presented in the Biophysical Component Study, air quality in the GMA is considered to be relatively good, although emissions of air contaminants of concern, and
ambient concentrations of these contaminants, are tending towards a slightly increasing trend (AMEC, 2005a). It is difficult to predict whether emissions and/or ambient concentrations of contaminants will continue to increase beyond the 2005 baseline in the foreseeable future, and into 2025. It is also apparent in the Biophysical Component Study that both ambient air quality and provincial emissions (and by extension, emissions in the GMA) tend to vary from one year to the next (AMEC, 2005a). The contribution to ambient concentrations of air contaminants as a result of long-range transport is considered to be substantial (with ground-level ozone concentrations being a case in point), with very little control over such contributions affecting airsheds (a geographic area that shares the same air) in southern New Brunswick.

With that stated, other than variations in emissions and ambient air quality that tend to occur from year to year, and the contributions to ambient air quality from long-range transport, the Status Quo is not expected to result in any measurable change with regard to air quality. There are no elements of the Status Quo that would be expected to result in measurable changes to emissions or ambient air quality on a local or regional scale. Emissions and ambient air quality concentrations on a local and provincial basis may well increase as a result of increased use of transportation fuels as well as from industrialization, but it is also possible that emissions and ambient air quality could improve by 2025 as a result of increased use of alternative fuels, renewable energy sources (e.g., hydroelectric dams) and conservation measures, for example. While these changes are not predictable, it is not likely that these changes, positive or negative, will occur solely as a result of the Status Quo.

The completion of the new Petitcodiac River Bridge is likely to result in some localized air quality benefits near the causeway due to changes in traffic patterns, as commuter vehicles traffic increases on the new bridge as opposed to the causeway. Although this may reduce traffic in the vicinity of the causeway (and consequently, localized emissions), on a regional basis there would be very little measurable overall change in air quality in the GMA, as vehicles would simply be displaced from one traffic route to another.

With the Status Quo, from a regional perspective, it is not likely that the existing exposed mudflats currently part of the Petitcodiac River system would be altered such that significant environmental effects would occur with respect to air quality. From historical experience, these existing exposed mudflats tend to be sufficiently moist so that dust emissions resulting from wind erosion are likely to be nominal and are therefore considered to be not significant. This would not be expected to change as part of the Status Quo.

Overall, it is difficult to predict what changes to air quality would be expected to occur in the GMA under a Status Quo situation. However, it can be concluded with some certainty that changes that occur to air quality would likely be the result of other factors rather than being directly attributable to the Status Quo, and the potential environmental effects that could occur to air quality from these other factors would by far outweigh any issues that may arise directly as a result of the Status Quo. In summary, the potential negative environmental effects of the Status Quo on air quality in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.
Project Options

During construction, a number of activities have the potential to affect air quality for the Project Options. The Project Options will involve the removal of an existing bridge deck (i.e., the causeway surface), and the construction of a new bridge deck. Other construction activities to replace the existing bridge deck will include some land preparation for the new bridge deck (possibly involving earth moving, excavation, concrete blasting, grading and levelling), the physical construction of the new bridge deck (which may involve pile driving; placement of footings, foundations and piers; installation of bridge spans; and placement of the new deck), possible improvements to roadway approaches and surfacing and finishing.

Emissions from the above construction activities will likely consist of emissions from heavy equipment used during construction and airborne dust from earth moving and demolition of the bridge surface. These emissions are not expected to be substantive nor distinguishable from current levels in the GMA. In addition, given that construction activities will likely occur over a relatively short period of time, that the land on either end of the causeway is already developed, and that emissions from construction activities will be localized, intermittent and of short duration, the emissions from these activities are not expected to cause significant negative environmental effects on local air quality during most atmospheric conditions.

Several mitigation measures will be applied during construction to minimize the potential environmental effects to air quality, including:

- Conducting all construction activities in accordance with NBDOT Standard Specifications (NBDOT, 2003) and all applicable regulations and guidelines.
- Ensuring that equipment is properly maintained to minimize emissions of contaminants from heavy construction equipment, ensuring the proper preventative maintenance of heavy equipment and diesel engines, and shutting off such equipment when not in use.
- The application of dust suppressants, such as water, during periods of heavy activity and during extended dry periods will be used to minimize airborne dust emissions and to ensure that the airborne dust remains below the ambient standards.
- Where feasible, construction activities that have the potential to create airborne dust will be scheduled to be conducted during periods of low winds to minimize the transport of airborne dust to nearby residential areas.
- Concrete and asphalt materials required for construction will be procured from existing approved concrete ready-mix and asphalt plants in the area.
- Any aggregate or fill material required for construction will be sourced from nearby existing approved pits or quarries.
- Contractors will be encouraged to use biodiesel fuel blends (currently available in Moncton) where possible.

During operation, the Project Options are not expected to result in significant changes to air quality compared to 2005 baseline conditions. There are no features of the Project Options that would be expected to result in measurable changes to emissions or ambient air quality on a local or regional scale, solely as a result of the Project Options. There is no expected increase
in vehicle traffic solely as a result of the future operation of the Project Options, nor are there any other activities during operation that have the potential to generate substantive emissions of air contaminants as a result of the Project Options.

As discussed above, the completion of the new Petitcodiac River Bridge is likely to result in some localized air quality benefits due to changes in traffic patterns, due to increased use of the new river crossing as opposed to the causeway. This, however, is not expected to result in any measurable change in air quality on a regional basis, as vehicles would simply be displaced from one traffic route to another.

The implementation of the Project Options will re-establish the free flow of tidal waters upstream of the current location of the causeway. As evidenced by the hydrodynamic modelling, a narrower river channel is expected upstream of the current causeway location, and increased deposition of sediment is expected at these locations, likely resulting in additional mudflats being created. Downstream of the causeway, additional sediment deposition from the tidal waters is expected to result in existing wetland areas becoming additional mudflats. However, as discussed previously, it is known from historical experience that the existing exposed mudflats in the Petitcodiac River system tend to be sufficiently moist such that dust emissions as a result of wind erosion are likely to be nominal and are therefore considered to be not significant. Therefore, despite the expected increases in mudflat areas as a result of the Project Options, the potential for airborne dust emissions from existing and future exposed mudflats would not likely result in any significant environmental effects with respect to air quality.

Overall, there may be localized reductions in commuter vehicle traffic (and consequently, reductions in emissions of particulate matter and combustion gases) as a result of other planned Projects (e.g., the new Petitcodiac River Bridge), but these would likely occur regardless of whether or not the Project Options are implemented. Any emissions that may occur as a result of the operation of the Project Options are not expected to negatively affect air quality in the GMA, nor are they expected to be detectable from current levels. The overall effect of improved road transportation infrastructure from the Project Options and other planned Projects on emissions in the GMA as a whole is expected to be neutral or positive (due to more efficient driving speeds, giving rise to lower emissions). In summary, the potential negative environmental effects of the Project Options on air quality in consideration of the proposed mitigation during construction and the residual environmental effects significance rating criteria are predicted to be not significant.

Comparative Assessment

The potential negative environmental effects of the Status Quo and Project Options on air quality in consideration of the mitigation proposed during construction of the Project Options and the residual environmental effects significance rating criteria are predicted to be not significant. There are no characteristics of the Status Quo or the Project Options that would be expected to result in significant environmental effects to air quality on a local or regional scale. While there is some uncertainty with respect to the potential for future increases or decreases in emissions, or ambient air quality concentrations as a result of industrialization or future use patterns for fossil fuels, and while there may be some variation in emissions or ambient air quality conditions
on the local or provincial scale occurring by 2025, it is not expected that these changes will be directly or indirectly attributable to the Status Quo or the Project Options.

### 9.1.4.3 Odour

#### Status Quo

Based on the information presented in the Biophysical Component Study, odour has not historically been of major concern in the AMEC, 2005a. Several point sources were identified from personal interviews and other sources as potentially causing odours along the Petitcodiac River, including residual sewage, the former Moncton Landfill, the Swift meat packing plant, and other industrial or commercial sources. While none of these sources were believed to have resulted in chronic odour concerns in the GMA, there was at least non-scientific evidence suggesting that these sources, at one time or another, have resulted in distinguishable odours in the GMA, particularly on or along the Petitcodiac River.

There is no evidence to suggest that the existing Petitcodiac River system itself has been or could become a source of objectionable odours. While mudflats in general tend to have a characteristic odour (referred to as the “mudflat odour”, which is also characterized as a “marine” smell), there is no reason to suggest that such odours would be considered objectionable or cause significant negative environmental effects. In fact, two specific odour monitoring events conducted by the AMEC Study Team did not indicate any objectionable odours at high or low tide during the monitoring events (AMEC, 2005a). There was, however, some indication from the Water Quality Field Study Team that a characteristic “mudflat odour” could be detected on at least one occasion near Outhouse Point. This odour was reported to be readily detectable but mild and unobjectionable. The observed presence of water quality issues (low dissolved oxygen (DO), high fecal coliform) downstream of the causeway is attributable to sewage effluent from the GMA and other sources. This issue is worse in summer due to limited dilution during low flow conditions. At times this loading may result in odour issues close to the Petitcodiac River.

The decomposition of organic matter, either as a result of submerged vegetation or increased nutrient loadings leading to algae blooms (i.e., eutrophication), also has the potential to result in odours from decay processes. This typically occurs in an anaerobic environment (i.e., in the absence of oxygen). The Biophysical Component Study suggested that there was evidence of residual treated sewage, as evidenced by relatively high levels of microbiological species (i.e., animals and plants that can only be seen under a microscope) such as fecal coliforms, in the Petitcodiac River system which has the potential to lead to increased growth rates of aquatic vegetation and organisms (AMEC, 2005a). While this could indirectly lead to increased odours, there is no evidence to suggest that this has occurred in the past, nor has it been observed as part of 2005 baseline conditions.

Overall, with all other factors being equal (i.e., no changes to existing point sources, no changes to existing residual sewage loadings, and no changes to agricultural and farming activity, to name a few), it is expected that odour in the Assessment Area as a result of the Status Quo would be similar to, or no worse than the 2005 baseline conditions and earlier periods. While
there are many factors that could result in an increased incidence of odours, there is no reason to suggest that the Status Quo would result in any increased or decreased odours in the Assessment Area, nor any evidence to suggest that any such odours that do arise would be objectionable to humans who experience the odour so as to cause a loss of use or enjoyment of property. In summary, the potential negative environmental effects of the Status Quo on odour in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

**Project Options**

During construction, there are no significant environmental effects expected with respect to odour. There are no unique aspects of construction that would be expected to lead to an increased incidence of odours in the Assessment Area. Small fuel spills could occur from heavy equipment during construction, potentially creating a fuel-like odour, but it is expected that any such spills would be quickly cleaned up and thus any resulting odours would only be present for a short period of time.

The Project Options would result in the replacement of the headpond with a narrow and free flowing river channel, and any previously submerged vegetation and mudflats would be exposed during construction and potentially cause odours. However, potential environmental effects resulting from the mudflats and decaying exposed vegetation during construction would be similar to those during operation (discussed below).

During operation of the Project Options, with the replacement of the headpond with a narrow free flowing river channel, some previously submerged vegetation in the bed of the former headpond, as well as mudflats, would be permanently exposed to the elements, potentially creating odours. It is expected for a short period following implementation of the Project Options that some previously submerged vegetation would be exposed to the elements and then decay. While the decay of organic matter in an anaerobic (i.e., the absence of oxygen) environment can result in pungent odours, the previously submerged and newly exposed vegetation would be continuously exposed to ambient air (oxygen), and therefore the decomposition process would likely occur aerobically (i.e., in the presence of oxygen), thereby minimizing any odours that could otherwise result from the decay processes. The potential odours as a result of decaying vegetation would not be continuous and would be very localized. In addition, the decay processes would occur over a relatively short period (i.e., one to two years during warmer seasons), after which new vegetation growth would have taken over these areas, or they would have been covered by mudflat. Odours generated as a result of the decay processes are not expected to be of sufficient intensity or duration to cause significant negative environmental effects to nearby residential receptors.

With respect to odours from mudflats, the Project Options will result in the replacement of some existing wetland habitat by mudflats, particularly downstream of the current causeway location. Some mudflat would also be generated upstream of the current causeway location, although it is expected that this will occur to a more limited extent. It is also expected that portions of the former lake bed of the headpond, potentially consisting of mud, would also be exposed, at least for a short period following implementation of the Project Options. Wetland habitat and
vegetation growth is expected to develop in the exposed portions of the former headpond bed. With increased mudflats being exposed as a result of the Project Options, it is possible the characteristic “mudflat odour” could be detected by nearby human receptors. The increased turbulence and microclimatic effects caused by the tidal bore upon the rising tides could stimulate the dispersion of any mudflat odours. However, as evidenced by the odour monitoring events conducted by the AMEC Study Team (AMEC, 2005a), there is no reason to suggest that such odours would be considered objectionable or cause significant negative environmental effects that would be significant with respect to odour. Therefore, the odours potentially resulting from exposed mudflats are not expected to exhibit any characteristics, or be of sufficient intensity or duration, as to cause any significant negative environmental effects. Any mudflat odours detected by human receptors would likely be intermittent and of short-duration in nature, such that it is unlikely that these odours would result in any loss of use or enjoyment of properties by local residents.

Upon implementation of the Project Options, it is likely that any sewage present in the tidal waters may be carried further upstream by the tidal action of the river, upstream of the current causeway location. Sewage may enter the river directly from municipal sources, including combined sewer outflows from the City of Moncton during extreme rain events or from subdivisions lacking treatment facilities (e.g., Greensborough Subdivision in Riverview). Contaminants or nutrients contained in this effluent could result in possible odours. This is not expected to occur due to the dramatic dilution that will be associated with the greatly increased tidal exchange. If it occurs, the odour is expected to be not significant both upstream and downstream of the causeway.

In summary, while there may be some localized or short-term environmental effects with respect to odours from the decay of previously submerged vegetation, from exposed mudflats, or sewage, these odours are not expected to result in any loss of use or enjoyment of properties by local residents. The potential negative environmental effects of the Project Options on odour in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

**Comparative Assessment**

The potential negative environmental effects of the Status Quo and Project Options on odour in consideration of the residual environmental effects significance rating criteria are predicted to be not significant. While there may be some short-term environmental effects on odour in some localized areas as a result of decaying vegetation following the implementation of the Project Options, new vegetation growth should quickly take hold in these areas. Odours generated as a result of the decay processes are not expected to be of sufficient intensity or duration to cause negative effects to nearby residential receptors. Any mudflat odours detected by human receptors would likely be intermittent and of short-duration in nature, it is unlikely that these odours would result in any loss of use or enjoyment of properties by local residents.
9.1.4.4 Sound Quality

Status Quo

There is limited published information on existing or historical noise levels in the GMA (AMEC, 2005a). A baseline noise monitoring assessment, intended to establish existing sound quality conditions to serve in the characterization of 2005 baseline conditions (AMEC, 2005a), indicated that sound quality at existing residential properties in the vicinity of the causeway (identified as NSAs) was considered to be typical of urban environments where the sound quality is dominated by vehicle traffic.

While being highly variable with respect to intensity, traffic sound emissions are generally not impulsive or tonal in nature. Ambient sound pressure levels measured at both sides of the causeway were fairly consistent with an average 24-hour $L_{eq}$ range of 58 dBA to 66 dBA (AMEC, 2005a). Ambient sound levels dropped during the night time, with a minimum 1-hour equivalent sound pressure level between 49.8 dBA and 57.0 dBA, which are comparable to daytime sound levels and may suggest that vehicle traffic during the night is sufficient to influence night time ambient sound pressure levels.

Based on these observations, there is no evidence to suggest that the Status Quo would result in significant negative environmental effects with respect to sound quality.

As discussed previously, the completion of the new Petitcodiac River Bridge is likely to result in some changes in local traffic patterns, as commuter vehicles make increased use of the new bridge as opposed to the causeway. With the potential for reduced vehicle traffic (the main source of noise emissions identified in the Assessment Area), a corresponding reduction in sound pressure levels could be expected, thereby benefiting sound quality. These benefits, although not specifically the result of the Status Quo but rather as a result of other planned projects to be carried out in the Assessment Area, would be likely to occur, regardless of whether the Status Quo or Project Options are implemented.

In summary, while there may be localized reductions in commuter vehicle traffic (and consequently, reductions in sound pressure levels) as a result of other planned projects (e.g., the new Petitcodiac River Bridge), the potential negative environmental effects of the Status Quo on sound quality in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options

During construction of the Project Options, noise can be expected as a result of construction activities such as the removal of the existing bridge deck, blasting (if applicable), pile driving (if applicable), earth moving and the operation of heavy equipment. Sounds generated from the friction of tires on roadways during wet weather may be evident. Depending on the number and location of NSAs (e.g., residential properties, schools and hospitals), and other factors affecting noise transmission (e.g., vegetation, topography and meteorological weather conditions), the environmental effects of noise also vary.
The construction activities associated with the Project Options are expected to create noise. However, any increased sound pressure levels generated by construction activities are expected to be of a short duration and temporary. Although there are residences within the vicinity of the causeway, the construction activities are expected to be relatively limited in duration, and noise levels are not expected to negatively affect the enjoyment of these properties. Since many residences are located near commercial developments and other features typical of an urban environment, as well as along existing roadways, noise levels during construction are not expected to be substantially different than the existing noise levels, most of the time.

Mitigation of noise during construction for the most directly affected areas will be accomplished by keeping the equipment in good working order and equipped with mufflers, as well as by restricting construction activities to the daytime hours, where warranted, and in compliance with the City of Moncton Excessive Noise Bylaw. While there may be short-term incidences of elevated sound pressure (i.e., peaks), since the machines will be constantly moving around and will not always be at the nearest point to any particular residence, the resulting noise levels are not expected to frequently cause an increase of 10 dB(A) (based on a 24-hour Leq) above existing background levels. Since construction activities will be of relatively short duration and timing restrictions where warranted, construction noise is expected to cause environmental effects that are not significant.

During operation, there are no features of the Project Options that would result in increases in noise in the Assessment Area. As discussed above, there may be a reduction in traffic volumes on the causeway itself, in favour of the new Petitcodiac River Bridge. As a result, sound pressure levels at nearby receptors may also be reduced on a localized scale as a result of reduced commuter traffic, should such traffic reductions occur.

The Project Options will result in the replacement of the headpond with a narrow free-flowing river channel during operation. This will result in a large sound reflecting surface (the headpond) having vanished from the local landscape (during low tide). Therefore, it is expected that the sound transmission characteristics of the area, particularly upstream of the current causeway location, will be altered in such a manner that sound waves may not be as readily transmitted from source to receptor (during low tide), compared to that which may occur with the headpond at present.

In addition, the expected re-growth of vegetation on the former headpond bed, as well as any new mudflats being formed, would create benefits with respect to sound quality. These materials absorb sound and will likely serve to attenuate (reduce the transmission of) noise levels from source to receptor. During post-causeway conditions, the drop in water levels downstream of the causeway altered the sound transmission characteristics of the area with the presence of sound absorbing surfaces such as wetlands that formed as a result of the causeway, as well as exposed mudflats downstream of the current causeway location. These are expected to have attenuated sound transmittal over the river downstream of the causeway. Similar effects can be expected as a result of the operation of the Project Options, upstream of the causeway.
In summary, the potential negative environmental effects of the Project Options on sound quality in consideration of the proposed mitigation during construction and the residual environmental effects significance rating criteria are predicted to be not significant. As discussed above, the sound transmission characteristics of the areas upstream of the current causeway location are expected to be altered in a beneficial way. This is due to the expected attenuation of sound waves resulting by the re-growth of vegetation on formerly submerged surfaces, the formation of additional mudflats, and the loss of the large sound-reflecting surface that is currently the headpond.

**Comparative Assessment**

Overall, the potential negative environmental effects of the Status Quo and Project Options on sound quality in consideration of the mitigation proposed during construction of the Project Options and the residual environmental effects significance rating criteria are predicted to be not significant. While there may be some short-term environmental effects on sound quality in some localized areas during construction of the Project Options, they are expected to be intermittent and of short duration. During operation of the Project Options re-vegetation of formerly submerged surfaces and the formation of additional mudflats upstream of the causeway, which will result in sound wave attenuation, and the removal of the large reflective surface that is the current headpond, will result in positive environmental effects on sound quality upstream of the causeway.

It is difficult to predict the sound pressure levels that may be experienced in 2025 as a result of the Project Options. It is unlikely that sound quality in the GMA will return to pre-causeway or even post-causeway construction conditions following the implementation of the selected Project Option, in light of factors such as increased population, increased industrialization, and wider use of vehicles and other consumer products that will have occurred since these time periods. These use patterns are likely to change by 2025 as well.

### 9.1.5 Future Trends (2055, 2105)

It is difficult to predict the potential changes to the Atmospheric Environment in the GMA that may occur as a result of the Project by 2055 and 2105. As evidenced by the preceding discussions, there are no significant negative environmental effects expected to Climate, Air Quality, Odour and Sound Quality by 2025 as a result of either the Status Quo or the Project Options. In a general sense, this would not be expected to change substantively as a result of the Project by 2055 or 2105. Any potential changes to the Atmospheric Environment that may occur in the Assessment Area by 2055 and 2105 would likely to be the result of more global factors (e.g., global climate change), rather than as a direct consequence of either the Status Quo or the Project Options.

### 9.1.6 Accidents and Malfunctions

In the AMEC Study Team’s professional experience, there are no foreseeable features of the Status Quo or the Project Options that would result in accidents or malfunctions which would lead to a significant negative environmental effect to the Atmospheric Environment, including climate, air quality, odour and sound quality.
Any accidents or malfunctions that may arise as a result of the Status Quo, or the construction or operation of the Project Options, will very likely be corrected by initiating immediate actions, or implementing mitigation, to cease, control, or prevent a reoccurrence of these events. These actions and mitigation measures can likely consist of conventional techniques to prevent, or remediate, the potential environmental effect.

Therefore, the potential environmental effects of accidents and malfunctions, for both the Status Quo and Project Options, are predicted to be not significant.

9.1.7 Summary

In summary, the potential environmental effects of the Status Quo and Project Options on the Atmospheric Environment (climate, air quality, odour and sound quality) in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant. Proposed mitigation measures (i.e., NBDOT Standard Specifications, regulations, guidelines, equipment maintenance, dust suppressants, and timing restrictions) during construction of the Project Options will minimize potential environmental effects to air quality and sound quality, and Project Options may result in a positive environmental effect upstream of the causeway on sound quality as a result of sound attenuation due to re-vegetation and mudflat formation and loss of the headpond.

9.2 Fish and Fish Habitat

9.2.1 Rationale for Selection of VEC

As stated in Chapter 1, the purpose of the Project is to bring the causeway and control structure into compliance with the intent of the original DFO requirement for a fishway. In this regard, the fish passage Project Objective was defined, in Chapter 6, as the “unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required to complete their life cycle”. Fish and Fish Habitat has therefore been selected as a VEC because of its direct relationship to the fish passage Project Objective and its ecological importance in the potential zone of influence of the Status Quo and Project Options. The key elements of the Fish and Fish Habitat VEC are sediment quality, water quality, fish and other aquatic animal species including species at risk and fish habitat. These elements overlap to a considerable extent. These are discussed below to elaborate on their relevance to the EIA.

9.2.1.1 Sediment Quality

Sediment quality was initially selected as a key element of the Fish and Fish Habitat VEC because: there is the potential for the Project Options to result in changes to sediment deposition and erosional patterns, including the re-suspension and movement of potentially contaminated sediment (if present); and the redistribution of contaminated sediment could potentially result in the exposure of fish to unacceptable concentrations of contaminants.

However, data collected from the field programs implemented in 2003 and 2004 suggest that sediment from the headpond down to Hopewell Cape are not contaminated to any discernible level of concern for either metals or organic compounds. However, it remains that some
contamination was detected (e.g., arsenic and ammonia), and that the potential for redistribution of contaminated sediments does therefore exist.

9.2.1.2 Water Quality

Water Quality may be affected by the potential environmental effects of the Project Options and the Status Quo. The Project Options and the Status Quo may result in the extension or elimination of the critical summer DO deficiency that presently occurs in the river and headpond. Other potential environmental effects include the release of leachate containing toxic parameters (e.g., heavy metals) as a result of erosion of the former Moncton Landfill, and the alteration of total suspended sediment (TSS) levels such that they directly affect fish survival, health or habitat.

9.2.1.3 Fish/Aquatic Animal Species

Environmental effects associated with the Project Options and the Status Quo with respect to fish and other aquatic animal species include change in habitat type (freshwater to estuarine), and the opportunity for an extension in range of several species or the continued and growing impediment to free fish passage that the causeway and its associated environmental effects represents. In addition, the Project Options could potentially affect species at risk, principally the Inner Bay of Fundy Atlantic salmon and the dwarf wedgemussel.

9.2.1.4 Fish Habitat

Environmental effects associated with Project Options and the Status Quo could include changes to fish habitat from the marine environment in Shepody and Upper Chignecto Bays, estuarine habitat within the tidal portion of the river, and the mainly freshwater habitat in the Petitcodiac River headpond. The potential changes may include those to TSS levels, such that fish habitat is affected. Most importantly, the fish passage Project Objective, and therefore the purpose of the Project Options, is to provide unimpeded and safe movement, upstream and downstream, of fish between aquatic habitats required to complete their life cycle. Therefore, a key consideration for Fish and Fish Habitat is fish passage.

9.2.2 Boundaries

The spatial and temporal boundaries for the assessment of the Fish and Fish Habitat VEC (the “Assessment Area”) are as defined in Table 4.7.1 and Section 4.7, respectively.

9.2.3 Threshold for Determination of Significance

9.2.3.1 Sediment Quality

A significant negative residual environmental effect on sediment quality is one that results in the concentration of specific parameters exceeding background concentrations and the Canadian Council of Ministers of the Environment (CCME) sediment Probable Effect Levels (PEL) on Aquatic Life, for a sufficient period of time and over a sufficient area that an exceedance of the significance criteria for fish and aquatic animal species (Section 9.2.3.3) may occur.
9.2.3.2 Water Quality

A significant negative residual environmental effect on water quality would be one that results in the concentration of specific parameters exceeding CCME Guidelines for the Protection of Aquatic Life.

9.2.3.3 Fish/Aquatic Animal Species

A significant negative residual environmental effect on fish and aquatic animal species in general is one that:

- affects fish and other aquatic animals (e.g., direct mortality, change in migratory patterns, habitat avoidance) in such a way as to cause a decline in abundance, an undesirable increase in the population or change in distribution of these common and secure population(s), of indicator/representative fish species over one or more generations within the regional population, and natural recruitment may not re-establish the population(s) to its original level; and/or
- affects species at risk not under the protection of the Species at Risk Act (SARA) or the New Brunswick Endangered Species Act (i.e., listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) but not in Schedule 1 of SARA; listed in SARA but not in Schedule 1; or listed as “Species of Special Concern” in SARA (including within Schedule 1) such that:
  - the aquatic habitat within the Assessment Area is altered physically, chemically, or biologically, in quality or extent, in such a way as to cause a change or decline in the distribution or abundance of a viable fish population that is dependent upon that habitat such that the likelihood of the long-term survival of these uncommon and/or non-secure population(s) within the regional population is substantially reduced as a result; and/or
  - the direct mortality of individuals or communities substantially reduces the likelihood of the long-term survival of these uncommon and/or non-secure population(s) within the regional population; and/or
  - in the case of “Species of Special Concern” listed in Schedule 1 of SARA, the Project activities are not in compliance with the objectives of management plans (developed as a result of Section 65 of SARA) that are in place at the time of Project construction; and/or
  - affects species listed in Schedule 1 of SARA as “Extirpated”, “Endangered” or “Threatened” and results in a non-permitted violation of any of the prohibitions stated in Sections 32-36 of SARA; or in violation of any of the prohibitions stated in Section 3 of the New Brunswick Endangered Species Act.

9.2.3.4 Fish Habitat

A significant negative residual environmental effect of the Status Quo or Project Options on fish habitat would be one that results in a non-compensated harmful alteration, disruption or destruction of the spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes (as determined by DFO per Section 35(2) of the Fisheries Act).
9.2.4 Evaluation of Potential Environmental Effects

9.2.4.1 Sediment Quality

Status Quo

The only contaminants of concern in sediment from the Petitcodiac River that marginally exceed the CCME *Interim Sediment Quality Guidelines* for baseline conditions are polycyclic aromatic hydrocarbons (PAHs), including napthalene, acenaphthylene, fluorene, anthracene and dibenz(a,h)anthracene and the metal arsenic. The PAHs were detected in only one borehole (19B) and at only 2.5 m below the sediment surface (Figure 3.3.43 in AMEC, 2005a). This borehole was taken downstream of the location of the outfall for the Greater Moncton Sewage Commission (GMSC) at Outhouse Point. Only arsenic was detected in the headpond for the upstream freshwater environment. Downstream of the causeway, arsenic was present only at borehole 19A, 3.3 m below the sediment surface, and at Dover near both sides of the riverbank.

PAHs and arsenic enter the aquatic environment from natural and anthropogenic (man-made) sources from atmospheric fallout or runoff. Arsenic in particular also has a strong affinity for aquatic particles containing iron and manganese oxides, resulting in its deposition in bed sediments in association with these materials, as found for the Petitcodiac River. However, these sediment contaminants did not exceed the threshold of the CCME PEL and the significance criteria used for this EIA, suggesting that no significant negative environmental effects are occurring under the baseline conditions as a result of human activities in the Petitcodiac River basin.

The Status Quo will likely result in a more elevated concentration of arsenic because of increased infilling of the river in comparison to the baseline. However, overall the potential negative environmental effects of the Status Quo on sediment quality in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options

The renewed tidal flow and tidal prism in the headpond as a result of the Project Options will likely result in more erosion of the shoreline and riverbed sediment, and redistribution of eroded sediments. The quality of sediments of this net sediment movement will not likely have a significant environmental effect for the Project Options because threshold values of significance criteria (CCME PEL) were not exceeded for baseline conditions and are not likely to be exceeded by 2025. While for Project Options 4B/4C, the net movement of this sediment will be greater than that for Project Options 3/4A, under neither Project Option is contamination a concern. Therefore, the potential negative environmental effects of the Project Options on sediment quality in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.
Comparative Assessment

The potential negative environmental effects of both the Status Quo and Project Options are predicted to be not significant. However, with the Project Options, any contaminants present in the surficial sediment will likely be diluted due to an increase in the erosion and depositional cycles associated with the larger tidal prism.

9.2.4.2 Water Quality

Status Quo

The water quality for 2005 baseline in the freshwater environment upstream of the causeway (Section 5.15.4.1) can be expected in the fair to marginal range, using the Water Quality Index of CCME (2001) and as determined in the Biophysical Component Study (AMEC, 2005a). The potential water quality by 2025 will remain in this range, or deteriorate even more as a result of urban, industrial and agricultural growth associated with expansion of the human population in the Petitcodiac River watershed. This is also likely to occur downstream of the causeway as a result of human population growth in this area, and as a consequence more drainage and effluent will be discharged into the river through additional sources and outfalls in addition to the GMSC. Furthermore, the tidal prism volume will continue to decrease and by 2025 will have decreased by almost 50 Mm$^3$. Therefore, the river will have less capacity for the dilution of effluents and less flushing capacity.

The baseline water quality in the fishway is good for the months of April to June. In the summer (July-September), however, the water quality in the fishway changes drastically with the incoming tide by having critically low DO levels (<5 mg/L), large changes in salinity by about 14 mg/L over a tidal cycle and over the small width of the causeway, potential sharp increases in TSS of about 40 g/L, and higher TOC (total organic carbon). This provides substandard conditions for fish to acclimatize (make the biological adjustment from saltwater to freshwater) during their migration between freshwater and marine environments because of abrupt changes related to the lack of estuarine conditions associated with non-flood freshwater flow. These water quality issues are also associated at the time of gate opening and immediately after. The water quality of the fishway during the summer is currently below the threshold of the significance criteria for DO and may lead to stressed fish and possible mortality. Downstream of the causeway, the water quality is also poor (unacceptable DO of <5 mg/L) from about Gunningsville Bridge to Dover, including the bottom water downstream of the causeway at the entrance to fishway. This downstream area of poor water quality during the summer spans about 16 km of the Petitcodiac River channel and has increased in size (from 13 km) since 1978 (AMEC, 2005a). This trend for the Status Quo will give rise to an even larger area of poor water quality in 2025, and possibly as far downstream as Belliveau Village. This area will have depleted or extremely low DO levels because of reduced circulation, reduced flushing rate in the estuary because of low river runoff, and combined with an abundant supply of organic matter from the accumulation of natural sources, sewage, agricultural runoff, or other human activities. This negative residual environmental effect may act as a boundary and impede the migration of fish and other aquatic species in the Petitcodiac River between the freshwater and marine environments.
The salinity gradient during the summer months between upstream freshwater and downstream saltwater is very steep and occurs over a relatively short distance that is the width of the causeway structure. Low freshwater runoff, river flow and sediment infilling of the channel downstream of the causeway give rise to this abrupt change in salinity and temperature between the adjacent upstream freshwater environment and the downstream marine environment, with practically no estuarine environment in between for aquatic species to acclimatize in their passage. This difference in salinity will be larger for the Status Quo compared to baseline and likely to occur over a larger period of the year (late May to early November) because of greater infilling of the river channel in the long-term. However, it should be noted that both juvenile gaspereau and salmon would not be affected by this drastic change in salinity.

Similar to salinity, there is a very large difference between the TSS concentration upstream and downstream of the causeway that may affect downstream fish migration when they encounter much higher suspended sediments. The concentration of TSS downstream of the causeway can be several orders of magnitude and about 100,000 times more than what is present in the upstream freshwater environment. This concentration difference is likely to be greater for the Status Quo in comparison to baseline conditions (2005) because of the availability of more deposited sediments (from infilling of the river) that can be re-suspended as a result of river runoff and tides.

Environmental effects of nutrient (nitrogen and phosphorus) discharge will likely be higher with the Status Quo for both upstream and downstream environments of the causeway compared to baseline conditions. This will likely occur because of increased runoff from agricultural practices that use fertilizer, and because of increased discharge into the Petitcodiac River from sewage and industrial effluents that also contain ammonia. Ammonia, which is converted to nitrogen, is produced naturally and is present in most waters as a result of biological degradation of nitrogenous organic matter present in organic wastes or soils. With the Status Quo, flow of the Petitcodiac River is halted during low flow periods to maintain the water level in the headpond. This provides for longer residence time of the water upstream of the causeway, settling of suspended sediments, and permits efficient nutrient uptake by aquatic vegetation that act as a major nutrient sink. This will likely lead to excessive growth of aquatic plants and floating mats of algae, reduction of species biodiversity and transformation of the headpond to an eutrophic (see Glossary) environment with frequent algal blooms and nuisance growths of rooted aquatic vegetation. These factors have begun to occur as the baseline currently suggests. Downstream of the causeway, increases from urban creek and effluent discharges because of human population growth will increase nutrient levels being discharged into the Bay of Fundy with the outgoing tide. This may cause blooms of algae in Shepody Bay and along the shoreline. The abrasive and smothering characteristics of mobile riverbed sediments and low light levels because of high suspended sediments will not likely promote eutrophic conditions in the Petitcodiac River downstream of the causeway. Discharge of excessively high ammonia concentrations in leachate seeps of the former Moncton Landfill is likely to occur. However, this source of ammonia could not be detected in waters from the Petitcodiac River as sampled at Gunningsville Bridge during low or high tide for baseline conditions. For the Status Quo, this closed landfill will likely continue to contribute ammonia to the Petitcodiac River, as will other
sources from sewage effluent, creeks and agricultural runoff. This contribution of ammonia will likely become detectable on the longer-term because of the lower assimilative capacity (see Glossary) of the river water and tidal flushing, and lower dilution potential associated with greater infilling of the river channel, lower river flow and lower tidal prism with the Status Quo.

Metals and organic compounds in water samples from the Petitcodiac River were not an issue, nor likely to be an important water quality problem for baseline (2005) conditions because only isolated cases exceeded threshold values to protect aquatic life and which did not reflect on general environmental conditions. Downstream of the causeway, low mercury concentrations were detected in water samples. However, the measured concentrations are believed to be associated with the organic matter of the suspended sediment fraction in the sample; the dissolved fraction of the water sample would have yielded negative results or close to the detection limit if analyzed separately. It is likely that environmental effects for the Status Quo with respect to metals and organic compounds are anticipated to be not significant, although the concentration for these parameters will most likely be higher for the Status Quo compared to baseline values.

In general, the Status Quo will lead to more abrupt changes related to the lack of estuarine (see Glossary) conditions. This is associated with the causeway structure, which in turn causes reduced non-flood freshwater flow, reduced tidal prism and reduced tidal flushing of the Petitcodiac River. These factors would continue to result in the water quality issues observed for baseline conditions (e.g., low DO) and could cause water quality to further decrease.

Overall, the potential negative environmental effects of the Status Quo on water quality in consideration of the residual environmental effects significance rating criteria are predicted to be significant. Under the Status Quo, deteriorating water quality may require the elimination of discharges of effluent into the river, separation of existing combined sewers into separate storm and sewage sewers in the City of Moncton, prevention of sewage lagoon overflows, improved treatment of waste effluents and/or changes in agricultural practices.

**Project Options 3/4A**

Project Options 3/4A will remove the causeway gates and piers, providing an opening of 68 to 72 m wide in the river at this location, and will establish tidal flow and tidal prism in the headpond, with the head of tide reaching as far upstream as the Salisbury area. Above this point, the quality of freshwater environment will likely be in the fair to marginal range using the Water Quality Index of CCME (2001), and as determined in the Biophysical Component Study (AMEC, 2005a). This is a result of continued runoff from agricultural and farming practices above the head of tide.

Bacterial concentrations in the newly created estuarine environment will be similar or slightly higher than the baseline when it was a freshwater environment. This is a result of tidal inflow from downstream waters that contain higher concentrations of bacteria, but diluted because of the flooding tide. Downstream of the causeway, Project Options 3/4A will likely result in more dilution of sewage effluents at low tide because of the river channel continuing to increase in width and in area in the downstream direction from the causeway. At high tide, bacterial dilution...
with the incoming tide in the Petitcodiac River will be higher in 2025 than in 2005 because the tidal prism will have increased in volume by about 50 Mm$^3$ (Section 8.3.2). This higher tidal prism will be a result of the increase in the river channel downstream of the causeway and as far as Hopewell Cape.

It is noteworthy to assess the dilution of bacteria of the effluent from the GMSC Wastewater Treatment Plant, which would equally apply to Project Option 4B/4C, and could apply to the dilution of other water quality parameters as well. The dilution of the effluent from the GMSC Wastewater Treatment Plant can be explained using the coliform data collected by Hydro-Com Technologies Ltd. in October 1999 (Hydro-Com, 2000). This data were collected during one tidal cycle using a helicopter survey in the lower estuary below the causeway. This data are shown in Figures 9.2.1 and 9.2.2.

As can be seen in these figures, under the present conditions, the *E-coli* and the *Enterococcus* concentrations remain high during low tide conditions. These concentrations are reduced greatly during high tide conditions in the reach between the outfall (about 6 km downstream of the causeway) and the causeway. They are also reduced in the lower portion of the estuary. In figure 9.2.2, the dilution factor of the *Enterococcus* concentrations is about 20/100 ml at the causeway.

Presently, the total water volume above Outhouse Point is about 3 Mm$^3$. Assuming that the river would approach the pre-causeway conditions under Project Options 3/4A, the total water volume above Outhouse Point would be about 20 Mm$^3$ for Project Option 3/4A. This is approximately a 7-fold increase in the water volume that would considerably increase the dilution factor as compared to baseline conditions. It should also be noted that under Project Options 3/4A, the river would widen and deepen increasing the volume of water at low tide; also, there will be a continuous freshwater flow in the channel. Both of these features will help dilute the effluent during low tide.

The anticipated DO concentrations for Project Options can only be qualitatively assessed. This is a result of the complexity of the Petitcodiac River estuarine ecosystem and the balance, or interactions between DO consumption and DO producing factors. These factors include anticipated biochemical oxygen demand (BOD) river loading, nutrient supply, metabolic activity of organisms like bacteria, assimilative capacity of the river, surface area of atmospheric contact with the water, river circulation and flushing rate and dilution factors. However, it can be safely assumed that DO levels will likely be higher in the estuarine environment for Project Options 3/4A. This is a result of reduced DO demand because of higher dilution potential and increased flushing rate of BOD, nutrients and bacteria. In addition, there will likely be a higher DO supply from increased river circulation and increased surface contact of the atmosphere with the river because of the wider river channel that will lead to more diffusion of atmospheric oxygen into the water. The higher tidal prism volume with Project Options 3/4A will also bring more DO-rich waters from the Bay of Fundy and supply DO to the Petitcodiac River.
In summary, the re-establishment of an estuarine environment will cause increased non-flood freshwater flow, increased tidal prism and increased tidal flushing of the Petitcodiac River. These factors will likely cause very positive environmental effects for water quality issues as compared to baseline conditions. The concentration of suspended sediments may increase if the eroded sediments are deposited within the marine environment of the lower reach of the Petitcodiac River. Further, a larger turbidity maximum layer may be present above the river bottom. However, the larger tidal volume with Project Options 3/4A will contain relatively clear water with an incoming tide from the Bay of Fundy. This will most likely dilute the additional deposited sediment that may become re-suspended or contribute to the turbidity maximum layer.

The estuarine environment will likely provide a gentler gradient of physical and chemical parameters for fish to acclimatize during their migration between freshwater and marine environments. Downstream of the causeway, the water quality with respect to DO will improve from about the Gunningsville Bridge to Dover because of the larger volume of the tidal prism, increased circulation and increased flushing rate in the estuary. This positive environmental effect will likely enhance the migration of fish and other aquatic species in the Petitcodiac River between the upstream freshwater environment and the downstream marine environment.

Overall, the potential environmental effects of Project Options 3/4A on water quality in consideration of the residual environmental effects significance rating criteria are predicted to be positive.

**Project Options 4B/4C**

Project Options 4B/4C will provide an opening 225 m wide in the channel of the river. This channel opening will provide more tidal flow and a larger tidal prism than Project Options 3/4A. The head of tide will likely reach the pre-causeway location of Salisbury. Above this point, the water quality of the freshwater environment will likely be in the fair range using the Water Quality Index of CCME (2001), and as determined in the Biophysical Component Study (AMEC, 2005a). This is a result of continued runoff from agricultural and farming practices above the head of tide.

Below the head of tide, differences in positive environmental effects on water quality between Project Options 3/4A and 4B/4C for the Petitcodiac River will be subtle or very similar. Positive environmental effects will be larger with Project Options 4B/4C because of the larger tidal flow, larger tidal prism and higher flushing rate. This is a result of the river channel having a higher increase in width and in area in the downstream direction from the causeway with Project Options 4B/4C.

Assuming that the river would approach the pre-causeway conditions under Project Options 4B/4C, the total water volume above Outhouse Point would be about 28 Mm$^3$ for Project Option 4B/4C, as compared to 20 Mm$^3$ for Project Option 3/4A. This is approximately a 9-fold increase in the water volume that would considerably increase the dilution factor as compared to baseline conditions.
The larger tidal prism and volume will provide more dilution of bacteria in both ebb and flood tides, more dilution of sewage effluent containing high nutrient levels, higher DO levels because of better mixing and more flushing capacity. The tidal prism volume available for dilution will be approximately 50 Mm$^3$ higher than for the baseline condition.

In summary, the potential environmental effects of Project Options 4B/4C on water quality in consideration of the residual environmental effects rating criteria are predicted to be positive.

**Comparative Assessment**

The potential negative environmental effects of the Status Quo in consideration of the residual environmental effects rating criteria are predicted to be significant with respect to water quality and parameters to sustain aquatic life. On the other hand, the potential environmental effects of the Project Options in consideration of the residual environmental effects rating criteria are predicted to be positive. The difference between Project Options 3/4A and Project Options 4B/4C is with respect to the higher magnitude and larger spatial scale of positive environmental effects with Project Options 4B/4C. Project Options 3/4A will result in a tidal prism volume that is 50 Mm$^3$ more than that of the Status Quo and Project Options 4B/4C will result in a tidal prism volume that is 100 Mm$^3$ more than baseline and 100 to 150 Mm$^3$ more than the Status Quo. The latter Project Options are anticipated to approach the water quality and environmental conditions in pre-causeway times, and therefore are anticipated to have water quality conditions that will help to improve fish migration.

**9.2.4.3 Fish and Other Valued Aquatic Animal Species**

**Status Quo**

In the freshwater environment, the Status Quo will continue to benefit fish populations that prefer the lentic (slow moving water) freshwater environment of the headpond. The primary valued fish species of this type would be the smallmouth bass. Smallmouth bass are recently established in the headpond and the population has not yet fully matured. Within the next five years as the smallmouth bass population ages, individuals as large as those living in well-known smallmouth bass lakes of New Brunswick may be produced in the headpond. The other freshwater fish species that will benefit from the continued existence of the headpond include less desirable species (from a recreational perspective) such as the white sucker, the brown bullhead, the white perch and various small minnow species. If, as reported by local recreational fishers, chain pickerel are present in the headpond, this species will also continue to benefit from the Status Quo.

The diadromous species that will benefit from the continued existence of the headpond include the American eel and gaspereau. In the case of the American eel, the headpond provides excellent rearing habitat; warm water in the summer with an abundance of small minnows for food. The benthic invertebrate population, which serves as food for smaller eels, has low diversity because the headpond is occasionally recovering from drawdown and saltwater intrusion. However, the benthic invertebrate productivity is sufficient to support a healthy population of pre-piscivorous (pre-fish eating) eels. The headpond also provides soft bottom
substrate that is ideal for overwintering eels. There will be no residual negative environmental effect of the Status Quo on American eel by the year 2025 in comparison with 2005.

The headpond also provides nursery habitat for young-of-the-year gaspereau. The zooplankton community on which juvenile gaspereau feed, has a low diversity and density in comparison with most lakes. This is because the zooplankton is physically flushed from the headpond because of its low turnover time due to the large drainage basin of the Petitcodiac River relative to the volume of the headpond. However, the headpond does provide a large lentic freshwater region for gaspereau production.

Under the Status Quo, upstream and downstream fish passage issues that exist in the baseline environment will continue and remain as the key limiting factors to gaspereau productivity. The bottleneck of the causeway causes delays in the upstream migration of gaspereau that result in a very high degree of mortality from predation by birds and eels. In the late summer and early autumn, the downstream migration of juveniles to the marine environment is delayed by typically low current speeds in the headpond that exist because of low river discharge. This results in increased opportunities for predators, potential breathing difficulties in freshwater prior to the late entrants reaching the marine environment, and potential non-synchronization between the juvenile gaspereau and available food in the marine environment. These factors increase mortality. Because of the extremely high fecundity (i.e., abundant reproduction) of gaspereau in comparison with other species such as Atlantic salmon, few individual spawners are required to fill the juvenile carrying capacity of a waterbody. Therefore, upstream fish passage conditions unless they were extremely deficient, would have little population level effect on gaspereau within a river system. It is the downstream passage issues that would logically be a more limiting factor. In years of high discharge in the late summer and early autumn, when juvenile gaspereau are safely flushed into the estuary, the residual effects of the Status Quo would be expected to be positive. During low discharge late summer/early autumn years there would be high mortality of downstream migrating juveniles, and the residual effects of the Status Quo would be negative. The net residual environmental effect of the existence of nursery habitat in the headpond under the Status Quo is offset by fish passage difficulties leaving no net residual environmental effects. However, if fish passage conditions continue to degrade under the Status Quo, then it is possible that a net residual negative environmental effect will result. The net residual negative environmental effect is rated not significant.

The other (for the most part anadromous (migrate from the sea to freshwater to spawn)) fish species that historically spawned in the freshwater environment upstream of the causeway include:

- Atlantic tomcod;
- rainbow smelt;
- sea lamprey;
- American shad;
- Atlantic sturgeon;
• brook trout; and
• Atlantic salmon.

Atlantic tomcod enter freshwater in the late autumn, and spawn in December and January. Currently only a small number of tomcod are able to gain entry to the freshwater environment upstream of the causeway when they are passively pushed through the existing fishway on high tides. It is not known whether these fish successfully spawn upstream of the causeway. This situation is expected to continue, and the significant negative residual environmental effect of the Status Quo on tomcod will therefore continue.

The rainbow smelt enters the freshwater environment to spawn just after ice-out in the spring (typically mid-April to early May). A large smelt spawning-run was identified in the lower end of Turtle Creek, which is the first major tributary to the Petitcodiac River upstream of the causeway. There may also be limited spawning occurring in the main stem of the Petitcodiac River upstream of the headpond. However, the observed size of the smelt spawning run in the Petitcodiac River is currently far smaller then reported prior to the construction of the causeway. The magnitude of the spawning run is negatively affected by fish passage problems at the causeway, which are mitigated to a degree by the gate opening strategy that allows smelt access through the gate openings during a narrow window on the rising tide. There will continue to be a limited smelt run into the system, and in the case of the anadromous rainbow smelt, this will continue to result in significant negative residual environmental effects.

As judged by the frequency of their observation during fieldwork in 2003, the sea lamprey enters the Petitcodiac River system in large numbers in late May and June. They spawn in the flowing water streams upstream of the headpond. They are known to hold their stations against the high flow of water during headpond discharge events by adhering to the gates and to large bottom substrate with their suction cup-like mouths. This keeps them in position to gain access through the gate openings when the water velocities are sufficiently low. They were also identified in small numbers in the fishway trap, which indicates they also use this facility for upstream passage to a minor degree. They will continue to be able to gain access in 2025, and in the case of the anadromous sea lamprey, there will be no negative residual environmental effect of the Status Quo on the species.

The occasional American shad still gains access to the Petitcodiac River through the existing fishway. One shad was taken during the fishway trap monitoring in 2003. This occurred on an extreme high tide, and the shad was found dead in the trap. Typically, shad will move in a school during a difficult migratory situation. The discovery of one shad in the fishway trap during a significant period of monitoring of the shad spawning migration indicates that an effective spawning population no longer exists in the river. In the case of the anadromous American shad, the Status Quo will continue to result in significant negative residual environmental effects.

Only one adult Atlantic sturgeon, a ripe female, has been seen upstream of the causeway since 1968. The discovery of this fish was taken as a definitive indication that the species spawned in
the Petitcodiac River prior to the construction of the causeway. Atlantic sturgeon also exist in large numbers in the estuary downstream of the causeway. The longevity of Atlantic sturgeon and observation of mature adults suggest that there remain some individuals from the pre-causeway population. The continued fish passage issues in the Petitcodiac River with the Status Quo will therefore continue to result in significant negative residual environmental effects on the Atlantic sturgeon, and may ultimately result in the extirpation of this species in the Petitcodiac River.

The brook trout is really not an anadromous species, but rather amphidromous, a life style in which most juveniles and adults feed in the estuary or downstream river reaches of their spawning rivers. Few enter the full marine environment, a tactic that is universally used by anadromous fish. Large brook trout travel downstream to overwinter in slow moving water near the mouths of streams in the early spring, and progressively move upstream through the spring and early summer. Their downstream movement may or may not bring them into the estuary or near-shore marine environment of their resident drainage basins. In the case of the Petitcodiac River system, no brook trout were taken in the fishway trap in June, 2003 (AMEC, 2005a) when one would expect a few sea-run brook trout to be entering the freshwater system, and from 1968 until 1991, there were no records of brook trout being taken in the fishway trap at the causeway (Ritter, 1991). It appears that the headpond may provide overwintering and spring feeding habitat, and is now the lower limit of the downstream migration of brook trout in the Petitcodiac River system. However, sea-run sized brook trout still exist, and are angled in the Petitcodiac River system in the late spring (Williams, pers. comm., 2003). It is likely that the overall baseline amphidromous brook trout populations are slightly depressed as a result of fish passage barriers. This condition is expected to continue under the Status Quo, and as such these small negative environmental effects on amphidromous brook trout are expected to continue but are rated as not significant.

The striped bass inhabited the Petitcodiac River occasionally prior to the construction of the causeway. The striped bass would occasionally enter the river to feed on fish such as spawning gaspereau. The striped bass no longer enters the river upstream of the causeway, but does continue to exist downstream of the causeway in the extreme lower estuary. The shad fishers in Belliveau Village report that they have not taken a striped bass in their gill nets for approximately a decade. If this is a function of infilling of the estuary, and this infilling will continue under the Status Quo, then the Status Quo could continue to result in significant negative residual environmental effects.

The most socio-economically important fish species that exists in the estuary (from the causeway to Shepody Bay) is the American shad. Many of the up to 30 million (McPhee, 2002) shad that migrate counter clockwise annually through the Bay of Fundy enter Shepody Bay during their migration. A portion of these fish enter the lower Petitcodiac River estuary on the rising tide, and move back into Shepody Bay on the ebb tide. Under the Status Quo, there will be a continued build up of sediment, and the water in the lower Petitcodiac River estuary will become shallower. Fewer shad will enter the estuary, and for a shorter duration. The implications of this are uncertain. It would make the shad less available to the small commercial fishery, which exists for them in the estuary, thus slightly decreasing this mortality factor.
However, considering the magnitude of the mixed stock assemblage of shad in the estuary and the availability of food in other locations such as Shepody Bay, the environmental effects of the Status Quo are likely to be not significant.

The two socio-economically important aquatic animal species potentially affected by the Status Quo and the Project Options are the American lobster and the sea scallop. The presence of the causeway has created a depositional area in the river where fine sediment, eroded from the bottom of outer Shepody Bay and Chignecto Bay and beyond, has been deposited. This appears to have resulted in a net loss of sediment in these eroded areas, as discussed in Section 5.2.4. As discussed in Section 5.4.5.2, the lobster landings in the Bay of Fundy, including Shepody and Chignecto Bays, have increased in general since the 1980s. The increased landings in Shepody and Chignecto Bays are apparently unrelated to the causeway construction, but may be due to a combination of factors including removal of fine sediment from habitat areas and reduction in predators. As a result, the Status Quo is not expected to result in significant negative residual environmental effects on lobster.

In the case of scallops, there are some scallop fishers who suggest that a bottom substrate comprised more of sand and gravel as opposed to finer material, and lower TSS levels benefit scallops (G. Copp, A.F.A., Pers. Comm.). The scallop fishery has moved somewhat into Chignecto Bay in recent years with some minor effort and success. However, as for lobster, it is unclear if the sedimentation of the Petitcodiac River has any causal relationship with the species itself or if observations by fishers are coincidental with an unrelated improvement of the fishery. As with the lobster, the Status Quo is not likely to have a significant negative residual environmental effect on scallops.

Although some aquatic species benefit under the Status Quo (e.g., smallmouth bass, chain pickerel and American eel), overall, the potential negative environmental effects of the Status Quo on fish/other valued aquatic animal species in consideration of the residual environmental effects significance rating criteria are predicted to be significant due to fish passage problems at the causeway (i.e., the Status Quo does not meet the fish passage Project Objective).

**Project Options 3/4A**

Project Options 3/4A involve the removal of the tidal barrier gates, and the establishment of renewed tidal flow into the area currently impounded by the causeway (the headpond). Associated with these changes will be the mitigation of other fish passage issues such as the sediment plug and downstream DO barrier, as well as a reduction in predation for most species. The following paragraphs describe the potential environmental effects for each of the aforementioned fish species.

The smallmouth bass will be likely eliminated from the area currently covered by the headpond, and restricted to the freshwater areas of the Petitcodiac River and its major tributaries that are suitable for bass production such as the lower end of the non-tidal portion of the main stem (above Salisbury) and the Turtle Creek reservoir. This is also true for the other resident (non-migratory) freshwater species that now benefit from the headpond (i.e., white sucker, white perch, brown bullhead, chain pickerel and other small freshwater fish species). Project Options
3/4A will negatively affect the size of the populations of these species in the Petitcodiac River system. The smallmouth bass, and to a much lesser degree the chain pickerel, are the only species that provide economic or recreational benefits in the headpond, and neither species are native to the Petitcodiac River system – the smallmouth bass having been introduced illegally in the late 1980s or early 1990s. Due to the decrease of freshwater area, there will be an negative environmental effect from Project Options 3/4A on resident freshwater fish. However, their populations within the Petitcodiac River system will not be eliminated, as suitable freshwater habitat will continue to exist for them in the Petitcodiac River system. DFO is striving for a solution to fish passage issues with the causeway, it is expected that the achievement of the fish passage Project Objective, and the overwhelmingly positive environmental effects on estuarine, marine, and diadromous fish species would be considered as compensation for the loss or reductions of these freshwater fish populations. As such, it is anticipated that these losses would be authorized under the Fisheries Act, if required, without need for further compensation. Therefore, Project Options 3/4A will not result in a significant negative residual environmental effect on freshwater fish populations in the Assessment Area.

Gaspereau will gain easy and safe upstream access to, and probably more importantly, downstream access from the Petitcodiac River under Project Options 3/4A. Improved access will decrease predation during the spawning run, and increase survival of downstream migrating juveniles and post-spawning adult fish as well. However, the nursery habitat provided by the headpond will be eliminated. Only such habitat in the lower slow moving sections of the main stem Petitcodiac River and its major tributaries will remain. On balance, the effect of Project Options 3/4A in comparison to the Status Quo for gaspereau will be near neutral.

The American eel will also have improved access to the Petitcodiac River during the elver and the juvenile overwintering stage. However, the American eel is one of the fish species least likely to be affected by the fish passage difficulties associated with the presence of the causeway. The elimination of the headpond feeding and overwintering area will negatively affect the American eel by reducing the carry capacity of the Petitcodiac River for eel production. As a catadromous fish, the eel is not imprinted to a specific river. On a population level, the resultant negative residual environmental effect of Project Options 3/4A is therefore predicted to be not significant.

The tomcod will gain access to former spawning grounds in the river from the head-of-tide at Salisbury and upstream 20 km. The tomcod population is anticipated to increase, they will migrate in the marine environment, which will provide food for larger predators and increased recreational fishing opportunities. Implementation of Project Options 3/4A will have a very positive residual environmental effect on the size of the Petitcodiac River tomcod population.

The rainbow smelt will easily gain access to the Petitcodiac River and quickly reoccupy former spawning grounds in the spring. Concerns about the potential negative effects on downstream migrating larvae of turbulent discharges from the headpond will be eliminated. The larval smelt will recruit to the marine environment in vastly greater numbers than under the Status Quo situation. The smelt will provide important food for large predator species and recreational fishing opportunities in freshwater during their spawning run. Project Options 3/4A will have a
very positive residual environmental effect on the size of the Petitcodiac River rainbow smelt population.

The sea lamprey will gain more rapid access to the freshwater environment of the Petitcodiac River system. However, this species was not greatly impeded from gaining access to the river under the baseline conditions, and egg deposition is unlikely to be increased substantially. There will be no net negative residual environmental effects to the sea lamprey from the implementation of Project Options 3/4A.

The American shad will once again have spawning access to the Petitcodiac River under Project Options 3/4A. Potential negative environmental effects from delay and physical smothering of downstream migrating juvenile shad (as with gaspereau) in the late summer will also be eliminated. Project Options 3/4A will have a very positive residual environmental effect on the size of the Petitcodiac River American shad population.

Under Project Options 3/4A, brook trout will have downstream access to the estuarine environment, where they conceivably would have more available food, particularly tomcod and smelt. This would benefit the growth of individual trout, and result in more egg deposition. On the other hand, brook trout in the system may have competition from restored populations of juvenile Atlantic salmon. Overall, Project Options 3/4A would have a small but positive residual environmental effect on the brook trout populations that use the Petitcodiac River for life cycle purposes.

Under Project Options 3/4A, it is predicted that mudflats in the Petitcodiac River upstream of Shepody Bay will decrease in size as material is flushed, and in Shepody Bay, the mudflats will grow in size or remain the same. There will be greater water depth for a longer duration on each tide, which will provide shad more opportunity to enter the lower, tidally influenced reach of the Petitcodiac River. This will provide more opportunity for commercial fishers, but the population level effects of a slightly increased fishery on the large mixed stock assemblage of shad will be negligible. Under Options 3/4A, mud flats in the lower estuary will be eroded. This may affect the availability of aquatic insect production used by shad as food. However, although shad occasionally feed on the mudshrimp and other benthic invertebrates such as worms (clam worms, bamboo worms, mud worms, capitellids and terebellids), their main source of nutrition is pelagic plankton such as copepods and eupausiids (Dadswell, pers. comm.). In the Inner Bay of Fundy, they often feed on small copepods (Acartia and Eurytemora) and mysid shrimp (Willey, A., 1923), however shad are sight feeders, and in the muddy water of the Inner Bay of Fundy, their feeding efficiency is very low. They can actually lose weight during the two or three weeks that individual shad are in the area (Dadswell, pers. comm.). Conditions for shad existence were suitable prior to the construction of the causeway. Since Project Options 3/4A will tend to move physical and biological conditions towards those that existed prior to the causeway’s construction, and shad flourished under these conditions, it is assumed that the environmental effects of Project Options 3/4A will be positive on the shad that inhabit the Petitcodiac River estuary in the late spring and summer.
As described in Section 5.2.4, the quantity of material that will be released into Shepody and Chignecto Bays under Project Options 3/4A will not be significant when compared to that which is annually moved from the estuary on a seasonal basis. Given that there is no linkage between the construction of the causeway and increased landings, there would be no effect on landings associated with the opening of the causeway under Project Options 3/4A.

However, even though the evidence does not support any potential effect on lobster landings, the consequences of any negative effect associated with the opening the causeway may be serious to lobster fishers. Any significant effect would be reflected in landings of lobster that would be seen in the affected area to a degree larger than such an effect in a non-affected area. Monitoring of landings in the Upper Bay and a control area (non-affected area) would clearly demonstrate any negative effect associated with modifications to the Petitcodiac River Causeway. Any loss in landings in the affected area, that are not seen in the control area, would form the basis of compensation to fishers for loss in livelihood.

Scallops feed more efficiently in water with low TSS values, and the export of material scoured from the Petitcodiac River estuary could increase TSS levels to a point where scallops would avoid the region inside Cape Chignecto. Presently the scallop numbers and condition, as revealed by standard monitoring tows, decline with increasing distance inside of Cape Chignecto, and the area is already marginal for scallops when compared with the Bay of Fundy to the west of the Cape. With the implementation of Project Options 3/4A, there is a possibility that increased scour will lead to increased TSS inside Cape Chignecto, and scallop productivity might be affected in this fringe area of the fishery. As such, it is predicted that Project Options 3/4A will result in negative residual environmental effects that are not significant. As for lobster, should the Follow-up Program demonstrate a residual negative environmental effect on scallops, and consequently on the scallop fishery, then the fishers should be compensated.

Although Project Options 3/4A will result in the loss of freshwater species from the area currently covered by the headpond, it is anticipated that these losses will be authorized under the *Fisheries Act*, and the potential environmental effects of Project Options 3/4A on fish/other valued aquatic animal species in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive as Project Options 3/4A achieve the fish passage Project Objective and have a very positive environmental effect on fish populations that use the Assessment Area for life cycle purposes.

**Project Options 4B/4C**

The difference in the level of environmental effects on fish species between Project Options 3/4A and Project Options 4B/4C are subtle, perhaps to the point of being not detectable.

A slightly greater tidal prism under Project Options 4B/4C in comparison with Project Options 3/4A would benefit the anadromous species including gaspereau because they are transported towards their desired destination by the flooding and ebbing tide.

In the estuary, the potential environmental effects on shad of Project Options 4B/4C would be similar to those predicted for Project Options 3/4A.
The potential environmental effects of Project Options 4B/4C on fish/other valued aquatic animal species in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive. Project Options 4B/4C achieve the fish passage Project Objective and have a very positive environmental effect on fish populations that use the Assessment Area for life cycle purposes.

**Comparative Assessment**

Upstream of the causeway, the Project Options will have very positive environmental effects on valuable anadromous fish species, and a negative environmental effect on freshwater fish populations in the headpond. Conversely, in comparison with the Project Options, the Status Quo results in certain negative and significant environmental effects on anadromous fish passage, with consequences at the population level to most anadromous species.

The effects on shad in the estuary are theoretical and minor under the Status Quo and Project Options, as are the potential environmental effects on brook trout that currently inhabit only the freshwater environment.

In the marine environment, there will not be negative residual environmental effects resulting from the Project Options on lobster and scallop. If the Follow-up Program (Chapter 13) demonstrates negative residual environmental effects on lobster and/or scallops, the fishers should be compensated accordingly (Section 9.11). There are no residual environmental effects associated with the Status Quo in the marine environment.

In summary, the potential environmental effects of the Status Quo on fish/other valued aquatic animal species in consideration of the residual environmental effects significance rating criteria are predicted to be significant, while the potential environmental effects of the Project Options are predicted to be not significant to positive; the Project Options meet the fish passage Project Objective.

**9.2.4.4 Fish Species at Risk**

**Status Quo**

The Petitcodiac River Atlantic salmon is a member of the genetically distinct Inner Bay of Fundy salmon population. In the Petitcodiac River system, the Atlantic salmon population declined drastically after construction of the causeway and establishment of the headpond. The Inner Bay of Fundy population, which is native to 32 rivers draining to the Inner Bay of Fundy, has been listed as “Endangered” by COSEWIC, is protected under SARA, and is currently gene banked at the Mactaquac Biodiversity Facility. The species continues to exist in the Petitcodiac River system because of occasional introductions of genetically similar Big Salmon River salmon. The collapse of the Inner Bay of Fundy salmon populations occurred suddenly in the late 1980s and early 1990s. There have been many suggested mechanisms for the collapse but there is currently no clear consensus among scientists, stakeholders and resource managers. However, the SARA description of the Inner Bay of Fundy Atlantic salmon on the SARA Species at Risk website states that “… The cause of the collapse of marine survival is unknown, but may be due to ecological changes in the Bay of Fundy, such as those brought
about by tidal barriers placed at the mouths of several rivers and streams...”. Unless the survival of the species in the marine environment improves, all Inner Bay of Fundy salmon rivers will rely on stocking of fish produced in the gene banks for the continued existence of Atlantic salmon in their waters. The baseline fish passage issues will continue under the Status Quo and will therefore continue to limit the potential for the recovery of Atlantic salmon and is therefore considered to be a significant negative residual environmental effect.

The implications of a low or extirpated American shad population in the Petitcodiac River extend to at least one other species. Juvenile shad are suspected to have been a host for a parasitic stage of the dwarf wedgemussel, which formerly inhabited the Petitcodiac River system (Hanson and Locke, 2000). After the causeway was constructed and the shad was largely eliminated from the river, the dwarf wedgemussel became “Extirpated” (see Glossary) according to COSEWIC. In the case of the dwarf wedgemussel, the significant negative environmental effects of the Status Quo will continue as the species is already extirpated. Conditions will persist in the Status Quo that will prohibit the existence of the species in the Petitcodiac River.

**Project Options 3/4A**

During high flow years, Project Options 3/4A would allow Atlantic salmon unrestricted upstream access in the autumn to spawning grounds in the Petitcodiac River. Project Options 3/4A would also eliminate the critically low DO levels that currently exist in the 16 km reach downstream of the causeway and eliminate the sediment plug. This could conceivably expand the upstream migration window for adult salmon. Project Options 3/4A would mitigate the smolt migration problems in the headpond. If the situation(s), which resulted in the Inner Bay of Fundy salmon population being declared “Endangered”, are addressed or reverse naturally, Project Options 3/4A would have a very positive residual environmental effect on the potential for re-establishment and the ultimate size of the Petitcodiac River Atlantic salmon population. As with the dwarf wedgemussel, it is possible that the implementation of Project Options 3/4A could result in the Inner Bay of Fundy Atlantic salmon population re-establishing to such a level that the population would be re-evaluated by COSEWIC and ultimately re-listed to a lower species at risk status.

The re-establishment of spawning American shad in the Petitcodiac River system will also re-establish conditions under which the dwarf wedgemussel could be re-introduced to the system and its “Extirpated” (see Glossary) status under COSEWIC eliminated. Project Options 3/4A could therefore have a very positive residual environmental effect on the extirpated Petitcodiac River dwarf wedgemussel population if efforts to restock the dwarf wedgemussel were undertaken.

**Project Options 4B/4C**

The environmental effects of Project Options 4B/4C on Atlantic salmon and the dwarf wedgemussel will be the same as previously discussed for Project Options 3/4A.
Comparative Assessment

The Project Options (3, 4A, 4B and 4C) will all have potential positive environmental effects on the Inner Bay of Fundy Atlantic salmon and the dwarf wedgemussel as they will remove the likely cause of the current endangered status of these species.

The Status Quo will continue to have significant negative environmental effects on the Inner Bay of Fundy Atlantic salmon and the dwarf wedgemussel as it is very likely that the construction of the causeway has resulted in the current endangered status of these species.

9.2.4.5 Invasive Fish Species

Status Quo

The smallmouth bass and chain pickerel are not native to the Petitcodiac River or to New Brunswick and are therefore considered to be invasive species (see Glossary). The development of the causeway moved the downstream extent of freshwater from Salisbury to the causeway. This may have allowed these species to obtain access to freshwater tributaries that enter the headpond, such as Turtle Creek, which is known to have a fishable smallmouth bass population. The muskellunge (esox masquinonge) is a non-native member of the pike and pickerel family that has become well established (unintentionally) in the Saint John River system. The freshwater habitat that exists in the headpond is suitable to the muskellunge, should this fish be accidentally or illegally introduced to the Petitcodiac River. The Status Quo will continue to provide the possibility for these and other invasive freshwater fish species to become established in the Petitcodiac River and to invade freshwater watercourses between Salisbury and the causeway.

Under the Status Quo, invasive diadromous (see Glossary) fish species could have gained access to the river above the causeway when the gates are open and/or some species could get through the fishway.

Project Options 3/4A

Implementation of Project Options 3/4A will likely eliminate invasive freshwater fish species (e.g., smallmouth bass and chain pickerel) from the headpond area, and will likely not permit the establishment of new invasive freshwater fish species (e.g., muskellunge) in the Petitcodiac River and its tributaries between Salisbury and the causeway.

There is limited potential for the incremental introduction of invasive diadromous fish species in the aquatic environment as a result of the Project Options 3/4A because these species would have also had access under the Status Quo when the gates are open and/or some species may have been able to get through the fishway. However, given the difficulties that native fish species have had migrating through the causeway, it is likely that Project Options 3/4A will improve the ability of non-native fish species to migrate through the causeway. The only known non-native invasive diadromous species that have the potential to migrate into the river above the causeway are the rainbow trout and the brown trout. These species are not known to occur in the river below the causeway (AMEC 2005a). There is a population of sea-run rainbow trout in the Big Salmon River which enters the Bay of Fundy approximately 100 km southwest from Hopewell Cape, and a population of sea-run brown trout in the Saint John River.
There is some potential for invasive species found in the lower portion of the Petitcodiac River estuary, Shepody and Chignecto Bays, the Bay of Fundy and the Gulf of Maine to become established in the area between Salisbury and the causeway once it has regained estuarine conditions. However, it is expected that native fish species that are adapted to life in estuarine habitats (e.g., mummichog and killifish) will form the majority of “new” species in the restored estuarine portion of the Petitcodiac River. There are no known invasive estuarine species of concern in the lower Petitcodiac River estuary.

**Project Options 4B/4C**

Project Options 4B/4C are not expected to result in a change to the distribution of invasive fish species that is measurably different from that anticipated for Project Options 3/4A.

**Comparative Assessment**

The Status Quo will continue to allow freshwater invasive fish species to exist in the headpond, while the Project Options will convert the area between the causeway and Salisbury back to an estuarine environment thereby likely eliminating the invasive freshwater fish species. There will likely be a small but limited incremental increase to the potential for invasive diadromous fish to gain access to the river above the causeway for all Project Options as compared to the Status Quo. The Project Options will expand the potential range of invasive estuarine species from the causeway up to Salisbury, however, there are no known estuarine invasive species of concern.

**9.2.4.6 Fish Habitat**

The fish habitat in the Petitcodiac River estuary (from Salisbury to Hopewell Cape) was historically primarily used for migratory purposes. There are a few species that may have and continue to reside year round in this area (e.g., mummichog), and a few species that enter to feed (e.g., striped bass). For the most part, prior to the construction of the causeway, it was a transition zone where diadromous fish adjusted between freshwater and saltwater environments.

**Status Quo**

Fish habitat under the Status Quo is sharply divided by the causeway into a lentic (slow moving water) freshwater ecosystem that extends 20 km upstream of the causeway and a turbulent, physically dominated estuary downstream of the causeway that extends to Shepody Bay. The Assessment Area also includes the marine transitional zone of Shepody Bay, and the largely marine area of Chignecto Bay, which is the northern “leg” of the Inner Bay of Fundy.

When the headpond is at its normal level of approximately 6.1 m above mean sea level, the lentic freshwater area upstream of the causeway extends to a point just above the former railway bridge in Salisbury, and just downstream of the confluence of the Petitcodiac and Little Rivers. Except for under extremely low river discharge periods, there is a noticeable current in the upper reaches of the headpond because the river is narrow for a distance downstream almost to the confluence of Turtle Creek. Downstream of this point, the headpond widens and the current slows. In the lower end of the headpond, there is often a layer of brackish water on the bottom. This layer is produced by back flooding of the tide through the fishway and through the tidal gates as they are in the process of closing.
The muddy bottom of the headpond produces an abundance of burrowing invertebrates that support strong populations of benthic feeding white suckers, brown bullhead and American eels. White perch and chain pickerel are less abundant, although reported to inhabit the headpond were not observed in the 2003 fish surveys. Small minnow species provide forage for the introduced smallmouth bass. The headpond also serves as a nursery area for alewife and blueback herring (collectively called gaspereau) juveniles. These fish feed primarily on zooplankton, however because of the high flushing rates and variable salinities of the headpond, zooplankton densities are limited according to reports associated with the trial gate openings. This in turn negatively affects the carrying capacity of the headpond for juvenile gaspereau. The headpond does not thermally stratify (i.e., develop distinct zones of warm water overlaying cooler water). Therefore, in the summer headpond temperatures are too warm for coldwater fish such as brook trout. However, it may provide overwintering habitat for trout and is probably a rearing area for larger trout in the early spring.

The DO levels in the headpond are at least fair-to-marginal at all times of the year, a rating that is acceptable for the warmwater and coarse fish species that reside there. Very low DO levels that approached anoxic conditions (complete absence of DO) were measured in the winter under the ice near Turtle Creek in February 2004. However, this extreme level of DO was the exception. No pronounced winterkill of fish has been reported in the headpond.

The TSS concentrations in the Petitcodiac River estuary are natural very high. Although reliable pre-causeway data were not available, aerial photos from prior to the construction of the causeway clearly show that the river has very high TSS (typically between 2 to 6 g/L at Moncton). The function of most fish gills is considered to be seriously impaired at TSS levels exceeding 1.4 g/L (CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life). For this reason, and others, the Petitcodiac River estuary is primarily considered as migratory fish habitat. The presence of the causeway has reduced the energy available to suspend sediments in the headpond and has thereby reduced the TSS levels in the headpond to levels that are not considered harmful to fish (headpond TSS is typically less than 100 mg/L).

Downstream of the causeway, the estuary is dominated by tides that rise to as high as 8.1 m. The tides create movement in the water and maintain very high TSS loads in the water column. The construction of the causeway at a location within the tidal influence of the Bay of Fundy created a barrier that stops the free flow of the tide as it approaches its peak during average to above average high tides. At this time, the water flow stops, and the sediment falls from suspension. If the freshwater river discharge is insufficient to scour it, the sediment accumulates and itself becomes a barrier to water flow and fish movement. The sediment has been rapidly accumulating in the estuary since the construction of the causeway. This build-up is most noticeable on the shoreline, but the bottom elevation has been rising as well (e.g., Figure 5.2.5). The shoreline and the bottom are scoured somewhat during the spring freshet. However, the trend is towards a shallower and narrower river. All of these conditions will persist under the Status Quo.

The existence of the causeway has contributed to a number of impediments to fish passage as described in detail in Chapter 6. Between the headpond and estuary, there are two avenues
through which fish can gain access into or out of the headpond: through the open gates, or through the vertical slot fishway. Neither is particularly effective for providing fish passage. The gates slide up and down in guide slots, with water discharging from (or entering) the headpond on the bottom. Fish approaching the causeway from either direction normally do so near the surface where the current velocity is greatest and provides momentum. Fish must swim under the gates. This would normally cause at least a one gate-opening period delay. In addition, the headpond is managed to store water for sediment scouring. Water is released in periods of sudden turbulent discharge when there is a large difference between the height of the headpond and the estuary. This keeps the sediment from accumulating next to the gates where it might cause them to become stuck shut. The high speed of the water during the discharge scours the sediment, but also prevents fish from entering the headpond except for a short period just before the gates are closed as the tide is approaching the level of the headpond. Fish in the headpond that happen to be next to the gates, or those that are resting there in the deep water after having passed upstream through the fishway, can also be suddenly displaced from the headpond, and moved well downstream into the estuary. These conditions will persist under the Status Quo.

The fishway is a 19-pool vertical slot facility. The slots are 30 cm wide, and there is a 22.5 cm drop between pools. It was designed primarily to pass Atlantic salmon upstream, and in this capacity it was not completely ineffective. Its location within the tidal range of the estuary introduces problems that decrease its effectiveness for upstream fish passage that will persist with the Status Quo, as listed below.

- The accumulation of sediment during tidal back-flooding whereby the sediment is re-suspended when the tide falls, and acts as a deterrent to fish entering the facility.
- The lack of attraction flow whereby as the tide rises, the lower pools are drowned out and fish that normally ride the tide into a river would be delayed during their initial approach to the causeway because there is no downstream attraction current to mark the fishway entrance.

Specific to the fish species that must be passed, the existing fishway will have the following challenges under the Status Quo:

- water velocities are often too great for small-bodied tomcod and smelt;
- the vertical slots are too narrow for shad and Atlantic sturgeon; and
- horizontal structural beams and light levels that are inconsistent between inside and outside of the fishway are major impediments to shad passage.

For other species such as gaspereau, the fish passage facilities at the causeway introduce a period of delay in their migration. They are detained, sometimes for an extended duration during which they are subjected to heavy predation by birds and large eels. These issues will persist with the Status Quo.
Following is a species-by-species discussion of passage difficulties experienced by fish in the Petitcodiac River system that will persist with the Status Quo.

**Tomcod** – This small-bodied, weak swimming fish was observed in the fishway trap only during periods of reversing tide through the fishway. Water velocities are often too great in the fishway for tomcod, and upstream passage is negatively affected. The fish observed in the fishway trap were running ripe (full of eggs or milt (see Glossary)), and if they successfully spawn upstream of the causeway, larvae would be transported downstream in the late winter. They would probably be subjected to mortality during turbulent gate discharges.

**Rainbow smelt** - The Gate Management Plan allows for an opening at night during the period of smelt spawning. This provides some upstream passage. The fishway velocities are normally too great to pass smelt. Larvae are transported downstream in mid-spring. They are probably subjected to mortality during turbulent gate discharges.

**Gaspereau** – Extensive delays during upstream migration lead to heavy bird predation. Despite this, many successfully pass through the gate openings and the fishway. The carrying capacity of the nursery habitat of the river for the species is probably approached. Late summer and autumn discharge of juvenile gaspereau that are in the process of downstream migration onto built up mudflats leads to physical smothering and a high degree of bird predation. There is a question as to the effect of the abnormally late migration (migrating later in the season than is typical for no apparent reason) of a portion of the gaspereau population that was observed in 2003. Abnormally late migrating fish often experience high mortality rates because they miss important feeding opportunities. This negative environmental effect on gaspereau in the case of the Petitcodiac River is only hypothetical however.

**Atlantic sturgeon** – Upstream passage for this species is unavailable except for a small window during gate openings. Upstream passage via the fishway is impossible for this species, which is 2 m long or longer, and wider than the vertical slots of the fishway.

**American shad** – Upstream fish passage is unacceptable for this species due to the fishway and Gate Management Plan being incompatible with the behaviour of the species. Shad are very nervous fish. They are discouraged temporarily by the smallest obstacle to their upstream passage. They often advance and fall back downstream before finally moving upstream in a school. The dimensions of the fishway slots are not sufficient to accommodate this behaviour, and the variation in light level inside versus outside of the fishway is also a severe obstacle to their upstream passage. Downstream passage difficulties for juvenile shad would be similar to those of gaspereau.

**Atlantic salmon** – Once in the fishway, upstream passage through the fishway for this species has been demonstrated to be marginally effective (Semple, 1984). The smolt-tracking project in 2003 demonstrated high mortality (50%) within the headpond (Section 3.3.6.2.3 in AMEC, 2005a). When poor downstream migration conditions were mitigated in 1982 by drawing the headpond down (prior to the general decline in the Inner Bay of Fundy population), the salmon run rebounded to near pre-causeway levels. The headpond creates delays that disrupt smolt
physiology, and provide opportunities for predators to capture smolts. Downstream smolt passage is severely impeded under the Status Quo situation for this species. The downstream movement of kelt is also impeded by the presence of the headpond and the bottom opening gates. Adult salmon are subjected to potential delays in migration from accumulated sediment that impedes tidal flow. The area of depleted DO in the summer that exists downstream of the causeway is a factor that would potentially delay adult salmon passage in the estuary.

**Sea lamprey** – No obvious fish passage problems are evident with this species.

**American eel** – No obvious fish passage problems are evident with this species.

**Brook trout** – No brook trout have been found migrating from the estuary with the causeway in place. Therefore, it is assumed that no brook trout now migrate to the estuary. No fish passage is required under the Status Quo situation for this species.

Overall, although fish passage is not an issue or a problem with respect to some fish species (e.g., smallmouth bass, chain pickerel, American eel), the potential negative environmental effects of the Status Quo on fish habitat due to fish passage issues in consideration of the residual environmental effects significance rating criteria are predicted to be significant and do not meet the fish passage Project Objective.

**Project Options 3/4A**

Under Project Options 3/4A, the primarily freshwater region of the headpond will be incorporated into the tidal reach of the river. In its upper stretch, this area will still be primarily a freshwater zone with the water level changing according to the height of the tide. Further downstream, the current headpond area will become a brackish water region with the tidal prism constantly mixing the water column and creating a brackish region with uniform salinity top to bottom. The upper tidal region will be less physically dominated by tides and currents than downstream of the causeway, but will still become primarily a transportation corridor for fish rather than a rearing area. Marine, estuarine or anadromous fish, striped bass for example, may move into the area on the high tide for feeding purposes, but will not remain there. The elimination of the lentic freshwater region of the headpond is an negative residual environmental effect of Project Options 3/4A on this type of habitat.

Project Options 3/4A will result in virtually unimpeded fish passage into and out of the Petitcodiac River. The causeway will no longer be a point where fish passage will be prevented or significantly delayed. Slight delays might conceivably occur there for some species during high flows when water velocities might approach critical levels. Sediment deposition will occur in the former headpond area upstream of the causeway, and this deposition may cause occasional but rare fish stranding in this area at low tide, in a manner that occurred prior to the causeway’s construction. Sediment deposits downstream of the causeway will be scoured, and the river will revert towards habitat conditions that existed prior to the construction of the causeway.
Project Options 3/4A will result in TSS levels in the river above the causeway to return to pre-causeway levels. As mentioned above, the natural TSS levels in the Petitcodiac River are generally harmful to fish gill function. This will make the river from the causeway to Salisbury primarily migratory habitat for most fish (e.g., Brook trout and Atlantic salmon). Some fish (e.g., mummichog) seem relatively unaffected by these high TSS levels and natural occur year round in this high TSS environment.

In summary, the potential environmental effects of Project Options 3/4A on fish habitat in consideration of the residual environmental effects significance rating criteria are predicted to be not significant to positive. As noted in Section 9.3.4.2, it is anticipated that the negative residual environmental effects on lentic freshwater fish habitat will be compensated for by the improvements to fish passage and the subsequent opening up of new habitat to estuarine and diadromous fish species, and Project Options 3/4A will have very positive environmental effects on fish habitat (fish passage) in the Petitcodiac River and will meet the fish passage Project Objective.

Project Options 4B/4C

As described for Project Options 3/4A, the potential environmental effects of Project Options 4B/4C on fish habitat in consideration of the residual environmental effects significance rating criteria are predicted to be not significant to positive. Project Options 4B/4C will also have positive benefits for fish habitat (i.e., meet the Project Objective of fish passage), and negative environmental effects on lentic freshwater habitat.

Comparative Assessment

The Status Quo has significant residual negative environmental effects on fish habitat (fish passage). The Project Options address fish passage problems and provide very positive residual environmental effects on fish habitat (fish passage) and meet the fish passage Project Objective. The slightly larger capacity for tidal flow from a 225 m wide opening (Project Options 4B/4C) may result in fewer fish passage delays than with the 68 to 72 m wide opening of Project Options 3/4A, but this difference is considered negligible. In summary, the potential environmental effects of the Project Options on fish habitat in consideration of the residual environmental effects significance rating criteria are predicted to be not significant to positive, whereas the potential negative environmental effects of the Status Quo are predicted to be significant.

9.2.5 Future Trends (2055, 2105)

Under the Status Quo, the estuary should approach a relatively constant cross-sectional geometry after about 70 years (Section 8.3.1). Therefore, the trends for Fish and Fish Habitat will continue until approximately 2075. Eventually, in the distant future, the accumulation of sediment primarily from estuarine sources in the headpond will have decreased its volume considerably. The channel dimensions will decrease to accommodate the median high freshwater flow. However, the fish and fish habitat conditions still will not have changed substantially.
For the Project Options, equilibrium will occur when the channel dimensions correspond to the new tidal prism volume. The stated effects on Fish and Fish Habitat will remain effectively constant for each Project Option.

**9.2.6 Accidents and Malfunctions**

There is a possibility that hazardous materials used during construction of the Project Options could be accidentally spilled and introduced into the Petitcodiac River. These materials could temporarily degrade water and sediment quality and fish habitat, and directly kill fish. However, mitigation measures as outlined in the EMP (Section 7.5) will protect against such spills and provide for their safe and effective clean-up.

There is a potential under the Status Quo or Project Options during heavy precipitation events or flash floods for erosion control structures to fail at the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway. An accident of this nature could result in leaching or erosion of potentially toxic substances into the river, and a potential risk to fish and fish habitat. Uncontrolled leaching of the landfill is actually more probable under the Status Quo situation. The landfill is directly downstream of the lowest elevation section of the causeway, and there exists a real possibility of its over-topping when the flood control gates become wedged shut due to freezing or being clogged with mud. To reduce the possibility of this occurring during Project Option implementation, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Fish and Fish Habitat in the Assessment Area are predicted to be not significant.

**9.2.7 Summary**

Although the headpond creates habitat for freshwater aquatic species (e.g., smallmouth bass, chain pickerel) and may benefit American eel, overall the potential environmental effects of the Status Quo on Fish and Fish Habitat (sediment quality, water quality, fish/other valued aquatic animal species, fish habitat) in consideration of the residual environmental effects significance rating criteria are predicted to be significant. Sediment and water quality continue to worsen under the Status Quo, and the causeway has a significant environmental effect on many fish species by providing a barrier to fish passage; the Status Quo does not meet the fish passage Project Objective.

The potential environmental effects of the Project Options on Fish and Fish Habitat in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive. The environmental effects on sediment quality will be not significant, water quality will improve and the potential for fish passage will be achieved (i.e., the Project Options will meet the fish passage Project Objective). The loss of freshwater aquatic species in the headpond area will be compensated for by the overwhelmingly positive environmental effects on estuarine, marine and diadromous fish species, and should follow-up determine any negative environmental effects on commercial
fisheries as a result of the Project Options, the fishers will be compensated for that loss (Section 9.11).

9.3 Terrestrial and Wetland Environment

9.3.1 Rationale for Selection of VEC

The Terrestrial and Wetland Environment have been selected as a VEC because of its ecological importance in the potential zone of influence of the Status Quo and Project Options. The key elements of the Terrestrial and Wetland Environment VEC are wetlands, wildlife and vegetation, migratory birds, mudflat productivity and Managed Areas. These are discussed below to elaborate on their relevance to the EIA.

9.3.1.1 Wetlands

Wetlands may be at risk due to the potential environmental effects of the Status Quo and Project Options. The Status Quo and Project Options may result in a change in wetland habitat type, quantity and/or quality, both upstream and downstream of the causeway. Upstream of the causeway, the Project Options will change the freshwater environment to an estuarine environment and may alter wetland habitat quality and quantity. Downstream of the causeway, habitat may be altered or changed in quality (e.g., due to changes in channel width, depth, hydrodynamics and sediment transport).

9.3.1.2 Wildlife and Vegetation

Wildlife and vegetation may be at risk due to the potential environmental effects of the Status Quo and Project Options. The Project Options may result in the loss of or change in habitat, both upstream and downstream of the causeway similar to that described for wetlands in Section 9.3.1.1.

9.3.1.3 Migratory Birds

Potential environmental effects associated with the Project Options and the Status Quo with respect to migratory birds may include change in habitat type (freshwater to estuarine), change in the integrity of freshwater waterfowl areas (mainly Ducks Unlimited impoundments) upstream of the causeway, and changes in the quantity and quality of wetlands and mudflats both upstream and downstream of the causeway.

9.3.1.4 Mudflat Productivity

The productivity of mudflats in the Assessment Area may change as a result of Project Options and the Status Quo. On December 5, 2003, the AMEC Study Team met with representatives of NBDNR, NBDSS, Environment Canada’s Canadian Wildlife Service (CWS) and NBDELG to discuss the subject of wetlands. During this meeting, it was agreed that because mudflat productivity is linked to the success of shorebird populations, including a substantial portion of the worldwide population of a migrating shorebird species, the Semi-palmated Sandpiper (Calidris pusilla), mudflat productivity should be assessed separately from wetlands.
9.3.1.5 Managed Areas
Managed Areas, which include provincially designated Environmentally Significant Areas (ESAs) and Ducks Unlimited sites, may be at risk due to the potential environmental effects of the Status Quo and Project Options. The Status Quo and Project Options may result in a change in wetland and/or mudflat habitat type, quantity and/or quality, both upstream and downstream of the causeway.

9.3.2 Boundaries
The spatial and temporal boundaries for the assessment of the Terrestrial and Wetland Environment (the “Assessment Area”) are as defined in Table 4.7.1 and Section 4.7, respectively.

9.3.3 Threshold for Determination of Significance

9.3.3.1 Wetlands
A significant negative residual environmental effect is one that would result in a net reduction of wetland function and/or quality below that which existed before the causeway was built as documented in 1962 air photos.

9.3.3.2 Wildlife and Vegetation
A significant negative residual environmental effect on wildlife and vegetation would be one that:

- affects wildlife or vegetation (e.g., direct mortality, change in migratory patterns, habitat avoidance) or plant or wildlife habitat (loss or change) in such a way as to cause a decline in abundance or change in distribution of these common and secure population(s) of indicator/representative wildlife species over one or more generations within the regional population, and natural recruitment may not re-establish the population(s) to its original level; and/or
- affects species at risk not under the protection of SARA or the New Brunswick Endangered Species Act (i.e., listed by COSEWIC but not in Schedule 1 of SARA; listed in SARA but not in Schedule 1; listed as “Species of Special Concern” in SARA (including within Schedule 1); or ranked as S1, S2, or S3 by AC CDC; and also ranked “May Be At Risk” or “Sensitive” by NBDNR) such that:
  - the terrestrial or wetland habitat within the Assessment Area is altered physically, chemically, or biologically, in quality or extent, in such a way as to cause a change or decline in the distribution or abundance of a viable wildlife or vegetation population that is dependent upon that habitat such that the likelihood of the long-term survival of these uncommon and/or non-secure population(s) within the regional population is substantially reduced as a result; and/or
  - the direct mortality of individuals or communities substantially reduces the likelihood of the long-term survival of these uncommon and/or non-secure population(s) within the regional population; and/or
• in the case of “Species of Special Concern” listed in Schedule 1 of SARA, the Project activities are not in compliance with the objectives of management plans (developed as a result of Section 65 of SARA) that are in place at the time of Project construction; and/or
• affects species listed in Schedule 1 of SARA as “Extirpated”, “Endangered” or “Threatened” and results in a non-permitted violation of any of the prohibitions stated in Sections 32-36 of SARA; or in a non-permitted violation of any of the prohibitions stated in Section 3 of the New Brunswick Endangered Species Act (NB ESA).

9.3.3.3 Migratory Birds

Significant negative residual environmental effects of the Status Quo or Project Options on migratory birds would be the same as described in Section 9.3.3.2 for wildlife and vegetation.

9.3.3.4 Mudflat Productivity

A significant negative residual environmental effect of the Status Quo or Project Options would be one that affects mudflat productivity in such a way as to cause a decline in area or change in distribution of migrating shorebird populations dependant upon it, particularly the Semi-palmated Sandpiper, over one or more generations such that natural recruitment may not re-establish the population(s) to its original level.

9.3.3.5 Managed Areas

A significant negative residual environmental effect on naturally occurring Managed Areas is one that results in loss of, or substantive damage to, the Managed Area as compared to pre-causeway conditions. A significant negative residual environmental effect on constructed Managed Areas (e.g., Ducks Unlimited sites) is one that results in loss of or substantial damage to the constructed Managed Area.

9.3.4 Evaluation of Potential Environmental Effects

9.3.4.1 Wetlands

Status Quo

As discussed in Section 5.2.1, the construction of the causeway resulted in the infilling of much of the river channel with sediment. Much of this infilled material was subsequently colonized by wetland vegetation. As a result, the overall area of wetlands along the Petitcodiac River had increased substantially by 2005. However, while there is more wetland area at baseline conditions than there was pre-causeway and it is likely this trend will continue under the Status Quo, the type and characteristics of the wetlands have changed substantially since causeway construction. There are now freshwater wetlands upstream of the causeway, rather than saltwater marshes. In addition, the saltwater marshes that have formed downstream do not have the same characteristics (i.e., species diversity, tidal influence) as the saltwater marshes that were lost upstream or as the downstream saltwater marshes prior to construction of the causeway. Therefore, the overall environmental effect of the Status Quo on wetlands is considered to be significant as compared to baseline conditions and pre-causeway conditions.
Project Options 3/4A

During construction, Project Option 4A will result in a small loss of wetland area downstream of the causeway and north of the fishway as shown in Figure 7.2.1. Project Option 3 will not result in a loss of wetland area during construction.

During operation, the environmental effects of Project Options 3/4A will be similar. Both Project Options 3/4A will maintain free tidal flow along the Petitcodiac River with a similar increase in the available tidal volume and energy. Consequently, wetland habitat in the Assessment Area will be substantially modified.

Overall, Project Options 3/4A is predicted to result in the loss of -90 ha of freshwater wetland by 2025 as compared to baseline conditions. This loss will occur entirely upstream of the causeway, where freshwater wetlands created by the causeway will be replaced with saltwater wetlands, except for those that exist within protected Ducks Unlimited sites (approximately 20 ha upstream of causeway and 26 ha downstream in 2001). These Ducks Unlimited sites are located in former dykelands that will be repaired and maintained as freshwater wetlands as mitigation for Project Options 3/4A.

Project Options 3/4A will result in an estimated loss of -300 ha of saltwater wetland area by 2025 as compared to baseline conditions. This would occur as accumulated sediments in the river are flushed out and the width of the river increases. However, the wetlands that will be lost will be those that were created as a result of increased sedimentation caused by construction of the causeway. Total estimated saltwater wetland area downstream of the causeway in 2025 (1,300 ha) will continue to be approximately +100 ha more than pre-causeway conditions (1,200 ha interpreted from 1962 aerial photos; AMEC, 2005b), as the width of the river will approach but be less than that before the causeway was constructed.

Prior to construction of any of the Project Options, including Project Options 3/4A, there is a need to restore/improve some of the dykes surrounding Ducks Unlimited wetlands and around agricultural land upstream of the causeway. No other mitigation is proposed to prevent the conversion of freshwater wetlands to saltwater wetlands, as this process is a trend towards the more desirable pre-causeway conditions. Also, freshwater wetlands are well represented in the area (AMEC, 2005a), and saltwater wetlands are considered to be Provincially Significant. Additionally, no mitigation is proposed for the loss of Provincially Significant wetland habitat below the causeway, as it is believed that the conversion of freshwater wetland to saltwater wetland upstream of the causeway will at least partially mitigate this loss and the overall amount of saltwater wetland will continue to exceed pre-causeway total saltwater wetland area. Also, it is anticipated that the saltwater wetland quality will improve as the conditions approach those that existed prior to construction of the causeway.

Based on consideration of the potential environmental effects, the proposed mitigation, and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 3/4A on wetlands are predicted to be positive (as compared to the baseline conditions), as Project Options 3/4A will maintain an overall increase...
to total wetland area above that which existed before the causeway was built, and improved wetland quality as compared to the baseline conditions.

**Project Options 4B/4C**

During construction, Project Options 4B/4C have the potential to result in a loss of wetlands downstream of the causeway, north of the fishway as shown in Figures 7.2.2 and 7.2.3. Project Option 4C will result in the greatest loss of these wetlands due to the location of the bridge and the requirement for dredging. The amount of wetland area lost during the construction of Project Option 4B will be a function of the final selected opening width (Figure 7.2.2).

During operation, Project Options 4B/4C will have similar environmental effects on wetlands as those of Project Options 3/4A, although Project Options 4B/4C will permit greater tidal exchange and the tidal volume (depth and width) in the river will be greater than that predicted for Project Options 3/4A and will extend closer to the original river channel. As a result, headpond drainage and flushing of accumulated sediments will occur in a shorter period of time and will result in a wider channel. Subsequently, Project Option 4C, and to a lesser degree Project Option 4B, will more closely approach pre-causeway wetland conditions then will Project Options 3/4A. The same mitigation as proposed for Project Options 3/4A is recommended for Project Options 4B/4C.

Overall, Project Options 4B/4C are predicted to result in the same loss (-90 ha compared to baseline conditions) of freshwater wetland by 2025 as Project Options 3/4A. This loss will occur upstream of the causeway, as described for Project Options 3/4A.

Project Options 4B/4C will result in an estimated loss (-400 ha compared to baseline conditions) of saltwater wetland area by 2025 as compared to the -300 ha for Project Options 3/4A. The total saltwater wetland area will be the same as existed prior to the causeway (1,200 ha) by the year 2025. The total wetland area (saltwater and freshwater) will be approximately +60 ha more than existed prior to the construction of the causeway.

Based on consideration of the potential environmental effects, the proposed mitigation, and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 4B/4C on wetlands are predicted to be positive (as compared to the baseline conditions), as Project Options 4B/4C will maintain an overall increase to total wetland area above that which existed before the causeway was built, and improved wetland quality as compared to the baseline conditions.

**Comparative Assessment**

Upstream of the causeway, all of the Project Options will result in the conversion of freshwater wetlands to saltwater wetlands (except Ducks Unlimited sites and dyked agricultural sites), while the Status Quo will maintain freshwater wetlands associated with the headpond. All of the Project Options and the Status Quo will continue to maintain a surplus of wetland area as compared to pre-causeway conditions. Based on aerial photograph analysis, the Status Quo would likely continue to accrue both saltwater and freshwater wetlands as compared to baseline conditions. Based on the findings of the Modelling Component Study (AMEC, 2005b), Project
Options 3/4A and 4B/4C will result in the decrease of freshwater and saltwater wetlands as compared to baseline conditions, with the largest decrease occurring as saltwater wetland with Project Option 4C, but an overall improvement in wetland quality. Project Option 4C, and to a lesser degree Project Option 4B, will more closely approach pre-causeway wetland conditions then will Project Options 3/4A. However, it should be noted that all Project Options are predicted to result in more saltwater wetland area (and total wetland area) than existed prior to the construction of the causeway.

9.3.4.2 Wildlife and Vegetation

There were no animal species identified that were Species at Risk or Species of Conservation Concern. Animal species that use the riparian zone (see Glossary) of the Petitcodiac River are primarily small mammals such as raccoons, muskrat and voles. Individual animal or local population locations were not recorded as part of the field program (AMEC, 2005a). The environmental effects assessment of wildlife is based on an assessment of the available wildlife habitat as an indicator of the likely potential environmental effects on wildlife.

Status Quo

The Status Quo would likely result in a net increase in freshwater and saltwater wetland area over pre-causeway and 2005 baseline conditions. However, this new wetland is not considered to be of the same high quality of that which existed prior to the development of the causeway. Consequently, the Status Quo will have a negative but not significant environmental effect on wildlife and vegetation, including species at risk, that are dependent upon wetland habitat in the Assessment Area. No terrestrial habitat will be affected by the Status Quo.

The development of the causeway resulted in the conversion of saltwater habitat to freshwater habitat between the causeway and Salisbury. This has increased the distribution of some freshwater invasive (non-native) wetland and riparian plant species (e.g., purple loostrife) and a non-native form of the common reed. This will continue under the Status Quo.

Freshwater bivalves (clams) from five locations (three in the headpond) and four sediment samples from the Gunningsville Bridge were sampled for cadmium, copper, lead, zinc and mercury metal concentration in 1997 (Arsenault, 1998). Clams are filter feeders and are known to accumulate heavy metals in their tissue if heavy metals are in the water. These clams are a common food source for small mammals such as raccoons and some wading and diving birds. Arsenault (1998) reported that “the concentrations for cadmium, copper, lead, mercury and zinc measured in the sediment and bivalve samples were compared with guidelines listed in the Sediment Quality Guidelines for the Protection of Aquatic Life.” The range of values reported in Arsenault (1998) are summarized in Table 9.3.1.

Polychlorinated Biphenyls (PCBs; measured as total Arochlor) were also not detected in tissues of these same clams (Doe, 1998). The detection limit ranged from <112 to <140 ng/g dry weight.
Table 9.3.1 Metal Concentrations in Sediments and Clams

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<th>Cadmium (mg/kg) dry weight</th>
<th>Copper (mg/kg) dry weight</th>
<th>Lead (mg/kg) dry weight</th>
<th>Mercury (mg/kg) dry weight</th>
<th>Zinc (mg/kg) dry weight</th>
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<td>not detectable</td>
<td>0.08 – 0.24</td>
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<td>12</td>
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<td>5.7 – 8.5</td>
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<td>9.3 – 11.9</td>
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Notes

*Concentrations defining the high end of the overall distribution of concentrations measured in mollusks by the Mussel Watch Project (NOAA 1988).

Polycyclic Aromatic Hydrocarbons (PAHs) levels ranged from 87.4 to 145 ng/g dry weight in the sampled clams (Doe, 1998). The US Mussel Watch Project considers “high” concentrations of PAHs in mussels and oysters as greater than 1,020 ng/g.

Mummichog (*fundulus heteroclitus*) is a small (3-5 cm) estuarine fish that is common below the causeway. Mummichog are commonly consumed by wading birds (e.g., herons). Mummichog were collected, for an unrelated project, in Jonathan Creek and at a location 20 km downstream of the causeway, in 2002 (Jacques Whitford, 2002). Tissue (whole carcass) from 40 mummichogs was sampled for trace elements (i.e., arsenic, copper, iron and selenium). The study concluded that the levels of metals detected in the mummichog were not high enough to be of toxicological (see Glossary) concern.

Therefore, it is concluded that the existence of the causeway has not resulted in a situation where common wildlife food sources (i.e., clams and mummichogs) have contaminant concentrations that may lead to bioaccumulation of those contaminants in wildlife to a degree that is a toxicological concern. The Status Quo is not anticipated to result in a change to the baseline conditions in this regard.

**Project Options 3/4A**

Project Options 3/4A will have environmental effects on wildlife and vegetation, including species at risk, in the Assessment Area. These potential environmental effects are mostly related to the changes in wetland area or type however construction related activities (e.g., pier removal) may affect habitat quality through noise disturbance in habitat adjacent to the activity. During operation, Project Options 3/4A will cause a change in wetland habitat and river dimensions both upstream and downstream of the causeway. However, shoreline length will not change substantially.
A description of predicted changes to the wetlands in the Assessment Area caused by Project Options 3/4A is provided in Section 8.11, and in the Modelling Component Study (AMEC, 2005b). The conversion of freshwater wetland to saltwater wetland upstream of the causeway will have environmental effects on wildlife and vegetation in the Assessment Area; wildlife and vegetation species composition will more closely resemble those of pre-causeway conditions, when saltwater marsh extended up to Salisbury. The loss of a portion of the freshwater habitat area as a result of Project Options 3/4A is not expected to have a significant environmental effect on the regional population of wildlife and vegetation species, as suitable freshwater wetland habitat is well represented in the region surrounding the Assessment Area (AMEC, 2005a).

The loss of saltwater wetland downstream of the causeway will cause the loss of vegetation and wildlife habitat along the existing riverbanks, although the riverbanks will re-form at a different location. This is not expected to have significant environmental effects on regional populations of flora and fauna, as additional saltwater habitat will be created upstream of the causeway.

Project Options 3/4A may have environmental effects on individual plant Species of Conservation Concern, as they cannot necessarily escape either the conversion of their habitat to saltwater wetland or the flooding of their habitat along riverbanks. None of the 28 plant Species of Conservation Concern identified as occurring in close proximity to the Assessment Area are provincially or federally protected (AMEC, 2005a). The three plant Species of Conservation Concern identified within the Assessment Area during field surveys were salt grass (*Distichlis spicata*; AC CDC ranked S2), golden dock (*Rumex maritimus*; AC CDC ranked S2S3) and Gaspé peninsula arrow grass (*Triglochin gaspensis*; AC CDC ranked S2). The potential loss of a few individuals of these species is not expected to have a significant environmental effect on their regional populations, and these species may re-establish populations within the available habitat.

Project Options 3/4A are not expected to have significant environmental effects on wildlife Species of Conservation Concern. For a complete list of the 57 species of fauna identified by the AC CDC as occurring in close proximity to the Assessment Area, see the Biophysical Component Study (AMEC, 2005a). None of these species, excluding birds (Section 9.3.4.3), are federally or provincially protected, except for lynx, which is listed as “Regionally Endangered” under the New Brunswick *Endangered Species Act*. Project Options 3/4A will not have any environmental effects on lynx if present within the Assessment Area. Although no wildlife Species of Conservation Concern (e.g., wood turtle, snapping turtle or monarch butterfly) were observed during field surveys in 2003, Project Options 3/4A will not have any significant negative environmental effect on these species or their regional populations, if they were present in the Assessment Area.

Disturbance from noise during construction will be temporary and localized, and therefore no mitigation is proposed. Mitigation proposed for the conversion of freshwater wetland habitat to saltwater wetland habitat and for the loss of wetland habitat below the causeway is the same as described in Section 9.3.4.1.
Project Options 3/4A are not expected to result a substantial change to the distribution of invasive wildlife species. However, there is some potential for activities related to Project Options 3/4A to cause the introduction of invasive plant species. Invasive plant species are typically non-native and may out-compete local native plants due to the lack of natural predators or because of their ability to overwhelm other native plants by monopolizing sunlight and available nutrients. Invasive plant species may be introduced by Project Option construction-related activities if equipment is transported from a distant location or from a location which is already infested by such species into the Assessment Area with dirt on it containing seeds or pollen from the invasive species. This potential environmental effect will be minimized by ensuring that all equipment used during Project Option activities is thoroughly washed before transport to the site.

Mercury was the only metal of concern that was detected in the water during the field studies (AMEC, 2005a). The mercury concentrations in the water between the Gunningsville Bridge and Hopewell Cape exceeded the CCME Guidelines for Aquatic Life (marine) of 0.015 µg/L. Mercury was not detected in the water above the causeway. Project Options 3/4A will result in an increased tidal prism and a dilution factor in the range of 5 to 7 times the baseline conditions. It is anticipated that this will decrease the concentration of mercury in the water, and therefore decrease the already low potential for bioaccumulation of mercury in aquatic animals (e.g., clams) and subsequently in the wildlife (e.g., raccoons and birds) that consume aquatic animals and plants.

Polychlorinated Biphenyls (PCBs) were non-detectable in all sediment samples and Polycyclic Aromatic Hydrocarbons (PAHs) were more than an order of magnitude below the Ontario Guideline for Lowest Effect Levels in all samples except for one anomalous sample collected near the causeway in 1999. Likewise, cadmium, copper, lead, mercury and zinc were all below the marine sediment Interim Sediment Quality Guidelines for the Protection of Aquatic Life. The Project Options 3/4A will result in much of this sediment being moved out into Shepody and Chignecto Bays and beyond. The sediment was not found to be contaminated and will move through the river ecosystem quickly. Therefore, it is expected that this movement of sediment will not result in the exposure of wildlife or their food source (e.g., clams) to unacceptable levels of contamination, and therefore the movement of sediment should not lead to an incremental accumulation of contaminants in the tissue of wildlife over baseline conditions.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 3/4A on wildlife and vegetation are predicted to be not significant.

**Project Options 4B/4C**

The environmental effects of Project Options 4B/4C on vegetation and wildlife and mitigation measures will be similar to those described for Project Options 3/4A. Project Option 4C, followed by Project Option 4B, will result in a greater loss of wetland habitat and associated changes to the plant and wildlife species that use it, than Project Options 3/4A. Mitigation
proposed for the conversion of freshwater wetland habitat to saltwater wetland habitat and for the loss of wetland habitat below the causeway is the same as described in Section 9.3.4.1.

Project Options 4B/4C are not expected to result in a change to the distribution of invasive plant and wildlife species that is measurably different from that anticipated for Project Options 3/4A.

Project Options 4B/4C are not expected to result in a change to the potential for bioaccumulation in wildlife species that is measurably different from that anticipated for Project Options 3/4A.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 4B/4C on wildlife and vegetation are predicted to be not significant.

Comparative Assessment

Neither the Status Quo nor the Project Options will result in significant negative environmental effects on vegetation and wildlife in the Assessment Area. The Status Quo has a positive environmental effect on vegetation and wildlife as it increases wetland habitat, while the Project Options will convert freshwater wetland to saltwater wetland habitat upstream of the causeway and will result in a loss of saltwater habitat downstream of the causeway, but not below pre-causeway levels. Proposed mitigation includes protection of existing Ducks Unlimited wetlands upstream of the causeway. The Status Quo will continue to allow freshwater invasive plant species to exist in the headpond, while the Project Options will convert the area between the causeway and the village of Salisbury back to a saltwater environment that is less conducive to invasive species.

The accumulation of contaminants in wildlife food sources has not been observed to be a problem since the development of the causeway in the headpond (clams) or below the causeway (mummichog). The Status Quo is not anticipated to change these baseline conditions. The Project Options are anticipated to reduce the level of mercury in the water through the process of dilution. The Project Options will result in the movement of sediment, but the sediment is not contaminated to a level that is of concern. Therefore, the Project Options are not expected to increase the potential for bioaccumulation in wildlife that consumes aquatic animal tissue.

9.3.4.3 Migratory Birds

The migratory birds that are known to use the Assessment Area are listed in Section 5.5.3, and in the Biophysical Component Study (AMEC, 2005a).

Status Quo

The Status Quo would likely result in a net increase in wetland area over pre-causeway and 2005 baseline conditions. Consequently, the Status Quo will have a positive environmental effect on migratory birds, including Species of Conservation Concern, dependent upon wetland habitat in the Assessment Area. It is recognized that this analysis is somewhat contradictory to
the Wetlands analysis. That is because a higher premium is placed upon overall wetland area then wetland quality in this case.

The environmental effects of the Status Quo on migratory birds associated with mudflat productivity are predicted to be negative but not significant as the Status Quo will not substantially affect mudflat productivity in Shepody Bay, the principle habitat for mudshrimp in the Assessment Area (Section 9.3.4.4).

**Project Options 3/4A**

Project Options 3/4A will have environmental effects on migratory birds, including migratory bird Species of Conservation Concern, in the Assessment Area. Construction activities have the potential to affect habitat quality through noise disturbance and through the relatively sudden loss/change in wetland habitat following opening of the gates. However, these environmental effects will be of short duration. During operation, Project Options 3/4A will cause a change in wetland habitat both upstream and downstream of the causeway as described in Section 9.3.4.1.

The conversion of freshwater wetland to saltwater wetland upstream of the causeway will have environmental effects on migratory birds in the Assessment Area, as species composition will more closely resemble that of pre-causeway conditions, when saltwater marsh extended up to the village of Salisbury. The loss of freshwater habitat upstream of the causeway is not expected to have a significant environmental effect on migratory birds or migratory bird Species of Conservation Concern, as 46 ha of freshwater wetlands (upstream and downstream of the causeway) will remain in the Assessment Area as protected Ducks Unlimited sites, 126 ha of freshwater wetland will remain protected by the dykes in Dieppe, and other suitable freshwater wetland habitat is well represented in the region surrounding the Assessment Area (Table 3.4.6 in AMEC, 2005a).

The loss of saltwater wetland habitat downstream of the causeway is not expected to have significant environmental effects on migratory birds or migratory bird Species of Conservation Concern, as additional saltwater habitat will be created upstream of the causeway, and there will be substantially more wetland habitat than what existed in the pre-causeway period. Environmental effects on shorebird species dependent upon mudflats will not be significant, as mudflat productivity in Shepody Bay will not be affected substantively by Project Options 3/4A (see Section 9.3.4.4.2).

A complete list of the 30 bird Species of Conservation Concern that have some potential for interaction with the Project are described in the Biophysical Component Study (AMEC, 2005a). Three of these species are listed on Schedule 1 of SARA: Piping Plover (“Endangered”); American Peregrine Falcon, “Threatened”); and Least Bittern (“Threatened”). Peregrine Falcon and Piping Plover are also listed as “Endangered” under the New Brunswick *Endangered Species Act* and Bald Eagle is listed as “Regionally Endangered”. Project Options 3/4A will not have any significant environmental effects on any of these species, as their breeding habitat will not be affected by the Project Options and critical habitat for other life stages are not limiting in the Assessment Area.
Mitigation for migratory birds during construction activities is limited to releasing the majority of the headpond water (i.e., opening the gates) during the spring freshet, thereby avoiding drops in water level during the migratory bird nesting season. As disturbance from causeway pier removal noise will be temporary and geographically limited, no mitigation is necessary or proposed. There is no mitigation proposed for the conversion of freshwater wetlands to saltwater wetlands (other than protection of Ducks Unlimited sites), as this process is a trend toward pre-causeway conditions, freshwater wetlands are well represented in the area (AMEC, 2005a), and saltwater wetlands are considered to be Provincially Significant. There is no mitigation proposed for the loss of wetland habitat below the causeway, as this process is a trend toward pre-causeway conditions (but will not result in less wetland area than pre-causeway conditions) and additional saltwater wetland habitat will be created upstream of the causeway.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 3/4A on migratory birds are predicted to be not significant.

**Project Options 4B/4C**

The environmental effects of Project Options 4B/4C on migratory birds and mitigation measures will be similar to those described for Project Options 3/4A in Section 9.3.4.3. Project Option 4C, followed by Project Option 4B, will result in a greater loss of wetland habitat than Project Options 3/4A during construction and operation (Section 9.3.4.1). Environmental effects on shorebird species dependent upon mudflats will not be significant, as mudflat productivity in Shepody Bay will not be substantially affected by Project Options 4B/4C (see Section 9.3.4.4).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of construction and operation of Project Options 4B/4C on migratory birds are predicted to be not significant.

**Comparative Assessment**

The Status Quo will have a positive environmental effect on migratory birds and Project Options will result in negative environmental effects on migratory birds in the Assessment Area that are not significant. The Status Quo has a positive environmental effect as it increases wetland habitat for migratory birds, while the Project Options convert freshwater wetland to saltwater wetland habitat upstream of the causeway and result in a loss of saltwater habitat downstream of the causeway, but not to pre-causeway levels.

**9.3.4.4 Mudflat Productivity**

The Status Quo will have negative environmental effects on mudflats in the Assessment Area. In the Petitcodiac River downstream of the causeway, the post-causeway mudflat area continues to decrease due to vegetation by wetland species caused by the rising elevation of the mudflats as a result of accelerated deposition since installation of the causeway.
The estimation of the environmental effects of the Status Quo and Project Options on the future mudflat area and distribution was attempted simultaneously with the future wetland area and distribution as described in Section 8.11, and in the Modelling Component Study (AMEC, 2005b).

Mudflat productivity is linked to the success of shorebird populations, particularly the Semi-palmated Sandpiper. In 2003, mudshrimp were abundant in Shepody Bay and at the mouth of the river (Hopewell Cape) but became less abundant as one moved upstream; no mudshrimp were present in field surveys at Outhouse Point. These conditions are not anticipated to change as there appears to be one or more limiting factors (e.g., salinity) preventing mudshrimp from existing further up the river. The narrow bands of mudflats in the Petitcodiac River, which are exposed for a short period of time in the tidal cycle, are believed to be considerably less important as feeding habitat for migrating shorebirds than the much larger and productive mudflats in Shepody Bay. Therefore, the success of migrating shorebird populations is largely linked to mudflat productivity in Shepody Bay. While the distribution of the mudflat in Shepody Bay has not changed substantially since 1965, tidal currents, sedimentation processes and, consequently, the biological nature of the mudflat has changed considerably since the introduction of causeways and dams on the Bay of Fundy estuaries, including the Petitcodiac River. Within the Petitcodiac River just downstream of the causeway, the channel was largely filled in with sediment following construction.

**Status Quo**

During the post-causeway, evidence suggests that Petitcodiac River mudflat area has been declining due to vegetation by wetland plants. Mudflat productivity in Shepody Bay, which is more critical to overall mudflat productivity in the Assessment Area, would not be changed. Therefore, the environmental effects of the Status Quo on mudflat productivity are predicted to be negative, but not significant as sufficient productive mudflat will remain in Shepody Bay.

**Project Options 3/4A**

Project Options 3/4A will have environmental effects on mudflats in the Assessment Area. Construction activities may affect mudflat distribution through increased erosion and sedimentation and operation of Project Options 3/4A will result in a change in mudflat distribution in the Petitcodiac River.

Project Options 3/4A, which will restore tidal flow to the Petitcodiac River, will have a greater tidal prism than 2005 baseline conditions and will consequently increase mudflat area, both upstream and downstream of the causeway. Mudflat area in the river will however be less than what existed before the causeway was constructed, as the tidal prism will not reach pre-causeway proportions. Project Options 3/4A will result in the erosion of accumulated sediments in the river and it is anticipated that these sediments will be deposited on existing mudflats in Shepody and Chignecto Bays or be transported out into the Bay of Fundy (Section 8.1). As a result, mudflat area in Shepody Bay will have the potential to increase and provide additional habitat for mudshrimp, increasing their productivity. As discussed previously in this section, the success of migrating shorebird populations is linked to mudflat productivity in Shepody Bay.
There is no mitigation proposed for the increased erosion of accumulated sediments in the Petitcodiac River or mudflat formation upstream and downstream of the causeway, as this process is a trend toward pre-causeway conditions.

Based on consideration of the potential environmental effects and the residual environmental effects significance rating criteria, the environmental effects of Project Options 3/4A on mudflat productivity are predicted to be positive.

**Project Options 4B/4C**

Project Options 4B/4C have similar environmental effects on mudflat productivity as do Project Options 3/4A, although Project Option 4C, followed by Project Option 4B, will permit a more natural tidal exchange and a greater tidal prism than for Project Options 3/4A. As a result, mudflat area in the river will be greater for Project Options 4B/4C than for Project Options 3/4A, although still less than pre-causeway conditions. Project Options 4B/4C, which will erode more sediment from the river, have the potential to deposit greater amounts of sediment on the mudflats in Shepody Bay and may increase their size and productivity.

Based on consideration of the potential environmental effects and the residual environmental effects significance rating criteria, the environmental effects of Project Options 4B/4C on mudflat productivity are predicted to be positive.

**Comparative Assessment**

The Status Quo will continue to result in a gradual decline of mudflat area downstream of the causeway and will maintain the loss of mudflat area upstream, and therefore will maintain a loss of mudflat productivity. The Project Options will substantively increase the mudflat area upstream of the causeway. Although the Project Options may reduce overall mudflat area downstream of the causeway due to channel widening, the overall mudflat productivity in the estuary may increase due to the potential to deposit eroded sediments from the river onto the mudflats in Shepody Bay.

**9.3.4.5 Managed Areas**

**Status Quo**

The Status Quo is not expected to have significant negative environmental effects on ESAs or Managed Areas in the Assessment Area. The Status Quo will continue to have positive environmental effects of Lower Coverdale Island and Outhouse Point.

**Project Options 3/4A**

Project Options 3/4A will erode sediments in the Petitcodiac River and discharge them in Shepody and Chignecto Bays where they will either be deposited or transported out into the Bay of Fundy. As a result, ESAs at Outhouse Point and Lower Coverdale Island, which were formed as a result of the causeway, will be partially eroded (i.e., approaching pre-causeway conditions). Mitigation for Project Options 3/4A includes the restoration/improvement of the dykes surrounding Ducks Unlimited sites.
Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of Project Options 3/4A on Managed Areas (i.e., ESAs and Ducks Unlimited sites) are predicted to be not significant for ESAs (Outhouse Point and Lower Coverdale Island) and other Managed Areas (e.g., Ducks Unlimited sites) in the Assessment Area.

**Project Options 4B/4C**

Project Options 4B/4C have similar environmental effects on Managed Areas as do Project Options 3/4A, although Project Options 4C/4B will permit a more natural tidal exchange, as the opening across the river will be wider than that for Project Options 3/4A. As a result, the erosion of ESAs in the Petitcodiac River downstream of the causeway will occur over a shorter period of time and will be greater for Project Options 4C/4B than for Project Options 3/4A (although less than pre-causeway conditions). Mitigation measures for Project Options 4B/4C are the same as outlined for Project Options 3/4A.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of Project Options 4B/4C are predicted to be not significant for other Managed Areas in the Assessment Area.

**Comparative Assessment**

The Status Quo and Project Options are not expected to have significant negative environmental effects on ESAs or other Managed Areas in the Assessment Area.

**9.3.5 Future Trends (2055, 2105)**

Under the Status Quo, the estuary should approach a relatively constant cross-sectional geometry after about 70 years (Section 8.1.1). Therefore, the trends for wetlands, wildlife and vegetation, migratory birds, mudflat productivity and Managed Areas, as described previously, will continue until approximately 2075, after which time wetland and mudflat area will remain relatively constant.

**9.3.6 Accidents and Malfunctions**

There is a possibility that hazardous materials used during construction of the Project Options could be accidentally spilled and introduced into the Petitcodiac River. These materials could temporarily degrade water quality and wetland habitat, thus resulting in the ingestion/uptake of contaminants by wildlife, including birds. However, mitigation measures as outlined in the EMP (Section 7.5) will protect against such spills and provide for their safe and effective clean-up, should they occur.

There is a potential for both the Status Quo and the Project Options during heavy precipitation events or flash floods for erosion control structures to fail at the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway. An accident of this nature could result in leaching or erosion of potentially toxic substances into the river and a potential risk to vegetation and wildlife, including birds, Managed Areas and
mudflats. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this project (Section 7.5).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, potential accidents and malfunctions on the Terrestrial and Wetland Environment in the Assessment Area are not likely, and should they occur, are predicted to be not significant.

9.3.7 Summary

In summary, the potential environmental effects of the Project Options on the Terrestrial and Wetland Environment (wetlands, wildlife and vegetation, migratory birds, mudflat productivity and managed areas) in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant. The Status Quo would continue to result in significant environmental effects on wetlands; not significant environmental effects on mudflat productivity, wildlife and vegetation; and positive environmental effects on migratory birds.

9.4 Municipal Services and Infrastructure

9.4.1 Rationale for Selection of VEC

Municipal Services and Infrastructure was selected as a VEC because of the potential interactions between the Status Quo and Project Options and the integrity and continued functionality of municipal services and infrastructure within and adjacent to the Petitcodiac River and headpond.

Key issues regarding infrastructure located along the banks of the river and headpond are erosion, sedimentation, ice jamming, ice damming and increased flooding associated with the environmental effects of the Status Quo and Project Options. Erosion may expose and/or undermine existing infrastructure such as outfalls, buried pipes or cables. Sedimentation may block or inhibit the functioning of existing infrastructure (e.g., infilling ditches and blocking outfalls). Flooding may cause damage to existing infrastructure and/or private property connected to the infrastructure. An associated issue is in regard to municipal services and the potential interference that the Status Quo and Project Options may have on water and wastewater services.

Municipal services and infrastructure include wastewater and stormwater sewers, watermains, dykes and aboiteaux, walking trails, utilities and former landfills constructed along the banks of the Petitcodiac River.

9.4.2 Boundaries

The spatial and temporal boundaries for the assessment of Municipal Services and Infrastructure (the “Assessment Area”) are the same as defined in Table 4.7.1 and Section 4.7, respectively.
9.4.3 Threshold for Determination of Significance

A significant negative residual environmental effect on municipal services and infrastructure is one that results in an uncompensated decrease in the integrity and/or functionality of municipal services and infrastructure over 2005 baseline conditions within the Assessment Area.

9.4.4 Evaluation of Potential Environmental Effects

9.4.4.1 Water Distribution Systems

Status Quo

As the Status Quo is not expected to affect water distribution systems in the Assessment Area, the potential negative environmental effects are predicted to be not significant.

Project Options 3/4A

Project Options 3/4A will have environmental effects on water distribution systems in the Assessment Area. Operation of Project Options 3/4A will erode sediments that have been deposited since construction of the causeway and would expose the water transmission line that crosses the Petitcodiac River upstream of the control structure. The invert elevation of the pipeline varies across the river, with the highest invert elevation being -2.0 m. The line joins the causeway just north of the fish passage structure where it crosses eastward through the causeway and joins the City of Moncton water supply system near the traffic circle at Moncton. Mitigation, as outlined in the implementation strategy (Chapter 7), will lower the water transmission line to an elevation deeper below the current river channel bottom at the control structure.

In summary, the potential environmental effects of Project Options 3/4A on water distribution systems in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant, as Project Options 3/4A are not expected to decrease the integrity or functionality of these systems over 2005 baseline conditions.

Project Options 4B/4C

Project Options 4B/4C have similar environmental effects on water distribution systems as do Project Options 3/4A. However, the greater tidal flow and width of the river associated with Project Options 4B/4C will result in increased erosion and potential to expose the water line over Project Options 3/4A. Mitigation for Project Option 4B includes the extension of the lowered water line to a point north of where the approach road from the new bridge will join the causeway. Mitigation for Project Option 4C includes the lowering of the water line below the river channel at the new bridge location.

The potential environmental effects of Project Options 4B/4C on water distribution systems in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant, as Project Options 4B/4C are not expected to decrease the integrity or functionality of these systems over 2005 baseline conditions.
Comparative Assessment

The Status Quo will not have any significant negative environmental effects on water systems in the Assessment Area, while the Project Options have the potential to expose the water line that crosses through the causeway. Mitigation, which involves lowering the line to an elevation that protects it from erosion, will ensure that the Project Options have no significant negative environmental effects on water systems in the Assessment Area.

9.4.4.2 Sanitary Sewer Systems

Status Quo

The Status Quo will have negative residual environmental effects on sanitary sewer systems in the Assessment Area as the issues that resulted from construction of the causeway continue into the future (Section 5.6.2). Sedimentation in the river and along the riverbanks will continue to increase with the Status Quo, building up sediment at some of the flapgates associated with the GMSC collector sewer overflow pipes (see Section 5.6.2 for more information on the flapgates). During dry periods, especially in the summer, this excess build up can affect flapgate operation by preventing the gates from sealing properly and allowing backflow of silty river water into the system. In the winter months, ice, snow and sediment can build up at the flapgates and prevent proper gate operation. The Status Quo will not have any environmental effects on sewage lagoons in villages located within the Assessment Area.

In summary, the potential negative environmental effects of the Status Quo on sanitary sewer systems in consideration of the residual environmental effects significance rating criteria are predicted to be significant.

Project Options 3/4A

Project Options 3/4A will have environmental effects on sanitary sewer systems in the Assessment Area. The increase in tidal flow and increased erosion of sediments associated with Project Options 3/4A will have a positive environmental effect on the GMSC overflow flapgates by keeping them clearer of sediment, snow and ice. However, Project Options 3/4A may alter the river channel from its current position, which could result in damage caused by erosion to sewer infrastructure located adjacent to the river and/or require modifications to the infrastructure as a result of sediment build-up (these areas will be addressed as noted in Section 7.1.1). Project Options 3/4A will not have any environmental effects on sewage lagoons in villages located within the Assessment Area.

Overall, the potential environmental effects of Project Options 3/4A on sanitary sewer systems in consideration of the residual environmental effects significance rating criteria are predicted to be not significant to positive, as Project Options 3/4A will increase erosion of the river channel and subsequently improve the functionality of GMSC overflow flapgates over 2005 baseline conditions.

Project Options 4B/4C

The greater tidal flow associated with Project Options 4B/4C will result in increased erosion of sediment, snow and ice build-up at the GMSC overflow flapgates, and will result in a river
channel that is altered to a greater extent than for Project Options 3/4A. Mitigation for Project Options 4B/4C is the same as outlined for Project Options 3/4A and will be similarly effective.

Overall, the potential environmental effects of Project Options 4B/4C on sanitary sewer systems in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive, as Project Options 4B/4C will increase erosion of the river channel and subsequently improve the functionality of GMSC overflow flapgates over 2005 baseline conditions.

**Comparative Assessment**

The Status Quo will have a significant negative environmental effect on the GMSC sewer as problems associated with blockage of the overflow flapgates continue to increase. Project Options, along with mitigation, will have not significant to positive environmental effects on sanitary sewer systems in the Assessment Area, due to overall improved functioning of the GMSC overflow flapgates.

### 9.4.4.3 Storm Sewer Systems

**Status Quo**

The Status Quo will have negative environmental effects on storm sewer systems in the Assessment Area, as it will continue to decrease their functionality (Section 5.6.3) over 2005 baseline conditions. Sedimentation in the river and along the riverbanks continues to increase, which results in the build-up of sediment in storm drainage channels to the river and the blockage of aboiteaux flapgates by sediment, ice and snow. As a result, flooding of adjacent roadways occurs during heavy rainfalls (e.g., at the Moncton causeway traffic circle and Babineau Creek). The potential negative environmental effects of the Status Quo on storm sewer systems in consideration of the residual environmental effects significance rating criteria are predicted to be significant.

**Project Options 3/4A**

Project Options 3/4A will have environmental effects on storm water systems in the Assessment Area. The increase in tidal flow and increased erosion of sediments associated with Project Options 3/4A will have a positive environmental effect on storm sewer systems by keeping drainage ditches and aboiteaux more free of sediment, snow and ice. However, Project Options 3/4A may alter the river channel from its current position, which could result in damage caused by erosion to storm sewer infrastructure located adjacent to the river and/or require modifications to the infrastructure in the Assessment Area as a result of sediment build-up (these areas will be addressed as noted in Section 7.1.1).

Overall, the potential environmental effects of Project Options 3/4A on storm sewer systems in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive, as Project Options 3/4A will increase erosion of the river channel and subsequently improve the functionality of GMSC overflow flapgates over 2005 baseline conditions.
Project Options 4B/4C

The greater tidal flow associated with Project Options 4B/4C will result in increased erosion of sediment, snow and ice build-up at drainage ditches and aboiteaux, and will result in a river channel that is altered to a greater extent than for Project Options 3/4A. Mitigation for Project Options 4B/4C is the same as outlined for Project Options 3/4A.

Based on consideration of the potential environmental effects, the proposed mitigation, and the residual environmental effects significance rating criteria, the environmental effects of Project Options 4B/4C on storm sewer systems are predicted to be not significant to positive, as Project Options 4B/4C will improve their functionality over 2005 baseline conditions.

Comparative Assessment

The Status Quo will have a significant negative environmental effect on storm sewer systems as problems associated with blockage of aboiteaux and drainage ditches continue to increase. Project Options, along with mitigation, will have not significant to positive environmental effects on storm sewer systems as increased erosion will decrease sediment build-up at aboiteaux and drainage ditches.

9.4.4.4 Dykes and Aboiteaux

Status Quo

As the Status Quo is not expected to affect dykes and aboiteaux in the Assessment Area, the potential negative environmental effects are predicted to be not significant.

Project Options 3/4A

Project Option 3/4A will have environmental effects on dykes and aboiteaux in the Assessment Area. Upstream of the causeway, dykes and aboiteaux have fallen into disrepair since protection from flooding is provided by the causeway. Project Options 3/4A, which will restore tidal flow upstream of the causeway, has the potential to flood these dyked lands, which include Ducks Unlimited freshwater marshes and agricultural lands as noted in Section 7.1.1. Mitigation for Project Options 3/4A includes either the repair/improvement of these dykes and aboiteaux prior to Project Option implementation to prevent flooding and loss of Ducks Unlimited sites, or compensation for these losses.

The potential negative environmental effects of Project Options 3/4A in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options 4B/4C

Project Options 4B/4C have the potential to result in greater flooding of dyked lands upstream of the causeway, as the tidal flow will be closer to pre-causeway conditions than Project Options 3/4A. Mitigation for Project Options 4B/4C is the same as outline for Project Options 3/4A.
The potential negative environmental effects of Project Options 4B/4C in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant, as Project Options 4B/4C will either ensure the protection of dyked lands in the Assessment Area or compensate for their loss.

**Comparative Assessment**

The Status Quo will not have any significant negative environmental effects on dykes or aboiteaux in the Assessment Area. Project Options have the potential to flood dyked lands upstream of the causeway, however, mitigation will ensure that the environmental effects of the Project Options are not significant.

### 9.4.4.5 Other Infrastructure

**Status Quo**

The Status Quo will not have any substantive incremental environmental effects on other infrastructure in the Assessment Area over 2005 baseline conditions (i.e., walking trails, landfill sites, marina, wharves). Therefore, the potential negative environmental effects of the Status Quo in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

**Project Options 3/4A**

Project Options 3/4A will have environmental effects on infrastructure in the Assessment Area not discussed previously. Project Options 3/4A, which will restore tidal flow upstream of the causeway, will result in the loss of the Tri Community Marina and the Sea Cadet’s facility, as some forms of recreational boating will no longer be safe (see Section 9.6, Vessel Traffic and Navigation). Downstream of the causeway, Project Options 3/4A will result in the widening of the river channel over 2005 baseline conditions (although less than pre-causeway conditions), which has the potential to erode the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway. Mitigation will ensure protection of the landfill from erosion and will compensate the Town of Riverview, the Tri Community Marina and the Sea Cadets for loss of infrastructure and their investment. Project Options 3/4A are not expected to have negative environmental effects on any other infrastructure in the Assessment Area, as the river channel will not expand beyond the original boundaries of the river (pre-causeway conditions) and trails constructed on infilled sediment are not expected to be affected.

In summary, although Project Options 3/4A have the potential for negative environmental effects on the Tri Community Marina, the Sea Cadets, the Town of Riverview public dock and the former Moncton Landfill, the negative environmental effects of Project Options 3/4A in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.

**Project Options 4B/4C**

Project Options 4B/4C will have similar environmental effects on other infrastructure in the Assessment Area as Project Options 3/4A (i.e., on the former Moncton Landfill, Tri Community Marina, the Sea Cadets, the Town of Riverview public dock). However, Project Options 4B/4C
will result in a greater width of the river than Project Options 3/4A and will have a greater potential for eroding the landfill, especially Project Option 4C, which will result in a river channel that is the widest and closest to the landfill, but this has been mitigated through protection measures as addressed in Section 7.1.1. Other infrastructure in the Assessment Area will not be affected, as the river will not approach pre-causeway proportions for any of the Project Options. Mitigation for Project Options 4B/4C is the same as for Project Options 3/4A. As for Project Options 3/4A, the potential negative environmental effects of Project Options 4B/4C in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.

**Comparative Assessment**

The Status Quo and Project Options, with mitigation protecting the former Moncton Landfill and compensation for loss of the marina, will have negative residual environmental effects on other infrastructure in the Assessment Area that are predicted to be not significant.

### 9.4.5 Future Trends (2055, 2105)

The Status Quo and Project Options will have similar environmental effects on municipal services and infrastructure in the future (2055, 2105) as in 2025. Future trends will continue for the Status Quo as the negative environmental effects on sanitary and storm sewer systems and dykes and aboiteaux in the Assessment Area continue to worsen as sedimentation in the river downstream of the causeway continues. Environmental effects of the Project Options will not alter substantially over 2025, as the sanitary and storm sewer systems and dykes and aboiteaux will be functioning and the former Moncton Landfill will be protected.

### 9.4.6 Accidents and Malfunctions

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail at the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway. An accident of this nature could result in a decrease in the integrity of the landfill and the leaching or erosion of potentially toxic substances into the river. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5). Based on consideration of the potential environmental effects, the proposed mitigation, and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Municipal Services and Infrastructure in the Assessment Area are predicted to be not significant.

### 9.4.7 Summary

Overall, the Status Quo will have significant environmental effects on Municipal Services and Infrastructure. Blockage of overflow flapgates, aboiteaux flapgates and drainage ditches will continue and worsen under the Status Quo. In contrast, increased tidal flow associated with the Project Options will increase erosion of sediments, ice and snow and improve the functioning of this infrastructure. Both the Status Quo and Project Options (with mitigation for the loss of the marina and protection of the former Moncton Landfill) will have potential environmental effects with respect to water distribution systems, dykes and aboiteaux and other infrastructure that are not significant. Overall, the potential environmental effects of the Project Options on Municipal
Services and Infrastructure in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive.

9.5 Road Transportation Network

9.5.1 Rationale for Selection of VEC

The Road Transportation Network is defined as the public road and bridge infrastructure, and the traffic conditions within the spatial boundaries of this VEC, as described in Section 9.5.2 below. The causeway is an essential highway link within the GMA and to communities located along the river (Section 5.7) and provides one of two road transportation connections between Moncton and Riverview. The second river crossing in the GMA is the Gunningsville Bridge. A third river crossing is located upstream in Salisbury, which serves the Village of Salisbury and links Route 112 with Route 106 and the Trans-Canada Highway.

The Guidelines require that environmental effects of the Status Quo and Project Options on traffic flows, level of service (LOS) and accident rates be assessed. Section 9.13.4.2 addresses traffic accidents. The scoping phase of the study pointed to two key issues with regards to the road transportation network. One issue is the potential changes in traffic patterns that could occur as a result of the Project Options and the Status Quo. This issue pertains to the potential environmental effects that may be attributable to the Project Options and the Status Quo regarding traffic flows, LOS and accident occurrence (Section 9.13.4.2) during all phases of the Status Quo and Project Options.

The other potential road transportation network issue is its potential interaction with the activities and physical changes that may occur with the Project Options and the Status Quo. Of particular concern are the potential environmental effects of flooding and/or erosion on the integrity of the road infrastructure that may result from changes in the river associated with the Status Quo and Project Options. The environmental effects of flooding are considered in Section 9.13.4.6.

The Road Transportation Network has been selected as a VEC to address the above-mentioned issues with respect to road traffic and infrastructure due to its importance to the public who live in the area and to all who use the roads.

9.5.2 Boundaries

The spatial boundaries of the Road Transportation Network VEC (i.e., the "Assessment Area") include all provincial roads that run alongside and/or cross the Petitcodiac River, or run alongside the mouths of tributaries of the Petitcodiac River (Table 4.7.1).

The Road Transportation Network infrastructure and traffic is concentrated in the GMA, which is the area most likely to be affected by changes as a result of the Project Options or Status Quo. Therefore, the GMA road transportation network will be the primary focus of the Road Transportation Network VEC, which includes portions of Route 15, Route 106, Route 112, and Route 114.
The temporal boundary of the Road Transportation Network VEC includes the current and projected periods defined in Section 4.7.

**9.5.3 Threshold for Determination of Significance**

A *significant negative residual environmental effect* is one that results in a substantial reduction in the Level of Service (LOS), continuous or semi-continuous obstruction of traffic flow, or the permanent physical loss of any portion of the road transportation network as a result of the Project Options or the Status Quo.

**9.5.4 Evaluation of Potential Environmental Effects**

**9.5.4.1 Status Quo**

It is not anticipated that the Status Quo will not affect the LOS in the Assessment Area.

**9.5.4.2 Project Options**

The Project Options will affect traffic patterns during construction activities. Project Options 4A and 4B each require a minor disruption (1 lane for a few days) to traffic during the joining of the bridge approaches to the causeway and the interchange connections in Riverview. During construction of Project Option 3, traffic will continue over the causeway but will be confined to 2 lanes and Project Option 4C will require the construction of a temporary 2-lane roadway bypass (Section 7.2.3.2). The temporary decrease to 1 or 2 lanes during construction of the Project Options will be offset by the new 4-lane Petitcodiac River Bridge, which will be in operation by the time of construction, and will not result in a substantial decrease in LOS.

During operation, the Project Options will not affect the LOS.

Overall, the potential environmental effects of the Project Options on the Road Transportation Network in consideration of the proposed mitigation during construction and the residual environmental effects significance rating criteria are predicted to be not significant. There will be some decrease to the LOS, but it will be temporary as the Project Options will maintain the LOS in the Assessment Area during operation.

**9.5.4.3 Comparative Assessment**

The Status Quo is predicted to have a significant negative environmental effect on the Road Transportation Network. By restoring the tidal exchange to the Petitcodiac River and improving drainage and decreasing sedimentation rates of the Petitcodiac River and its tributaries, the Project Options will decrease the flooding risk for roads. Therefore, the Project Options are predicted to have environmental effects on the Road Transportation Network that are not significant to positive.

**9.5.5 Future Trends (2055, 2105)**

The Status Quo and Project Options will have similar environmental effects on the Road Transportation Network in the future (2055, 2105) as in 2025.
9.5.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long lasting effects if properly cleaned up. Therefore, the potential exists for a hazardous material spill to temporarily impact the traffic flow rate and patterns; however, long lasting effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the destruction of roads within the Assessment Area and may be a potential risk to the Road Transportation Network. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

The potential for vehicular collisions to affect the Road Transportation Network is small and would only result in a temporary disruption to traffic patterns and rates.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on the Road Transportation Network in the Assessment Area are predicted to be not significant.

9.6 Vessel Traffic and Navigation

9.6.1 Rationale for Selection of VEC

Vessel Traffic and Navigation has been selected as a VEC to address concerns regarding potential changes that have occurred in the past and in navigational opportunities and vessel traffic on the Petitcodiac River and the headpond, that will occur as a result of the potential interactions between the Status Quo and Project Options and the Petitcodiac River, upstream and downstream of the causeway.

The causeway and associated changes to the Petitcodiac River that have occurred since its construction have resulted in changes to navigation and navigability. Since construction of the causeway, the downstream river channel has narrowed, become more shallow and thus more difficult to navigate. Currently the causeway is an obstruction to vessel navigation as no vessels can pass upstream or downstream through the causeway. Downstream river navigation since completion of the causeway has been affected negatively by sedimentation and regulation of flow. Upstream, construction of the causeway established a shallow headpond with an initial operating level of 4.6 m. Sedimentation limited navigation but this was improved slightly with an increase in operating level to 6.1 m to address fishway operational issues. The creation of the headpond has facilitated some recreational boating activity (with shallow draft watercraft) on this part of the river that has included sailing, canoeing, kayaking, hydropplaning and windsurfing as well as dragon boat racing and access to float planes. As such, sedimentation and changing water levels associated with the Status Quo and Project Options are key issues as they will affect navigation on the headpond.
Currently there is no commercial vessel traffic associated with the transportation of freight, upstream or downstream of the causeway. There was a tour boat operation on the headpond, but it has not been operational for the past three years (AMEC, 2005a).

Vessel Traffic and Navigation has been selected as a VEC to address concerns regarding potential changes in navigational opportunities and vessel traffic on the Petitcodiac River and headpond, as a result of the potential interactions between the Status Quo and Project Options and the river, upstream and downstream of thecauseway.

9.6.2 Boundaries
The spatial and temporal boundaries for the assessment of Vessel Traffic and Navigation (the “Assessment Area”) are as defined in Table 4.7.1 and Section 4.7, respectively.

9.6.3 Threshold for Determination of Significance
A significant negative residual environmental effect is one where the Project Options or Status Quo restricts or degrades the existing potential for Vessel Traffic and Navigation in the Assessment Area such that there is a non-compensated net loss of the potential for Vessel Traffic and Navigation in the Assessment Area.

9.6.4 Evaluation of Potential Environmental Effects

9.6.4.1 Status Quo

Causeway Construction and Post-Causeway
As noted in Section 5.1.4, the headpond has been created as a secondary benefit of the Project that undertaken in 1966-1968 to provide flood protection and a transportation link between Riverview and Moncton. Sedimentation in the order of 4.9 Mm$^3$ resulted in the severe limitation of the headpond for navigation at the original planned operational elevation of 4.6 m, except perhaps in the main channel. The change in the operational elevation to 6.1 m has afforded some limited navigation as currently occurs in the headpond by shallow-draft recreational watercraft.

Downstream of the causeway, sedimentation has very negatively affected vessel navigation due to the extensive sedimentation that has occurred since the causeway was constructed. That sedimentation has degraded navigation between Gunningville Bridge and the causeway, especially during summer, and very negatively limited navigation between Belliveau Village and Moncton; fishermen based in Belliveau Village can only fish briefly at the crest of high tide due to limitations imposed by the infilling that has occurred. Navigation opportunity has been very negatively affected by sedimentation between the causeway and Belliveau Village, and limited below this to Hopewell Cape.

Vessel Traffic and Navigation Above the Causeway
The Status Quo will result in continuation of sedimentation of the headpond estimated to be in the order of 0.25 Mm$^3$ between 2005 and 2025. This sedimentation will reduce the depth of the
already shallow headpond and further limit navigation even by the shallow-draft boats that currently use the headpond for recreational purposes.

**Vessel Traffic and Navigation At the Causeway**

The causeway will continue to be an obstruction for all vessels. Its presence prevents uninterrupted navigation along the length of the estuary from Hopewell Cape to the Village of Salisbury, as existed in the pre-causeway period.

**Vessel Traffic and Navigation Below the Causeway**

Sedimentation of the channel downstream of the causeway will continue to narrow the Petitcodiac River channel and decrease available draft, which will negatively affect current navigation activities, and continue and progressively limit navigational opportunity for vessel traffic in the future.

**Vessel Traffic and Navigation Overall**

Overall, the Status Quo will continue to result in sedimentation that will further limit opportunities for vessel traffic and navigation, both in the headpond and below the causeway. The causeway will continue to be an obstruction to navigation. Overall, the potential negative environmental effects of the Status Quo on Vessel Traffic and Navigation in consideration of the residual environmental effects significance rating criteria are predicted to be significant because of these increasing limitations on navigation activities due to the presence of the causeway as an obstruction and continued sedimentation of the headpond and below the causeway.

**9.6.4.2 Project Options 3/4A**

**Vessel Traffic and Navigation Above the Causeway**

Construction activities may temporarily affect Vessel Traffic and Navigation above or below the causeway, but these environmental effects would be of short duration and magnitude. After construction, restored tidal flow upstream of the causeway will change the character of navigation in the former headpond. The main channel will widen and provide navigational opportunity within it even at low tide. At high tide, water levels in the former headpond area will typically be in the order of 1.0 m deeper, greatly enhancing navigational opportunity at those times. The tidal nature of the area will return the opportunity to navigate the full length of the estuary from the Village of Salisbury to Hopewell Cape and beyond, removing the obstruction of the causeway. It is expected that the opportunity for recreational boating, including that of an extreme nature will be enhanced, affording opportunities related to the tides (e.g., the tidal bore). Recreational boating based at the Tri Community Marina, Town of Riverview public boat launch, sea cadets base and private docks may change as a result of the tidal nature of the water body. Changes that may be required to facilitate access to the River for boating purposes are addressed in relation to Recreation in Section 9.10. This will not preclude navigation, but rather may change the nature and timing of access to the channel at low tide and change the physical characteristics of the water body (e.g., current, depth, salt water). Some of those changes (e.g., depth at high tide, the presence of a deep navigable channel even at low tide) will overall greatly enhance boating opportunities throughout the estuary from the Village of Salisbury to Hopewell Cape.
Vessel Traffic and Navigation At the Causeway
Project Options 3/4A, will restore vessel passage at the causeway, removing it as an obstruction to navigation. Project Option 3 may have some temporary limitations on some tidal cycles (based on tide and river flow conditions) to navigation due to the presence of a -1.5 m elevation concrete sill. The bridge clearances under the Project Options will be set at 9.5 m (elevation of the bottom of the girders) and would at a typical high tide, afford approximately 2.5-3.5 m of clearance for navigation. At low tide, clearance would be in the order of 12.5-13.5 m depending upon the specific tidal range on a particular tidal cycle.

Vessel Traffic and Navigation Below the Causeway
The opportunity for power boating, canoeing and kayaking will be enhanced on the river and as a result of the return of tidal exchange and widening of the river downstream of the causeway. Vessel traffic and navigation in the marine portion of the Assessment Area is not expected to be affected as a result of the flushing of accumulated sediments into Shepody Bay. As a result of the widening and deepening of the river however, the potential for the return of commercial vessel traffic will exist, including commercial fishing from Belliveau Village and other wharves.

Vessel Traffic and Navigation Overall
Project Options 3/4A will remove the obstruction to navigation at the causeway and facilitate longer distance travel by vessels. The widening and deepening channels will afford navigation throughout the estuary from the Village of Salisbury to Hopewell Cape even at low tide and improve water depth in the former headpond at high tide. Navigation along the Petitcodiac River will resemble pre-causeway conditions when the potential for commercial and fishing vessel traffic and recreational boating opportunities existed. The improvements in navigational opportunity will likely result in a substantial increase in recreational boating.

Although Project Options 3/4A will result in changes to some recreational boating activities above the causeway, that may be considered by current recreational boaters to be negative, these are greatly offset by removal of the obstruction to navigation, provision of navigation from the Village of Salisbury to Hopewell Cape even at low tide, and deeper water in the former headpond area at high tide, and can be mitigated through changes to infrastructure and/or compensation (Section 9.10). Overall, the potential environmental effects of Project Options 3/4A on Vessel Traffic and Navigation are, in consideration of the proposed mitigation and the residual environmental effects significance rating criteria, predicted to be positive.

9.6.4.3 Project Options 4B/4C
Project Options 4B/4C have similar environmental effects on Vessel Traffic and Navigation as do Project Options 3/4A. Under Project Options 4B/4C, the tidal exchange will be improved and the width and depth of the main channel will be greater. Options 4B/4C will have wider openings to facilitate navigation. The gate sill present in Project Option 3 will be removed so passage at the causeway will be unrestricted at depth. Clearance under the bridges will be similar to that of 3/4A.

Although Project Options 4B/4C will result in changes to some recreational boating activities above the causeway that may be considered to be negative, these are greatly offset by removal
of the obstruction to navigation, provision of navigation from Salisbury to Hopewell Cape even at low tide, and deeper water in the former headpond area at high tide, and can be mitigated through changes to infrastructure and/or compensation (Section 9.10). Overall, the potential environmental effects of Project Options 4B/4C on Vessel Traffic and Navigation are, in consideration of the proposed mitigation and the residual environmental effects significance rating criteria, predicted to be positive.

9.6.4.4 Comparative Assessment

Due to continued infilling of the river downstream of the causeway and the obstruction to navigation at the causeway, the potential negative environmental effects of the Status Quo on Vessel Traffic and Navigation in consideration of the residual environmental effects significance rating criteria are predicted to be significant. The Project Options are predicted overall to have positive environmental effects (i.e., removal of the obstruction to navigation at the causeway and the improvement in navigation conditions in the estuary between the Village of Salisbury and Hopewell Cape).

9.6.5 Future Trends

The Status Quo and Project Options will have similar environmental effects on Vessel Traffic and Navigation in the future (2055, 2105) as in 2025. Under the Status Quo, sedimentation of the headpond will continue to 2025 and beyond and downstream of the causeway will continue until equilibrium is reached by approximately 2075 with the associated significant negative environmental effects on Vessel Traffic and Navigation. The Project Options will not alter Vessel Traffic and Navigation substantially past 2025, as restoration of the natural estuarine ecosystem will begin to occur immediately after implementation of the selected Project Option. The positive environmental effects of the selected Project Option will continue.

9.6.6 Accidents and Malfunctions

Accidents and malfunctions as described in Section 7.3 are not anticipated to affect Vessel Traffic and Navigation and are therefore predicted to be not significant.

9.7 Land Use and Value

9.7.1 Rationale for Selection of VEC

Land Use and Value was selected as a VEC because of the potential for interactions between the Project Options and the Status Quo and land uses and market value along the Petitcodiac River, both upstream and downstream of the causeway. For this VEC, Land Use and Value is defined as the current state or function of private and public land and the market value of that land, within the zone of influence of the Petitcodiac River. The Guidelines require that the environmental effects of the Project Options and the Status Quo on local property market values, and how any changes in flood risk could affect land use, be assessed.

A key issue regarding Land Use and Value is in regard to potential changes in property market value and use that may occur as a result of changes in aesthetic quality, landowner access to land and to the Petitcodiac River, and loss of agricultural land as a consequence of the Project Options or the Status Quo. The issue of flooding relates to the potential environmental effects
that changes in the river and headpond could have on the use of agricultural land located along the Petitcodiac River as a result of the Project Options or the Status Quo. This issue extends to the potential environmental effects the changes to the river have had, and could have, on the value and use of agricultural property, and farmland dykes, aboiteaux and access road infrastructure. The potential environmental effects of a change to flood risk on residential properties in Moncton, Dieppe and other residences and communities along the Petitcodiac River are assessed in relation to Public Health and Safety in Section 9.13.

9.7.2 Boundaries

The spatial boundary for Land Use and Value (i.e., the “Assessment Area”) is focused on the area along both sides of the Petitcodiac River that extends from the Village of Salisbury to the causeway and from the causeway to the mouth of the river at Shepody Bay (Table 4.7.1). The urban/suburban communities of Moncton, Dieppe and Riverview and a number of smaller communities are located within this area, as are large tracts (areas) of vacant land.

The temporal boundary of the Land Use and Value VEC includes the current and projected periods defined in Section 4.7.

9.7.3 Threshold for Determination of Significance

A significant negative residual environmental effect is one where the Project Options or Status Quo result in a change or disruption that restricts or degrades present land uses such that the current activities cannot continue to be undertaken at current levels, or causes a non-compensated decrease in market value of property (compared to baseline market value).

9.7.4 Evaluation of Potential Environmental Effects

9.7.4.1 Status Quo

The Status Quo will continue to allow the current land use practices to occur. For example, access to the Petitcodiac River by residents for boating or float plane use will continue unimpaired.

In the Socio-economic Component Study, it is demonstrated that the value of vacant lots above the causeway exceed the value of similar vacant lots below the causeway by 5%. However, the value of developed residential lots above and below the causeway was determined to be the same in value. Therefore, the existence of the headpond does not appear to have resulted in an increase to developed property value above the causeway, as the value continues to be the same as that below the causeway. However, the causeway may have contributed to a 5% increase in the value of vacant lots upstream of the causeway.

Conversely, downstream of the causeway, the Petitcodiac River has experienced a significant amount of infilling since the construction of the causeway. This is particularly the case in downtown Moncton along Jonathan and Halls Creeks. In at least one case, the increased flooding (as a result of the infilling) has resulted in the foreclosure of commercial property near Fox Creek. It is possible that the diminished vacant lot values observed downstream of the
causeway (as compared to upstream of the causeway) are the result of the increased flood risk. These trends are anticipated to continue with the Status Quo.

As a result, it is believed that the Status Quo will not result in a substantive change in the land use and value (i.e., greater than 5%) of properties upstream of the causeway during the next 25 years due to current real estate trends and the relatively stable environment of the headpond (e.g., flood risk not substantially increasing). However, modelling results suggest that the continued narrowing of the Petitcodiac River downstream of the causeway may lead to increased flooding (magnitude and frequency) of the properties along the river and its tributaries (e.g., Jonathan Creek, Halls Creek and Fox Creek) as the river’s ability to convey the tidal prism and freshwater drainage decreases. As a result, property owners downstream could see a decrease in market property value and an increase in property insurance rates.

The Status Quo is expected to maintain all current access to property and current land use (residential, commercial, recreational and agricultural) is not expected to be negatively affected. Overall, the potential environmental effects of the Status Quo on Land Use and Value in consideration of the residual environmental effects significance rating criteria is predicted to be significant as the increased risk due to flooding downstream of the causeway may lead to increased insurance rates and/or decreased property value.

9.7.4.2 Project Options 3/4A

According to The Appraisal of Real Estate (Appraisal Institute of Canada, 1992), there are a variety of factors such as social, economic, governmental and physical that typical buyers consider when purchasing residential property (see AMEC, 2005a for details). Physical considerations include natural or anthropogenic (man-made) features that affect the neighbourhood such as open or green space, the attractiveness and safety of street patterns, and the presence of pollution or other nuisances. While it is recognized that access to and/or a view of the Petitcodiac River and headpond may influence certain owners or buyers, it has been demonstrated that there is no current appreciable increase in market worth for this intrinsic value (perceived actual value as opposed to market value) for residential properties (AMEC, 2005a).

As determined during the public consultation process, some current residential property owners in sight of the river and/or headpond, feel that an alteration or change of the headpond will decrease the intrinsic value of their residential property and that they may choose to sell and relocate if the headpond will be lost. Similarly, access to the Petitcodiac River for recreational purposes (e.g., boating, docks and float planes), would be negatively affected. The presence of the estuary or headpond is not currently a price discriminator for residential property although there is a 5% premium on vacant land; therefore these residential landowners are expected to receive the current market price for their property, should they decide to sell their property. Although not anticipated, any negative change in property value attributable to the implementation of Project Options 3/4A should be compensated for on a case by case basis.

Decreased risk of flooding as a result of the Project Options 3/4A will help prevent increases in insurance rates and subsequent decreases in property value. Also, restoration of tidal
exchange and the natural estuarine ecosystem, with the creation of mudflats that will support a more natural and dynamic community of wildlife species, may increase the intrinsic value of those properties currently in close proximity to the headpond. These new physical features may become selling features for some prospective buyers and have a tendency to increase the market value of the above mentioned properties.

Project projections suggest that the changes in the estuary may result in increased fog generation that may prove to be a factor for potential property buyers. However, there is currently fog in the area on occasion and the measured incidence of fog as a result of the Project Options 3/4A is not expected to be substantive. Also, by restoring tidal flow and ultimately altering the headpond, new mudflats may create an undesirable odour from dying vegetation and exposed mud in the short-term, but are not likely to be issues in the long-term as new vegetation growth occurs, as described in the Atmospheric Environment (Section 9.1). Therefore, these are not likely to be factors for potential property buyers.

With Project Options 3/4A, the headpond will be restored to a more natural estuarine ecosystem that would without mitigation, affect adjacent agricultural lands due to tidal saltwater flooding. Therefore, dykes will be built or restored to protect these lands from flooding or alternatively, the land will be purchased at current market value. Any loss of future agricultural productivity as a result of the Project Options 3/4A would be compensated by the purchase of the affected land at the current market value for agricultural land.

All property access for landowners adjacent to both the Petitcodiac River and the headpond are from roads running parallel to these water bodies and above these properties. This road infrastructure will not be negatively affected and access will be maintained.

Loss of access (property owners only) to the Petitcodiac River by dock (for boats) or for float planes will be considered for compensation for that specific use on a case by case basis.

In summary, the potential environmental effects of Project Options 3/4A in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive.

**9.7.4.3 Project Options 4B/4C**

The environmental effects of Project Options 4B/4C on Land Use and Value would be approximately the same as those described for Project Options 3/4A, and are therefore determined to be not significant to positive, with compensation provided for any negative changes to property value or access to the Petitcodiac River by property owners.

**9.7.4.4 Comparative Assessment**

The Status Quo is predicted to have significant environmental effects due to increased flood risk and the potential to increase insurance rates and/or decrease property values. Alternatively, the Project Options are predicted to have environmental effects on Land Use and Value that are positive with respect to flood risk and the potential for an increase in market value as a result of restoration of the natural estuarine ecosystem, which will provide views of more natural
estuarine conditions. Potential environmental effects of the Project Options are not significant with respect to agricultural land, as any loss of future agricultural productivity as a result of the Project Options would be compensated.

9.7.5 Future Trends

The Status Quo and Project Options will have similar environmental effects on Land Use and Value in the future (2055, 2105) as in 2025.

9.7.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long last effects if properly cleaned up. Therefore although the potential exists for a hazardous material spill to temporarily impact Land Use and Value, long lasting effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the erosion of land adjacent to the Petitcodiac River and may be a potential risk to Land Use and Value. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

It is anticipated that failure of agricultural dykes and aboiteaux will affect agricultural land use and value, especially by damage caused by salinity of the water. The dykes and aboiteaux will be repaired and maintained according to the EMP (Section 7.5) developed for this Project and will be monitored to ensure their effectiveness (Section 13.2.4.5). Remedial action will be taken as prescribed and necessary in the event of failure of the dykes and aboiteaux.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Land Use and Value in the Assessment Area are predicted to be not significant.

9.8 Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons

9.8.1 Rationale for Selection of VEC

Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons was selected as a VEC because of the potential for interactions between the Status Quo and Project Options, and the current use the land and resources by the Aboriginal Community. For this VEC, Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons is defined as the use of lands, and resources within those lands, that are within the zone of influence of the Petitcodiac River or on adjacent lands where those uses and resources are potentially affected by the Status Quo and Project Options. This “use” refers to contemporary hunting, fishing and gathering activities for subsistence purposes as well as the use of lands and resources for social and ceremonial activities. The Guidelines require consideration of this issue.
9.8.2 Boundaries

The spatial boundary for Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons (i.e., the “Assessment Area”) is focused on the Petitcodiac River basin with focus on both sides of the river from the Village of Salisbury to the mouth of the river at Shepody Bay (Table 4.7.1).

The temporal boundary of the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons VEC includes the current and projected periods defined in Section 4.7.

9.8.3 Threshold for Determination of Significance

A significant negative residual environmental effect is one where the Project Options or Status Quo would result in an unmitigated long-term Project-induced negative change in the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons or Aboriginal Communities. If it was determined that negative changes to the access to, or the availability of, such land and resources to members of the local Aboriginal Community was the result of the Project, this was considered an negative environmental effect.

9.8.4 Evaluation of Potential Environmental Effects

9.8.4.1 Status Quo

It is believed that the Status Quo may continue to negatively effect the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons in the foreseeable future, as has been experienced since the construction of the causeway. Modelling projections suggest that the continued narrowing of the Petitcodiac River channel may lead to continuing fish passage issues in the Petitcodiac River.

Therefore, the potential negative environmental effects of the Status Quo on Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons in consideration of the residual environmental effects significance rating criteria are predicted to be significant.

9.8.4.2 Project Options 3/4A

According to the sources available with the Aboriginal Community (Fort Folly First Nation), the construction of the causeway resulted in the decline of availability of the resources that were used for traditional purposes by Aboriginal Persons such as hunting and gathering of various wildlife species in the shoreline wetlands, and the fishing of various species in the Petitcodiac River. The modelling results have indicated that there will be an opportunity for the reversal of some of these negative trends. Fish passage will be restored and the opportunity for fish stocks to return. Water quality issues (DO, fecal coliform) in the estuary will be mitigated. There will be an overall increase in the amount of shoreline wetland above the causeway and a change from the current freshwater wetlands to estuarine wetlands. In other words a return, at some level, to the pre-causeway conditions.

The restoration of the natural estuarine ecosystem, with the creation of mudflats, will support a more natural and dynamic community of wildlife species.
The potential environmental effects of the Project Options in consideration of the residual environmental effects significance rating criteria are predicted to be positive due to their restorative nature with respect to fish and estuarine environment.

9.8.4.3 Project Option 4B/4C

The environmental effects of Project Options 4B/4C on Current Use of Land and Resources for Traditional Purposes would be approximately the same as those described for Project Options 3/4A, and are therefore determined to be positive.

9.8.4.4 Comparative Assessment

The Status Quo is anticipated to continue and potentially increase the reported significant negative environmental effects to the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons that have resulted since the construction of the causeway.

The Project Options are predicted to have positive environmental effects on Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons since they are anticipated to at least partially reverse the current river and shoreline conditions that have resulted in the decreased availability of the land and resources. The restoration of fish passage and tidal exchange will likely improve fish stocks and the natural estuarine conditions.

The implementation of the Project Options is anticipated to improve wetland function and quality in the portions of the river above the causeway. This may result in the restoration of the growing conditions for traditionally gathered plants (e.g., sweet grass) in these areas and may provide the opportunity for traditional plant gathering activities by members of the Fort Folly First Nation to resume. As stated in Section 5.10, there were no identified gathering activities in the area of the newly developed mudflats along the Petitcodiac River, and therefore loss of the wetlands/mudflats created post 1967 will not result in a negative environmental effect on the opportunity for traditional plant gathering activities.

9.8.5 Future Trends

The Status Quo and Project Options will have similar environmental effects as described in the text above on Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons in the future (2055, 2105) as in 2025. That is the Status Quo will continue to have a negative environmental effect, while the Project Options are anticipated to provide the opportunity for positive environmental effects.

9.8.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long last effects if properly cleaned up. Therefore although the potential exists for a hazardous material spill to temporarily impact Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons, long lasting effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the erosion of land adjacent to the
Petitcodiac River, including wetlands. This may be a potential risk to Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons which includes hunting and gathering activities in these areas. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

Based on consideration of the potential environmental effects and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons in the Assessment Area are predicted to be positive.

9.9 Tourism

9.9.1 Rationale for Selection of VEC

For the EIA, Tourism is defined as an economic subsector of the commercial retail sector of the local Moncton/Petitcodiac River/Fundy region. As such, Tourism is an economic generator and is identified as commercial activity realized by the attraction of consumers originating elsewhere (i.e., visitors) to the tourism area. The tourism attraction is identified as the natural attributes (e.g., the Petitcodiac River tidal bore) and supporting infrastructure (e.g., accommodations, restaurants, and cultural/heritage facilities) that appeal to and serve tourists.

Tourism is an important economic sector to New Brunswick and the GMA. The Bay of Fundy tides and/or the tidal bore are tourism attractions that have drawn visitors from around the world to see the unique and extreme tidal flows. It should be noted that tourism interests and activities are constantly changing due to factors such as demographics, education and technology. That is, tourism opportunities and attractions popular during the period prior to construction of the causeway differed from those of today (e.g., the emergence of eco-tourism), or the trends of the future.

The Guidelines require that the environmental effects of the Status Quo and Project Options on existing tourism activities be assessed and the scoping phase of the study indicated the tidal bore to be an important tourism issue. The Petitcodiac River tidal bore and the related aesthetics of the river (i.e., sight, sound and smell) have historically been an important tourism theme and attraction for the GMA. Changes to the river tidal action attributed to the construction of the causeway have resulted in a substantial reduction in the height of the tidal bore (Section 8.6). Concerns have been raised that this has affected the nature of tourism development opportunities available to the GMA since construction of the causeway. Another concern is the potential changes in the Petitcodiac River and headpond that may occur as a result of the Status Quo and Project Options and the potential environmental effects that changes to the river and headpond may have on future tourism opportunities of the area.

9.9.2 Boundaries

The spatial boundaries for Tourism (i.e., the “Assessment Area”) are the tourism and related activities associated with the Petitcodiac River from the Village of Salisbury to Chignecto Bay, with a focus on the river and its shoreline areas (Table 4.7.1). The economic implications of the
tourism attractions in the tourism sector extend beyond the river and its shoreline areas to the GMA, the Westmorland/Albert Counties region and to the Province of New Brunswick.

For the purpose of this EIA, the temporal boundary of the Tourism VEC includes the periods defined in Section 4.7.

**9.9.3 Threshold for Determination of Significance**

A *significant negative residual environmental effect* is one where the Project Options or Status Quo restricts or degrades the ability of the tourism industry to attract consumers to the area such that the activities cannot continue to be undertaken at 2005 baseline conditions, or causes a substantial decrease in tourist market value.

**9.9.4 Evaluation of Potential Environmental Effects**

**9.9.4.1 Status Quo**

The Petitcodiac River and headpond are not major tourist attractions and are not listed on the New Brunswick Government’s list of “must see and do” attractions (Tourism New Brunswick, 2003). The tidal bore has been reduced to a very minor phenomenon in 2005 and will be diminished even further by 2025. Modelling projections speculate that current sedimentation rates would result in the narrowing of the Petitcodiac River channel, which may have an environmental effect on recreational tourism activities currently based on the river (i.e., boating, canoeing and kayaking). The Status Quo will not affect the use of the current trail system located on either side of the river below the causeway.

Overall, the potential negative environmental effects of the Status Quo on Tourism in consideration of the residual environmental effects significance rating criteria are predicted to be significant as the Status Quo continues to diminish the tidal bore.

**9.9.4.2 Project Options 3/4A**

New Brunswick tourist attractions are usually based on coastal features, natural wonders and heritage and cultural sites (NB Tourism and Parks, 2004). Project Options 3/4A will allow for the return of a tidal exchange in the headpond, which is currently not a tourist attraction, along with the potential to increase the tidal bore (Section 8.6). The tidal bore was a major attraction of the local area prior to construction of the causeway, which essentially resulted in the reduction of this natural wonder. By restoring this natural estuarine ecosystem, with all its characteristics (including an increased tidal bore relative to the current conditions), the marketability of the GMA may be increased such that it would fit well with the other local natural attractions such as Shediac Beach, Magnetic Hill, Fundy National Park and Hopewell Rocks. Increased tourism in the form of tours, increased boating, canoeing and kayaking, bird watching and tourist infrastructure (i.e., shops, restaurants, trails and museums) may draw more tourists to the GMA that may also have spin-off business for the service and retail industries (supporting walkways and relative infrastructure in the GMA). Anticipated negative environmental effects of the Project Options 3/4A on Tourism are minor (e.g., loss of infrequent access of headpond by tourists that visit by float planes.
In summary, the potential environmental effects of Project Options 3/4A in consideration of the residual environmental effects significance rating criteria are predicted to be positive, as Project Options 3/4A are expected to restore natural tidal exchange to Salisbury and widen the channel in the Moncton/Riverview area, thus creating greater opportunities for natural-based tourism in the GMA. In addition, the marine quality of the GMA will be enhanced by the presence of full tidal exchange.

9.9.4.3 Project Options 4B/4C

Project Options 4B/4C have similar environmental effects on Tourism as do Project Options 3/4A, although Project Options 4B/4C will permit greater tidal exchange, as the tidal volume depth and width across the river will be wider than that for Project Options 3/4A. Under Project Option 4C, followed by Project Option 4B, the river will most closely approach pre-causeway proportions and conditions, which will create a more dynamic ecosystem than the other Project Options and may result in a greater attraction for tourists. With a predicted wider and deeper channel with greater flow rates under Project Options 4B/4C, there may be an increase in boating as bigger recreational vessels may be able travel up the river during high tides. This condition may also prove beneficial for guided canoe and kayaking tours.

As described for Project Options 3/4A, the potential environmental effects of Project Options 4B/4C in consideration of the residual environmental effects significance rating criteria are predicted to be positive.

9.9.4.4 Comparative Assessment

The Status Quo is predicted to have significant negative environmental effects on Tourism as sedimentation continues to diminish the tidal bore. However, the Project Options are predicted to have positive environmental effects on Tourism by restoring tidal exchange to the Petitcodiac River and increasing the tidal bore. Consequently, Project Options have the potential to create more tourism opportunities for the GMA and it is expected that an increase in tourism levels would ultimately create spin-off business for the retail and service industries of the GMA.

9.9.5 Future Trends

The Status Quo and Project Options will have similar environmental effects trends on Tourism in the future (2055, 2105) as in 2025.

9.9.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long lasting effects if not cleaned up properly. Therefore, the potential exists for a hazardous material spill to impact and degrade wildlife and wetland habitat (which could be tourist attractions); however, long lasting effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the destruction of possible wildlife habitat or a natural feature that may draw tourists and may be a potential risk to Tourism. To
reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Tourism in the Assessment Area are predicted to be not significant.

9.10 Recreation

9.10.1 Rationale for Selection of VEC

For the purpose of this EIA, Recreation is defined as any physical activity and supporting infrastructure located on the Petitcodiac River, along the shores of the river, or the headpond, that are reliant on the river for the enjoyment of those activities. These activities include swimming, boating, canoeing, kayaking, recreational fishing and bird watching and any supporting infrastructure such as riverside trails and boat facilities.

The Guidelines require the assessment of potential changes to existing recreational activities and facilities that may occur as a result of the Status Quo and Project Options. The key issue is that any changes to the river upstream (the headpond) and downstream of the causeway as a result of the Status Quo and Project Options may lead to changes in recreational opportunities.

Recreation has been selected as a VEC, partially due to its growing social importance and healthier lifestyle aspects, but also because of the concerns raised by area residents and visitors regarding the potential changes in recreational opportunities and facilities upstream and downstream of the causeway that may occur as a result of the changes in the river associated with the Project Options and the Status Quo.

9.10.2 Boundaries

The spatial boundaries for the Recreation VEC (i.e., the “Assessment Area”) are the Petitcodiac River from the Village of Salisbury to Chignecto Bay, including its shoreline areas, as it presently exists (Table 4.7.1).

For the purpose of this EIA, the temporal boundary of the Recreation VEC includes the current and projected periods defined in Section 4.7.

9.10.3 Threshold for Determination of Significance

A significant negative residual environmental effect is one where the Project Options or the Status Quo results in net losses in recreational opportunity, over 2005 baseline conditions, that cannot be compensated.

9.10.4 Evaluation of Potential Environmental Effects

9.10.4.1 Status Quo

The headpond and shore areas play a role in recreation opportunities for residents in the GMA. Construction of the causeway resulted in physical changes to the river that have had some
positive environmental effects (i.e., creation of the headpond, associated infrastructure and activities such as sailing, boating, float planes and the non-native smallmouth bass and chain pickerel fisheries). However, sedimentation of the headpond since construction has imposed limitations on navigation in the headpond and navigation is restricted to shallow-draft watercraft. The causeway has also had some very negative environmental effects (i.e., loss of various native recreational fish species, obstruction to navigation at the causeway and the loss of uninterrupted navigation along the length of the estuary from the Village of Salisbury to Hopewell Cape) environmental effects on marine and shore-based recreation that have resulted in changes to the type, location and nature of recreational opportunities.

Under the Status Quo environmental effects on Recreation are anticipated to be negative upstream of the causeway due to continued sedimentation of the headpond and the resultant environmental effects on navigation by recreational watercraft (Section 9.6.4.1). Downstream of the causeway, continued infilling will further restrict navigation and the tidal bore, and decline in fish stocks, will result in significant adverse environmental effects on recreation and recreational opportunity.

**9.10.4.2 Project Options 3/4A**

Project Options 3/4A will allow for the return of tidal exchange and natural estuarine conditions. The river is expected to widen and deepen, but not to the extent of pre-causeway conditions. The small amount of walking trail located on the pre-causeway river bottom downstream of the causeway may experience seasonal flooding and may have to be relocated or experience a temporary loss of access while flooded. Other recreational trails established in Riverview and Moncton will not be negatively affected and the quality of experience and opportunity for recreational activity may be enhanced due to the magnitude of tidal exchange and the potential for increased tidal bore (Section 8.6). Currently, the Petitcodiac River provides numerous opportunities for bird watching. Project Options 3/4A, which will restore the natural estuarine ecosystem, has the potential to increase bird watching opportunities.

Local freshwater fish species (i.e., smallmouth bass and chain pickerel) will be eliminated under Project Options 3/4A, but other saltwater recreational species such as sea-run brook trout, Atlantic salmon (increased potential for return), striped bass, rainbow smelt, sturgeon, eel and shad may return to the system. Most of these species were very popular recreational fish in the pre-causeway period. Therefore, although the species composition will change, the opportunity or potential for recreational fishing will likely increase in the Assessment Area due to improved fish stocks and species diversity.

Alteration of the headpond would, without mitigation, affect the activities of the Tri Community Marina, the Town of Riverview public boat launch, the sea cadet training facility and private docks. These losses will be mitigated by altering facilities to ensure continued access to the Petitcodiac River so that recreational opportunities (e.g., fishing, tidal bore, unobstructed navigation of the estuary) afforded by enhanced navigational opportunities can be accessed (Section 9.6). Alternatively, if desired, compensation could be offered to the Tri Community Marina, Town of Riverview, sea cadets, and private dock owners (where licensed) should they...
decide not to pursue changed recreational and navigational opportunities that are afforded by the changes to the River.

The removal of the causeway as an obstruction to navigation and the free tidal exchange in a deeper and wider channel will afford greatly enhanced opportunity for river-based recreation. The improved tidal bore will provide the opportunity for kayakers and rafters to ride along the tidal bore as currently occurs in the Shubenacadie River.

Overall, the potential environmental effects of Project Options 3/4A in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be positive, as recreational potential and opportunity in the Assessment Area will be greatly enhanced. Changes to river access for recreational boating at existing infrastructure will be mitigated to allow access to the Petitcodiac River for recreational boating or compensated.

9.10.4.3 Project Options 4B/4C

Project Options 4B/4C have similar environmental effects on Recreation as do Project Options 3/4A, although Project Options 4B/4C will permit greater tidal exchange, as the tidal volume depth and width across the river will be wider than that for Project Options 3/4A. Therefore, the potential exists to affect the walking trails that are currently on marshland areas that were once the river bottom, which may at some locations have to be reconstructed outside the projected new flood plain. Project Option 4C, followed by Project Option 4B, has the greatest potential to approach pre-causeway conditions, which would create a more dynamic ecosystem than both the Status Quo and Project Options 3/4A. This may result in greater recreation opportunities (i.e., fishing, bird watching, walking, hiking, canoeing and kayaking). With a predicted wider and deeper channel with greater flow rates, Project Options 4B/4C may increase recreational boating use of the river, which may also create the demand for associated marine services (e.g., marina and wharves) in support of recreational boating.

Project Options 4B/4C will have similar environmental effects on the recreational fishing and boating infrastructure of the headpond as Project Options 3/4A and will require the same mitigation or compensation.

As described for Project Options 3/4A, overall the potential environmental effects of Project Options 4B/4C in consideration of the proposed mitigation or compensation and the residual environmental effects significance rating criteria are predicted to be positive.

9.10.4.4 Comparative Assessment

The Status Quo will continue to have significant negative environmental effects on Recreation due to continued sedimentation of the headpond and the Petitcodiac River estuary downstream of the causeway, and the associated decline in recreational and navigational opportunity. In contrast, although the Project Options will affect the headpond and its associated infrastructure (i.e., Tri Community Marina, the Town of Riverview public boat launch, the Sea Cadet’s facility) and activities (e.g., sailing, smallmouth bass fishing), the Project Options are predicted to have positive environmental effects overall due to increased recreational and navigational opportunity afforded by the changes to the Petitcodiac River (i.e., the potentially increased tidal bore,
removal of navigation obstruction at causeway, improved navigational opportunity, opportunity for the return of native fish stocks) and in consideration of mitigation or compensation for water-based recreational infrastructure.

9.10.5 Future Trends

The Status Quo and Project Options will have similar environmental effects on Recreation in the future (2055, 2105) as in 2025. Under the Project Options it is expected that increased municipal investment in recreational infrastructure will continue and capitalize on the estuary’s enhanced natural condition, resulting in the development of a stronger recreational and cultural relationship between the community, its people, and the river. Under the Status Quo, continued sedimentation of the headpond and the Petitcodiac River below the causeway will further limit recreational opportunity.

9.10.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long lasting environmental effects. Therefore the potential exists for a hazardous material spill to affect and degrade wildlife and wetland habitat (which could be recreational attractions), the long lasting environmental effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in damage to recreational trails in the Assessment Area and may be a potential risk to Recreation. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Recreation in the Assessment Area are predicted to be not significant.

9.11 Labour and Economy

9.11.1 Rationale for Selection of VEC

For the purpose of this EIA, labour refers to the supply and demand for direct skilled and non-skilled labour requirements, as well as the indirect creation of employment in other economic sectors, that may be affected by Project Options and the Status Quo. Economy refers to the production base of the Petitcodiac River region and provincial industry sectors that may be affected during all phases of the Status Quo and Project Options.

The Status Quo and Project Options will generate labour employment and expenditures within the local and provincial economies during the construction, operation and maintenance phases. Ultimately, the selected causeway modification and associated operation and maintenance activities will involve varying degrees of employment and economic activity.
Employment and economic activity may also be created or lost in other sectors of the economy, such as commercial fishing, agriculture, or tourism, as a result of the Status Quo or Project Options. These economic changes will indirectly affect other production and service sectors of the local and provincial economy through the "spin-offs" of indirect employment and economic activity generated or lost in those other sectors.

The Guidelines require that the socio-economic environmental effects of the Status Quo and Project Options on the local economy and labour force be assessed. The key issue is with respect to the potential direct and indirect economic benefits, or losses, that may result from changes in labour employment and/or economic activity attributable to the Status Quo and Project Options. These relate to the changes in direct labour and economic activity created by the causeway modifications, as well as the indirect "spin-offs" of employment and economic activity generated within the local region and provincial economies.

Due to the importance of jobs and economic well being to society, Labour and Economy has been selected as a VEC to address the changes in employment and economic activities that may result from the Status Quo and Project Options.

9.11.2 Boundaries

The spatial boundaries of the Labour and Economy VEC (i.e., the "Assessment Area") include the local Petitcodiac River region, which includes the urban and rural communities along the Petitcodiac River on both the western (Albert County) and eastern (Westmorland County) sides of the river from the Village of Salisbury to Chignecto Bay (Table 4.7.1).

For the purpose of this EIA, the temporal boundary of the Labour and Economy VEC include the periods defined in Section 4.7.

9.11.3 Threshold for Determination of Significance

A significant negative residual environmental effect on labour is one where the Project Options or Status Quo directly affects the current supply and demand of skilled and unskilled labour, ultimately causing degradation to the production base such that there is an uncompensated net loss of employment opportunity.

A significant negative residual environmental effect on the economy is one where the Project Options or Status Quo induces negative changes in the regional economy of the GMA.

9.11.4 Evaluation of Potential Environmental Effects

9.11.4.1 Status Quo

All current employment opportunities associated with the Petitcodiac River and the headpond are anticipated to continue to exist, as well as those associated with the maintenance of municipal infrastructure, the causeway and its gates. However, the Status Quo will continue to result in the loss of the opportunity to commercially fish within the Petitcodiac River for navigational reasons and may have caused the loss of the Atlantic salmon and American shad and is, therefore, considered to have a significant negative environmental effect.
9.11.4.2 Project Options 3/4A

Employment associated with engineering, design, construction and maintenance of Project Options 3/4A, as well as the potential for business opportunities associated with construction and maintenance, will have positive environmental effects on Labour and the Economy in the Assessment Area. In addition, Project Options 3/4A may create more tourism related service, construction and operation opportunities by returning the Petitcodiac River back into a natural estuarine ecosystem.

Project Options 3/4A may result in the loss of the commercial eel fishery in the headpond and all jobs associated with this fishery may be lost. It is anticipated that eel will continue to exist in the Petitcodiac River, but should a substantial reduction in eel harvest occur as a result Project Options 3/4A, then fishers should be compensated based on current harvest levels. Project Options 3/4A also have the potential to affect the commercial lobster and scallop fisheries. It is not expected that sedimentation of habitat will occur as a result of Project Options 3/4A will be sufficient to affect these fisheries, as it is anticipated that sedimentation from the Petitcodiac River estuary would be transported out into the Bay of Fundy (Section 8.3). If a substantial reduction in landings occurs as a result of the Project Options, compensation will be provided based on current harvest levels. However, with an increase in the variety of potential commercial fish species predicted to return to the Petitcodiac River as a result of the Project Options, there is an increased potential for other commercial fishing opportunities that would create an employment demand potential for spin-off supply and service opportunities.

Overall, the potential environmental effects of Project Options 3/4A on Labour and Economy in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant (mitigated loss of commercial fisheries) to positive (potential for increased employment and business opportunities).

9.11.4.3 Project Options 4B/4C

Project Options 4B/4C have a greater potential for creating more employment opportunities during construction than Project Options 3/4A and will give a temporary boost to the local economy in the way of capital expenditures and spin-off of supply and service businesses. As described in Chapter 7, Project Option 4C will provide the greatest boost to the economy by way of capital expenditures, followed by Project Option 4B, then Project Option 4A, then Project Option 3.

The environmental effects of Project Options 4B/4C on commercial eel, lobster and scallop fisheries and proposed mitigation are similar to those described for Project Options 3/4A. Although Project Options 4B/4C will result in greater erosion of sediments from the Petitcodiac River than Project Options 3/4A, they are still not predicted to have significant negative environmental effects on the lobster and scallop fisheries.
Overall, the potential environmental effects of Project Options 4B/4C on Labour and Economy in consideration of the proposed mitigation (compensation for potential decrease of commercial fisheries) and the residual environmental effects significance rating criteria are predicted to be not significant to positive.

### 9.11.4.4 Comparative Assessment

Other factors being equal, the Status Quo will maintain the current Labour and Economy within the Assessment Area. The Project Options will have positive environmental effects on Labour and Economy due to increased employment and business opportunities. The environmental effects of the Project Options on the commercial fishery for American eel is anticipated to be negative, but not significant in consideration of the proposed mitigation (i.e., compensation for decrease of fishery). The Project Options are not anticipated to result in a decrease to the lobster and scallop fishery.

### 9.11.5 Future Trends

The Status Quo and Project Options will have similar environmental effects on Labour and Economy in the future (2055, 2105) as in 2025.

### 9.11.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long lasting effects. Therefore the potential exists for a hazardous material spill to affect tourism and recreation activities which may be linked to the local labour force and economy and therefore affect the Labour and Economy of the area. However, long lasting effects are not anticipated.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the degradation of tourism and recreational activities and agricultural land use in the Assessment Area and may be a potential risk to Labour and Economy. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Labour and Economy in the Assessment Area are predicted to be not significant.

### 9.12 Heritage and Archaeological Resources

#### 9.12.1 Rationale for Selection of VEC

Heritage and Archaeological Resources are defined as any physical remnants found on top of and/or below the surface of the ground that inform us of past human use of and interaction with the physical environment. These resources may be from the earliest prehistoric times of human occupation up to the relatively recent past and may include both built and depositional resources (e.g., trash or lost goods). Significant archaeological resources are defined as those sites, such as living areas, that can inform us on the lifeways of First Nations and early
European settlers on the Petitcodiac River. Individual artifacts (described by provincial archaeological regulator, Archaeological Services Unit, as “find spots”) are not typically considered significant as they provide only minimal information on the past. For this EIA, Heritage and Archaeological Resources will also include historic structures and palaeontological resources (e.g., fossil remains of plants and animals).

Heritage and Archaeological resources (pre-European contact or post-European contact archaeological sites, structures, features, artifacts, eco-facts (e.g., environmental or biological remnants that may suggest something about the human use) and sacred and/or significant historical event sites) are known to exist along the banks of the Petitcodiac River and its tributaries; however no comprehensive archaeological survey has ever been conducted.

The Status Quo and Project Options may cause changes to the flow patterns of the Petitcodiac River and changes to the water level of the headpond, which could potentially affect Heritage and Archaeological Resources. Heritage and Archaeological Resources therefore are included as a VEC in recognition of the interest of potentially affected First Nations, the general public as a whole, and provincial and federal regulatory agencies assuring the effective management of these resources.

Heritage and Archaeological Resources may be affected by surficial or subsurface Project-related disturbance of the area within which these resources are located. The assessment of potential Project related environmental effects on Heritage and Archaeological Resources is focused principally on those Project activities (including related geotechnical investigations) that entail ground disturbance, and are within the physical limits of those activities. The mudflat areas created since the construction of the causeway, for example, do not have potential for significant heritage resources due to their relative age.

9.12.2 Boundaries

The spatial boundaries for the Heritage and Archaeological Resources VEC (i.e., the “Assessment Area”) are the Petitcodiac River from Salisbury to Chignecto Bay and the locations where there are likely to be environmental effects to lands that may contain heritage or archaeological resources, such as any ground disturbance or increased erosion of riverbanks (Table 4.7.1).

For the purpose of this EIA, the temporal boundary of the Heritage and Archaeological Resources VEC includes the current and projected periods defined in Section 4.7.

9.12.3 Threshold for Determination of Significance

A significant negative residual environmental effect is a Project-related disturbance to, or destruction of, an archaeological or heritage resource (including palaeontological resources) considered by the provincial heritage and archaeological regulators to be of major importance due to factors such as rarity, undisturbed condition, spiritual importance, or research importance, that cannot be mitigated.
9.12.4 Evaluation of Potential Environmental Effects

9.12.4.1 Status Quo

The construction of the causeway did not cause any erosion of the Petitcodiac River shoreline below the causeway itself, therefore no causeway induced changes to archaeological and heritage resources are anticipated for the Status Quo. The wetland areas created since construction of the causeway do not have potential for significant heritage resources due to their relative age. The current headpond water levels are well below the pre-causeway high tide water levels. Therefore, the presence of the causeway has not likely had any negative environmental effects on unknown archaeological sites in the headpond area due to flooding.

The Status Quo is not expected to cause any damage or destruction to the historic shorelines (i.e., pre-causeway shorelines) of the Petitcodiac River; therefore the potential negative environmental effects of the Status Quo on Heritage and Archaeological Resources in consideration of the residual environmental effects significance rating criteria are predicted to be not significant, and possibly non-existent.

9.12.4.2 Project Options

The Project Options restore, to some degree, the tidal flow of the Petitcodiac River; however neither Project Option will return the width of the river to pre-causeway conditions. Therefore, it is not anticipated that there will be any erosion to pre-causeway shorelines, which is where Heritage and Archaeological Resources are thought to be located, as a result of Project Options. The causeway itself is a man-made structure that would have affected archaeological and heritage resources, if present, upon its construction; therefore any construction activities on or near the causeway are not predicted to affect Heritage and Archaeological Resources.

The potential negative environmental effects of the Project Options on Heritage and Archaeological Resources in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

9.12.4.3 Comparative Assessment

The Status Quo and Project Options are not predicted to affect the pre-causeway shorelines and thus the potential environmental effects on Heritage and Archaeological Resources are predicted to be not significant.

9.12.5 Future Trends

The Status Quo and Project Options will have similar environmental effects on Heritage and Archaeological Resources in the future (2055, 2105) as in 2025.

9.12.6 Accidents and Malfunctions

Hazardous material spills, although they have serious environmental consequences, tend to only affect a local area and tend not to have long lasting effects. However, in the event of a hazardous material spills along a shoreline, contaminated soil will have to be excavated and disposed of in an appropriate manner. In such an event, the provincial regulator may,
depending upon the potential of the location, require that a licensed archaeologist be present as the soil is excavated in the event that the contaminated site is actually an archaeological site.

There is a potential during heavy precipitation events or flash floods for erosion control structures to fail. An accident of this nature could result in the erosion of pre-causeway shorelines in the Assessment Area and may be a potential risk to Heritage and Archaeological Resources. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).

It is anticipated that agricultural dyke failure may affect Heritage and Archaeological Resources should the resultant flooding erode pre-causeway shorelines. Mitigative measures will be implemented to ensure existing dykes and aboiteaux are repaired/restore to prevent their erosion. However, if the dykes and aboiteaux were washed out in the case of an accident, it is anticipated that the areas behind the dyke, which would have been seasonally flooded or wetlands prior to the dyke’s construction, would revert to the pre-dyke condition. Any potential early archaic (i.e., a period marked by the extensive development of new technologies and subsistence patterns in many parts of North America from approximately 2,000 to 8,000 years before present) or earlier period archaeological sites located under those wetland soils are not likely to be affected by this scenario. Due to decreased water velocity in the portion of the river above the causeway, these wetland areas are unlikely to be eroded whether or not the dyke remains in place.

Based on consideration of the potential environmental effects, the proposed mitigation and the residual environmental effects significance rating criteria, the environmental effects of accidents and malfunctions on Heritage and Archaeological Resources in the Assessment Area are predicted to be not significant.

9.13 Public Health and Safety

9.13.1 Rationale for Selection of VEC

The Status Quo and Project Options have the potential to result in environmental effects on public health and safety. These environmental effects may arise primarily from accidents (i.e., vehicular/non-vehicular accidents) and unplanned events, or through changes in the environment that may have implications for public health and safety (i.e., groundwater quality and quantity, contaminated effluents, disease vectors and flooding). Given these issues and concerns, Public Health and Safety has been selected as a VEC. Each of these issues and concerns are outlined below.

9.13.1.1 Vehicular Accidents

Project Options and the Status Quo may result in changes in traffic patterns during construction and maintenance, which may result in increased traffic congestion and potential for related vehicular accidents. There is the potential that Project Options or the Status Quo may result in changes to the environment (e.g., microclimate changes such as frequency of fog or icing) affecting accident rates. In addition, a rise in traffic volumes due to potential induced increases in tourism and recreational activities could potentially alter accident rates.
9.13.1.2 Non-Vehicular Accidents and Unplanned Events

Project Options and the Status Quo may result in changes to the environment that could result in changes in non-vehicular accident rates or in changes in the response to unplanned events such as forest fires. Non-vehicular accidents could relate to tourism and/or recreational activities for which increased or decreased accidents may occur, and new tourism and recreational activities could introduce the potential for new non-vehicular accidents. Project Options and the Status Quo may have an environmental effect on the use of the Petitcodiac River headpond as a fire fighting water source.

9.13.1.3 Groundwater Quality and Quantity

Project Options and the Status Quo may result in changes to groundwater resources, either through a change in quality (e.g., saltwater intrusion adjacent to the headpond) or quantity (e.g., changes in hydraulic relationships between the estuary/headpond and adjacent aquifers).

9.13.1.4 Contaminated Effluents and Redistribution of Contaminants

Project Options have the potential to redistribute contaminated effluents (e.g., sewage outfall, stormwater outfall, landfill leachate). These changes may result in changes in water quality that could lead to potential public health and safety issues through recreational contact or exposure, including food resources. Some Project Options may introduce or redistribute contaminants that are of public health concern within the zone of influence. The Status Quo may result in the concentration or accumulation of contaminated effluents.

9.13.1.5 Human Disease Vectors

Project Options and the Status Quo may affect insect and wildlife habitat such that certain human disease vectors (e.g., mosquitoes) could result in changes to public health risk of exposure. In particular, there has been concern about the West Nile Virus due to increased mosquito populations during periods when the causeway gates have been opened. Some Project Options and the Status Quo have the potential to increase breeding areas for biting flies such as the Culex mosquito.

9.13.1.6 Flooding

Project Options and the Status Quo may potentially change the risk of flooding in areas adjacent to the Petitcodiac River and its tributaries. Sedimentation at the gates and therefore inability to open them, as well as ice jamming at the gates, also pose a concern with respect to flood risk.

9.13.2 Boundaries

The spatial and temporal boundaries for the assessment of Public Health and Safety (the “Assessment Area”) are the same as defined in Table 4.7.1 and Section 4.7, respectively.

9.13.3 Threshold for Determination of Significance

A significant negative residual environmental effect on Public Health and Safety is one that results in an increase in risk to public health and safety over 2005 baseline conditions.
9.13.4 Evaluation of Potential Environmental Effects

9.13.4.1 Vehicular Accidents

Status Quo

As the Status Quo is not expected to have any environmental effects on vehicular accidents in the Assessment Area, the potential negative environmental effects are predicted to be not significant.

Project Options 3/4A

During construction and maintenance of Project Options 3/4A, vehicular accidents could increase as a result of changes in traffic patterns and increased traffic congestion (Section 9.5). Project Options 3/4A may increase the amount of traffic over 2005 baseline conditions as a result of increased river-based tourism and recreation; however, this increase in traffic is not expected to substantially increase the amount of traffic or number of vehicular accidents in the Assessment Area over 2005 baseline conditions. Any increase in traffic during construction or operation is expected to be offset by the new 4-lane Petitcodiac River Bridge, which will be in operation by the time of construction.

Mitigation during construction and maintenance activities, as outlined in the EMP (Section 7.5), will ensure the safety of the motoring public. Therefore, potential negative environmental effects of Project Options 3/4A on vehicular accidents in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options 4B/4C

Project Options 4B/4C are expected to have similar environmental effects during construction and operation as Project Options 3/4A. During construction, changes in traffic patterns will vary between the Project Options (Section 9.5), however mitigation ensuring the safety of the motoring public will be implemented (Section 7.5). During operation, traffic levels due to increased tourism may be greater than for Project Option 3/4A, as Project Options 4B/4C will permit greater tidal exchange and possibly a larger tidal bore (although not as large as pre-causeway conditions). This increase in traffic is not expected to substantially increase traffic or the number of vehicular accidents. Any increases in traffic volume/congestion either during construction or operation are expected to be offset by the new 4-lane Petitcodiac River Bridge, which will be in operation by the time of construction.

Mitigation for Project Options 4B/4C is similar to that proposed for Project Options 3/4A. Therefore, potential negative environmental effects of Project Options 4B/4C on vehicular accidents in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.
Comparative Assessment

The potential negative environmental effects of the Status Quo and Project Options on vehicular accidents are predicted to be not significant. Project Options may increase tourism-related traffic due to restoration of the estuary and improved tidal bore, but are not expected to incrementally increase the number of vehicular accidents over 2005 baseline conditions.

9.13.4.2 Non-VEhicular Accidents and Unplanned Events

Status Quo

The Status Quo may have environmental effects on the number of boating accidents in the Assessment Area, as the continued deposition of sediments downstream and upstream of the causeway results in increasingly shallow water conditions potentially leading to an increase (although not substantial) in the number of stranded boaters or related accidents. The Status Quo is not expected to have any environmental effects on the use of the headpond as an emergency fire fighting water source. Therefore, the potential negative environmental effects of the Status Quo on non-vehicular accidents and unplanned events in consideration of the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options 3/4A

Project Options 3/4A may have environmental effects on non-vehicular accidents and unplanned events. Restoration of pre-causeway tidal flow throughout the Assessment Area will create the potential for some recreational boating activities. Due to the large tide and flow, and rapid changes, there may be increased accidents due to these activities (e.g., people stranded in the mud). Project Options 3/4A will result in loss of the headpond, which was used in 2004 as a location for water-bombers and helicopters to obtain water to fight a forest fire (AMEC, 2005a). However, there are other acceptable sources of water nearby (i.e., Bay of Fundy and Shediac Bay) and chemical fire retardants are generally more effective and more often used than water. Therefore, Project Options 3/4A will not result in a significant negative environmental effect on water resources availability for fighting fires.

Mitigation includes signage and education in boating safety to warn boaters of the potential danger. It is assumed that the rate of accidents would not be greater than for the same type of activity elsewhere. As a result, the potential negative environmental effects of Project Options 3/4A on non-vehicular accidents and unplanned events in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.

Project Options 4B/4C

Project Options 4B/4C will permit greater tidal exchange and will result in a greater potential for hazardous boating conditions and related accidents than Project Options 3/4A. Proposed mitigation is the same as for Project Options 3/4A. The potential negative environmental effects of Project Options 4B/4C on non-vehicular accidents and unplanned events in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant.
Comparative Assessment

The potential negative environmental effects of the Status Quo and Project Options on non-vehicular accidents and unplanned events in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant. The Status Quo may slightly increase the number of non-vehicular accidents and strandings due to increased sedimentation of the river over 2005 baseline conditions but will have no environmental effects on the use of the headpond as a fire fighting water source. Project Options, which will restore tidal flow and may increase recreational boating and introduce the potential for more accidents related to that activity, are expected to have environmental effects on non-vehicular accidents that are not significant. The Project Options are expected to have environmental effects that are not significant in relation to use of the headpond as a fire fighting water source.

9.13.4.3 Groundwater Quality and Quantity

Status Quo

The Status Quo is not expected to have any significant negative environmental effects on groundwater quality or quantity over 2005 baseline conditions.

Project Options 3/4A

Project Options 3/4A are not expected to have any significant negative environmental effects on groundwater quality or quantity. Restoration of tidal flow upstream of the causeway is not expected to result in saltwater intrusion into wells or decrease the amount of groundwater available in adjacent aquifers, as this did not occur during pre-causeway conditions; Project Options 3/4A will not restore the river to its pre-causeway dimensions.

Project Options 4B/4C

For the same reasons as for Project Options 3/4A, Project Options 4B/4C are not expected to have any significant negative environmental effects on groundwater quality and quantity. Although Project Options 4B/4C will result in a greater width and depth of the river than Project Options 3/4A, the river will not reach pre-causeway proportions.

Comparative Assessment

Neither Project Options nor the Status Quo are expected to have significant negative environmental effects on groundwater quality or quantity over 2005 baseline conditions.

9.13.4.4 Contaminated Effluents and Redistribution of Contaminants

Status Quo

The baseline bacterial conditions in the Petitcodiac River currently exceed the threshold of the significance criteria (the acceptable CCME Recreational Water Quality Guidelines for Aesthetics for Enterococcus is equal to or below 35/100 mL), from the freshwater environment upstream of the causeway where it is less frequent and tied to precipitation and river flow, to the estuarine and marine waters as far downstream as Hopewell Cape and the confluence (see Glossary) with the Memramcook River from June to December. These environmental effects generally
exceed aesthetic and recreational guideline values, and are more likely to affect Public Health and Safety (Section 9.13) than fish or their habitats that have higher threshold levels. Bacterial concentrations are likely to increase even more at low tide for the Status Quo in comparison to baseline conditions. This is a result of the river channel continuing to decrease in width and in area in the downstream direction from the causeway, higher volumes of sewage effluent and bacteria because of anticipated human population growth, and higher TSS to which free-living bacteria can attach and grow in nutrient-rich waters arising from sewage effluent. At high tide, bacterial dilution with the incoming tide in the Petitcodiac River will be less in 2025 than in 2005 because of a reduction in the volume of the tidal prism. This lower tidal prism will be a result of the decrease in the river channel downstream of the causeway and as far as Hopewell Cape.

The Status Quo will have negative environmental effects on contaminated effluents and redistribution of contaminants in the Assessment Area over 2005 baseline conditions. Downstream of the causeway, water quality continues to deteriorate as sedimentation decreases the width and depth of the river, thereby decreasing the river’s assimilative capacity for sanitary and storm sewer discharge; fecal coliform concentrations are expected to increase under the Status Quo, which could affect food resources from the Petitcodiac River (i.e., fish and plant resources) and water quality for recreational purposes. Upstream of the causeway, the Status Quo is not expected to have significant negative environmental effects on contaminated effluents over 2005 baseline conditions, however, the recreational water quality throughout the Assessment Area will at times continue to be unsuitable for many recreational water purposes (e.g., swimming). The Status Quo is not expected to have any environmental effects on the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway.

In summary, the potential negative environmental effects of the Status Quo on contaminated effluents and redistribution of contaminants in consideration of the residual environmental effects significance rating criteria are predicted to be significant.

**Project Options 3/4A**

Project Options 3/4A are expected to have positive environmental effects on contaminated effluents and redistribution of contaminants in the Assessment Area over 2005 baseline conditions, as restoration of tidal flow and erosion of sediments will enable the river to more effectively flush contaminated effluents out of the system. Refer to Section 9.2.4.2 for a more thorough description on the predicted dilution of contaminants under Project Options 3/4A.

Project Options 3/4A will result in the widening of the river channel over 2005 baseline conditions (although less than pre-causeway conditions), which has the potential to erode the former Moncton Landfill located on the north side of the Petitcodiac River immediately downstream of the causeway. This could result in the leaching or erosion of potentially toxic substances into the river. Mitigation will ensure protection of the landfill from erosion, however, there exists a potential during heavy precipitation events or flash floods for erosion control structures to fail. To reduce the possibility of this occurring, protection measures will be followed as described in the EMP developed for this Project (Section 7.5).
In summary, the potential negative environmental effects of the Project Options 3/4A on contaminated effluents and redistribution of contaminants in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive.

**Project Options 4B/4C**

Project Options 4B/4C are expected to permit greater flushing and erosion of contaminated effluents than Project Options 3/4A, as the width of the river and tidal prism will be greater. However, this also results in a greater potential for these Project Options to erode the former Moncton Landfill, especially Project Option 4C, which will result in a river channel that is the widest and closest to the landfill. Mitigation (landfill protection) for Project Options 4B/4C is the same as for Project Options 3/4A and the negative environmental effects are predicted to be not significant.

The potential negative environmental effects of the Project Options 4B/4C on contaminated effluents and redistribution of contaminants in consideration of the proposed mitigation and the residual environmental effects significance rating criteria are predicted to be not significant to positive.

**Comparative Assessment**

Water quality conditions downstream of the causeway are expected to continue to deteriorate with the Status Quo as the river continues to infill and decrease in assimilative capacity, and upstream of the causeway, water quality is expected to remain questionable and continue to be unsuitable for many recreational purposes (e.g., swimming, kayaking, boating). In contrast, the Project Options are expected to improve water quality conditions upstream and downstream of the causeway by restoring tidal flow, increasing the assimilative capacity of the river. The Status Quo and Project Options will not have significant negative residual environmental effects on the redistribution of contaminants associated with the former Moncton Landfill. In summary, the potential environmental effects of the Status Quo on contaminated effluents and redistribution of contaminants are predicted to be significant whereas the potential environmental effects of the Project Options are predicted to be not significant to positive.

**9.13.4.5 Human Disease Vectors**

**Status Quo**

The Status Quo will increase the amount of wetland area in the Assessment Area over 2005 baseline conditions (Section 8.11); the *Culex* mosquito, a human disease vector for the West Nile Virus, can breed in saltmarsh habitats, but prefers freshwater impoundments (Rutgers University Mosquito Homepage, http://www.rci.rutgers.edu/~insects/sp11a.htm). However, the potential environmental effects of the Status Quo on human disease vectors is predicted to be not significant as the virus has not occurred in birds or humans in 2004 or 2005 in New Brunswick. Ultimately, the continued presence of the headpond and the potential for more freshwater wetland may lead to increased risk from the virus, if found in the region.
Project Options 3/4A

Project Options 3/4A will have positive environmental effects on public health and safety with regards to human disease vectors (i.e., the *Culex* mosquito), as Project Options 3/4A will decrease the area of freshwater wetland habitat in the Assessment Area over 2005 baseline conditions (Section 9.3.4.1).

Project Options 4B/4C

Project Options 4B/4C will result in the loss of additional freshwater wetland habitat in the Assessment Area over 2005 baseline conditions compared to Project Options 3/4A and will consequently have positive environmental effects on human disease vectors in the Assessment Area.

Comparative Assessment

The Status Quo is predicted to have the potential for environmental effects on public health and safety with regards to human disease vectors should the risk of the West Nile Virus be realized in the GMA. Project Options are expected to decrease the amount of habitat available to the *Culex* mosquito and consequently have a positive environmental effect on public health and safety should the virus occur in the GMA.

9.13.4.6 Flooding

Status Quo

The Status Quo will have negative environmental effects on flooding in the Assessment Area. The conveyance capacity (see Glossary) of the river continues to decrease, adjacent creeks will continue to narrow, and marshlands and drainage ditches will continue to fill in as deposition of sediments associated with the Status Quo continues. The situation is further complicated by related ice accumulation in the narrower channels. The Status Quo also poses the risk of catastrophic failure of the causeway (i.e., breach of the causeway), as sediments accumulate against the gates in periods when the gates are not operated and estuarine or river ice result in ice jams at or in the vicinity of the gates. Modelling results show that under a heavy fall rainfall and associated high flows, there is a risk of flooding upstream of the causeway under the Status Quo (Section 8.6) and overtopping of the causeway. Also, under a heavy fall rainfall associated with a storm passage, there is a risk of flooding along the Petitcodiac River in the GMA and upstream of the causeway (Section 8.6). For the Status Quo, the magnitude and the extent of flooding should be quantified through a detailed flood risk assessment. The potential negative environmental effects of the Status Quo on flooding in consideration of the residual environmental effects significance rating criteria are predicted to be significant.

Project Options 3/4A

Restoration of tidal flow and flushing within the Assessment Area as a result of Project Options 3/4A will keep the main channel open, increase its conveyance capacity, and prevent ice accumulation. Increased erosion of accumulated sediments will reduce the infilling of creeks, marshlands, and drainage ditches, enabling the system to accommodate increased flows during tides and rainfall events. Additionally, failure of gate opening at the causeway will not be an issue as Project Options 3/4A will remove the fishway, gates and piers. Modelling results show
that the risk of flooding during a heavy autumn rainfall will be alleviated under Project Options 3/4A, although a flooding risk at Moncton and upstream of the causeway will still exist in the case of a heavy autumn rainfall associated with a storm passage (although less of a risk than for the Status Quo) (Section 8.6). The potential environmental effects of Project Options 3/4A on flooding in consideration of the residual environmental effects significance rating criteria are predicted to be positive.

**Project Options 4B/4C**

Project Options 4B/4C will have similar environmental effects on flooding as does Project Options 3/4A. Project Options 4B/4C will result in greater tidal flow and erosion of sediments in the Assessment Area than for Project Options 3/4A and will subsequently result in a lower flood risk during heavy fall rainfalls associated with storm passage. Therefore, the potential environmental effects of Project Options 4B/4C on flooding in consideration of the residual environmental effects significance rating criteria are predicted to be positive.

**Comparative Assessment**

The Status Quo is predicted to have significant negative environmental effects on flooding whereas Project Options are expected to decrease the risk of flooding in the Assessment Area over 2005 baseline conditions, and consequently have a positive environmental effect on flooding.

**9.13.5 Future Trends (2055, 2105)**

The Status Quo and Project Options will have similar environmental effects on Public Health and Safety in the future (2055, 2105) as in 2025. Future trends will continue for the Status Quo as the negative environmental effects on contaminated effluents, disease vectors and flooding continue to worsen as deposition of sediments in the river downstream of the causeway continues. Environmental effects of the Project Options will not alter substantially over 2025, as restoration of tidal flow will continue to flush contaminated effluents from the river and prevent infilling of creeks, marshlands and drainage ditches, which result in flooding.

**9.13.6 Summary**

Overall, the potential negative environmental effects of the Status Quo on Public Health and Safety in consideration of the residual environmental effects significance rating criteria are predicted to be significant as a result of continued infilling of the river and its tributaries, which leads to deteriorating water quality conditions and increased risk of flooding.

The potential environmental effects of the Project Options on Public Health and Safety in consideration of the proposed mitigation (i.e., former Moncton Landfill protection) and the residual environmental effects significance rating criteria are predicted to be not significant to positive, as increased erosion and tidal flow will improve water quality conditions and decrease the risk of flooding in the Assessment Area.
10.0 EFFECTS OF THE ENVIRONMENT ON THE PROJECT OPTIONS AND THE STATUS QUO

10.1 Background

The definition of “environmental effect” under Section 2(1) of CEAA includes “any change to the project that may be caused by the environment”. The guidance documentation of the Canadian Environmental Assessment Agency does not specifically address how this aspect is to be assessed. Typically, this is accomplished by: identifying and describing the aspects of the environment (e.g., saltwater) that could have an effect on the Project design, construction and operation; describing the nature of the effects (e.g., corrosion of the bridge); and providing a description of the mitigation (e.g., design codes and standards) to minimize the risk from the identified effects of the environment on the Project. The aspects of the environment that may cause a change in the design or construction of the Status Quo and Project Options are:

- sediment transport process (erosion and deposition);
- tidal prism (energy and extent);
- weather (precipitation, temperature and wind);
- flooding;
- ice;
- climate change (including sea level rise); and
- earthquake activity.

As mentioned in Chapter 1 of this EIA Report, this is not a typical Project (comparative assessment of Status Quo and Project Options with the purpose of minimizing or reversing the negative environmental effects that resulted from construction and operation of the existing causeway) and the Petitcodiac River is not a typical river (i.e., macro-tidal with extremely high suspended sediment concentration and extreme weather/ice). As such, this is not a typical EIA. One fundamental difference of this EIA from a typical project EIA is that implementation of the Project Options will result in many substantial changes to the environment. These changes are most pronounced for the riverine/estuarine environment and may subsequently negatively affect the Project Options.

To further illustrate this concept, some aspects of the existing environment (baseline conditions) were created in part by the presence of the causeway as described in the Biophysical and Socio-economic Component Study (AMEC, 2005a); and these causeway induced aspects of the environment (e.g., sediment plug upstream of the causeway) affect the design, implementation and operation of the Project Options (e.g., dredging of a portion of sediment plug). The implementation of the Project Options then (as per their designed intent) affects the existing environment (e.g., removal of the sediment plug by increased tidal prism) as predicted in the Modelling Component Study (AMEC, 2005b). Finally, the altered future environment (e.g., increased tidal prism as a partial result of removed sediment plug) directly affects the operation of the Project Options (e.g., more water moving through the channel), and was also considered for the design and implementation phase (e.g., precautionary protection of shoreline near the
causeway). Although all of these changes and predictions have been described previously in this EIA Report, they are summarized in this chapter for the convenience of the reader, with reference to other sections where appropriate.

Note that the term “Project Options” includes Project Options 3, 4A, 4B and 4C (Project Options that meet the fish passage Project Objective); specific mention of a Project Option (e.g., Project Option 4B) is given when warranted. Table 10.1.1 provides a brief description of the baseline condition (2005) compared to the pre-causeway condition for each of the aspects of the environment that may cause a change in the Project Options or the Status Quo. Table 10.1.1 then compares the baseline conditions and trends with the future predicted environment from

**Table 10.1.1 Determination of the Aspects of the Environment that will be Changed by the Project Options and that May Act to Affect the Project Options**

<table>
<thead>
<tr>
<th>Aspects of the Environment that may Cause a Change in the Project Options or Status Quo</th>
<th>Baseline Condition (2005) as Compared to Pre-causeway</th>
<th>Future Environment (2025) as Compared to Baseline Conditions (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Transport Process</td>
<td>The causeway resulted in a decrease in energy available for sediment transport and subsequent river channel infilling.</td>
<td>The baseline condition is not at equilibrium and thus channel infilling will continue.</td>
</tr>
<tr>
<td>Tidal Prism</td>
<td>The causeway resulted in a reduction in the extent and energy of the tidal prism.</td>
<td>The baseline condition is not at equilibrium and thus a further reduction in tidal prism extent and energy is expected.</td>
</tr>
</tbody>
</table>
| Weather | Freezing of gates. | No change, freezing of gates continues. | No gates under Project Options.
* These are the aspects of the environment that will be changed by implementation of the Project Options and that may in turn act to affect the Project Options. |
the Modelling Component Study (AMEC, 2005b). Those aspects of the environment that will be altered by implementation of the Project Options are then determined to be the aspects of the environment that will be changed by implementation of the Project Options and that may, in turn, affect the Project Options.

From Table 10.1.1, the aspects of the environment that will be changed by implementation of the Project Options and that may, in turn, affect the Project Options include:

- sediment transport process;
- tidal prism;
- flooding; and
- ice (particularly sea ice).

10.2 Threshold for Determination of Significance

A significant negative effect of the environment on the Status Quo and Project Options:

- would result in damage to Project Options or Status Quo infrastructure, resulting in a long-term interruption in service or in repairs that could not be technically or economically implemented; or
- would result in failed mitigation (e.g., landfill protection) causing environmental damage that could not be technically and economically corrected or compensated in a feasible manner.

10.3 Evaluation of the Effects of the Environment on the Project Options and the Status Quo

The section provides the evaluation of how each aspect of the environment (baseline and future) affects the design, implementation and operation of the Project Options and the operation of the Status Quo.

10.3.1 Sediment Transport Process

Sediment transport is determined by forces such as tidal energy and river base flow acting to erode and suspend sediment particles in areas of high energy and deposit sediment particles in areas of low energy. This process is hereafter referred to as the sediment transport process. In the period since construction of the causeway, this process has not been in equilibrium as evidenced by the continued infilling of the river channel below the causeway. This trend is expected to continue into the future under the Status Quo. As a result, the Gate Management Plan will continue to be necessary to prevent sediment plugs from forming directly above and below the causeway. Similarly, the fishway will continue to fill in with sediment keeping it in a non-effective state (i.e., does not pass most fish species most of the time). Infilling in the river channel will also continue to cause other related problems such as decreased tidal energy and extent (Sections 8.3 and 8.7), increased flood risk (Section 8.8 and 9.13.4.6) and poor water quality (Section 8.2.4.2). These are considered negative environmental effects of the Status Quo on the sediment transport process. However, many of these issues would likely require future mitigation (e.g., enhanced Gate Management Plan including possible dredging and other
drastic measures such as blasting) and in this regard, the Status Quo is also affected progressively by the sediment transport process.

The unique sediment transport process within the Petitcodiac River was one of the primary reasons that replacing the fishway (Project Option 1) was not technically and economically feasible as presented in Chapter 6. Specifically, sediment was deposited in the fishway making it non-effective as described above. Project Option 2 required the gates to be open year round and this became, in effect, the same as Project Option 3. Project Options 3 and 4 were determined to have channel opening widths that were sufficient in size to allow for the successful transportation of sediment and migration of fish.

The large volumes of sediment (i.e., mudflats) adjacent to the existing causeway and control structure will require construction techniques specific to working within soft sediment. Where possible, some work may be conducted under frozen ground conditions to improve the ability of earth moving machines to work in this normally almost liquid mud environment.

As a result of increased tidal energy and extent (Sections 8.3 and 8.7), sediment stabilization mitigation will be required in areas identified as sensitive (including the wetland area between the former Moncton Landfill and the river channel) during Stage 1 of the implementation process. In addition, dredging of a channel in the sediment plug above the causeway may be required to increase the size of the initial tidal prism to accelerate the redistribution of sediment.

### 10.3.2 Tidal Prism

The tidal prism will not directly affect the causeway or control structure under the Status Quo as the causeway is designed to withstand a more substantive tidal prism then exists at baseline conditions. Under the Status Quo, it is predicted that the extent and energy of the tidal prism will continue to diminish. As a result, sediment will continue to be deposited with all the associated negative outcomes previously described (e.g., increased flood risk), the wastewater from the GMSC will be increasingly concentrated near the source at Outhouse Point, and the tidal bore will become even less of a tourist attraction. These are considered negative environmental effects of the Status Quo on the tidal prism. However, these issues will likely require future mitigation (e.g., improved municipal water treatment).

After implementation of the Project Options, the tidal prism will extend upstream of the causeway as far as the original head of tide near Salisbury. The increased extent of the tidal prism will bring saltwater in proximity with freshwater vegetation and with Ducks Unlimited constructed wetlands and dyked agricultural land. As a result, the Project Options include mitigation to protect the Ducks Unlimited wetlands and dyked agricultural land from saltwater intrusion. The increased tidal prism extent and energy may result in the flooding of agricultural land with saltwater. As a result, the Project Options include mitigation to protect agricultural land by improving the existing dykes and aboiteaux where required.

After the implementation of the Project Options, the increased tidal prism extent and energy may bring water in contact with the former Moncton Landfill at extreme high tides. As a result, the Project Options include mitigation to prevent the erosion of the landfill. In addition, the
increased tidal prism extent and energy may cause shoreline erosion on the Riverview side of the river just above the causeway, and in Moncton near the confluence (see Glossary) with Halls Creek (site of the Château Moncton Hotel). As a result, the Project Options include mitigation (i.e., riprap) for the protection of shoreline in identified erodible areas.

### 10.3.3 Weather (Precipitation, Temperature and Wind)

Extremely cold temperatures have caused the gates to freeze in the past, making the gates inoperative. This can be a dangerous situation if opening of the gates is required to prevent flooding. This will continue under the Status Quo.

The climate, including weather, of the Assessment Area is described in Section 5.3.1. The primary effect of weather on the Project Options is the temporary delay of construction activities during periods of inclement weather. Inclement weather may present a safety hazard for workers, or may make it difficult to perform specific construction techniques. This may include periods of unseasonably warm weather in the winter that prevent frozen ground conditions. The Project Options development schedule will be designed in anticipation of weather induced delays.

The Project Options infrastructure will be designed to National Building Code of Canada standards that include consideration of temperature, precipitation and wind, as appropriate. The effects of predicted climate change on the Project Options are presented in Section 10.3.6.

### 10.3.4 Flooding

For the Status Quo, it is anticipated that the frequency and occurrence of flooding in communities along the Petitcodiac River, particularly in the GMA, will continue to increase as a result of sediment infilling the river channel (Sections 5.2.6 and 9.13.4.6). The future risk of flooding may further be increased by the effects of climate change (Section 10.3.6). Implementation of the Project Options will reduce the likelihood of future flooding events as described in Section 8.8.

### 10.3.5 Ice

For the Status Quo, ice will continue to gather on the upstream side (Section 5.2.6) of the control structure and will require management through the Gate Management Plan.

For Project Option 3, the possibility of ice jams due to the existence of the piers resulted in three piers being removed as a modification to the design of this Project Option. Project Option 3 now has a minimum channel width of 24 m, which is 3 times greater than the maximum expected piece of entrained ice (8 m).

For the Project Options, the possibility of sea ice travelling as far upstream as the causeway due to the increased tidal prism energy and extent (Sections 8.3 and 8.7) has resulted in the need to protect the base of the former Moncton Landfill from the erosional force of ice. Given this mitigation and frequent monitoring of effectiveness and competency of the mitigation over the life of the Project Options, it is very unlikely that substantive damage to the landfill would occur as a result of sea ice.
10.3.6 Climate Change

In 2001, the Intergovernmental Panel on Climate Change issued the following predictions for the effects of climate change in the Bay of Fundy over the next 100 years (Intergovernmental Panel on Climate Change, 2001):

- an increase in annual mean temperature of 4 to 5 Celsius degrees;
- a slight increase in annual mean precipitation (daily amount on a day when it rains or snows) of 5 mm; and
- an increase in the mean sea level between 9 and 88 cm (average predicted value of 50 cm).

In addition, the Environment Canada Climate Change Division has made the following predictions using the Canadian Global Coupled Model, CGCM1, for the City of Moncton (Environment Canada, unpublished):

- annual precipitation (total) is predicted to increase by 2% (2.3 cm) within the next 30 years, and by 5% (5.7 cm) within the next 90 years; and
- annual mean temperature (maximum) is predicted to increase by 1.3°C within the next 30 years, and by 4.1°C within the next 90 years.

The global climate modelling work of Meteorological Service of Canada scientists at the Climate Modelling and Analysis Centre in Victoria, British Columbia determined that return periods for significant rainfalls could be reduced by as much as a factor of two. Therefore, heavy rainfall amounts with a return period of 100 years could occur once in 50 years, for example.

On the Environment Canada website “Backgrounder: Sea level Rise and Climate Change Impacts and Adaptation Needs on Prince Edward Island Study Results” (Environment Canada, 2005), a subsidence rate of 20 cm/100 years is suggested for Prince Edward Island. This risk-conservative estimate of subsidence is due primarily to “post-glacial adjustments to changing ice and water loads”, and is representative of the subsidence rate that occurs within the Assessment Area. If this value is added to the extreme estimate of sea level rise for this region (88 cm), a resulting 108 cm relative sea level rise may occur by the end of the next 100 years. If this were to occur during an 8.0 m tide (approximately once per year), then the resulting water elevation at the causeway would be 9.08 m. If there were also to be an extreme storm occurring that caused a storm surge of 1.5 m at Moncton, then the resulting water elevation at the causeway would be 10.58 m. Even given this extraordinary set of overlapping and highly improbable circumstances, the resulting water elevation (10.58 m) would still be 1.42 m below the bridge deck of Project Option 3, and 1.92 m below the bridge deck of Project Option 4(A-C).

This sea level rise scenario also increases the risk of water coming over the existing causeway bridge deck for the Status Quo. The deck height of the existing causeway structure (and therefore the structure under the Status Quo) is 9.5 m. Therefore, the worst case scenario event described above (resulting in a water elevation of 10.58 m) would certainly overtop the
causeway structure. In fact, given a subsidence rate of 20 cm/100 years, the conditions that could cause a water elevation that would overtop the causeway (in 2105) would range from:

- a sea level rise of 88 cm and a storm surge of 0.42 m; to
- a sea level rise of 9 cm and storm surge of 1.21 m.

The sensitivity to sea level rise for the Petitcodiac River estuary has been rated as moderate by Natural Resources Canada (NBDNR, 2004).

These precipitation and sea level climate change predictions greatly increase the likelihood of flooding events for the Status Quo in the communities along the Petitcodiac River, both above and below the causeway. Implementation of the Project Options will reduce the likelihood of future flooding events compared to the Status Quo as described in Section 8.8.

It is not anticipated that an increase in annual mean temperature of 4 to 5 Celsius degrees will cause a change to the Project Options or the Status Quo.

**10.3.7 Earthquake Activity**

The following text is an excerpt from the internet publication “A summary of the historical earthquake activity in the province of New Brunswick” by Dr. Kenneth B.S. Burke (Burke, 2004).

February 8th, 1855 earthquake was reported by Dawson (1868) to have occurred at "the bend of the Petticodiack", the nineteenth [century] name for the Moncton region in southeastern New Brunswick. ... This earthquake was felt throughout most of New Brunswick and Nova Scotia and as far to the southwest as Boston, Massachusetts. A felt area IV magnitude of 5.2 was proposed in a reevaluation of this event by Leblanc and Burke (1985) and the epicentre proposed by Smith (1962) of 46.0°N, 64.5°W was accepted. ... Minor damage was reported for this earthquake, such as in an account from Hopewell, a village 17 km south-southwest of the epicentre, which states "At the chemical factory in this place, the shock caused the plastering of walls to crack and rend from top to bottom ....", New Brunswick Reporter, February 16, 1855.

Reports of two other felt earthquakes in the Moncton region were found during the scanning of the newspaper Le Moniteur Acadien for the years 1867 to 1926. An event on August 11, 1867 was felt in a number of communities from Buctouche to Sackville, along the coast northeast of Moncton, with an estimated felt area magnitude of 3.8. A smaller event was felt only in Moncton and Shediac, 20 km northeast of Moncton, on June 19, 1899, with an estimated felt area magnitude of 3. Another 24 small magnitude events are listed for the region (45.5°N to 46.5°N; 64°W to 65°W) in the Canadian National Seismological Database for the period 1800 to October 1, 1999. Two earthquakes of magnitudes mN =3.0 and mL =2.2 respectively in the Dorchester area in 1972, 35 km south-southeast of Moncton, and two earthquakes of magnitudes mN =3.6 in the Turtle Creek area, 10 km southwest of Moncton, in 1984 and 1988, were felt.
Examining the relationship of the earthquake activity to the structural geology of the Moncton region suggests that the seismicity is associated with the reactivation of faults, first created during the pull-apart formation of the Moncton Carboniferous sedimentary sub-basin.

The Project Options will be designed and constructed to the applicable design standards for earthquake activity in this area. A seismic source zone including events as large as magnitude 7.0, has been incorporated into Earthquakes Canada’s 4th Generation seismic hazard model. The 4th Generation seismic hazard model has been adopted as the basis for the forthcoming 2005 edition (fall release) of the National Building Code of Canada. Developments since the seismic hazard model that was likely used at the time of the existing control structure include (but are not limited to):

- refined recurrence statistics for the earthquake populations;
- better appreciation of the maximum size of earthquakes to be expected (for example magnitude 6.0 was likely used for design of the existing causeway control structure, while Earthquakes Canada’s 4th Generation model uses 7.0);
- new seismotectonic models (i.e., models linking seismic activity to movement of the earth’s crust) to explain the origins of the earthquakes, and hence which earthquake clusters may form earthquake populations;
- new ground motion relations, better reflecting the strong short-period shaking to be expected in eastern Canada, reflecting the observed ground motions from the 1988 Saguenay earthquake (approximately 150 km north of Quebec City); and
- estimation using different ground movement parameters.

In addition to these and other improvements, the 2005 code will be based on seismic hazard computed for a 2% probability in 50 years (0.04% per annum or 1/2450 years).

Values intended for 2005 edition of the National Building Code of Canada have been tabulated for some 650 locations (including Moncton) across Canada in an Open File. Although these values have yet to be formally adopted and are subject to change, the next National Building Code of Canada is expected to be adopted in the fall of 2005. This open file can be accessed and downloaded from Earthquakes Canada’s website at: www.seismo.nrcan.gc.ca/hazards/OF4459/index_e.php.

A seismic disturbance greater than the design base earthquake could result in damage to the Project Options infrastructure. However, given the probability of occurrence of 1/2450 years, it is very unlikely that this will be exceeded during the lifespan of the Project Options infrastructure.

10.4 Summary

Engineering planning and design always involves consideration of effects of the environment on a project and the planning and engineering design for the Project Options are no exception. The mitigation (e.g., riprap of erodible shorelines) for potential effects of the environment on the
Project is inherent in the planning and engineering design presented in this EIA Report. In addition, Stage 1 of the Project Options implementation plan will further define the mitigation for construction and operation of the Project Options and monitoring and follow-up, as described in Chapter 13, will further minimize the likelihood of a substantive effect of the environment on the Project Options from occurring.

In consideration of the likely effects of the environment on the Project Options and the proposed mitigation (including follow-up), the residual effects of the environment on the Project Options are determined to be not significant.

By contrast, the Status Quo will continue to result in a changing environment due to sedimentation and reduction in tidal exchange. This will in some instances result in an effect of the environment on the Status Quo that is significant (e.g., increased flooding risk due to decline in channel conveyance, climate change related sea level rise made worse).
11.0 CUMULATIVE ENVIRONMENTAL EFFECTS ASSESSMENT

11.1 Background

The Guidelines require that “an assessment of cumulative effects must be conducted . . . in consideration of each identified VEC”, for both positive and negative (negative) cumulative effects. Within these parameters, and as stated in the Terms of Reference, “Cumulative environmental effects will be assessed following the guidance of the CEA Agency (e.g., CEA Agency 1994; 1999) and Operational Policy Statements”.

Under CEAA 16(1)(a), every screening of a project shall include a consideration of “any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out”. As defined in the Cumulative Effects Assessment Practitioners Guide (the “Practitioners Guide”) (Hegmann, et al., 1999), cumulative environmental effects are “changes to the environment that are caused by an action in combination with other past, present and future human actions”; where actions are defined as “any project or activity of human origin”.

The first step of cumulative environmental effects analysis is to quantify if there are environmental effects of the Project Options or Status Quo. If so, then it must be established if the environmental effects of the Project Options or Status Quo overlap with those of other past, present, or future actions. Finally, the significance of the cumulative environmental effects that result from the overlap must be determined. In this regard, cumulative effects assessment is an analysis of how the environmental effects of the Status Quo and Project Options contribute to the cumulative environmental effects of past, present and future actions acting on an environmental component (e.g., wetland).

As also stated in the Practitioners Guide, “Cumulative effects are not necessarily that much different from effects examined in an EIA; in fact, they may be the same.” For this EIA, the above statement is true with few exceptions. These exceptions are further described in Section 11.2. This is consistent with the following excerpt from the Practitioners Guide, “With the exception of the consideration of future actions, the requirements of cumulative effects assessment are identical to the requirements of a good EIA (the consideration of the effects of other actions is not necessarily new to cumulative environmental effects as the existing environmental setting of a project has typically recognized other actions at least within the EIA’s study area).” In this regard, Table 11.1.1 summarizes what cumulative environmental effects have been considered in the EIA Report prior to this chapter.

11.2 Methodology

11.2.1 General

As previously mentioned, this EIA is different than most EIAs in many ways. First, it is an EIA on a mitigative measure (provision of fish passage) that clearly was a Condition of Approval by DFO to construct the causeway. Another key difference that affects the assessment
Table 11.1.1 Cumulative Environmental Effects Considered in Previous Chapters

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description of How Cumulative Environmental Effects Were Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 5 (Description of Past and Existing Environment)</td>
<td>Provided a summary of the detailed past (pre-causeway), present (post-causeway) and baseline (2005) conditions as characterized in the Biophysical and Socio-economic Component Study (AMEC, 2005a). For example, Chapter 5 provided trends over the timeframe of available information (pre-causeway and post-causeway) for wetland change (e.g., type and area) using aerial photos, fish passage using past counts at fishway, fish stocks using past DFO estimates and angler catch rates, odour levels using information such as interviews and reports, changes in tourism activity, changes to vessel traffic, etc. Chapter 5 also included mention of past and present projects such as the tri-community sewage treatment facility at Outhouse Point, the discharge of untreated sewage from communities along the Petitcodiac River, the former landfill sites, the Gunningsville Bridge, agricultural dykes and aboiteaux, etc.</td>
</tr>
<tr>
<td>Chapter 6 (Evaluation of Existing Fish Passage Conditions and the Status Quo and Project Options in Achieving the Fish Passage Project Objective)</td>
<td>Expanded on the discussion in Chapter 5 for the issue of fish passage. In Section 6.2, the combined environmental effects of past and present actions on the ability of fish to migrate within the Petitcodiac River for life cycle purposes were provided in detail. A detailed description of the past and present operation of the causeway, fishway and gate structure (including the Gate Management Plan) on fish passage was provided. Also included in the discussion were other past and present impediments to fish passage such as the accumulation of sediment, caused by the existence of the causeway and the reduction of DO levels from discharge of effluents into the river.</td>
</tr>
<tr>
<td>Chapter 7 (Project Description and Implementation Strategy)</td>
<td>Presented a detailed description of the Project Options that meet the fish passage Project Objective. Included in the Project Options descriptions was mitigation (e.g., protection of shoreline) intended to minimize the magnitude and/or likely occurrence of environmental effects, and therefore cumulative environmental effects.</td>
</tr>
<tr>
<td>Chapter 8 (Description of the Future Anticipated Changes to the River)</td>
<td>Provided a summary of the results of the Hydrodynamic and Sediment Transport Modelling Component Study (AMEC, 2005b). These results were used to predict what the future (year 2025) environmental conditions would be in consideration of many factors, including consideration of the actions of other past and present projects and activities. For example, the modelled river channel included the presence of the remaining causeway and control structure, the Gunningsville Bridge, the former landfill sites, the road at Outhouse Point, the dykes downstream and upstream of the causeway, the Ducks Unlimited wetlands and the shoreline protection near Halls Creek. In addition, the modelling also included consideration of known future projects within the river channel such as the New Petitcodiac River Bridge, the planned modifications to Jonathan Creek, and global factors like projected mean sea level rise due to climate change. Trend analysis was used to look forward 50 and 100 years from baseline to 2055 and 2105, respectively.</td>
</tr>
<tr>
<td>Chapter 9 (Environmental Effects Analysis)</td>
<td>Presented the environmental effects assessment for each VEC. In Chapter 9, the environmental effects of the Project Options and the Status Quo on the baseline (as described in Chapters 5 and 6) and future modelled conditions (as described in Chapter 8) were assessed. In this regard, the environmental effects assessment did consider the cumulative environmental effects of the Status Quo and Project Options with those other past, present and future actions that were identified in Chapters 5, 6 and 8.</td>
</tr>
</tbody>
</table>

of cumulative environmental effects is that the causeway and control structure are part of a past project that will act in combination with the proposed modification of the causeway and control structure (i.e., Project Options) to a much greater extent than all other actions combined. This presents a unique challenge to this cumulative environmental effects assessment. In order to better understand the complicated nature of this relationship, the modelling of the river included a consideration of the baseline conditions (that are the result of the existing causeway and control structure) in combination with the future actions of the Status Quo and Project Options,
as described in Section 11.1. The modelling also offered consideration of how the future changed environment (altered by the Status Quo and Project Options) will act on the Status Quo and Project Options (Chapter 10). The resulting predicted future environment therefore included consideration of the Status Quo and Project Options acting in combination with all of the known past, present and future environmental effects of the causeway and control structure (both existing and modified as under the Project Options).

As explained in Section 11.1, the EIA Report has already considered the cumulative environmental effects of the Status Quo and Project Options acting in combination with other past and present actions and future actions as included in the hydrodynamic and sediment transport modelling. However, there are other cumulative environmental effects of the Status Quo and Project Options that have not been previously considered. Most notably these include the cumulative environmental effects of the Status Quo and Project Options with other future actions on socio-economic VECs (e.g., Tourism) and on biophysical VECs (e.g., Terrestrial and Wetlands) outside of the modelled river channel.

11.2.2 Scope of the Cumulative Environmental Effects Assessment

The Guidelines do not provide a definition of the scope of the cumulative environmental effects assessment. Therefore, the scope of the cumulative environmental effects assessment was done following the guidance of the Practitioners Guide. As per the Practitioners Guide, it is important to note that for a project (i.e., Project Options or Status Quo) to have the potential to result in a cumulative environmental effect, the project must have a measurable environmental effect. Therefore, it follows that this cumulative environmental effects assessment will specifically consider the following types of interactions:

- the measurable environmental effects of the Status Quo and Project Options acting in combination with predicted measurable effects of future actions on biophysical VECs outside of the modelled river channel (e.g., regional change in wetland area);
- the measurable environmental effects of the Status Quo and Project Options acting in combination with predicted measurable effects of future actions on biophysical VECs within the river channel, but not included in the hydrodynamic and sediment transport model (e.g., changes to water quality); and
- the measurable environmental effects of the Status Quo and Project Options acting in combination with the predicted measurable effects of future actions on socio-economic VECs (e.g., changes in tourism).

Generally, the environmental effects of the Project Options (i.e., Project Options 3, 4A, 4B, 4C) do not differ substantially as compared to the environmental effects of the Status Quo, that are in many cases quite different. Therefore, the cumulative environmental effects analysis compares the Status Quo with the Project Options, with no mention of a specific Project Option unless the difference in environmental effects is sufficient to merit further discussion.
The cumulative environmental effects assessment follows these steps:

- describe the environmental effects of the Status Quo and Project Options;
- describe the potentially measurable environmental effects of other actions that may interact with the Status Quo and Project Options;
- identify the potential interactions (cumulative environmental effects) of the Status Quo and Project Options with the other actions;
- evaluate the significance of the resulting cumulative environmental effects; and
- suggest mitigation to minimize the identified cumulative environmental effects, if and as appropriate.

The description of the environmental effects of the Status Quo and the Project Options (Step 1) was carried out in Chapter 9 (Environmental Effects Analysis) of this EIA Report. The remaining four steps are carried out in Sections 11.3-11.6, respectively.

11.2.3 Cumulative Environmental Effects Assessment Area

The spatial boundaries for the consideration of cumulative environmental effects analysis (Assessment Area) was defined by the extent of the measurable environmental effects of the Project. For example, for the cumulative environmental effects analysis of changes to wetlands, the Assessment Area is defined as the Petitcodiac River from Salisbury to Chignecto and Shepody Bays.

The temporal boundaries for the consideration of cumulative environmental effects analysis was defined as beginning at the point in time at which background knowledge was sufficient (approximately 1965 for most VECs) and extending into the reasonably foreseeable future (approximately 5 years) for the selection of other projects that will be carried out.

11.3 Description of Actions that may Interact with the Status Quo and Project Options

As stated in the Practitioners Guide, “Cumulative effects occur as interactions between actions, between actions and the environment, and between components of the environment.” Figure 11.3.1 is a graphical representation of how different categories of actions may have environmental effects that may occur in isolation, or that may overlap one another (cumulative environmental effects of overlapping actions), or that may overlap with those of the Project Options and the Status Quo (cumulative environmental effects of actions with the environmental effects of the Status Quo and Project Options). The actions represented in Figure 11.3.1 are divided into the following categories:

- land use actions;
- cultural actions;
- economic actions; and
- global actions.
These categories are further described in the following subsections. In general, the global and
land use actions tend to affect the biophysical environmental components while the cultural and
economic actions tend to affect the socio-economic environmental components. This is shown
by noting the area of overlap of each the action category circles. There are of course
exceptions and these will be discussed in Section 11.4 where warranted.

Only those actions that have measurable environmental effects were considered for the purpose
of the cumulative environmental effects analysis, as described in Section 11.2.

11.3.1 Land Use Actions

There are a number of land use actions the environmental effects of which may act in
combination with the environmental effects of the Status Quo and Project Options. The specific
land use actions that are considered in this cumulative environmental effects assessment are:

- development projects;
- urbanization;
- wetland conversion and/or wetland loss; and
- creation of wetland.

Figure 11.3.2 shows the known land-use presently occurring within the Assessment Area, and
also includes the locations of development projects that will be carried out (as discussed in
Section 11.3.1.1.

11.3.1.1 Development Projects

The selection of projects that will be carried out was accomplished in consultation with NBDELG
(Gagnon, pers. comm.) and in communication with the municipalities along the Petitcodiac
River. These projects were selected based on their proximity to the Petitcodiac River, the
potential for interactions with the environmental effects of the Project, and the likelihood of the
project(s) being carried forward (e.g., the project is registered, or is in the EIA process, with the
Province under the Environmental Impact Assessment Regulation, or is included in a municipal
development plan).

Future activities were selected based on public and regulatory consultation, municipal
development plans, the Biophysical and Socio-economic Component Study (AMEC 2005a), and
the professional experience of the AMEC Study Team.

The projects that will be carried out and the environmental effects of which could potentially act
in combination with the environmental effects of the Project are presented and described in
Table 11.3.1. Included in the table is a summary of the potential environmental effects of the
projects. It should be noted that the level of information for each project varies as most have
not undergone the environmental assessment process (i.e., the project is registered, or is in the
process of being registered, with the Province under the Environmental Impact Regulation; or is
included in a municipal development plan) and do not have well developed project descriptions
at this time.
### Table 11.3.1 Other Future Projects for Consideration of Cumulative Environmental Effects

<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Description of Project</th>
<th>Potential Environmental Effects of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Petitcodiac River Bridge</td>
<td>• Bridge connecting Riverview and Moncton to replace Gunningsville Bridge.</td>
<td>• Direct loss of 0.6 ha of saltwater marsh along the Petitcodiac River.</td>
</tr>
<tr>
<td></td>
<td>• Scheduled for completion in 2005.</td>
<td>• Improved traffic flow between the City of Moncton and the Town of Riverview with a bridge deck elevation of 16 m.</td>
</tr>
<tr>
<td></td>
<td>• Emission of greenhouse gases, noise and dust during construction.</td>
<td>• Reduced risk of vehicular accidents during operation.</td>
</tr>
<tr>
<td>City of Moncton Assomption Boulevard Phase II and Vaughan Harvey Boulevard Extension</td>
<td>• Extension of boulevards to meet up with New Petitcodiac River Bridge.</td>
<td>• Direct loss of 1.1 ha of saltwater marsh and isolation of 0.3 ha of saltwater marsh along the Petitcodiac River.</td>
</tr>
<tr>
<td></td>
<td>• Scheduled for completion in June, 2006.</td>
<td>• Improved traffic flow between City of Moncton, City of Dieppe and Town of Riverview as well as the neighbouring communities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Emission of greenhouse gases, noise and dust during construction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased ambient noise during operation.</td>
</tr>
<tr>
<td>Virginia Avenue Extension Project in Dieppe</td>
<td>• 350 m extension joining Virginia Avenue with Paul Street.</td>
<td>• Direct loss of 0.1 ha of impounded freshwater marsh along the Petitcodiac River.</td>
</tr>
<tr>
<td></td>
<td>• Scheduled for completion in 2005.</td>
<td>• Emission of greenhouse gases, noise and dust during construction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Improved traffic flow during operation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased ambient noise during operation.</td>
</tr>
<tr>
<td>Riverview East-West Corridor Phase I</td>
<td>• A 4.7 km road that connects the New Petitcodiac River Bridge to Findlay Boulevard.</td>
<td>• Direct loss of 1.8 ha of freshwater wetland.</td>
</tr>
<tr>
<td></td>
<td>• Scheduled for completion in 2007.</td>
<td>• Emission of greenhouse gases, noise and dust during construction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Improved traffic flow during operation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased ambient noise during operation.</td>
</tr>
<tr>
<td>Name of Project</td>
<td>Description of Project</td>
<td>Potential Environmental Effects of Project</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Jonathan Creek Diversion| • Construct a new watercourse channel for Jonathan Creek. The current channel has begun to erode the soils adjacent to the former Moncton Landfill and has been creating environmental issues in Jonathan Creek. This project proposes the construction of a diversion channel in order to redirect the water flow from the existing channel and away from the former Moncton Landfill. | • Creation of 2.9 ha of saltwater marsh along the Petitcodiac River.  
• Reduced risk of former Moncton Landfill erosion and attendant environmental consequences.  
• Improved water quality of former Moncton Landfill leachate entering Jonathan Creek due to treatment from wetlands. |
| Fundy Gateway           | • A multi-use facility that is proposed to be built on disturbed and landscaped upland habitat bordering the coastal wetland immediately east of the old Gunningsville Bridge in the Town of Riverview. The facility will house Tourism Riverview and the Farmer’s Market and will provide offices and meeting rooms for other uses. Related infrastructure includes a boardwalk with kiosks. | • Improved tourism opportunities.                                                                                                                                  |
| Turtle Creek 2nd Dam     | • The construction of a 2nd dam in the Turtle Creek watershed to increase the water storage capacity of the City of Moncton, City of Dieppe and the Town of Riverview water supply. The current average daily consumption for the three municipalities is approximately 11 million gallons. Estimates provided show that by the year 2021, the average daily demand is anticipated at 18.32 million gallons. The 2nd dam is being proposed in order meet the tri-community with the anticipated demand. | • Increased available surface freshwater for human potable use.  
• Reduction of groundwater extraction.                                                                                                                            |
<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Description of Project</th>
<th>Potential Environmental Effects of Project</th>
</tr>
</thead>
</table>
| Chocolate River Holdings Ltd. - (Edgetts Landing south of Hillsborough) | • Motel, Restaurant & Campground Wastewater Treatment System Upgrade. | • Improved tourism opportunities  
• Improved water quality of receiving waters.  
• Reduction to public health risk from exposure to sewage-related bacteria. |
| Bedford Buck Ltd. - Westlake Subdivision Development | • A residential subdivision along the Petitcodiac River, near Riverview, with approximately 25 lots on the Riverview side of the headpond. | • Increased development within 30 m of a wetland.  
• Will create additional waterfront property. |
| City of Dieppe - Water Supply Development | • Groundwater exploration in Dieppe to supply potable drinking water. | • Increased groundwater extraction. |
| Village of Alma - Wastewater treatment | • Construction is underway. Site conditions require that the location and construction method of the outfall to the Upper Salmon River be revised.  
• Scheduled for completion in 2005. | • Improved water quality of receiving waters.  
• Reduction to public health risk from exposure to sewage-related bacteria. |
| Village of Salisbury - Wastewater treatment | • New lagoon wastewater treatment facility.  
• Scheduled for completion in 2005. | • Improved water quality of receiving waters.  
• Reduction to public health risk from exposure to sewage-related bacteria. |
| Village of Petitcodiac - Wastewater treatment | • Lagoon wastewater treatment facility expansion.  
• Scheduled for completion in 2005. | • Improved water quality of receiving waters.  
• Reduction to public health risk from exposure to sewage-related bacteria. |
| NBDOT - Complex Watercourse Crossing at Jonathan Creek | • Replacement of three culverts along Jonathan Creek with larger culverts. | • Reduce the likelihood of occurrence and the extent of seasonal flooding upstream. |
| Replacement of combined sanitary and storm sewers in the tri-community area (primarily downtown City of Moncton) | • Replace old combined sanitary/storm sewers with separate sanitary and storm sewers. | • Reduce the likelihood of exceeding the capacity of the partial primary sewage treatment facility at Outhouse Point and also reduce risk of untreated sewerage being released due to overflow of combined systems.  
• Improved water quality of receiving waters.  
• Reduction to public health risk from exposure to sewage-related bacteria. |
<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Description of Project</th>
<th>Potential Environmental Effects of Project</th>
</tr>
</thead>
</table>
| Molson Brewery in Moncton             | • Development of the only Molson Brewery in Atlantic Canada by 2007. | • Creation of approximately 50 jobs.  
• Increased employment opportunity may improve labour and economy. |
| Moncton Downtown Development          | • Development along Assumption Boulevard was approved by City of Moncton Council on January 18, 2005 and includes a 150-room hotel, 60-unit apartment complex and a convention center.  
• The Province of New Brunswick is also planning to construct a new courthouse in Downtown Moncton. | • Increased capacity for tourism and hosting of conferences may lead to increases in tourism.  
• Increased employment opportunity may improve labour and economy. |

### 11.3.1.2 Urbanization

Urbanization projects typically include the development of buildings, roads and services infrastructure (e.g., sewers and electrical distribution lines). Urbanization projects also include the development of suburbs and their associated municipal services such as water treatment facilities and connector roads, and common developments such as building commercial structures (e.g., grocery stores and parking lots). Urbanization activities include road maintenance (e.g., use of sand and salt for winter safety and snow removal and deposition) and vehicle traffic.

The sum total of the environmental effects of urbanization project and activities to date on a particular VEC is likely greater than any of the projects listed in Table 11.3.1. For example, the past urbanization of the City of Moncton in small increments has created a situation where flood risk is elevated due to increased paved surface area resulting in a "flashy" storm water drainage response (i.e., water level goes up and down faster than normal) combined with decreased drainage capacity from channel infilling. Past urbanization within the Assessment Area (Figure 11.3.1) is measurable as the total amount of land that has been paved, or is used as residential, commercial or industrial within a municipality. Within the Assessment Area, this includes, but is not limited to, Moncton, Riverview and Dieppe, as well as Salisbury, Dover and Sackville.

The consideration of future urbanization is limited to known projects as listed in Table 11.3.1.

### 11.3.1.3 Wetland Conversion and/or Wetland Loss

The largest contributing action to wetland loss along the Petitcodiac River has most likely been the conversion of saltwater marsh to agricultural land through the use of dykes and aboiteaux. The extent of wetland conversion cannot be accurately quantified, as these actions have been occurring for more than 300 years. A conservative estimate of the proportion of saltwater marsh that has been converted to agricultural land in the Upper Bay of Fundy is at least 65% (NWGG,
1988). Using the estimate of a 65% conversion (wetland loss) and the total pre-causeway saltwater marsh area of 1,170 ha, it is conservatively estimated that 2,170 ha of saltwater marsh has been converted to agricultural land within the Assessment Area.

Development projects are one of the key anticipated future reasons for wetland loss in the Assessment Area. The development of the causeway and control structure has already had a significant environmental effect on wetlands within the Assessment Area, as described in Section 9.3.4.1. From Table 11.3.1, it is calculated that the sum total amount of wetland that will be lost to known future development projects is 3.9 ha. This includes the following projects:

- New Petitcodiac Bridge (-0.6 ha);
- City of Moncton Assomption Boulevard and Vaughan Harvey Boulevard Extension (-1.4 ha)
- Dieppe Virginia Avenue Extension (-0.1 ha); and
- Riverview East-West Corridor (-1.8 ha).

11.3.1.4 Creation of Wetlands

Wetland creation is generally done to provide habitat for waterfowl, as is the case with wetlands created by Ducks Unlimited, or is done as compensation for wetlands that have been lost to development projects. Wetland creation results in a net gain of wetland area while the intent of wetland compensation is to ensure that there is no net loss of wetlands.

The total amount of wetland that has been created by Ducks Unlimited within the Assessment Area is approximately 46 ha (AMEC, 2005a). The Ducks Unlimited wetlands will be preserved with the Project Options and the Status Quo, and therefore there are no anticipated environmental effects. As a result, Ducks Unlimited wetlands are not considered further in this cumulative environmental effects assessment.

The total amount of wetland creation that will occur as a result of compensation of projects included in Table 11.3.1 will vary from 3.9 ha to 39 ha, pending the ratio of compensation that will be required, but for the purpose of this cumulative environmental effects analysis will be conservatively considered as 3.9 ha (i.e., no net loss).

The total amount of wetland creation that will occur as a result of projects included in Table 11.3.1 is 2.9 ha by the Jonathan Creek Diversion Project.

11.3.2 Cultural Actions

There are many cultural actions that have the potential to generate environmental effects on both biophysical and socio-economic VECs. As a result, these cultural actions have the potential for interaction with the environmental effects of the Project Options and the Status Quo. Cultural actions are primarily activities that may include abstract concepts like changes in what is valued by society. The cultural actions that were considered for the cumulative environmental effects assessment relate to the following concepts:
changes in societal values;
changes in recreation and tourism pursuits; and
changes in environmental protection legislation.

11.3.2.1 Changes in Societal Values

A good example of a changing societal value (i.e., the general values held by a society) is the changing understanding of what a river means to a community. In the past, rivers were generally considered as a means of transportation and as a means of removing wastes from a community. Over the past few decades, there has been a general change in the way society perceives rivers and there has been a movement towards the restoration of urbanized rivers towards their original, natural state. This has been observed in many cities along the eastern coast of the United States (and in many places elsewhere), such as the Kennebec and Penobscot Rivers in Maine, the Connecticut River in Hartford and the Patapsco River in Baltimore. The establishment of a Petitcodiac River Riverkeeper is an example of this occurring within the Assessment Area. Another example of this occurring in the Assessment Area is the Fundy Gateway project as noted in Table 11.3.1. The Fundy Gateway project will provide a waterfront location for tourism information, and will include kiosks and a boardwalk. There have been other improvements along the Riverview riverfront downstream of the causeway as well, including a garden of native plants, and a paved walking path. As noted in Section 4.5.6.3 of the Biophysical and Socio-economic Component Study, the City of Moncton moved the downtown visitor information centre from City Hall to the Tidal Bore Park (on the waterfront) in 2003. These types of activities suggest that there is increasing public interest in the aesthetic aspects of the natural river, and that a societal change in how a river is valued is occurring.

Another related example of a changing societal value that has the potential to have environmental effects is the lessening in societal acceptance of the discharge of untreated sewage into waters, even where it is demonstrated that the receiving waters have sufficient assimilative capacity. This has fostered a movement towards improved sewage treatment facilities in many communities (e.g., Halifax, Nova Scotia; Saint John, New Brunswick; St. John’s, Newfoundland). This has been observed within the Assessment Area as indicated by the following projects in Table 11.3.1:

• Chocolate River Holdings Ltd. (Campground Wastewater Treatment upgrade);
• the Village of Alma Wastewater Treatment project (upgrade);
• the Village of Salisbury Wastewater Treatment project (upgrade);
• the Village of Petitcodiac Wastewater Treatment project (expansion); and
• the Replacement of Combined Sanitary Storm Sewers in the Tri-Community Area (separate sanitary and storm sewers).

These types of projects suggest that there is increasing public interest in improving/maintaining the aesthetic aspects of the river for recreational and public health reasons.
11.3.2.2 Changes in Recreation and Tourism Pursuits

Other types of cultural actions are related to changes in recreational and tourism pursuits. In recent years, the smallmouth bass has gained acceptance in New Brunswick as a sportfish, and smallmouth bass fishing tournaments, professional fishing guides and tackle stores now occur regularly in New Brunswick. Bird watching is also increasing in popularity as a recreational activity, and the walking paths along the river are popular locations for this recreational pursuit.

Similarly, kayaking has gained in popularity in New Brunswick and participants tend to prefer more swiftly moving water than do most canoers. The sport of riding the tidal bore with a kayak has become popular on other Inner Bay of Fundy rivers where a large tidal bore remains, such as exists on the Shubenacadie River of Nova Scotia.

New Brunswick Tourism and Parks has recently prioritized the development of coastal, natural wonders and heritage and culture tourism opportunities. Within the Assessment Area, changes in recreation and tourism pursuits has also followed the changing understanding of what a river means to a community (Section 11.3.2.1). There is a growing number of planned tourism opportunities along the natural river front. An example is the Fundy Gateway project in Table 11.3.1. These types of projects and activities suggest that there is increasing interest in exploiting the aesthetic aspects of the natural river as a tourism opportunity.

The Moncton Downtown Development project in Table 11.3.1 is not strongly linked to the presence of the river, but rather is linked to the presence of the historic and commercial downtown centre. However, it does provide additional capacity for tourism in the region.

11.3.2.3 Changes in Environmental Protection Legislation

Another type of cultural action is related to Changes in Environmental Protection Legislation. Protective legislation have the potential to result in environmental effects on biophysical VECs and socio-economic VECs. For example, the City of Moncton has a Heritage Preservation By-law (as of 1996) that is based on the protection of architecturally or historically important buildings. Other municipal and provincial laws exist to prevent illegal dumping of wastes, burning of hazardous materials (e.g., asbestos) and to ensure the non-compensated loss of wetlands. The purpose of the recently issued Code of Practice for the Management of Road Salts (Environment Canada, 2004b) is in fact to reduce the cumulative environmental effects of road salt application on the receiving waters. Many similar protective laws exist for other environmental components such as air quality and water quality, and these laws may be altered in the future, and new laws may be passed.

The measurable environmental effects of Changes in Environmental Protection Legislation include the planning and development of projects such as those wastewater treatment projects listed in Section 11.3.2.1 for Changes in Societal Values, and the development and implementation of road salt management plans in the City of Moncton and Town of Riverview.
11.3.3 Economic Actions

There are many economy related actions that have the potential to generate environmental effects that overlap with those of the Project Options and Status Quo. Economic actions are activities that affect the economy, and may indirectly affect other socio-economic and biophysical environmental components. The economic actions that were considered for the cumulative environmental effects assessment relate to the following concepts:

- population growth and demographic shift; and
- change in market structure.

11.3.3.1 Population Growth and Demographic Shift

Changes to the population census (i.e., number of people) and the population demographics (e.g., age, gender and race) has the potential to indirectly lead to environmental effects on the available labour force, the need for public services, recreational activities and other factors. The following excerpt is from the City of Moncton Municipal Development Plan (City of Moncton, 2002).

“There is a direct relationship between prevalent socio-economic conditions within the City and region and the population and demographic trends affecting the community. The population, as a whole, is aging. It is anticipated that the population of seniors older than 85 years of age will increase by 158% in Moncton ... by the year 2006... At this age, there is generally a need for extensive medical services, special housing and a variety of other services that younger populations do not require. Regionally, the 15 to 19 year old populations are projected to decline by 19% over the same period. Schools will be affected. Demand levels for active and team sport recreation will tend to decline, proportionately.”

More obvious is that changes to population numbers and demographics requires appropriate changes to infrastructure and services. The following excerpt the City of Moncton Municipal Development Plan (City of Moncton, 2002) provides an example of this concept.

“The City has invested substantial funds in major roads, a large sewerage collection and treatment system, recreation and cultural facilities and a soon-to-be-developed potable water treatment system. All of these infrastructures, quite rightly, are designed for a larger, ultimate population. City Council ... wants to insure that the rate at which growth occurs is balanced so as to insure public services are not overburdened.”

The measurable environmental effects of Population Growth and Demographic Shift, and therefore the environmental effects considered further in this cumulative environmental effects analysis, are the same as those identified previously for Land Use Actions in Section 11.3.1.
11.3.3.2 Change in Market Structure

Another key group of actions that have the potential to affect the economy within the Assessment Area are those that relate to a change in the market structure. This is recently observed within the Assessment Area as an overall trend for the economy to change away from goods manufacturing towards a services based economy (City of Moncton, 2002). It is currently anticipated that the primary future business in the Assessment Area will be transportation and distribution of goods that are produced elsewhere. Also, growth in knowledge and communications based industries is expected (City of Moncton, 2002). This change in market base may result in less industrial development and more transportation and communication infrastructure development.

Table 11.3.1 does not necessarily reflect this trend towards a goods and services based economy. For example, the Molson Brewery project is an industrial project. This is mostly the result of Table 11.3.1 including only those projects that are in the provincial registration process, that is not applicable to most commercial developments such as stores and light industry such as call centres.

The measurable environmental effects of a Change in Market Structure, and therefore the environmental effects considered further in this cumulative environmental effects analysis, are the same as those identified previously for Land Use Actions in Section 11.3.1.

11.3.4 Global Actions

There are a number of Global Actions that may act in combination with the environmental effects of the Status Quo and Project Options. This cumulative environmental effects assessment focuses on Global Actions that have measurable environmental effects within the Assessment Area (e.g., regional air quality as a measurement of the cumulative emissions of global burning of fossil fuels acting on the regional airshed), or that have measurable environmental effects that affect the Assessment Area (e.g., offshore commercial fishing), to interact with the environmental effects of the Status Quo and Project Option. These Global Actions are:

- burning of fossil fuels; and
- commercial fishing.

The environmental effects of climate change overlapping those of the Project Options and Status Quo are considered in Chapter 10 (Effects of the Environment on the Project).

11.3.4.1 Burning of Fossil Fuels

The air quality in a given region is the result of local, regional and global actions contributing gases and contaminants to the regional airshed. For example, the air quality recorded at the City of Moncton monitoring station reflects the overall input of local, regional and global actions on the City of Moncton air quality at that particular moment. A general review of air quality within the Assessment Area is provided in Section 5.3.2 of this EIA Report. Specific air quality values are provided in Section 3.1 of the Biophysical Component Study (AMEC 2005a).
For the purpose of this cumulative environmental effects analysis, the measurable environmental effects of the global Burning of Fossil Fuels in the air quality within the Assessment Area are the measured levels of greenhouse gases within the near vicinity of the Petitcodiac River (e.g., as measured in Moncton).

### 11.3.4.2 Commercial Fishing

The Commercial Fishing industry has environmental effects on the target species of fish. Ideally, commercial fisheries are managed such that fish populations remain healthy while a maximum sustainable yield is obtained for market. However, this is often not achieved due to commercial fishing pressures under multiple jurisdictions with different quotas and seasons. This commonly occurs with migratory fish such as the Atlantic salmon and American shad. Commercial Fishing typically exerts a very large short-term effect on a fish community that is basically density dependent. Habitat loss or gain, as is predicted to result from the Status Quo and Project Options, tends to have a more subtle and longer term environmental effect on the populations.

Fish stocks within the Assessment Area may be directly and measurably affected by Commercial Fishing activities within the Assessment Area. Directly, there are currently a number of Commercial Fishing vessels that may operate within the Assessment Area. Although the number of vessels is not fixed, they service approximately 25 scallop licenses, 3 American shad licenses, 1 eel license (in the headpond) and approximately 100 lobster licenses. Only a portion of these vessels may actively fish within the Assessment Area during any given year/season, and most operate within the marine environment (i.e., Shepody and Chignecto Bays). The annual harvest data for the commercial fisheries operating within the Assessment Area are provided in Section 4.7.6.5 of the Biophysical Component Study (AMEC, 2005a).

Fish populations may also be indirectly affected. For example, the Inner Bay of Fundy Atlantic salmon is potentially affected by the accidental bycatch in the commercial and recreational fisheries within the Bay of Fundy, as has been documented for the gill net fishery for gaspereau in rivers in Nova Scotia (DFO, 2001).

Commercial fish populations within the Assessment Area may also be affected by Commercial Fishing activities outside of the Assessment Area as many populations of commercial fish that use the Petitcodiac River estuary migrate to foreign waters for part of their life cycle. For example, the American shad may spawn in rivers in the United States, and come to the Petitcodiac River to feed (or vice versa), and the Inner Bay of Fundy Atlantic salmon may migrate beyond the Assessment Area and may be affected (trapped) by commercial fishing activities off the coast of Greenland, or in Labrador. Indirectly, commercial fisheries may catch and kill species at risk as an unintended bycatch of an authorized fishery. For the purpose of this cumulative environmental effects assessment, the current fish stock estimates of fish species using the Assessment Area are viewed as a measurement of the combined actions of the aforementioned Commercial Fishing global activities on a specific fish stock.
11.4 Identification of Potential Cumulative Environmental Effects

The second step of the cumulative environmental effects assessment is to identify the environmental effects of the Project Options and Status. This has been done using an interaction matrix, included here as Table 11.4.1. In Table 11.4.1, the key environmental effects of the Project Options as compared to the Status Quo are provided in column format and are grouped by the key aspects for consideration that were presented in Table 4.7.1, and that were used within the environmental effects assessment (Chapter 9). The action categories are provided across the top of the table. Step 3 of the cumulative environmental effects assessment was accomplished by comparing the environmental effects of the Project Options and the Status Quo with the anticipated environmental effects of the other actions (as described in Section 11.3). A “Y” was placed where a likely interaction could occur (Y = yes), and an “N” was placed where no interaction is expected to occur (N = no). The evaluation of the identified potential cumulative environmental effects occurs in Section 11.5.

11.5 Evaluation of Potential Cumulative Environmental Effects

This section is the evaluation of the potential cumulative environmental effects that were identified in Section 11.4.

11.5.1 Atmospheric Environment VEC

11.5.1.1 Climate

As mentioned in Section 11.3.1.1, global warming occurs as a result of increased carbon dioxide (CO₂) gas and other greenhouse gas concentration in the Earth’s atmosphere. The Status Quo and Project Options contribute to this process by releasing CO₂ as a result of the burning of fossil fuels (e.g., petroleum); the biodegradation of organic matter (e.g., rotting wetland vegetation); or by changing the total available carbon sinks (e.g., loss or gain of wetlands).

The Status Quo and Project Options, the Development Projects and Urbanization (Table 11.3.1), will all result in the release of greenhouse gases during construction, maintenance and operation from the burning of fossil fuels. These greenhouse gases will act cumulatively with all of the other greenhouse gases emitted around the world on the air quality within the Assessment Area (measured as baseline conditions within the Assessment Area). The baseline air quality, including greenhouse gases, within the Assessment Area is considered good as characterized in Section 5.3.2. The contribution of greenhouse gases to the Assessment Area will not result in an exceedance of the New Brunswick Air Quality Regulation – Clean Air Act, as determined in Section 9.1.4.2, will be temporary (during construction only). Therefore, it is reasonable to conclude that the greenhouse gas emissions of both the Project Options and the Status Quo overlapping those of other regional and global actions will not result in a significant cumulative environmental effect on Climate within the Assessment Area.
### Table 11.4.1 Identification of Potential Interactions of the Project Options or Status Quo with Other Actions

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect for Consideration (from Table 4.7)</th>
<th>Key Environmental Effects of the Project Options or Status Quo as Compared to 2005 Baseline</th>
<th>Land Use Actions</th>
<th>Cultural Actions</th>
<th>Economic Actions</th>
<th>Global Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atmospheric Environment</strong></td>
<td>Climate</td>
<td>• change in carbon sink capacity&lt;br&gt;• change in greenhouse gas emissions</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Air quality</td>
<td>• dust and emissions during construction and operation</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Sound quality</td>
<td>• change in ambient noise levels</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Odour</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Fish and Fish Habitat</strong></td>
<td>Fish Populations and Biology (passage and spawning)</td>
<td>• change in fish passage at causeway&lt;br&gt;• change in fish passage elsewhere in the headpond and Petitcodiac River estuary&lt;br&gt;• change in spawning opportunity&lt;br&gt;• change in opportunity for improved populations of diadromous fish</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Water quality</td>
<td>• change in water quality</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Sediment quality</td>
<td>• dilution or concentration of contaminants</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Benthic community</td>
<td>• change in the benthic community</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Terrestrial and Wetland Environment</strong></td>
<td>Wetlands</td>
<td>• change in wetland area&lt;br&gt;• change in wetland type or function</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Wildlife and vegetation</td>
<td>• change in wetland habitat</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Birds</td>
<td>• change in wetland habitat</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Mudflat productivity</td>
<td>• change in mudflat productivity</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Managed areas</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Municipal Services and Infrastructure</strong></td>
<td>Services and infrastructure</td>
<td>• change in blockage of flaggates (GMSC sewer system)&lt;br&gt;• change in blockage of drainage ditches and aboiteaux (storm sewer system)&lt;br&gt;• change to risk of damage to upstream dykes and aboiteaux&lt;br&gt;• change to risk of damage to water transmission line</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Road Transportation Network</strong></td>
<td>Traffic flow</td>
<td>• change in level of service&lt;br&gt;• change in traffic patterns, including disruptions&lt;br&gt;• change in flood risk of the road network</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Vessel Traffic and Navigation</strong></td>
<td>Navigational opportunities</td>
<td>• change in navigational opportunities</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Land Use and Value</strong></td>
<td>Land use</td>
<td>• change in opportunity for land use</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Land value</td>
<td>• change in property value</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Aboriginal Land</strong></td>
<td>Opportunity to pursue</td>
<td>• change in opportunity to pursue identified traditional uses of&lt;br&gt;change in opportunity to pursue identified traditional uses of</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>
Table 11.4.1 Identification of Potential Interactions of the Project Options or Status Quo with Other Actions

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Key Aspect for Consideration (from Table 4.7)</th>
<th>Key Environmental Effects of the Project Options or Status Quo as Compared to 2005 Baseline</th>
<th>Land Use Actions</th>
<th>Cultural Actions</th>
<th>Economic Actions</th>
<th>Global Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>and Resource Use</td>
<td>identified traditional uses of land and resources use</td>
<td>land and resources use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tourism</td>
<td>Opportunity for tourism</td>
<td>• change in tidal bore height</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Recreational Opportunity for tourism</td>
<td>Opportunity for recreation</td>
<td>• change in recreational opportunity (loss of headpond, improved tidal bore, natural river in urban environment)</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Labour and Economy</td>
<td>Local and provincial economies</td>
<td>• change in local economy</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Heritage and Archaeological Resources</td>
<td>Loss of heritage and archaeological resources</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Public Health and Safety</td>
<td>Vehicular Accidents</td>
<td>• change in risk of vehicular accidents</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Non-vehicular accidents</td>
<td>• change in risk of boating accident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Groundwater</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Contaminated effluents and redistribution of contaminants</td>
<td>• change in character of contaminated effluents (sewage)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Human disease vectors</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Flooding and flood risk</td>
<td>• change in flood risk</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Human food resources</td>
<td>• none identified</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Y = Yes, there is potential for overlap between environmental effects of the Status Quo and Project Options and the environmental effects of Actions on a VEC

N = No, there is no identified potential for overlap between environmental effects of the Status Quo and Project Options and the environmental effects of Actions on a VEC

N/A = Not Applicable, because there is no identified environmental effects of the Project Options or Status Quo
The Project Options will result in a reduction in the total available carbon sinks, as wetland loss, by 0.07% (Project Option 3/4A) to 0.9% (Project Option 4B/4C) of the total carbon sink volume for Westmorland and Albert counties as described in Section 9.1.4.1. This calculation demonstrates that the vast majority of carbon sink volume loss occurs in the forestry sector, and that the contribution of the Project Options to this loss is not significant. The Status Quo will result in an overall increase in the total available carbon sinks, as wetland gain.

Wetland conversion and/or wetland loss will result in the initial loss of -3.9 ha of wetland area, and will thereby initially reduce carbon sink capacity. However this wetland loss will be compensated (in respect to carbon sink capacity) by the effective creation (i.e., no net loss) of a minimum of +3.9 ha of wetland area. The Jonathan Creek Diversion project will result in the creation of +2.9 ha of wetland. Therefore, the net total change in wetland area is +2.9 ha (-3.9 (loss) ha + 3.9 ha (compensated) + 2.9 ha (Jonathan Creek Diversion project)).

Overall, the environmental effects of the Project Options acting in combination with those of other future actions on carbon sinks within the Assessment Area is determined to be negative, but not significant. The Status Quo will result in a positive environmental effect on carbon sink capacity, but the cumulative environmental effects will continue to be negative as carbon sink capacity continues to decline within the Assessment Area as a result of ongoing forestry operations. Therefore, it is reasonable to conclude that the changes in carbon sink capacity of both the Project Options and the Status Quo overlapping those of other regional and global actions will not result in a significant cumulative environmental effect on Climate within the Assessment Area.

11.5.1.2 Air Quality

The Project Options will result in temporary measurable environmental effects on air quality during construction (e.g., heavy machinery emissions including dust) and to a lesser extent, during operation. Emissions during operation would be from maintenance equipment (e.g., lawn mowers and snow plows) and would be intermittent, small in magnitude and very localized.

Development projects will result in localized environmental effects on air quality during construction. However, as shown in Table 11.3.1, most of the larger development projects will be completed prior to implementation of the Project Options and will therefore not have construction related environmental effects (e.g., emissions from heavy machinery) that overlap in time with those of the Project Options construction related environmental effects. In particular, the following road development projects will be completed prior to implementation of the Project Options:

- New Petitcodiac River Bridge;
- City of Moncton Assomption Boulevard Phase II and Vaughan Harvey Boulevard Extension;
- Virginia Avenue Extension Project in Dieppe; and
- Riverview East-West Corridor Phase I.
However, most of the development projects will have operation related environmental effects on air quality that will overlap those of the Status Quo and Project Options for both the construction and operation phases. These include changes to traffic volumes and patterns causing a change in distribution and quantity of air contaminants for road development projects. The baseline air quality within the Assessment Area is considered good as characterized in Section 5.3.2. The contribution of air contaminants to the Assessment Area from Project Options or the Status Quo will not result in an exceedance of the New Brunswick Air Quality Regulation – Clean Air Act, as determined in Section 9.1.4.2, and will be temporary (during construction only). Therefore, it is reasonable to conclude that the emissions of both the Project Options and the Status Quo overlapping those of other regional and global actions will not result in a significant cumulative environmental effect on Air Quality.

11.5.1.3 Sound Quality

The majority of incremental noise associated with the Project Options occurs as a result of construction activities, and with the Status Quo, occurs as a result of maintenance activities (e.g., Gate Management Plan or control structure upgrades or repairs). As described in Section 11.5.1.2, the majority of the other identified development projects will be completed prior to implementation of the Project Options and will therefore not have construction related environmental effects on Sound Quality that overlap those of the Project Options construction, or maintenance under the Status Quo. This will reduce the cumulative environmental effects of construction related nuisance noise on human receptors. However, the other development projects, as well as urbanization in general, will have operation related noise that will interact with noise generated during construction of the Project Options, or maintenance for the Status Quo. The Project Options and the Status Quo will also both result in traffic related noise during operation, and this noise will act cumulatively with noise generated from other sources. However, the Project Options and the Status Quo are not predicted to result in any additional (incremental) traffic. Therefore, the future contribution (during operation) of the Project Options or Status Quo to ambient noise levels in the area will be similar to that of the existing causeway.

In the foreseeable future, ambient noise levels (includes noise from all sources acting on a receptor) are predicted to be greater than those measured at baseline, but are not predicted to exceed the threshold for significance for sound quality, as presented in Section 9.1.3.4. Therefore, the potential cumulative environmental effects of the Project Options or Status Quo on Sound Quality are considered as negative, but not significant.

11.5.1.4 Odour

There were no measurable environmental effects on Odour identified from other sources that could overlap the environmental effects of the Project Options or Status Quo on Odour. Therefore, there are no identified cumulative environmental effects on Odour.

11.5.2 Fish and Fish Habitat VEC

11.5.2.1 Fish Populations (size and range) and Biology (passage and spawning)

Implementation of the Project Options will result in the following key environmental effects compared to baseline conditions:
• restored fish passage at the causeway and improved fish passage elsewhere in the Petitcodiac River (Section 6.2);
• opportunity for improved spawning upstream of the causeway for anadromous fish;
• opportunity for improved populations (size and range) of diadromous fish; and
• loss of freshwater fish and fish habitat upstream of the causeway.

The Status Quo will not result in any of the above mentioned positive environmental effects. Instead, fish passage issues will persist, upstream spawning opportunity will continue to be significantly impeded, and diadromous fish populations may continue to decline (e.g., Atlantic sturgeon and Atlantic salmon), resulting in significant negative environmental effects. The Status Quo would continue to have positive environmental effects on freshwater fish and fish habitat upstream of the causeway.

There were no other actions identified that would improve or restore fish passage at the causeway for all species requiring fish passage as listed in Section 6.1, and therefore there are no other actions that could act cumulatively with the Status Quo that would improve spawning opportunity upstream of the causeway or the population range for all species requiring fish passage at the causeway. Therefore, the Status Quo acting in combination with other actions will continue to have negative and significant environmental effects on fish passage.

The Project Options and the Status Quo are not predicted to result in measurable environmental effects on commercial marine species (e.g., lobster and scallop), and therefore there are no predicted cumulative environmental effects between the Project Options or Status Quo and the commercial fisheries.

The environmental effects of Commercial Fishing could overlap the environmental effects of the Project Options or Status Quo for some fish species such as Atlantic salmon, American shad, gaspereau and American eel, as described in Section 11.3.2.4. The commercial fishery allowable harvest is managed by DFO, and as such it is determined that there will not be a significant negative cumulative environmental effect resulting from the commercial fishery acting in combination with the Project Options or Status Quo on commercial fish species. This is because the commercial harvest, under the management of DFO, would be suspended prior to the occurrence of a significant cumulative environmental effect on a given species.

Although it is probable that Commercial Fishing has had negative environmental effects on Species at Risk (i.e., Atlantic salmon and subsequently the dwarf wedgemussel), it is considered likely that the installation of the causeway has been the primary action that caused the extirpation (see Glossary) of these species in the Petitcodiac River (Environment Canada, 2004c). The Status Quo will not result in improved opportunity for the re-introduction of Atlantic salmon or the dwarf wedgemussel, and therefore the cumulative environmental effects of the Status Quo in combination with those of other actions on Species at Risk will continue to be negative and are rated as significant. The Project Options will result in improved opportunity for the re-introduction of Atlantic salmon and the dwarf wedgemussel, and this will overlap the Species at Risk Act protected status and management plans for these species resulting in a positive cumulative environmental effect.
11.5.2.2 Water Quality

The Project Options will result in improved water quality as a result of the increased tidal prism causing a reduction in the concentration of contaminants (e.g., fecal coliforms), through the process of dilution.

Development projects may have overlapping environmental effects with the Status Quo and Project Options on water quality including the environmental effects of sediment and road salt runoff from winter safety activities (that includes snow removal and deposition on riverbanks, on new and existing roads). The natural condition of Petitcodiac River is near saturation with respect to salinity and TSS. The release of sediment from construction of development projects are mitigated (e.g., sedimentation and erosion control) to comply with the CCME Water Quality Guidelines for Aquatic Life. The release of sediment from operation of development projects included in Table 11.3.1 is mitigated (e.g., sediment-catch storm water drains and future compliance with Environment Canada Road Salt Management Plan for the Cities of Moncton and Dieppe and the Town of Riverview) so that they are small in magnitude, temporary in duration, and do not exceed the CCME Water Quality Guidelines for Aquatic Life. Therefore, it is determined that the contribution of development projects to cumulative environmental effects on water quality (for both the Projects Options and Status Quo) would be negative but not significant.

Other Land Use Actions, such as agriculture and forestry practices, will continue to have environmental effects on water quality that may overlap those of the Project Options and the Status Quo. Similar to the reasons described above for development projects (e.g., mitigation includes the Turtle Creek forest management plan that considers the environmental effects of runoff on receiving water quality), the contributions of these other land uses to cumulative environmental effects on water quality (for both the Projects Options and Status Quo) will be negative but not significant.

The potential environmental effects from Changes in Environmental Protection Legislation and Changing Societal Values, such as increased DO levels from a reduction in the discharge of human wastes to the river, would occur from changes in wastewater treatment effluent guidelines. This would overlap positively with the reduction in these human wastes from an increased tidal prism (dilution of wastes with increased volume of water) as is predicted for the Project Options. This would also overlap positively with the Status Quo by reducing the overall negative environment effect of the Status Quo as the Status Quo would continue to reduce the tidal prism. The implementation of salt management plans in communities that drain into the Petitcodiac River is not expected to result in a change to salinity levels within the river because the conditions will be estuarine (mixture of salt water and freshwater) after implementation of the Project Options.

The Jonathan Creek Diversion project will have a positive contribution to the cumulative environmental effects for the Project Options and Status Quo due to diversion of the channel from the edge of the former Moncton Landfill and enhanced leachate attenuation.
The cultural trend towards improved sewage treatment in municipalities will continue to have a positive cumulative environmental effect with the environmental effects of the Project Options on water quality. As presented in Table 11.3.1 and listed in Section 11.3.2.1, there are currently four planned wastewater treatment facility projects, and an upgrade to the City of Moncton sewer system. In addition, the replacement of combined sewers with separate sewer lines will improve the capacity of the sewage treatment facility at Outhouse Point. These actions will provide a positive contribution to the cumulative environmental effects of both the Status Quo and Project Options on water quality (i.e., improving DO levels). However, the overall cumulative environmental effects of the Status Quo on water quality will continue to be negative, and significant (as DO measured at baseline is seasonally unsuitable for aquatic life), while the cumulative environmental effects of the Project Options on water quality will be positive.

11.5.2.3 Sediment Quality

The cumulative environmental effects of actions and those of the Status Quo and Project Options on sediment quality will be similar to those described for water quality (Section 11.5.2.2). This is because water quality is a direct pathway to sediment quality.

11.5.2.4 Benthic Community

The cumulative environmental effects of actions and those of the Status Quo and Project Options on the benthic community will be similar to those described for water quality (Section 11.5.2.2). This is because water quality and sediment quality are directly related to the benthic community.

11.5.3 Terrestrial and Wetland Environment

11.5.3.1 Wetlands

The largest contributing action to wetland loss (approximately 2,170 ha) to date has been the conversion of saltwater marsh to agricultural farmland. Although the installation of the causeway has contributed to the development of additional wetland area as compared to pre-causeway conditions (estimated at +640 ha), the overall quality and function of the wetlands within the Assessment Area is considered to have been reduced.

As presented in Table 8.11.1, the Project Options are predicted to result in the loss of 400 to 500 ha of wetland as compared to baseline. However, it is important to remember that all of this wetland that will be lost, is wetland that was gained as a result of installation of the causeway, and is not considered to be of high quality. Therefore wetland loss caused by the Project Options or Status Quo was determined to be not significant in Section 9.3.4.1.

The only actions that were determined to have potentially overlapping and measurable environmental effects with those of the Project Options and Status Quo on Wetlands were wetland conversion and/or wetland loss. Wetland conversion and/or wetland loss will result in the initial loss of -3.9 ha of wetland area as described in Section 11.3.1.3. This loss will be compensated so that there is no net loss as described in Section 11.5.1.1. The Jonathan Creek Diversion project will result in the creation of +2.9 ha of wetland. Therefore, the net total change in wetland area is +2.9 ha (-3.9 ha (lost) + 3.9 ha (compensated) + 2.9 ha (Jonathan Creek
Diversion project)). Therefore, the overlapping environmental effects of development projects and the Project Options and Status Quo on wetland area is considered to be negative but not significant.

11.5.3.2 Wildlife and Vegetation

The cumulative environmental effects on wildlife and vegetation are similar to those described for wetlands in Section 11.5.3.1, and are considered not significant. This is because wetland is the key habitat for wildlife and vegetation that will be affected by the Status Quo and Project Options.

11.5.3.3 Birds

The loss of freshwater habitat upstream of the causeway is not expected to have a significant environmental effect on migratory birds or migratory bird Species of Conservation Concern, as 46 ha of freshwater wetlands (upstream and downstream of the causeway) will remain in the Assessment Area as protected Ducks Unlimited sites, 126 ha of freshwater wetland will remain protected by dykes near Dieppe, and other suitable freshwater wetland habitat is well represented in the region surrounding the Assessment Area (AMEC, 2005a). In total, approximately 172 ha of freshwater wetland will be maintained for all Project Options.

The loss of saltwater wetland habitat downstream of the causeway is not expected to have significant environmental effects on migratory birds or migratory bird Species of Conservation Concern, as additional saltwater habitat will be created upstream of the causeway. Environmental effects on shorebird species dependent upon mudflats will not be significant, as mudflat productivity in Shepody Bay will not be affected substantively by the Project Options or the Status Quo (Section 9.3.4.4). The development projects will result in a net gain of 3.0 ha of saltwater marsh and thus will have a positive cumulative environmental effect on bird habitat with both the Project Options and the Status Quo.

11.5.3.4 Mudflat Productivity

There were no identified measurable environmental effects of other future actions on Mudflat Productivity. The environmental effects of the existing causeway on mudflat productivity were presented in Section 5.5.4.

11.5.3.5 Managed Areas

There were no identified measurable environmental effects of other future actions on Managed Areas.

11.5.4 Municipal Services and Infrastructure

There were no identified measurable environmental effects of other future actions on Municipal Services and Infrastructure.

11.5.5 Road Transportation Network

The Project Options will result in a short disruption to traffic flow during a portion of the construction process, primarily while the access roads are being re-aligned. The improved bridge deck of Project Option 3 and the partial bridges of Project Options 4A, 4B and 4C will all
offer the same level of service as the existing causeway. In this regard, there are no long-term environmental effects to the road transportation network.

It should be noted that the replacement of the Jonathan Creek culvert will not significantly reduce upstream flooding, under the Status Quo conditions, due to the substantial accumulation of sediments at the mouth of the Creek. Further, the present gate operation in relation to the tidal elevations and the raised bed levels can result in persistent high water levels in the main channel at the mouth of Jonathan Creek (for as long as 24 hours as was experienced in the flooding event of September 1999) and therefore, increased back-up flooding along Jonathan Creek.

The Status Quo will result in increased flooding potential to some low lying roads (e.g., the causeway circle) on the road transportation network. Although some urban land development projects will help to reduce flood potential (e.g., replacement of culverts at Jonathan Creek), this will not be enough to offset the loss of river conveyance under the Status Quo, and will therefore continue to result in significant negative cumulative environmental effects.

The New Petitcodiac River Bridge will be completed prior to the implementation of the Project Options and will offer a greater level of service than the Gunningsville Bridge that it will replace. The New Petitcodiac River Bridge will also have a bridge deck of 16 m and will thereby maintain access between Riverview and Moncton in all conditions, including extreme estimates of climate change and sea level rise, as described in Section 10.3.6. In this regard, the New Petitcodiac River Bridge will act cumulatively to offset any traffic disruptions during construction and operation. Other road network improvement projects listed in Table 11.3.1, specifically the Town of Riverview East-West Corridor and the City of Dieppe Virginia Avenue Extension, will act cumulatively to improve the overall flow of traffic in the Assessment Area.

Therefore, the cumulative environmental effects of the Project Options with other development projects will be negative, but temporary, during construction and therefore not significant, and positive during future operation.

11.5.6 Vessel Traffic and Navigation

Prior to construction of the causeway, the Petitcodiac River estuary was navigable in the Assessment Area. There were 12 wharves in the Assessment Area that both facilitated and to some limited extent altered local navigation due to their physical presence. The Gunningsville Bridge was constructed in 1915 and comprises 5 piers, with an elevation of the bottom girder set at 10.5 m. The causeway was constructed between 1966 and 1968 and resulted in the obstruction of navigation at the causeway, dividing the former estuary into a lower estuary and an upper headpond with freshwater. Sedimentation in the estuary and the headpond have progressively limited navigation in the river. The headpond is navigable by small recreational watercraft, but sedimentation will continue to limit headpond volume and draft into the future. Downstream, the Status Quo would see increasing sedimentation, and a related decline in navigability. Sedimentation below the causeway has seen a severe decrease in navigability down to Dover and this trend is continuing for 70 years into the future with decreasing navigability out to Hopewell Cape by that time. The New Petitcodiac River Bridge is under
construction and will be completed in 2005. Comprising 7 piers, the lowest bridge girder is set at elevation 13.0 m. The Project Options will restore tidal exchange, increase channel dimensions and depth throughout the Assessment Area, and overall improve Vessel Traffic and Navigation. Changes to navigation in the headpond will be mitigated through change in access and/or compensation. No future projects are known that would affect navigation negatively. Overall, the cumulative environmental effects of the Project in combination with other projects or activities are considered to be positive as compared to the current baseline.

11.5.7 Land Use and Value

The Status Quo will result in an overall negative environmental effect on Land Use and Value due to a projected increase in flood risk, as described in Section 9.7.4. The Project Options will result in an overall positive environmental effect on Land Use and Value due to a projected decrease in flood risk.

The Project Options and other development projects listed in Table 11.3.1, such as the NBDOT Complex Watercourse Crossing at Jonathan Creek and the replacement of combined sanitary and storm sewers in the tri-community area, will act cumulatively to reduce the flood risk in the urban city centres and will therefore have a positive cumulative environmental effect on Land Use and Value. The other planned development projects will not offset the increased flood risk resulting from the Status Quo, and therefore the Status Quo will continue to result in significant negative cumulative environmental effects.

11.5.8 Aboriginal Land and Resource Use

There were no identified measurable environmental effects of other future actions on Aboriginal Land and Resource Use.

11.5.9 Tourism

The Status Quo will continue to maintain the loss of the tidal bore. However, the Status Quo will continue to provide a smallmouth bass fishery in the headpond that is predicted to improve as the stock matures and may offer growing opportunity for the continuation of tournament fishing. Also, the headpond will continue to provide some opportunity for tourism related to recreational boating and from landing of float planes by tourists. Overall, this would be more than offset by the continued loss of tourism potential from the diminished tidal bore and is therefore considered negative and significant.

The Project Options will result in a positive environmental effect on tourism opportunities within the Assessment Area by partially restoring the tidal bore and providing a natural river in an urban environment.

The smallmouth bass is an increasingly popular sport fish. The Project Options will result in negative environmental effects on tourism opportunities by eliminating the smallmouth bass fishery in the headpond area.

Other development projects listed in Table 11.3.1 may also improve tourism opportunity (e.g., the City of Moncton Downtown Development Centre and the Fundy Gateway project) and are
therefore predicted to have a positive cumulative environmental effect with the Project Options on tourism.

**11.5.10 Recreation**

The environmental effects of the Status Quo and Project Options acting in combination with those of other actions will result in cumulative environmental effects similar to those described for tourism in Section 11.5.9.

**11.5.11 Labour and Economy**

The environmental effects of the Project Options acting in combination with those of other actions may result in positive cumulative environmental effects on labour and economy due in part to increased opportunities for tourism and recreation, and the expenditures and labour with construction and operation of the Project Options and other development projects.

As described for Land Use and Value (Section 11.5.7) the Project Options will act in combination with other development projects to reduce the future flood risk. This has the potential to save millions of dollars that may have been spent on flood protection under the Status Quo.

Therefore, the cumulative environmental effects of the Project Options acting in combination with those of other actions on Labour and Economy are rated as positive. The cumulative environmental effects of the Status Quo acting in combination with those of other actions on Labour and Economy are rated as negative and significant.

**11.5.12 Heritage and Archaeology Resources**

There were no identified environmental effects on heritage or archaeology resources from the Project Options or Status Quo.

**11.5.13 Public Health and Safety**

**11.5.13.1 Vehicular Accidents**

The cumulative environmental effects of the Project Options on the risk of vehicular accidents will parallel those described for the Road Transportation Network (Section 11.5.5). That is, there will be a slight increase to vehicular accident risk during construction (negative cumulative environmental effect), followed by an overall decrease to risk during operation as a result of an improved road traffic network (positive cumulative environmental effect). The road development projects in Table 11.3.1 have taken into consideration the added traffic and changes to traffic patterns from a growing and aging population (City of Moncton, 2002).

The cumulative environmental effects of the Status Quo acting in combination with other road development projects on the risk of vehicular accidents will be positive for the continued operation of the causeway and control structure.
11.5.13.2 Non-vehicular Accidents

There are no identified interactions between the environmental effects of the Project Options or Status Quo and the environmental effects of other future actions on the risk of non-vehicular accidents.

11.5.13.3 Groundwater

There were no identified environmental effects on groundwater from the Project Options or Status Quo.

11.5.13.4 Contaminated Effluents and Redistribution of Contaminants

The Status Quo will result in the continued water quality issues associated with the concentration of sewage effluent downstream of the causeway, and to a lesser degree, in the headpond. Planned improvements and expansions to sewage treatment facilities will help to improve this situation, although ultimately a costly upgrade to the sewage treatment facility at Outhouse Point may be required.

The Project Options will result in a greater assimilative capacity of the receiving waters (i.e., the Petitcodiac River). This will help to offset the growing population and subsequent usage of the existing sewage treatment facilities. In addition, many municipalities along the river are upgrading existing or installing new wastewater treatment facilities (Table 11.3.1). These improved facilities will further act to reduce overall contaminated effluents from entering the river. The City of Moncton is currently in the process of replacing many of its existing combined storm/sewage sewer system with separate sewers for each. This will ultimately reduce the demand on the existing wastewater treatment facility and effectively increase the capacity of the wastewater treatment facility. Currently, excess wastewater (including sewage) is dumped untreated into the Petitcodiac River during periods of excessive rain (City of Moncton, 2002). The increased tidal prism resulting from the Project Options will also dilute any existing contaminants that become redistributed due to increased hydraulic energy.

The potential environmental effects from Changes in Environmental Protection Legislation, such as a reduction in bacteria associated with human wastes, would occur from changes in wastewater treatment effluent guidelines. This would overlap positively with the reduction in these bacteria from an increased tidal prism (dilution of bacteria with increased volume of water) as is predicted for the Project Options. This would also overlap positively with the Status Quo by reducing the overall negative environment effect of the Status Quo as the Status Quo would continue to reduce the tidal prism.

Therefore, the cumulative environmental effects of the Project Options acting in combination with other actions with measurable environmental effects on contaminated effluents and redistribution of contaminants is considered to be positive, and the cumulative environmental effects of the Status Quo acting in combination with other actions is considered to be negative and significant.
11.5.13.5 Human Disease Vectors
There were no identified environmental effects on human disease vectors from the Project Options or Status Quo.

11.5.13.6 Flooding and Flood Risk
As described for Land Use and Land Value, the environmental effects of the Project Options acting in combination with those of other actions is considered to result in a positive cumulative environmental effect on flooding and flood risk, while the environmental effects of the Status Quo acting in combination with those of other actions considered to result in a significant negative cumulative environmental effect.

11.5.13.7 Human Food Resources
There were no identified environmental effects on human food resources from the Project Options or Status Quo.

11.6 Recommended Mitigation for Potential Cumulative Environmental Effects
The Project Options will result in some negative cumulative environmental effects (e.g., a temporary loss of level of service and increased risk of traffic accidents during construction). However, in all cases, these cumulative environmental effects are similar in magnitude, duration and extent to the environmental effects presented in Chapter 9, and are rated as not significant. In this regard, the mitigation presented in Chapters 7 and 9 mitigate the potential cumulative environmental effects of the Project Options. Therefore, there is no recommended mitigation for minimizing the magnitude, duration, or extent of potential cumulative environmental effects of the Project Options in addition to that identified for the mitigation of environmental effects in Chapter 7 and Chapter 9.

The Status Quo will result in significant negative environmental effects on some VECs (e.g., Public Health and Safety, flood risk) that cannot be easily mitigated. Although it is not considered necessary to provide mitigation for the Status Quo as it is not a Project Option, the potential mitigation for the environmental effects of the Status Quo is further considered in Chapter 12 (Economic Considerations).
12.0 ECONOMIC CONSIDERATIONS

This chapter addresses the economic considerations (i.e., benefits and costs) of the causeway to date, and into the future with the Project Options that meet the Fish Passage EIA Objective (Chapter 6) and the Status Quo. Note that the term “Project Options” includes Project Options 3, 4A, 4B and 4C; specific mention of a Project Option (e.g., Project Option 4B) is given when warranted. The Guidelines contemplated a full cost accounting analysis (benefit/cost analysis) to allow for comparison of the estimated costs and benefits of the Status Quo and Project Options, including all identified environmental intangibles (i.e., volunteer fund raising groups to support local nonprofit organizations, things that are valued by people in a non-monetary way, such as placing a value on the view of a lake). The purpose of this approach, as described in the Guidelines, was to add important information into economic considerations that tend to neglect unsustainable environmental effects on natural resources and social wellbeing. By considering these benefits and costs that are external to economic transactions (i.e., the direct capital and operating costs), the sustainability of different Project Options could be evaluated and compared to the Status Quo. The full cost accounting analysis called for in the Guidelines was intended to attempt to quantify benefits and costs (e.g., opportunity benefits and costs associated with changes to commercial fisheries, habitats, land use, etc.) that are not included in traditional costing techniques.

The EIA TOR that was developed in response to the Guidelines outlined the approach to be taken by the AMEC Study Team and noted that each Project Option must be considered separately, including the Status Quo. It was proposed that a benefit/cost analysis be undertaken for each of the four Project Options that met the fish passage Project Objective for comparison with the Status Quo.

In conducting this EIA, the AMEC Study Team has come to some important conclusions that have affected the scope and level of this benefit/cost analysis. As outlined in Chapter 6, only Project Options 3 and 4 meet the fish passage Project Objective. Project Options 3 and 4, as modified and described in Chapter 7, are alternative means of carrying out what is in concept the same project. Project Options 3 and 4 involve different technical solutions for opening the causeway permanently; Project Options 3, 4A and 4B create a permanent opening (of differing dimension) at the existing gates while Project Option 4C involves a permanent opening near the middle of the causeway.

Project Options 1 and 2 were very different potential solutions for meeting the fish passage Project Objective as compared to Project Options 3 and 4. It is likely that there would have been a number of key differences among the potential environmental effects between the Project Options, if it had been determined that Project Options 1 and 2 could have achieved the fish passage Project Objective. There would have been benefits and costs with maintaining the headpond under Project Option 1 and possibly 2, versus loss of headpond under Project Options 3 and 4.

Most environmental effects of the Project Options that meet the fish passage Project Objective (Project Options 3, 4A, 4B and 4C) are the same or very similar in magnitude and are related to
the degree in which the Petitcodiac River estuary is predicted to return towards pre-causeway conditions. In all instances, the environmental effects are in the same direction (i.e., they are either all positive or negative as outlined in Chapter 9). Key differences from a benefit and cost perspective are quantifiable as capital and operating costs, including the costs of mitigation of potentially significant negative environmental effects. There are no significant negative environmental effects that are predicted to be likely to occur as a result of the Project Options (Chapter 9), and those environmental effects that are predicted to be positive are similar and may only vary in the degree to which they are positive. Consequently, it remains that the only significant negative environmental effects identified in this EIA are those identified for the Status Quo, the majority of which are a continuation of significant negative environmental effects that occurred as a result of the causeway. It is important to reiterate that the Status Quo is not a Project Option as it does not meet the Project Objectives and that it has been carried forward in this EIA for comparative purposes.

Recognizing these conclusions of the environmental effects assessment, the AMEC Study Team has focused efforts on identifying those items that could have an economic value/loss associated with the Project Options characterizing the benefits and costs of the causeway to date in a qualitative way, and where data allow, quantitatively. This analysis, coupled with the environmental effects assessment, enables an understanding of the benefits and costs of the Status Quo as many of the past environmental effects of the causeway would persist in a similar manner into the future.

Recognizing the important results of the preceding chapters of the EIA, the economic considerations addressed in this chapter are therefore divided into three categories:

- economic considerations associated with the causeway to date;
- capital and operating costs of the Status Quo and Project Options; and
- other economic considerations of the Status Quo and Project Options.

The first and final categories involve primarily qualitative analyses based on the findings of this EIA with quantification using benefit/cost analysis, where feasible. The second category involves “hard costs” of the construction and operation of the Status Quo and Project Options that meet the fish passage Project Objective.

12.1 Economic Considerations for the Causeway to Date

This section considers the economic costs and benefits of the causeway to date compared with the pre-causeway condition. This analysis was undertaken in an effort to assign values to those environmental effects that developed as a result of the causeway construction and support the valuation of the environmental effects arising from the Status Quo and the Project Options.

The construction cost of the causeway, as estimated by the Maritime Marshland Rehabilitation Administration in 1964, was $3,000,000 for the causeway structure only. The Moncton Times and Transcript reported the cost to be $4,000,000 in 1965, which included the new roadway approaches and infrastructure on both the Moncton and Riverview sides of the river. In 2004 dollars, these costs are $18,000,000 and $24,000,000, respectively.
The average annual costs to NBDOT for maintenance of the control gate and bridge structure were $70,300 per annum (in 2004 dollars) from fiscal years 1992/93 to 2002/03. In addition, annual maintenance costs of the causeway, excluding ordinary snowplowing, sand and salting and street cleaning works, averaged $14,200 per annum (in 2004 dollars) over the same period.

It should be noted that if the causeway was not built, another transportation link across the river would have been constructed in its place (i.e., a bridge structure). Assuming that bridge construction costs have not increased for reasons other than inflation, construction of a bridge in place of the causeway would have cost approximately $21,500,000 in 2004 dollars. This figure is based on the cost for the new bridge that will be completed in 2005 and includes only the cost of the structure and does not include costs associated with engineering, connecting road infrastructure, operation and maintenance, or environmental monitoring.

Overall, it would appear that the cost of a bridge would have been similar to construct as compared with the causeway, but maintenance of a bridge might have been more expensive. Regardless, it is important to recognize that a transportation link would have been built and that in a full cost accounting context, the cost of the causeway as compared to the bridge is likely close to being comparatively neutral.

Table 12.1.1 summarizes the discussion and analysis presented in this section by VEC and key aspects of each VEC. Where there are no apparent economic benefits or costs for a particular VEC, it is indicated to be “not a factor” from a benefit/cost perspective. The table includes some semi-quantitative estimates of benefits and costs, which involve many assumptions and in most cases represent the worst or best case estimates. These estimates cannot be combined or summed as they are a combination of both qualitative and quantitative estimates, each based on different assumptions. A detailed description for each VEC is provided following the table.

<table>
<thead>
<tr>
<th>Economic Consideration by VEC/Key Aspects</th>
<th>Economic Cost/Benefit of Causeway Compared with Pre-causeway Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Environment</td>
<td>Not a factor.</td>
</tr>
<tr>
<td>Fish and Fish Habitat</td>
<td>Cost: Overall the migration of fish has been impeded for many species such that they can no longer access critical habitat. These significant negative environmental effects have resulted in the fish passage Project Objective and the resultant proposed Projects associated with this EIA.</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Cost: Even though there has been an increase in saltwater and freshwater wetland, the type and characteristics of the wetlands (species diversity, tidal influences) have changed significantly, resulting in overall negative environmental effects.</td>
</tr>
<tr>
<td>Wildlife and Vegetation</td>
<td>Benefit: Increase in wetland habitat for wildlife and vegetation.</td>
</tr>
<tr>
<td>Migratory Birds</td>
<td>Benefit: Increase in wetland habitat for birds. Decrease in mudflat habitat in the river for migratory shorebirds (e.g., Semi-palmated Sandpiper) not a factor, as the mudflats in Shepody Bay are substantially more important as feeding habitat.</td>
</tr>
</tbody>
</table>
### Table 12.1.1 Economic Benefits/Costs Associated with the Causeway as of 2005

<table>
<thead>
<tr>
<th>Economic Consideration by VEC/Key Aspects</th>
<th>Economic Cost/Benefit of Causeway Compared with Pre-causeway Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mudflat Productivity</td>
<td>Cost: Reduction of mudflat area in Petitcodiac River estuary.</td>
</tr>
<tr>
<td>Managed Areas</td>
<td>Benefit: ESAs created at Outhouse Point and Lower Coverdale Island.</td>
</tr>
<tr>
<td>Water Distribution Systems</td>
<td>Not a factor: No substantial difference with a bridge if causeway was not built.</td>
</tr>
<tr>
<td>Sanitary Sewer Systems</td>
<td>Cost: The sewage treatment facility at a cost of $56.6M was required due to causeway effects, even though ultimately society’s preference to prevent pollution may have led to its construction and the costs would have been moved forward and a different solution may have been found.</td>
</tr>
<tr>
<td>Storm Sewer Systems</td>
<td>Cost: Increased maintenance caused by sedimentation.</td>
</tr>
<tr>
<td>Dykes and Aboiteaux</td>
<td>Benefit: About $330,000 per year in maintenance costs upstream of causeway avoided.</td>
</tr>
<tr>
<td>Other Infrastructure</td>
<td>Benefit: Opportunity to construct Tri Community Marina, Town of Riverview public dock and walking trails on infilled former river bed.</td>
</tr>
<tr>
<td>Road Transportation Network</td>
<td>Not a factor: It is presumed that if a causeway were not built, a bridge link would have been constructed.</td>
</tr>
<tr>
<td>Vessel Traffic Navigation Downstream of the Causeway</td>
<td>Cost: Sedimentation of the river has reduced navigability downstream of the causeway to a point well below Belliveau Village. The causeway is an obstruction to navigation.</td>
</tr>
<tr>
<td>Vessel Traffic Navigation Upstream of the Causeway</td>
<td>Benefit: The headpond affords some benefit through boating and sailing opportunities for recreational vessels.</td>
</tr>
</tbody>
</table>
| Risk of Flooding                          | Cost: Causeway has resulted in increased risk and magnitude of flooding from stormwater runoff or ice jamming, due to the reduction in channel conveyance. This has and could result in very substantial costs due to damage and/or increased property insurance rates.  
Cost: The existing aboiteaux at Babineau Creek is completely buried with silt which blocks all flow from the creek to the river. In 1992 the City of Dieppe excavated a drainage ditch on the inside of the dyke from the creek to opposite Virginia Avenue at which point they installed a pipe through the dyke. Riprap protection and a flap gate allows for flow to the river as the dyke is adjacent to the present river channel. The cost for the ditching and outfall pipe was $65,000. The City’s cost to keep the ditch and pipe open in the winter is $5,000 per year. This system is not considered as a permanent solution as flooding of the roadway and several private properties at the creek area is still a concern.  
Cost: a flood risk assessment should be carried out to identify the extent and the cost of flooding under the Status Quo. The results of the flood risk assessment will be used to recommend additional flood risk reduction measures, as warranted. |
### Table 12.1.1 Economic Benefits/Costs Associated with the Causeway as of 2005

<table>
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<tbody>
<tr>
<td><strong>Property Value</strong></td>
<td><strong>Benefit:</strong> Vacant lots slightly higher price adjacent to headpond as compared to downstream of the causeway.</td>
</tr>
<tr>
<td><strong>Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons</strong></td>
<td><strong>Cost:</strong> According to the sources available within the Aboriginal Community, the causeway resulted in the decline of availability of the resources that were used for traditional purposes such as hunting and gathering of various wildlife species and plants in shoreline wetlands, and the fishing of various species in the Petitcodiac River.</td>
</tr>
<tr>
<td><strong>Tourism</strong></td>
<td><strong>Cost:</strong> The seriously declined tidal bore has resulted in its loss in status as a main or promotable tourism destination. The tidal bore remains as a modest tourism attraction contributing from $15,700 to $612,000 per year in direct expenditure. If it had maintained its status as a tourism destination, its contribution to expenditure would likely be at least twice as great as it is today.</td>
</tr>
<tr>
<td><strong>Recreational Fisheries</strong></td>
<td><strong>Cost:</strong> Loss of an estimated $53,520 to $120,420 to the economy annually from Atlantic salmon may be attributable at least in part to the causeway. Using a willingness to pay approach, the combined market and non-market value of the Atlantic salmon fishery of between $348,415 to $415,315 annually. <strong>Cost:</strong> May have been a slight decrease in sea-run brook trout due to the causeway. <strong>Benefit:</strong> Value of annual smallmouth bass fishery may be as high as $470,000 annually. No data are available on chain pickerel. <strong>Cost:</strong> Most other recreational species in decline with the exception of gaspereau that seem to be relatively unaffected by the causeway. <strong>Overall:</strong> There has been an overall cost based on the net effects on recreational fishing stocks.</td>
</tr>
<tr>
<td><strong>Sea Cadet Training</strong></td>
<td><strong>Benefit:</strong> The causeway resulted in the opportunity for sea cadet training to be developed in the GMA.</td>
</tr>
<tr>
<td><strong>Vessel Traffic and Navigation Upstream of the Causeway</strong></td>
<td><strong>Benefit:</strong> Headpond has created opportunity for boating in GMA and resulted in the development of a marina.</td>
</tr>
<tr>
<td><strong>Vessel Traffic and Navigation at the Causeway</strong></td>
<td><strong>Cost:</strong> The causeway prevents vessel traffic and navigation at the causeway.</td>
</tr>
<tr>
<td><strong>Vessel Traffic and Navigation Downstream of the Causeway</strong></td>
<td><strong>Cost:</strong> Sedimentation of the river has reduced navigability downstream of the causeway to a point well below Belliveau Village. The causeway is an obstruction to navigation.</td>
</tr>
<tr>
<td><strong>Other Water-based Recreational Activities</strong></td>
<td><strong>Cost:</strong> Water quality frequently does not meet CCME Guidelines for Recreation and may be considered a cost.</td>
</tr>
<tr>
<td><strong>Labour and Economy (Commercial Fishery - Other factors addressed indirectly under other VECs (e.g., Land Use, Tourism))</strong></td>
<td><strong>American eel</strong> <strong>Benefit:</strong> Eel fishery of $10,000-$60,000 annually may have been facilitated by gates and causeway. <strong>American shad</strong> <strong>Cost:</strong> Loss of up to average annual pre-causeway fishery of $31,200.</td>
</tr>
</tbody>
</table>
Table 12.1.1 Economic Benefits/Costs Associated with the Causeway as of 2005

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Atlantic salmon</strong></td>
<td><strong>Cost:</strong> Causeway may have contributed to the decline and closure of the commercial fishery, although no cause-and-effect relationship can be established between the causeway and the recent protection under SARA.</td>
</tr>
<tr>
<td><strong>Atlantic sturgeon</strong></td>
<td><strong>Cost:</strong> Lost of access to freshwater spawning habitat above the causeway resulted in loss of potential for continued commercial fishery based on Petitcodiac River stock.</td>
</tr>
<tr>
<td><strong>Gaspereau</strong></td>
<td><strong>No apparent net effect:</strong> Gaspereau continue to negotiate fishway/gates and successfully use freshwater habitat; commercial fishery declined possibly due to demand.</td>
</tr>
<tr>
<td><strong>Lobster</strong></td>
<td><strong>Not a factor:</strong> Although no casual relationship has been established between the causeway and improved lobster fishing in Shepody Bay, the increased landings in the inner Bay, similar to increases experienced elsewhere in the Bay of Fundy, have contributed about $85,000 to $175,000 annually to the fishery.</td>
</tr>
<tr>
<td><strong>Scallop</strong></td>
<td><strong>Benefit:</strong> There may have been some very minor improvement in landings in the upper Chignecto and Shepody Bays due to the causeway, although no causal relationship has been established.</td>
</tr>
<tr>
<td><strong>Heritage and Archaeological Resources</strong></td>
<td><strong>Not a factor.</strong></td>
</tr>
<tr>
<td><strong>Public Health and Safety</strong></td>
<td><strong>Cost:</strong> Increased risk of flooding and potential release of contaminants from the former Moncton Landfill. <strong>Cost:</strong> Loss of assimilative capacity of the river resulted in unacceptable water quality for contact recreation both upstream and downstream of the causeway. Other aspects of Public Health and Safety not a factor.</td>
</tr>
</tbody>
</table>

12.1.1 Atmospheric Environment

Changes in the Atmospheric Environment as a result of the causeway are relatively minor and do not have obvious benefit/cost implications.

12.1.2 Fish and Fish Habitat

The causeway has resulted in very substantial significant negative environmental effects on Fish and Fish Habitat and the fish passage solution currently in place does not meet the requirements of DFO when construction of the facility was approved. The migration of fish is being impeded for many species such that they can no longer access critical habitat. These significant negative environmental effects have resulted in the fish passage Project Objective. The resultant proposed Project Options are described in Section 6.2. The very substantial cost of addressing these Fish and Fish Habitat issues are in “hard terms,” the total capital and operating costs of the Project Options that meet the fish passage Project Objective as described...
in Section 12.2. Other economic considerations related to the fish passage Project Objective are described in Section 12.3.

12.1.3 Terrestrial and Wetland Environment

While the causeway has resulted in an increase in saltwater and freshwater wetlands that are presently important to wildlife and migratory birds, the type and characteristics of the wetlands have changed significantly since causeway construction. This has resulted in an overall negative environmental effect of causeway construction on wetlands. Additionally, the causeway has created ESAs at Outhouse Point and Lower Coverdale Island. The causeway has resulted in the reduction in mudflat area, and hence mudflat productivity through flooding of the headpond and sedimentation of the estuary downstream of the causeway. However, because mudflats in the river are believed to be considerably less important as feeding habitat for migrating shorebirds than mudflats in Shepody Bay (Section 9.3.4.4), the loss of mudflats in the river has not had substantial affects on migratory shorebirds. Therefore, the causeway has had an overall benefit to the terrestrial and wetland environment.

12.1.4 Municipal Services and Infrastructure

The causeway is not a factor for the water distribution system as there would have been no substantive differences had another transportation link been built (e.g., a bridge). However, the causeway has had benefit/cost implications to the following elements.

12.1.4.1 Sanitary Sewer Systems

Construction of the causeway changed the water flow conditions on the Petitcodiac River and created the conditions (an identified health risk) leading to the need to install a wastewater collection and treatment system in the Moncton area (Section 5.6.2). The cost of this system, which from 1983 to 2004 totalled $56.6 million, can be regarded as an indirect cost of the causeway as the flushing afforded by the tidal flux in the pre-causeway period was sufficient to dilute or assimilate the municipal effluent. However, given the increasing preference by society to preserve the environment, it is likely that the wastewater treatment system would have been installed at some later point in time even if the causeway had not been constructed. Therefore, the effect of the causeway was to shift the wastewater treatment costs to an earlier point in time.

12.1.4.2 Storm Sewer Systems

Increased sedimentation in the river as a result of the causeway has resulted in the build-up of sediment and ice at sanitary sewer and aboiteaux flapgates and in storm drainage channels (Sections 9.4.4.2 and 9.4.4.3), which has resulted in ongoing monitoring and maintenance costs to ensure proper functioning.

12.1.4.3 Dykes and Aboiteaux

Since construction of the causeway, upstream dyke and aboiteaux structures have either been destroyed or fallen into disrepair, since protection from flooding is provided by the causeway and they are no longer needed. As such, monitoring and maintenance of these structures are not required by the New Brunswick Department of Agriculture, Fisheries and Forestry (NBDAFA), which monitors and provides regular maintenance on dykes and aboiteaux downstream of the causeway. It is estimated that the causeway avoids about $330,000 in
annual maintenance costs, as NBDAFA currently spends about $300,000 annually in downstream dyke capital maintenance works and there are approximately 10% more dyke structures upstream than downstream.

12.1.4.4 Other Infrastructure
The headpond has afforded the opportunity for the construction of the Tri Community Marina, the Town of Riverview public dock, the Sea Cadet’s facility and the major infilling along the riverbanks in Moncton, Riverview and Dieppe has facilitated the establishment of various walking trails, resulting in benefits to the GMA.

12.1.5 Road Transportation Network
The causeway is not an economic consideration with respect to the Road Transportation Network. Had the causeway not been built, some other transportation link would have been constructed (e.g., bridge).

12.1.6 Vessel Traffic Navigation

12.1.6.1 Boating Upstream of the Causeway
Upstream of the causeway, the headpond has created opportunities for boating and development of related recreational uses and infrastructure (i.e., Sea Cadet training, Tri Community Marina and the Town of Riverview public dock). These are limited by shallow draft over much of the headpond due to siltation that has occurred since construction of the causeway.

12.1.6.2 Boating at the Causeway
The causeway itself is an obstruction to navigation.

12.1.6.3 Boating Downstream of the Causeway
Sedimentation of the Petitcodiac River downstream of the causeway has resulted in reduced navigability. This reduction in navigability has been recognized to a point below Belliveau Village where fishers report being able to pursue shad fishing only at the peak of high tide due to restricted draft because of sedimentation, and as such is a potential cost.

12.1.7 Land Use and Value

12.1.7.1 Risk of Flooding
The causeway has resulted in an increased risk and magnitude of flooding associated with stormwater runoff and ice jamming in the GMA due to the reduction in channel conveyance (Section 5.2.6). This has resulted in an increased risk of flooding and related increase in potential damage and cost of flood insurance. It is not possible to quantify the costs of flooding as a result of the causeway without a detailed flood risk study that better defines the level of risk and required mitigation measures.
12.1.7.2 Property Value

As noted in Section 5.9.2, there has been a 5% premium in property value for water-front vacant lots above the causeway (Moncton to Salisbury) as compared with water-front vacant lots below the causeway (Moncton to Shepody Bay). The slightly higher vacant property values upstream (+5%) may be attributable to proximity of the headpond and thus the causeway or to the increased risk of flooding below the causeway. There is no significant difference in property value for water-front developed lots upstream compared to downstream of the causeway.

12.1.7.3 Access to the Petitcodiac River

The causeway has created the headpond, which maintains a relatively stable elevation during the open water season. This has resulted in some property owners installing docks (17 private docks) for personal use and there are reports that some property owners may also use their property to access float planes on the Petitcodiac River.

12.1.8 Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons

The Fort Folly First Nation has a long history of fishing and hunting activities in the region, including some that occurred along and in the Petitcodiac River and estuary. These have reportedly declined since the construction of the causeway (Section 5.10) and as such, the causeway has resulted in a cost to the Aboriginal Community. There has been no recorded use of the headpond by members of the Aboriginal Community.

12.1.9 Tourism

The Petitcodiac River tidal bore has historically been an important tourism theme and attraction for the GMA. The key aspect of the analysis of tidal bore viewing is the identification of the importance of the tidal bore and the River to the tourism and visitor industry. After discussions with municipal and provincial tourism officials, as well as tourism industry officials, it was determined there is no pre-causeway quantitative information on the number of visitors that travelled to the GMA to view the tidal bore. There is some information on the post-causeway period level of interest in the River and tidal bore. However, there is no specific information on the contribution that the River makes, or has made, to the overall tourism industry, which has experienced considerable growth in the post-causeway period.

Prior to the construction of the causeway, the Fundy tides and the tidal bore were promoted by both the GMA and the provincial government. This included publication and distribution of the tidal bore schedule (newspapers, tourist literature, etc.), explanation of the tides and the bore and the ongoing development of Boreview Park. The tidal bore has not been promoted as a visitor attraction by the GMA or provincial government over the last 20 years. Officials at the GMA tourism office indicated that the number of visitors to view the tidal bore would have been greater over the period from 1968 to present if the causeway had not been constructed.

The New Brunswick Department of Tourism and Parks and the communities of Moncton, Riverview and Dieppe were contacted to obtain any current and historical tourism and visitor statistics (Duggan, pers. comm.).
During the peak tourism season, (July through August), an average of 60 to 70 visitors go to the Visitor Information Centre at Boreview Park per day, with the number of visitors decreasing to around 30 to 40 per day, on average, in the shoulder season (May, June, September and October). In 2003, an estimated total number of 3,500 visitors visited the Boreview Park to view the tidal bore overall, with a total of 7,600 inquiries at the Visitor Information Centre. Visitors to Boreview Park may be there to view the tidal bore, as well as to hike along the trails, or engage in bird watching. Additional information would have to be collected from visitors at Boreview Park to strictly determine the purpose of their visit. Visitors to Boreview Park spend on average 0.75 to 4 hours in the Park. This extends the length of stay for visitors to the GMA by as much as a half to a full day and overnight. The expenditures per visitor realized in the GMA because of the tidal bore are approximately $175 per person, which includes an overnight visit. Based on the number of visitors to view the tidal bore in 2003, the total direct expenditures realized in the GMA would be about $600,000 per year.

Officials at the City of Moncton tourism office indicated that if the causeway had not been built, the tidal bore would most likely have continued to be promoted as a visitor destination in New Brunswick as it was prior to the construction of the causeway. As a result, the number of visitors to the Boreview Park Information Centre would most likely be 200 to 300 per day during the peak period with an estimated 80 to 90 per day in the shoulder season. This would represent an increase of roughly 5,000 visitors per year to view the tidal bore. To put this figure in perspective, note that currently, between 600 to 700 vehicles visit Magnetic Hill per day during the peak season, with between 13,000 to 15,000 visitors going to Magic Mountain in July and between 10,000 to 13,000 visitors in August, (based on tourism data for Magic Mountain visitation, 2002). Based on the range of average expenditures generated per visitor, an increase of 5,000 visitors per year to view the tidal bore would result in an increase of about $900,000 in direct expenditures per year. This assumes that the tidal bore will be as effective of a tourist attraction as it was prior to the construction of the causeway. These additional expenditures could become higher as a result of aggressive promotions to target audience for viewing the tidal bore in the shoulder season (May, June, September and October).

During the public consultation process, it was reported that there is some use of the headpond by tourists who use the headpond to land float planes. Presumably, these tourists also spend money in the local communities, but specific expenditure values are not available.

12.1.10 Recreation

12.1.10.1 Recreational Fisheries

Atlantic Salmon

Atlantic salmon in the Petitcodiac River system has declined drastically since construction of the causeway and the Inner Bay of Fundy population crash in the late 1980s and early 1990s. Evidence (catch data) suggests that the decline in the recreational fishery in the Petitcodiac River was clearly attributable to fish passage difficulties at the causeway (AMEC, 2005a) although it is unclear the extent to which the causeway may have contributed to the decline in Inner Bay of Fundy population of which the Petitcodiac River salmon are one component stock.
There is no longer an open season for Atlantic salmon on the Petitcodiac River. Based on the average angling effort from 1951 to 1968 (Locke and Bernier, 2000), there was an average annual effort of 1,010 angler-days in the Petitcodiac River. This value includes both black and bright salmon effort. Over the 1951 to 1968 period, the angling effort increased, and in 1967, there were 2,818 angler-days expended on salmon in the Petitcodiac River system.

Mr. William Hooper (NBDNR; Hooper, pers. comm.) used the following rules-of-thumb to calculate the potential Atlantic salmon angling benefits for a river system:

- effort is proportional to the size of the spawning run;
- approximately one quarter of the spawning run is captured annually; and
- acceptable angling quality that maintains effort is one fish caught per three angler-days.

Using these rules on the Petitcodiac River, the annual potential angling effort would be:

\[
\text{Effort} = 3,000 \times 0.25 \times 3.0 = 2,250 \text{ angler-days per year.}
\]

This number agrees approximately with the annual effort in the late 1960s.

However, as mentioned previously, the Inner Bay of Fundy salmon collapsed, and it is assumed that the Petitcodiac River stock would have been affected by this collapse as well. The Big Salmon River is an index river for the Inner Bay of Fundy salmon population. Its numbers fell below 1,000 fish and have stayed below this number since 1990 (Gibson, et. al., 2003). The year 1990 was used to delineate the prior period of potentially acceptable angling quality on the Petitcodiac River from that when angling quality would have negatively affected participation (1990 to 2004). Using this assumption, there would have been 22 years of “good” angling, and 15 years of “poor” or closed angling. This represents 59.5% “good” angling since the causeway was constructed. Discounting the calculated angling effort of 2,250 angler-days per year by the good angling ratio, there would have been 1,338 days per year of salmon angling on the Petitcodiac River lost as a result of the causeway’s construction.

Assuming an average expenditure of $40-90 per rod day (in 2004 dollars) lost to the economy, the market value of the loss of the salmon fishery is estimated to range between $53,520 and $120,420 per year.

The “non-market” value of the salmon fishery can be estimated by using a “willingness to pay” value obtained through the use of a willingness to pay question on the DFO 1995 Survey of Recreational Fishing in Canada. Using the Consumer Price Index to measure inflation since 1995, the average additional costs resident anglers were willing to pay to fish in New Brunswick is $220.40 per rod day in 2004 dollars. This gives a combined market and “non-market” value range of the salmon fishery lost potentially or in part due to the causeway of $348,415 to $415,315 per year (in 2004 dollars) in the post-causeway period to the present.

**Brook Trout**

Brook trout is the primary recreational fish species in the Petitcodiac River drainage, as it is in the rest of the Province of New Brunswick (AMEC, 2005a). The causeway may have initially
caused a slight increase in the brook trout population and hence this recreational fishery because competitive juvenile salmon populations were depressed as a result of the causeway and headpond (Hooper, pers. comm.). The headpond is now thought to be the lower limit of the downstream migration of this amphidromous species. It is unlikely that sea-run brook trout experience fish passage difficulties at the causeway because they do not now enter the estuary. The blocking of brook trout from the estuary may have resulted in the decrease in the size of individual fish because of a decrease in access to food fish. However, it is unlikely that there would have been an effect on population numbers. Between 1970 and 2000, catch in the Petitcodiac River has ranged from between 37,000 and 213,000 trout per year (AMEC, 2005a). In the most recent year that statistics were compiled, there was a drastic decrease in catch per unit effort. The value of any causeway related effect cannot be quantified due to the absence of data regarding sea-run brook trout prior to the causeway.

**Smallmouth Bass and Chain Pickerel**

Smallmouth bass and chain pickerel, fish species that have no tolerance in any life stage for saltwater, were introduced into the headpond without the permission of regulators (Section 9.2.4.3). As a result, recreational fisheries have developed for both of these species on the headpond. The smallmouth bass fishery consists of approximately 277 anglers, each with approximately 5.46 angler days per year (AMEC, 2005a). An annual bass fishing tournament on the headpond serves local area participants. There is no available information on the pickerel fishery. No pickerel were taken during electrofishing on the headpond in 2003. It is suspected that the pickerel population is either in decline, or was never at a significant level in the Petitcodiac River headpond.

Based on the 2000 DFO Survey of Recreational Fishing in Canada, 277 anglers fish for bass on the headpond, including the 150 bass fishers attracted from the GMA. With an average of 5.46 angler-days per year per angler, this represents a total of 1,511 angler-days for bass. These angler days are predominantly local bass fishers. The value of the smallmouth bass fishery is comprised of the market value associated with expenditures made in the study area due to the bass fishery as well as the non-market value of the bass fishery. Based on a maximum average expenditure of $90 per angler day to the number of bass angler days yields a market value of the smallmouth bass fishery of $136,000 per year (in 2004 dollars). The non-market value of the smallmouth bass fishery is the value bass fishers would have been willing to pay for bass fishing in addition to the amount they actually paid. Using the additional willingness to pay value for recreational fishing in New Brunswick of $220.40 per angler day (in 2004 dollars) based on the DFO 1995 Survey of Recreational Fishing in Canada, the estimated non-market value of the smallmouth bass is $330,000 per year (in 2004 dollars). This gives a combined market and non-market value of the smallmouth bass fishery on the headpond of $470,000 per year (in 2004 dollars).

The bass population was sampled by using electrofishing techniques during the 2003 field season. The oldest bass that was sampled was approximately 10 years old, and had grown at an equivalent rate as bass from well known New Brunswick bass lakes. Bass of over 15 years old, such as those from well known New Brunswick bass fishing lakes, are considerably larger than the oldest taken from the headpond (Curry, pers. comm.). There is potential for an older
bass population with larger individuals to provide a perceived “better” angling experience, which in turn might increase angling effort for bass. This is supposition however, and no allowances have been made for this in the value calculations.

Other Species

Most other recreationally fished species in the Petitcodiac River system have suffered declines since construction of the causeway as a result of fish passage difficulties or increased infilling of the estuary. These species include American shad, Atlantic tomcod, rainbow smelt and striped bass. However, gaspereau populations do not appear to have been negatively affected by the causeway; they have been observed to successfully use the fishway, are greatly aided during upstream passage by the gate-opening strategy, and the headpond provides nursery habitat for young-of-the-year (AMEC, 2005a).

12.1.10.2 Sea Cadet Training

The sea cadet sailing program may not have developed on the Petitcodiac River if the causeway had not been constructed. However, the benefits of the program would not have been completely lost if the causeway had not been built; alternative locations exist outside the Moncton area (e.g., Shediac Bay, Grand Lake) and such activities could have occurred on the estuary within the constraints of current and tidal fluctuation. By using one of those locations, the benefits of the program would have been retained, although in a less convenient form. There would possibly be higher costs for transporting the cadets to the weekend training sessions if they were to occur outside of the GMA (although not necessarily higher for cadets coming from outside the GMA).

12.1.10.3 Vessel Traffic and Navigation Upstream of the Causeway

Many of the recreational boating activities that take place upstream of the causeway (i.e., on the headpond) may not have been developed if the causeway had not been constructed (e.g., power boating, sailing) in the GMA although those activities would have been feasible in the estuary within the constraints of current and tidal fluctuation. This benefit may have been replaced with alternative recreational activities in the GMA, but it remains that the marina and associated boating are tangible benefits of the causeway.

12.1.10.4 Vessel Traffic and Navigation at the Causeway

The causeway is an obstruction to navigation.

12.1.10.5 Vessel Traffic and Navigation Downstream of the Causeway

Downstream of the causeway, sedimentation of the Petitcodiac River has resulted in reduced navigability to a point below Belliveau Village.

12.1.10.6 Other Water-based Recreation

The water quality in the headpond and estuary in summer frequently does not meet the CCME Guidelines for Recreation. This will prevent the safe use of the headpond and estuary for swimming, boating and kayaking where there is contact, and is a cost.
12.1.11  Labour and Economy

Labour and Economy is primarily addressed indirectly under other VECs (e.g., Land Use, Tourism). Capital and operating costs associated with the causeway would have been incurred had an alternative transportation link been constructed (e.g., a bridge), therefore this section focuses on the commercial fisheries.

12.1.11.1 Commercial Fisheries

American Eel

Eels existed in the estuary and above prior to the causeway. The presence of the causeway would appear to have improved conditions for fishing. The American eel fishery on the Petitcodiac River began in 1995, after the causeway was constructed, and stopped around 2002. A portion of the eel fishing, that for live elvers used as seed stock for grow-out in Europe, was conducted within 100 m of the causeway. Fishing boats used a push net on the front of the boat and circle near the shore. The elver fishery season lasted from mid-May to early June (approximately 20 nights). The upstream migrating elvers are attracted to the freshwater. A primary reason suspected to have helped the strong eel fishery in 1995 was that the stop logs used in gate #5 concentrated the elvers to that location. As a result of the stop logs, there was a constant flow of water that also kept the sediment accumulation to a minimum. When the stop logs came out in 1999, the eel fishery declined. Discussions with eel fishers indicate that in the last 3 years the elvers have not been worth fishing (2002-04) due to depressed prices.

In 1995 the price of elvers was $100/kg, which rose to $150/kg in 1997. After 1997, the price fluctuated but never went above $50/kg. Over the period 1995 to 2002, average catches of elvers per year ranged between 150 to 400 kg. Based on the fluctuation in prices over this period, the total value of the elver fishery ranged from an estimated high in 1997 of $60,000 to a low value of $7,500 per year since 1997. Given the late emergence of the elver fishery with the causeway in place, it is difficult draw definitive conclusions about the role of the causeway. The elver fishery has only been pursued in recent years and may be attributable or at least facilitated by the presence of the causeway and gates and the headpond. Landings to date have ranged from $10,000 to $60,000 annually.

There is also one fisherman who fishes large “green” eels in the headpond (license to fish in 2004). He has been fishing in the headpond since 1996, and in normal years catches 2 to 2.5 tonnes of “green” eels per year, and is able to sell them for $4.09 (US)/kg for a value of $9,250 US.

American Shad

An effective spawning population of shad no longer exists in the river due to the fact that few are able to pass through the fishway (Section 9.2.4.3). However, a small commercial fishery (three fishers in 2004) still exists in the estuary for shad that enter the river to feed on benthic invertebrates and plankton. In the years preceding construction of the causeway (1957-1968), landings in District 79 (Albert County) and 80B (Fundy part of Westmorland County) ranged from approximately 8 to 30 tonnes annually. Total landed value ranged from $1,000 to $8,000 annually (approximately $6,000 to $48,000 in 2004 dollars). The average annual landings from
1964-1968 were $5,200 (approximately $31,200 in 2004 dollars). While the fishery in these districts was not entirely derived from Petitcodiac River stock, it suggests that the causeway has resulted in a severe decline in the fishery and the loss of up to an average of $31,200 per year in 2004 dollars has occurred. The cause of the decline is thought to be a decrease in fishing opportunity due to shallower water in the fishing zone. Current fishing, although under commercial license is actually primarily of a recreational/subsistence nature, pursued by fishers that were at one time professional.

**Atlantic Salmon**

As mentioned in Section 12.1.10.1 (Atlantic salmon), after construction of the causeway, the Atlantic salmon population started to drastically decline in the Petitcodiac River system (Section 9.2.4.3); evidence (catch data) may suggest that the cause was impaired passage at the fishway (AMEC, 2005a). The Inner Bay of Fundy salmon population, of which Petitcodiac River salmon are members, collapsed suddenly in the late 1980s and early 1990s, leading to its "Endangered" status designation by COSEWIC and protection under SARA. Although it is unknown and widely debated as to the cause of this collapse, some believe that tidal barriers such as the causeway may be partly to blame (Section 9.2.4.3). The commercial fishery for Inner Bay of Fundy salmon has since disappeared.

**Atlantic Sturgeon**

Atlantic sturgeon exist downstream of the causeway, but have no, or limited access to freshwater spawning habitat upstream of the causeway. Commercial sturgeon fishing occurred both prior to and after construction of the causeway. The longevity of sturgeon suggests that the presence of adult fish downstream of the causeway may include remnants of the pre-causeway Petitcodiac River stock. It is likely that if a spawning population existed, it no longer has access to critical spawning habitat and there is therefore little or no recruitment from the Petitcodiac River to the population that currently inhabits the estuary.

**Gaspereau**

There never was a commercial gaspereau fishery in the Petitcodiac River estuary. The fishery listed in the statistics for District 81 is for the Cumberland Basin, where gaspereau are still fished in the Tantramar estuary around the Town of Sackville. Gaspereau successfully use the fishway and the headpond provides nursery habitat for young-of-the-year (AMEC, 2005a). As such, the causeway appears to have had no apparent environmental effect on the commercial gaspereau fishery. The gaspereau produced in the Petitcodiac River may contribute fish that are caught in the fishery conducted in the adjacent Cumberland Basin fishery for the species.

**Lobster**

The commercial lobster fishery in the region has increased (in lobster landings) since about 1996. According to DFO, increased landings in LFA 35 and adjacent LFAs in the area appear to be due to increased populations, improved fishing practices and lobster fishing further from the shore. Observations from local fishers indicates that the change in tidal action and sediment patterns as a result of the causeway may have had a positive effect on lobster landings (Section 9.2.4.3), permitting lobster fishing further into Shepody Bay. However, it is unclear if sedimentation of the Petitcodiac River as a result of the causeway has actually had any causal
relationship with the species itself as the increased landings occurred almost 30 years after the causeway was constructed.

To put the lobster fishery in context, Alma fishers report that they take approximately 5% of their lobsters from the area in question, primarily in spring, and expend 10% of their effort there. The combined value of landings in Districts 79 and 81 range between about $1.7M in 1996 and $3.5M in 2001. Assuming that 5% of those landings were taken from this area, the value of landings potentially affected positively could be as much as $85,000 to $175,000 annually. However, it is unlikely that a cause and effect relationship does exist between the establishment of the causeway and the value of landings from this area.

**Scallop**

It is thought that construction of the causeway has not affected the value of the scallop fishery since most of this fishery takes place some distance from the mouth of the Petitcodiac River. However, it is noted that some scallop beds have recently extended up to Apple River and observations and reports by fishers suggests that these beds would not have established if the causeway had not been built, because of the higher turbidity associated with high tidal flow under natural conditions. This is unlikely given that the major infilling due to the causeway took place more than 30 years ago. More recent infilling rates are much lower. Also, the seasonal movement of sediment will still occur under the Status Quo. The upper Chignecto and Shepody scallop fishing accounts only for a very small fraction of the $1-$3M annual landings in the Apple River area; a majority of the fishing effort takes place east of Alma, toward Apple River. As with the lobster fishery, it is unlikely that a cause and effect relationship does exist between the establishment of the causeway and the improvement in the fishery. This potential benefit of the causeway will be subject of a monitoring program to verify or negate it.

12.1.12 **Heritage and Archaeological Resources**

The causeway would appear to not have affected Heritage and Archaeological Resources as its footprint and the wetlands that have evolved since construction of the causeway are primarily within the former river channel.

12.1.13 **Public Health and Safety**

12.1.13.1 **Flooding**

Flood risk and the costs associated with this flooding are greater as a result of construction of the causeway (Sections 5.2.3 and 5.15.6). This increased risk occurs because of loss of water conveyance capacity, increased probability of dykeland flooding related to malfunctioning of aboiteaux, road flooding and flooding resulting from ice jams. As explained in Section 12.1.7.1, it is not possible to quantify these costs without a detailed flood risk study.

12.1.13.2 **Former Moncton Landfill**

The causeway has resulted in the deposit of sediment upon which the former Moncton Landfill has extended over. The landfill now results in the potential discharge of leachate directly and indirectly into the Petitcodiac River and as such is a potential cost.
12.1.13.3 Recreational Contact

As a result of the causeway and subsequent decrease in the river's assimilative capacity (i.e., for fecal coliforms), recreational water quality both upstream and downstream of the causeway became questionable and unsuitable for many recreational water activities (e.g., swimming) and is a cost.

12.2 Capital and Operating Costs of the Status Quo and Project Options

12.2.1 Status Quo Capital and Operating Costs

Section 7.3 presented capital costs associated with the status quo ($8,300,000) with respect to operation, at present NBDOT plans to replace the concrete barriers alongside the roadway of the causeway at an estimated cost of $150,000. They have no other capital works planned on the causeway, but there is a plan to repave the traffic circle in 2005. The report to NBDOT, “Analysis of Options for the Future of the Petitcodiac River Dam and Causeway” (ADI/Washburn & Gillis, 1992), estimated that a major repair of the gates would be required every 15 years. In 2004 dollars the equivalent 15-year major repair expenditure would be $666,800. There is ongoing operation and maintenance costs for the causeway as described in Section 12.1, and these will continue with the Status Quo.

It should be noted that the NBDOT were in the process of proposing major gate repair and upgrading prior to commencement of this EIA. NBDOT has postponed the proposed repairs pending the findings of the EIA.

12.2.2 Project Options Capital and Operating Costs

Table 12.2.1 shows the capital and operating costs associated with the Project Options that meet the fish passage Project Objective, including mitigation required for the implementation of each Project Option as described in Chapter 7 (Project Description and Implementation Strategy). The causeway will continue to be operated in Stage I. For more detailed cost information see Chapter 7.

The cost estimates in Table 12.2.1 include the tasks identified in the Section 7.1.1 for all of the Project Options.

12.3 Other Economic Considerations of the Status Quo and Project Options

This section qualitatively considers economic costs and benefits, other than the capital and operating costs discussed in Section 12.2, of the Status Quo and Project Options. Table 12.3.1 summarizes this information. Where there are no apparent economic benefits or costs for a particular VEC (or no anticipated change from baseline conditions), it is indicated to be “not a factor.” The discussion includes some semi-quantitative estimates of benefits and costs, which involve many assumptions and in most cases represent the worst or best case estimates. These estimates cannot be added as they are a combination of both qualitative and quantitative estimates, each based on different assumptions.
### Table 12.2.1 Capital and Operating Costs of the Project Options

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<tr>
<th>Activity</th>
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<th>Project Option 4A</th>
<th>Project Option 4B</th>
<th>Project Option 4C</th>
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<tr>
<td>Environmental monitoring for 5 years</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>Operation for 3 years</td>
<td>$150,000</td>
<td>$150,000</td>
<td>$150,000</td>
<td>$150,000</td>
</tr>
<tr>
<td>Subtotal Stage 3</td>
<td>$12,530,000</td>
<td>$17,600,000</td>
<td>$29,140,000</td>
<td>$78,660,000</td>
</tr>
<tr>
<td>Total Cost for Each Option</td>
<td>$34,080,000</td>
<td>$41,950,000</td>
<td>$54,610,000</td>
<td>$107,270,000</td>
</tr>
</tbody>
</table>
### Table 12.3.1 Other Economic Benefits/Costs of the Status Quo and Project Options

<table>
<thead>
<tr>
<th>Economic Considerations by VEC/Issues</th>
<th>Status Quo</th>
<th>Project Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Environment</td>
<td><strong>Not a factor</strong></td>
<td><strong>Not a factor</strong></td>
</tr>
<tr>
<td>Fish and Fish Habitat</td>
<td><strong>Cost:</strong> Status Quo will not meet the fish passage Project Objective due to fish passage problems.</td>
<td><strong>Benefit:</strong> Project Options meet the fish passage Project Objective by solving fish passage problems.</td>
</tr>
<tr>
<td>Wetlands</td>
<td><strong>Cost:</strong> Even though wetland area will be increased over existing conditions, the type and characteristics of the wetlands (species diversity, tidal influences) have changed significantly, resulting in overall negative environmental effects.</td>
<td><strong>Benefit:</strong> Wetland area will reduce overall as compared to existing conditions, but will remain considerably greater than under the pre-causeway condition.</td>
</tr>
<tr>
<td>Wildlife and Vegetation</td>
<td><strong>Benefit:</strong> Increased wetland area will increase wildlife and vegetation habitat.</td>
<td><strong>Benefit:</strong> Wetland area and wildlife habitat will be maintained well above pre-causeway levels.</td>
</tr>
<tr>
<td>Migratory Birds</td>
<td><strong>Benefit:</strong> Increased wetland area will increase migratory bird habitat.</td>
<td><strong>Benefit:</strong> Wetland area and migratory bird habitat will be maintained well above pre-causeway levels.</td>
</tr>
<tr>
<td>Mudflat Productivity</td>
<td><strong>Neutral:</strong> Reduction in mudflat productivity not likely to affect critical habitat for migratory birds.</td>
<td><strong>Benefit:</strong> Increased mudflat productivity.</td>
</tr>
<tr>
<td>Managed Areas</td>
<td><strong>Not a factor</strong></td>
<td><strong>Not a factor</strong></td>
</tr>
<tr>
<td>Water Distribution Systems</td>
<td><strong>Not a factor</strong></td>
<td><strong>Not a factor</strong></td>
</tr>
<tr>
<td>Sanitary Sewer Systems</td>
<td><strong>Cost:</strong> Sewage treatment requirements will cost $36,400,000.</td>
<td><strong>Benefit:</strong> Sewage treatment cost of $36,400,000 may be avoided or deferred.</td>
</tr>
<tr>
<td>Storm Sewer Systems</td>
<td><strong>Cost:</strong> Continued sedimentation of aboiteaux and flap gates will require ongoing maintenance.</td>
<td><strong>Benefit:</strong> Erosion and opening of channels will reduce maintenance requirements for aboiteaux and flap gates.</td>
</tr>
<tr>
<td>Dykes and Aboiteaux</td>
<td><strong>Benefit:</strong> Causeway prevents need for dyke and aboiteaux maintenance upstream.</td>
<td><strong>Cost:</strong> Annual maintenance of dykes and aboiteaux upstream of the causeway estimated at $550,000 per year to adequately maintain these structures.</td>
</tr>
<tr>
<td>Other Infrastructure</td>
<td><strong>Benefit:</strong> Continued use of sea cadet training facility and Tri Community Marina.</td>
<td><strong>Cost:</strong> Compensation for sea cadet training facility, Town of Riverview public dock and Tri Community Marina loss.</td>
</tr>
<tr>
<td>Road Transportation Network</td>
<td><strong>Cost:</strong> Sedimentation will result in increased flooding risk to some roads.</td>
<td><strong>Benefit:</strong> Reduced flooding risk to some roads.</td>
</tr>
</tbody>
</table>
Table 12.3.1 Other Economic Benefits/Costs of the Status Quo and Project Options

<table>
<thead>
<tr>
<th>Economic Considerations by VEC/Issues</th>
<th>Status Quo</th>
<th>Project Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Traffic and Navigation Upstream of the Causeway</td>
<td>Benefit: Headpond allows recreational boating and sailing.</td>
<td>No net benefit or cost: Vessel navigability upstream of the causeway will be restored to conditions similar to pre-causeway. Headpond recreational boating will be lost as currently practiced.</td>
</tr>
<tr>
<td>Vessel Traffic and Navigation at the Causeway</td>
<td>Cost: The causeway prevents navigation at that location.</td>
<td>Benefit: Vessel navigability at the causeway location will be restored.</td>
</tr>
<tr>
<td>Vessel Traffic and Navigation Upstream of the Causeway</td>
<td>Cost: Continued sedimentation prevents navigation downstream of causeway.</td>
<td>Benefit: Vessel navigability will be restored to conditions similar to pre-causeway.</td>
</tr>
<tr>
<td>Risk of Flooding</td>
<td>Cost: Increased risk of flooding due to sedimentation. This may warrant significant flood protection infrastructure to protect Moncton and Dieppe from flood damage and risk.</td>
<td>Benefit: Reduced flood risk and avoidance of need for flood protection infrastructure in Moncton and Dieppe.</td>
</tr>
<tr>
<td>Property Value</td>
<td>No net benefit or cost: Slight premium on vacant land upstream of causeway near headpond may persist but could be offset by overall restoration of natural estuarine ecosystem.</td>
<td>No net benefit or cost: Slightly lesser premium on vacant land near the river downstream of causeway may persist but could be offset by overall restoration of natural estuarine ecosystem.</td>
</tr>
<tr>
<td>Access to the Petitcodiac River</td>
<td>Benefit: Continued access of the headpond by property owners with docks or float planes.</td>
<td>Cost: Loss of access of the headpond by property owners with docks or float planes.</td>
</tr>
<tr>
<td>Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons</td>
<td>Cost: Reduction in land and resources currently used for traditional purposes.</td>
<td>Benefit: Restoration at least partly of land and resources currently used.</td>
</tr>
<tr>
<td>Recreational Fishing</td>
<td>Cost: Continued decline in recreational stocks, offset somewhat by introduced smallmouth bass and chain pickerel fisheries.</td>
<td>Benefit: Opportunity to restore native stocks, offset somewhat by loss of introduced smallmouth bass and chain pickerel fisheries.</td>
</tr>
<tr>
<td>Sea Cadet Training</td>
<td>Benefit: Continued use.</td>
<td>Cost: Compensation for loss required.</td>
</tr>
<tr>
<td>Headpond Boating</td>
<td>Benefit: Continued use.</td>
<td>Cost: Compensation for loss of Tri Community Marina and other recreational facilities required.</td>
</tr>
</tbody>
</table>
Table 12.3.1 Other Economic Benefits/Costs of the Status Quo and Project Options

<table>
<thead>
<tr>
<th>Economic Considerations by VEC/Issues</th>
<th>Status Quo</th>
<th>Project Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Fishery</td>
<td>Cost: Continued absence of lost commercial stocks and difficulty in fishing due to sedimentation. Benefit: Adult American eel fishery in the headpond nets an annual value of approximately $10,000</td>
<td>Benefit: Opportunity for restoration of commercial stocks and improved fishing conditions. Cost: Loss of the American eel fishery in the headpond.</td>
</tr>
<tr>
<td>Employment</td>
<td>Not a factor</td>
<td>Benefit: Construction and maintenance of Project Option.</td>
</tr>
<tr>
<td>Business</td>
<td>Not a factor</td>
<td>Benefit: Construction and maintenance of Project Option and increased business opportunity afforded by natural estuary (tidal bore, tidal flux).</td>
</tr>
<tr>
<td>Heritage and Archaeological Resources</td>
<td>Not a factor</td>
<td>Not a factor</td>
</tr>
<tr>
<td>Vehicular Accidents</td>
<td>Not a factor</td>
<td>Not a factor</td>
</tr>
<tr>
<td>Non-vehicular Accidents and Unplanned Events</td>
<td>Not a factor</td>
<td>Not a factor</td>
</tr>
<tr>
<td>Groundwater Quality and Quantity</td>
<td>Not a factor</td>
<td>Not a factor</td>
</tr>
<tr>
<td>Human Disease Vectors</td>
<td>Not a factor</td>
<td>Not a factor</td>
</tr>
</tbody>
</table>

12.3.1 Atmospheric Environment

Neither the Status Quo nor the Project Options are expected to result in significant environmental effects on the Atmospheric Environment (climate, air quality, odour, sound quality) (Section 9.1.4) as compared to the 2005 baseline. There may be localized climate and air quality changes with the Status Quo and Project Options but these cannot be considered a benefit or cost. Minor odour emissions with the Project Options are not expected to be of sufficient magnitude to be considered a cost. There will be some short-term increases in sound emissions during the construction of the Project Options and some potential benefits associated with the attenuation of sound in the area of the headpond. Overall, the changes in Sound Quality are not expected to be discernible as a benefit or cost.

12.3.2 Fish and Fish Habitat

The Status Quo does not meet the fish passage Project Objective and is the cause of the need for the Project Options because it continues to impede the migration of many fish species (Sections 9.2.4) so that they can no longer access critical habitat. In contrast, the Project Options meet the fish passage Project Objective (Section 6.6 and 6.7), allowing fish passage and resulting in substantial benefit. The Status Quo will continue to see smallmouth bass and
chain pickerel populations mature in the headpond. This can be considered a benefit of the Status Quo, although their introduction was illegal. These populations will be lost with the Project Options. Overall, the Project Options are considered to be of great benefit, despite the loss of smallmouth bass and chain pickerel, while the Status Quo an overall cost.

There could be additional costs associated with the consequences of ongoing violation of Section 20 of the *Fisheries Act* and future violation of Section 33 of the *Species At Risk Act* (Atlantic salmon and dwarf wedgemussel) that were not quantified as part of this study.

### 12.3.3 Terrestrial and Wetland Environment

#### 12.3.3.1 Wetlands

Wetlands will continue to develop downstream and upstream of the causeway as infilling in the river channel provides more suitable substrate for wetland plants. However, these wetlands that have developed post-causeway are not considered to be of particularly high value as they were not developed under a natural system.

Project Option 4C will result in the greatest increase to wetland value as the conditions would most closely approach those of the pre-causeway. The pre-causeway wetland conditions are considered to be more desirable, ecologically, then the post-causeway conditions, because they were part of a natural system. It is reasonably inferred that improved wetland quality would lead to increased wildlife and migratory bird use and an improvement in recreational viewing of these species. Project Options 3 and 4A will result in less of an increase to wetland value (than Project Option 4C). The environmental effects of Project Options 4B on wetland value would be between Project Option 4C and Project Options 3/4A, pending the selected channel width. This same assumption can be made for the remaining subcomponents of the Terrestrial and Wetland Environment VEC.

#### 12.3.3.2 Wildlife and Vegetation

The Status Quo will result in a benefit as it increases wetland habitat that is important for wildlife and vegetation over baseline 2005 and pre-causeway levels. The Project Options will convert freshwater wetland to saltwater wetland habitat upstream of the causeway and will result in a loss of saltwater habitat downstream of the causeway, but not below pre-causeway levels. Proposed mitigation includes protection of existing Ducks Unlimited wetlands upstream of the causeway. In meeting the Project Objectives while maintaining wetland area for wildlife and vegetation above pre-causeway levels, the Project Options in the context of a remediation project are considered to be a benefit.

#### 12.3.3.3 Migratory Birds

The Status Quo will increase wetland area and thus result in positive environmental effect on migratory birds. The Project Options convert freshwater wetland to saltwater wetland habitat upstream of the causeway and result in a loss of saltwater habitat downstream of the causeway, but not to pre-causeway levels. In both instances, the improved migratory bird habitat is a benefit.
12.3.3.4 Mudflat Productivity

The Status Quo will continue to result in some reduction in mudflat productivity. This reduction is not considered critical; mudflat productivity in Shepody Bay provides critical habitat for shorebird populations. The Project Options will increase mudflat area and presumably productivity in the estuary and have the potential to deposit eroded sediments from the river onto the mudflats in Shepody Bay, resulting overall in a positive environmental effect on mudflat productivity and the success of migrating shorebird populations. Consequently, the Project Options are considered to be a benefit.

12.3.3.5 Managed Areas

The Status Quo and Project Options are not expected to have significant negative environmental effects on Managed Areas in the Assessment Area.

12.3.4 Municipal Services and Infrastructure

12.3.4.1 Water Distribution Systems

The Status Quo will not have any environmental effects on water line in the Assessment Area, while the Project Options have the potential to expose the water line that crosses through the causeway. Mitigation, which involves lowering the line to an elevation that protects it from erosion, will ensure that Project Options have no significant negative environmental effects on water transmission systems in the Assessment Area. Overall, water distributions are not a factor.

12.3.4.2 Sanitary Sewer Systems

Due to worsening water quality conditions under the Status Quo (Section 9.13.4.4), it will become necessary to upgrade the existing GMSC wastewater treatment and collection system from chemically enhanced primary treatment (i.e., remove large solid objects with filters and sediment and organic matter in settling chambers and treat with chlorine) to secondary treatment (remove biodegradable organic matter from sewage using bacteria and other microorganisms). Tertiary treatment (use a variety of physical, chemical, or biological treatment processes to remove targeted pollutants) is not predicted to be necessary. The estimated cost of this is $32,700,000, which includes $3,700,000 for effluent disinfection. Under the Project Options, this expenditure will not be necessary from a fish passage perspective, as the restoration of the tidal prism and increased assimilative capacity will enable the river to more effectively dilute and flush effluents from the river channel. The resultant water quality is expected to meet current CCME objectives for the protection of aquatic life and recreation.

However, it should be noted that A Guideline for the Release of Ammonia Dissolved in Water Found in Wastewater Effluents was published in the Canada Gazette on December 4, 2004. Under Section 4(2) of the Guideline, it is indicated that a Canadian Strategy for the management of wastewater effluents is currently being developed by CCME, and that “Environment Canada intends to use a regulation under the Fisheries Act as its principal implementation tool [for this Strategy] to achieve effluent standards for wastewater treatment systems equivalent in performance to conventional secondary treatment, with additional treatment where required”. Therefore, it is possible that at some time in the future, improved
treatment may be required at the GMSC wastewater treatment facility regardless of the presence or absence of the causeway.

Since it is not yet known what the details of the new CCME strategy will be, or how, or when, it will be implemented under the *Fisheries Act*, for the purpose of this EIA, the current regulations are appropriately used. In this regard, it remains that the Project Options are considered to be a benefit due to the avoided cost of $36,400,000. If improved treatment is required under future regulation, then the direct costs of improvement (estimated at $36,400,000) could not be attributable to the Status Quo.

**12.3.4.3 Storm Sewer Systems**

Monitoring and maintenance of sanitary and storm sewer aboiteaux flapgates and drainage channels will continue to be necessary under the Status Quo, ensuring that sediment and ice build up does not interfere with their proper functioning. However, under the Project Options, increased erosion and a greater tidal prism are predicted to prevent this build up from occurring (Sections 9.4.4.2 and 9.4.4.3) and therefore considered a benefit.

The Project Options may result in alteration of the river channel to the extent that sewer infrastructure will be affected but this is not considered to be likely (Section 9.4.4.2).

**12.3.4.4 Dykes and Aboiteaux**

Currently, downstream dykes and aboiteaux require annual repairs and maintenance to ensure proper functioning. Approximately $300,000/year is spent by NBDAFA for these activities, although it is estimated that $500,000/year is required to adequately maintain these structures; these figures are not expected to change under the Status Quo.

Restored tidal exchange as a result of the Project Options will require maintenance and repairs to upstream dykes and aboiteaux as well those downstream. These additional costs are estimated to be $550,000 to adequately maintain these structures, as there are about 10% more structures upstream than downstream.

**12.3.4.5 Other Infrastructure**

Implementation of Project Options will result in the loss of the Tri Community Marina and the Town of Riverview public dock due to the loss of the headpond (Section 9.10.4). As a result, recommended mitigation includes compensation that will enable construction of new facilities at an alternate location. Alternatively, economic benefits will continue to be derived from these facilities, in terms of dollars spent to undertake the associated activities (i.e., sailing, kayaking), under the Status Quo.

**12.3.5 Road Transportation Network**

The Status Quo is a cost due to a predicted significant negative environmental effect on the Road Transportation Network arising from increased flooding potential for some roads. By restoring the tidal exchange to the Petitcodiac River and improving drainage and decreasing sedimentation rates of the Petitcodiac River and its tributaries, the Project Options will decrease this flooding risk. Therefore, the Project Options are expected to have a benefit.
12.3.6 Vessel Traffic and Navigation

12.3.6.1 Upstream of the Causeway

The Status Quo will maintain the headpond, which provides vessel navigation for recreational vessels, including sailboats, powerboats, kayaks, dragonboats and access for float planes. Continued sedimentation will further impede the recreational boating opportunities in the headpond. The Project Options will result in the loss of the headpond, however recreational navigation above the causeway will still be possible.

12.3.6.2 At the Causeway

The Status Quo will continue to be an obstruction to navigation. Project Options improve navigation by removing the obstruction, affording navigation along the entire length of the estuary.

12.3.6.3 Downstream of the Causeway

The Status Quo will continue to restrict vessel navigation in the headpond and downstream of the causeway due to continued sedimentation. The Project Options will improve vessel navigation downstream of the causeway as sediment will be removed from the river channel.

12.3.7 Land Use and Value

12.3.7.1 Risk of Flooding

Overall, the risk of flooding is considered to be a greater cost factor under the Status Quo. Very costly infrastructure to protect urban development in Moncton and Dieppe would likely ultimately be required under the Status Quo. Infrastructure similar to the Netherlands or Georgetown, Guyana might be required (i.e., dykes around to protect the communities from flooding and pumping systems to discharge freshwater runoff over those dykes). The capital cost of such infrastructure would likely be in the tens of millions of dollars. A detailed flood risk assessment would be absolutely necessary under the Status Quo to identify the magnitude of flooding, to provide the basis for developing a flood protection plan and to quantify the costs required for flood protection. The Project Options on the other hand, are considered to be a benefit due to decreased flooding risk and the avoided potential cost of substantial flood protection measures with continued sedimentation.

12.3.7.2 Property Value

Under the Status Quo, continued infilling of the river may reduce the river’s ability to handle tidal fluctuations and storm surges, and lead to increased flooding of the properties along the river and its tributaries (Sections 9.7.4.1 and 9.13.4.6). Increased insurance rates as a result may lead to decreases in property value. Reflective of existing conditions, these costs will be lessened under the Project Options.

Under the Status Quo, vacant land adjacent to the Petitcodiac River may continue to be slightly higher valued near the headpond as compared to the estuary downstream of the causeway and may be a slight benefit. However, this difference may be offset by the potential for increased market value under the Project Options, due to the restoration of an estuarine ecosystem.
12.3.7.3 Access to the Petitcodiac River

Under the Status Quo, access to the Petitcodiac River by property owners who have docks or float planes will remain unchanged. Under the Project Options, access to the Petitcodiac River by property owners who have docks or float planes will be lost.

12.3.8 Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons

The Status Quo will continue and potentially increase the reported negative environmental effects to the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons related to the construction of the causeway. This represents an important cost of the Status Quo.

The Project Options are predicted to have an overall positive environmental effect on Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons. The negative conditions that have resulted in the decreased availability of traditional land and resources uses will be at least partly reversed. The restoration of fish passage and tidal exchange will likely improve fish stocks and the natural estuarine conditions and overall considered to be of benefit for traditional use.

12.3.9 Tourism

The much reduced tidal bore will continue under the Status Quo. Consequently, under the Status Quo the economic benefits of the tidal bore may continue to be reduced or lost and considered to be a cost. The Project Options may allow for at least some increase in the tidal bore, a popular tourist attraction in the GMA during pre-causeway times.

The Status Quo will preserve the headpond, and will continue to provide the opportunity for tourists to visit by float plane. The Project Options will not preserve the headpond, and tourists arriving by float plane will have to seek other landing locations.

12.3.10 Recreation

12.3.10.1 Recreational Fisheries

The Status Quo will continue to have economic benefits in terms of the smallmouth bass and chain pickerel recreational fisheries on the headpond. Both species, which are not native to the headpond, will be eliminated under the Project Options as will the economic benefits derived from these fisheries. The loss or reduction of native recreational stocks due to the causeway will persist with the Status Quo and overall must be considered to result in a net cost, in spite of the recreational bass fishery that has emerged. It is likely that fishers will substitute these species with those that will replace them under the Project Options (e.g., American shad, Atlantic salmon, Atlantic tomcod, brook trout, rainbow smelt, striped bass). The restoration of native stocks is anticipated to be a long-term net benefit, as compared to the loss of the illegally introduced stocks.
12.3.10.2 Sea Cadet Training

The Status Quo will maintain the sea cadet training facility and continue related activities as a benefit. The Project Options will eliminate the headpond but with mitigation, access to the Petitcodiac River would be maintained or compensation provided for the loss of activity, if desired. As such, there will be a cost to maintain the benefit.

12.3.10.3 Headpond Boating

The Status Quo allows boating on the headpond and fosters the continued existence of the Tri Community Marina, the Town of Riverview public boat launch and private docks. The Project Options will afford greater recreational boating opportunities but may require modification to existing facilities as mitigation, or compensation, if desired. As such, there will be a cost to maintain the benefit. These costs would be offset by the recreational boating opportunities presented overall.

12.3.10.4 Other Water-based Recreation

The Status Quo will result in water quality that in summer frequently will not meet the CCME Guidelines for Recreation. This may at times prevent the safe use of the headpond and estuary for swimming, boating and kayaking, and is a cost. The Project Options will alleviate these water quality issues and be a benefit.

12.3.11 Labour and Economy

12.3.11.1 Commercial Fisheries

Under the Status Quo, it is expected that economic benefits will continue to be derived from the commercial adult American eel fishery in the headpond, and lobster and scallop fisheries in the marine environment. The adult American eel fishery in the headpond will be lost as a result of the Project Options, and affected fishers should be compensated at a value consistent with that of the fishery at the time of the baseline conditions (approximately $10,000 per annum for one known fisher). Under the Project Options, which will result in a change in sedimentation patterns and loss of the headpond, it is predicted that the lobster and scallop fisheries will continue unaffected. However, should the Follow-up Program identify any negative environmental effects on these fisheries, fishers would need to be compensated at levels that reflect that loss.

The causeway (and consequently the Status Quo) results in fish passage difficulties for many fish species, including those that were commercially fished (e.g., Atlantic salmon), and conditions that make the river inhospitable to many species (e.g., delayed or impeded migration, low DO, increased sediment, increased predation, poor food supply). Implementation of the Project Options will improve these conditions and provide the opportunity for a variety of commercially fished species to return to or increase in the Petitcodiac River (e.g., American shad, Atlantic salmon). Although the potential will be restored, economic benefits of some of these commercial fisheries may not be realized due to outside forces such as consumer and low fish species population numbers (i.e., the Inner Bay of Fundy Atlantic salmon, is currently designated as “Endangered” by COSEWIC and protected under SARA).
12.3.11.2 Employment

The Status Quo is not anticipated to affect employment in the region from that observed during baseline conditions, all other factors being equal. The Project Options will lead to an improved tidal bore that may lead to increased seasonal employment as part of the tourism industry. The Project Options will also result in very substantial engineering, design and construction employment, with continued maintenance employment during operation.

12.3.11.3 Business

The Status Quo is not anticipated to affect business from that observed under baseline conditions. The Project Options will result in business opportunity associated with their construction and maintenance. Additionally, a number of factors like the restoration of the natural river and perhaps the tidal bore will create tourism-related business opportunities.

12.3.12 Heritage and Archaeological Resources

Both the Status Quo and the Project Options are not predicted to affect the pre-causeway shorelines and thus the environmental effects on Heritage and Archaeological Resources are rated not a factor.

12.3.13 Public Health and Safety

12.3.13.1 Vehicular Accidents

Project Options and the Status Quo are expected to have environmental effects on vehicular accidents that are not significant. Project Options may increase tourism related traffic due to restoration of the tidal bore but are not expected to incrementally increase the number of vehicular accidents over 2005 baseline conditions. Neither is considered to be a benefit/cost factor.

12.3.13.2 Non-vehicular Accidents and Unplanned Events

The Status Quo may increase the number of non-vehicular accidents and strandings due to increased sedimentation of the river over 2005 baseline conditions but will have no environmental effects on the use of the headpond as a fire fighting water source or as a fire fighting training location. Project Options, which will restore tidal flow and may increase recreational boating and introduce the potential for more accidents related to that activity, are expected to have environmental effects on non-vehicular accidents that are not significant. The Project Options are expected to have environmental effects that are negative but not significant in relation to use of the headpond as a fire fighting water source and for fire fighting training purposes because there are other nearby bodies of water for this type of use (e.g., Mill Creek reservoir). Overall, both are not considered to be a factor from a benefit/cost perspective.

12.3.13.3 Groundwater Quality and Quantity

Neither Project Options nor the Status Quo are expected to have significant negative environmental effects on groundwater quality or quantity over 2005 baseline conditions and thus neither are a factor from a benefit/cost perspective.
12.3.13.4 Contaminated Effluents and Redistribution

Water quality conditions downstream of the causeway are expected to continue to deteriorate with the Status Quo as the river continues to infill and decrease in assimilative capacity, and upstream of the causeway, water quality is expected to remain questionable and continue to be unsuitable for many recreational purposes. Frequently in the summer, CCME Guidelines for water based recreation are not met. In contrast, the Project Options are expected to improve water quality conditions upstream and downstream of the causeway by restoring tidal flow, increasing the assimilative capacity of the river. The Status Quo and Project Options, with the appropriate mitigation in place, will have environmental effects on the redistribution of contaminants associated with the former Moncton Landfill that are not significant nor a cost. Overall, the Status Quo water quality issues are a cost, while the Project Options are a benefit.

12.3.13.5 Human Disease Vectors

The Status Quo is predicted to have the potential for environmental effects on public health and safety with regards to human disease vectors should the risk of the West Nile Virus be realized in the GMA. Project Options are expected to decrease the amount of habitat available to the *Culex* mosquito (the mosquito most likely to carry the West Nile Virus that prefers freshwater impoundments) and consequently have a positive environmental effect on public health and safety should the virus occur in the GMA. However, overall, this is not considered to be a differentiating benefit/cost factor.

12.3.13.6 Flooding

Under the Status Quo, the risk of flooding is worsening as sedimentation continues to fill in the river and its tributaries, wetlands and drainage ditches. Also, ice jams in the headpond and at the causeway occur despite the efforts of the Gate Management Plan (Section 5.2.6). As a result, economic costs are expected to be incurred due to damage of infrastructure and property. The increased risk is a cost from a public safety perspective.

Alternately, Project Options will help alleviate the flood risk by restoring the conveyance capacity of the river and its tributaries, eroding sediments from drainage channels, and preventing ice accumulation in the headpond (Section 9.13.4.6). The reduced risk is a benefit from a public safety perspective.
13.0 FOLLOW-UP PROGRAM

13.1 Requirements of the Follow-up Program

As part of the EMP, a Follow-up Program will be developed for the selected Project Option (Section 7.5). The Guidelines require that a well defined program of monitoring and follow-up initiatives regarding environmental effects resulting or potentially resulting from all Project Options must be outlined in the EIA Report (“Follow-up Program”). The Guidelines require that the Follow-up Program include its objectives, content, implementation and reporting schedules, and each Follow-up Program is required to:

- establish baseline conditions;
- determine regulatory compliance (compliance monitoring);
- test the predictions of the EIA Report (environmental effects monitoring); and
- evaluate the effectiveness of measures used to mitigate environmental effects (environmental effects monitoring).

The Guidelines also require that the Follow-up Program include protocols to guide interpretation of follow-up results and timely implementation of appropriate corrective actions.

The definition of “follow-up program” under Section 2(1) of CEAA means a program for:

- verifying the accuracy of the environmental assessment of a project; and
- determining the effectiveness of any measures taken to mitigate the negative environmental effects of the project.

As such, the Follow-up Program will be designed to meet the requirements of both the Guidelines and CEAA.

Note that the term “Project Options” includes Project Options 3, 4A, 4B and 4C; specific mention of a Project Option (e.g., Project Option 4B) is given when warranted. Because the Project Options will result in substantial changes to the current status of the Petitcodiac River estuary, a staged implementation strategy has been developed for each Project Option (Chapter 7) in part, to permit the verification of modelling and environmental effects assessment predictions, and to evaluate the effectiveness of mitigation measures throughout implementation of the selected Project Option. This staged approach allows for follow-up activities to be used to update the EMP developed for the selected Project Option (Section 7.5) before the next stage is implemented, and is a tool for refining the details of design and mitigation. This staged approach is very consistent with the normal project planning, design, construction and operation project cycle for projects of this nature. Although the AMEC Study Team is confident in the predictions made in the modelling and this EIA Report overall, and the likelihood of any significant negative environmental effects is very low, the consequences of an unanticipated change in the river or failure of mitigation could potentially be of great concern in some specific instances. As acknowledged by the Guidelines and under CEAA, this Follow-up Program
focuses on areas where the consequences of failed mitigation or unplanned changes to the river could be problematic, requiring an adaptive management approach to resolution. As such, the overall objective of the Follow-up Program is to facilitate the successful implementation of the selected Project Option so that it meets the Project Objective.

The Follow-up Program is divided into three stages that correspond with the implementation strategy that has been developed for each Project Option (Chapter 7). This precautionary approach to Project implementation follows the principles of adaptive management. Content and implementation and reporting schedules are provided in Section 13.2.

13.2 Follow-Up Program

13.2.1 Introduction

Once the preferred Project Option has been selected, a detailed terms of reference for the Follow-up Program including objectives, content, implementation and reporting schedules, will be prepared for all stages and filed with the appropriate regulatory authorities for verification and acceptance. The terms of reference will also be provided to the public, stakeholders and Aboriginal Community for review. Should modification of the Follow-up Program be required through the course of each program and subsequent review through adaptive management, the appropriate authorities will be notified and adjustments to the program will be made.

13.2.1.1 Stage I – Activities Required Prior to Opening the Gates

As noted in Chapter 7, Stage I includes those activities necessary before the gates are opened in Stage II. Activities include excavation of an upstream channel to initiate tidal exchange in the headpond, and mitigative measures such as watermain relocation, upstream dyke restoration, former Moncton Landfill protection, embankment protection, and channel bottom protection (Chapter 7). Throughout Stage I, standard operating procedures during construction (e.g., dust and noise control), which will be developed as part of the EMP for the selected Project Option (Section 7.5), will be implemented.

Before Stage II can proceed and the gates are opened during the spring runoff, follow-up as required and not already in existence, will be carried out to provide a benchmark for the verification of environmental effects assessment predictions. In this context, baseline does not refer to the 2005 baseline condition used for comparative purposes in the environmental effects assessment (Chapter 9), but rather information needed in support of the Follow-up Program. The Stage I Follow-up Program is described in Section 13.2.2.

13.2.1.2 Stage II – Gate Opening

During Stage II, which will possibly occur over 3 years, the gates will be opened each spring commencing with the spring runoff and will be closed in the late fall to prevent ice jamming (Chapter 7). The purpose of Stage II is to develop the river channel to allow for construction of the selected Project Option. Follow-up will be conducted over the three-year period to verify the accuracy of the short-term hydrodynamic and sediment transport modelling predictions (e.g., change in cross-sectional area) (AMEC, 2005b). In the unlikely event that predictions are proven to be highly inaccurate (i.e., sedimentation continues and the sediment plug is not
eroded), the gates can be closed and a new mitigation and/or design strategy could be developed in consultation with federal and provincial authorities, consistent with the adaptive management approach.

Follow-up of mitigation implemented in Stage I will commence. The Stage II Follow-up Program is described in Section 13.2.3.

13.2.1.3 Stage III – Project Option Construction and Operation

Construction of the selected Project Option (e.g., bridge construction, removal of control structure and fishway) and other required mitigation (e.g., drainage ditch diversion) occurs in Stage III. This is followed by operation. During the construction activities (i.e., prior to establishing the final opening at the causeway), a follow-up program is not required, as no significant negative residual environmental effects are predicted to occur during this stage and SOPs including inspection of mitigation measures for integrity and effectiveness and compliance with EIA commitment, permits and laws and regulations, will be implemented to ensure mitigation measures proposed during construction are implemented effectively.

After construction, and during operation, the follow-up program will involve verification of the accuracy of the environmental effects assessment and long-term modelling predictions, and determine the effectiveness of mitigation measures implemented to mitigate potential negative environmental effects of the selected Project Option. These follow-up activities will continue to contribute to adaptive management strategies if and where applicable. The Stage III Follow-up Program is described in Section 13.2.4.

13.2.2 Stage I Follow-up Program

13.2.2.1 Physical Characteristics of the Petitcodiac River Estuary

Baseline data describing the physical characteristics of the Petitcodiac River estuary already exist (e.g., cross sections of the river in 2003 and previously) (AMEC, 2005b); collection of additional cross sections will not be necessary as part of the Follow-up Program, as adequate information is available to benchmark future follow-up requirements of physical characteristics of the Petitcodiac River estuary. However, immediately prior to gate opening in Stage II, cross sections of the upstream channel will be made as a benchmark for Stage II follow-up.

13.2.2.2 Atmospheric Environment

Because no significant negative environmental effects are predicted for the Atmospheric Environment (climate, air quality, odour, sound quality) during operation, the collection of baseline data is not required. As such, there is no Follow-up Program for the Atmospheric Environment during Stage I.

13.2.2.3 Fish and Fish Habitat

Baseline data for the presence of fish/other valued aquatic animal species (other than lobster, scallop and eel as discussed in Section 13.2.2.12), although provided in AMEC (2005a), are not required as the Project Objectives include the provision of fish passage. Successful implementation of the Project Objectives will be confirmed as described in (Section 13.2.4.3.2).
Baseline data already exist for water and sediment quality (AMEC, 2005a); collection will therefore not be part of the Follow-up Program in Stage I.

**Bioaccumulation of Metals in Fish Tissue**

During Stage 1, a study will be designed and carried out (in consultation with Environment Canada) to gather baseline data on concentrations of metals in fish tissue. It is recommended that the mummichog be considered as a suitable indicator because the mummichog:

- is an estuarine fish with a natural range from Salisbury to Dover;
- is easily captured;
- is consumed by many types of birds and fish; and
- has been previously studied in the vicinity of the former Moncton Landfill.

**13.2.2.4 Terrestrial and Wetland Environment**

Baseline data already exist for wetlands, wildlife and vegetation, migratory birds and mudflat area (AMEC, 2005a); collection will therefore not be part of the Follow-up Program in Stage I. The fish bioaccumulation study will be used to support the bioaccumulation analysis for migratory birds and wildlife species.

**13.2.2.5 Municipal Services and Infrastructure**

Baseline data already exist for Municipal Services and Infrastructure (AMEC, 2005a); collection will therefore not be part of the Follow-up Program in Stage I.

**13.2.2.6 Road Transportation Network**

Because no significant negative environmental effects are predicted for the Road Transportation Network during operation, the collection of baseline data is not required (Section 9.5.4) in Stage I.

**13.2.2.7 Vessel Traffic and Navigation**

Baseline data already exists (AMEC, 2005a) for Vessel Traffic and Navigation. Therefore, no follow-up is required for this VEC during Stage I.

**13.2.2.8 Land Use and Value**

No follow-up is required for Land Use and Value during Stage I, as baseline data already exist (AMEC, 2005a).

**13.2.2.9 Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons**

No significant negative environmental effects are predicted for Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons. Therefore, the collection of baseline data is not required in Stage I.

**13.2.2.10 Tourism**

The collection of baseline Tourism data is necessary to determine the effectiveness of the Petitcodiac River as a tourist attraction after Project Option implementation, and to verify the
predictions of the environmental effects assessment. The Follow-up Program will involve an annual survey, taken in the summer, of visitors to Boreview Park in downtown Moncton. The content of this survey will determine the number of visitors and the purpose of their visit to the GMA and the importance and role of the tidal bore, and will provide a benchmark to evaluate the draw of the Petitcodiac River and the tidal bore to tourists.

13.2.2.11 Recreation

Baseline data already exist (AMEC, 2005a), therefore follow-up is not required for Recreation.

13.2.2.12 Labour and Economy

The Follow-up Program for Labour and Economy will include the assembly of baseline catch data for commercial lobster and scallop fisheries in the Bay of Fundy and eel fisheries in the Petitcodiac River system, to provide a benchmark for the determination of compensation (if required) for loss of landings. Included in this program are the catch statistics for the previous 10 years and a determination of who is fishing in the potentially affected areas (if any). Similar information will be collected from an agreed upon control location that is distant from the area felt to be at risk by the local fishers. The Follow-up Program will include the approach used by DFO to monitor lobster fishery and populations during the trial gate openings (Lawton and Robichaud, 2000). This information will be collected until Stage II.

Follow-up for the collection of baseline data for river-based tourism has previously been described in Section 13.2.2.10. These data will be used as a benchmark to determine environmental effects of the Project Option on river-based tourism and evaluate environmental effects assessment predictions.

13.2.2.13 Heritage and Archaeological Resources

The shoreline of the headpond area will be walked over by an experienced archaeological team prior to the implementation of any of the Project Options that may result in the raising of the water levels along the shoreline of the headpond. Also, any headpond substrate that becomes exposed due to the Project Options will be walked over to the extent possible (as limited by safety concerns). If any significant archaeological sites are discovered during this walkover, an appropriate level of study and/or possibly excavation will be implemented in consultation with Archaeological Services Unit and the Fort Folly First Nation, where appropriate. This walkover will take place in sufficient time to allow any mitigation to take place, prior to the implementation of the Project Options.

13.2.2.14 Public Health and Safety

Vehicular Accidents

Baseline data collection is not required, as there are no significant negative environmental effects predicted for vehicular accidents as a result of the Project Options (Section 9.13.4.1).

Non-vehicular Accidents and Unplanned Events

Baseline data already exist for non-vehicular accidents and unplanned events (AMEC, 2005a), therefore no follow-up is required in Stage I.
Groundwater Quality and Quantity

Baseline data collection is not required, as there are no significant negative environmental effects predicted for groundwater quality and quantity and a very low likelihood of any potential negative environmental effects occurring as a result of the Project Options (Section 9.13.4.3).

Contaminated Effluents and Redistribution of Contaminants

Baseline data already exist for contaminated effluents and redistribution of contaminants (AMEC, 2005a), therefore no follow-up is required.

Human Disease Vectors

Baseline data for human disease vectors are not required as there are no significant negative environmental effects predicted as a result of the Project Options because the risk of West Nile Virus has not been realized in the GMA (Section 9.13.4.5). Any suspected cases of West Nile Virus in birds or humans should be reported to the New Brunswick Department of Health and Wellness.

Flooding

Baseline data already exist for flooding (AMEC, 2005a) and the environmental effects are predicted to be positive (Section 9.13.4.6), therefore no follow-up during Stage I is required.

13.2.3 Stage II Follow-up Program

The objective of the Follow-up Program during Stage II is to verify short-term hydrodynamic and sediment transport modelling predictions (e.g., change in cross-sectional area, erosion of upstream sediment plug) and determine if opening of the gates results in problems with the physical environment that need to be addressed before implementing Stage III (adaptive management of the implementation strategy). In addition, the Follow-up Program for Stage II will verify the effectiveness of the mitigation and construction activities implemented in Stage I (e.g., former Moncton Landfill protection, upstream channel excavation). If mitigation measures fail or are inadequate to the extent that risks to sensitive locations are unacceptable, adaptive management in consultation with regulators, the public, stakeholders and the Aboriginal Community will modify the implementation strategy to ensure protection of the estuary.

The Follow-up Program for Stage II will involve taking seasonal cross sections along the length of the Petitcodiac River over a short time frame during ice-free periods. The location of each cross section will correspond with those locations in the Modelling Component Study (AMEC, 2005b) so that trends can be observed and compared to baseline data collected (AMEC, 2005b) (selected cross sections only). Cross-sectional information will include, in relation to the reference elevation, elevation of the deepest point, cross-sectional area, cross-sectional water surface width, mean depth, mean bed elevation and a width to depth ratio (AMEC, 2005b).

During Stage II, the follow-up of mitigation implemented during Stage I will involve annual visual inspection of upstream dyke restoration, former Moncton Landfill erosion protection, watermain relocation and embankment protection measures. Cross-sectional information as described previously will verify the effectiveness of channel bottom protection and upstream channel excavation. In addition, tourist surveys and commercial fisheries data will continue to be
collected annually, as described in Sections 13.2.2.10 and 13.2.2.12, respectively. These Follow-up Program components relate to the following VECs:

- Terrestrial and Wetland Environment (Section 9.3.4.1) – upstream dyke restoration;
- Municipal Services and Infrastructure (Section 9.4) – watermain relocation, upstream dyke restoration, former Moncton Landfill erosion protection;
- Land Use and Value (Section 9.7.4) - upstream dyke restoration;
- Tourism (Section 9.9.4) - river-based tourism;
- Labour and Economy (Section 9.11.4) - commercial fisheries; and
- Public Health and Safety (Section 9.13.4.4) – former Moncton Landfill erosion protection.

Embankment protection measures, channel bottom protection and upstream channel excavation are associated with physical characteristics of the Petitcodiac River estuary and are discussed in the implementation strategy for each Project Option in Chapter 7.

13.2.4 Stage III Follow-up Program

13.2.4.1 Physical Characteristics of the Petitcodiac River Estuary

Long-term follow-up of the physical characteristics of the Petitcodiac River estuary will continue annually for 3 years, biannually for the next 6 years, and again at 20 and 30 years, to evaluate the accuracy of long-term modelling predictions. If the river does not evolve as predicted, adaptive management will be employed to mitigate the environmental effects (e.g., erosion protection, excavation). The number of cross sections will be reduced as the monitoring progresses. Only selected cross sections will be monitored as per Stage II (Section 13.2.3).

13.2.4.2 Atmospheric Environment

As there are no significant negative environmental effects predicted with respect to the Atmospheric Environment (i.e., climate, air quality, odour and sound quality) during operation of the Project Options (Section 9.1.4), follow-up is not required.

However, in the event that odour complaints are reported, then a qualitative odour survey would be undertaken to verify the complaint and assess the nature, character, intensity, frequency and duration of the odour. If the anaerobic decay of organic matter is suspected as the cause, then dissolved oxygen sampling will be carried out in the nearby vicinity of the odour to assess the potential for anaerobic (see Glossary) decay. If anaerobic decay is found to occur that results in odour problems, then further investigation into odour levels may be necessary. After evaluation it may be determined that ambient air monitoring is required to adequately assess the impacts.

In the unlikely event that monitored ambient air quality levels exceed health based air quality standards, an ambient air quality advisory would be issued by the New Brunswick Department of Health and/or NBDELG. In addition, the Province of New Brunswick would initiate a public relations plan that would inform the public regarding the nature of the odour, the source of the odour and the likely duration of the odour.
13.2.4.3 Fish and Fish Habitat

Sediment and Water Quality

Long-term follow-up of sediment and water quality will verify predictions of the environmental effects assessment and permit adaptive management of these parameters if mitigation is required. Once construction of the Project Option is complete, a sampling program will be implemented that is consistent with the protocol (i.e., sampling period and locations) developed in the Biophysical Component Study (AMEC, 2005a). This will allow comparison of long-term follow-up data with baseline data. Sampling will occur seasonally for the first three years after construction and will decrease to once every three years if the results are positive (as predicted in the environmental effects assessment, Section 9.2.4), until the ninth year.

Fish/Aquatic Animal Species and Fish Habitat

The Follow-up Program for fish and fish habitat will verify the environmental effects assessment prediction that the fish passage Project Objective will have been met with the selected Project Option. The Follow-up Program will also verify compliance with the *Fisheries Act* (regulatory compliance). Follow-up will consist of verification of an open channel at all seasons capable of allowing fish passage in a manner similar to pre-causeway conditions. Overall inspection of cross section data (Section 13.2.4.1) will be employed. Fish communities above the causeway will be surveyed to demonstrate the presence/absence of the nine fish species that require passage for life cycle purposes (Section 6.1). Fish sampling should be conducted for two days in June, two days in August, and two days in October in the freshwater sections of the Petitcodiac River to get an indication of what species are present in that portion of the River. The presence of the targeted fish species would confirm the effectiveness of the fish passage opportunities within the Petitcodiac River system. This follow up should be conducted for three years after construction, but each year, the need for continuation of the program should be considered based on the results of the previous year, in consultation with DFO (the Responsible Authority).

Bioaccumulation of Metals in Fish Tissue

During Stage 3, a study will be designed and carried out (in consultation with Environment Canada) to monitor concentrations of metals in fish tissue to verify the EIA prediction that the implementation of the Project Options would not result in significant bioaccumulation of metals occurring in fish.

13.2.4.4 Terrestrial and Wetland Environment

Wetlands

Follow-up for wetlands will test the predictions of the environmental effects assessment and evaluate the effectiveness of mitigation. The Follow-up Program will involve annual visual inspection of dykes protecting freshwater Ducks Unlimited sites. If these sites are continue to be effectively protected by the dyke structures after five years, follow-up will discontinue. Wetland and mudflat areas in the Assessment Area will be monitored through aerial photo interpretation every five years for 20 years, with some field verification. If the net loss of saltwater wetlands (Provincially Significant) exceeds baseline conditions (i.e., pre-causeway
conditions), then the adaptive management approach will consider various mitigation strategies, including the purchase of dyked farmlands for conversion to saltwater wetlands (Section 9.3.4.1).

**Wildlife and Vegetation**

No follow-up is required for wildlife and vegetation as verification of the environmental effects assessment will be accomplished through follow-up of wetland habitat as described in Section 13.2.4.4 and the fish bioaccumulation study as described in Section 13.2.4.3. There is no mitigation proposed for wildlife and vegetation (Section 9.3.4.2).

**Migratory Birds**

As for wildlife and vegetation, there is no follow-up required for migratory birds. No mitigation is proposed (Section 9.3.4.3) and verification of the effects assessment will be accomplished through follow-up of wetland habitat as described above, mudflat productivity as described below, and the fish bioaccumulation study as described in Section 13.2.4.3.

**Mudflat Productivity**

Mudflat productivity was assessed by comparing the area and distribution of the mudflats of the Project Options and the Status Quo to the pre-causeway area and distribution of mudflats. This methodology is based on the assumption that the mudflats that exist/develop as part of a natural system are healthier and more productive than those of an unnatural system (i.e., an estuary with altered flow and sediment transport). The Project Options are predicted to result in positive changes to mudflat area and distribution by restoring the river flow and sediment transport processes to near pre-causeway conditions, and returning the mudflats to a more natural condition. Changes to mudflat area will be most pronounced primarily in the area above the causeway, between the causeway and Dover, and Lower Coverdale Island. As the environmental effects of the Project Options are anticipated to be positive (i.e., closer to pre-causeway conditions then the Status Quo) no mitigation has been recommended, or is appropriate, for the Project Options. Follow-up will consist of monitoring the distribution and overall area of mudflats and comparing the results to the 1962 aerial photos.

**Managed Areas**

Environmental effects assessment predictions will be tested through analysis of cross-sectional data collected as described in Section 13.2.4.1. This analysis will determine the effects of erosion and sedimentation at Managed Areas in the Assessment Area (i.e., Outhouse Point ESA and Lower Coverdale Island ESA).

**13.2.4.5 Municipal Services and Infrastructure**

**Water Distribution Services**

Follow-up for water distribution services will involve regular visual inspection in cooperation with municipalities to ensure that the watermain lowered in Stage I does not become exposed due to erosion. No other follow-up is required.
Sanitary Sewer Systems

Follow-up of physical characteristics of the Petitcodiac River estuary will demonstrate the degree to which channel conveyance improvements are achieved (Section 13.2.4.1). This follow-up will address predictions regarding improvement to existing conditions that result in the blockage of outfall flapgates.

Storm Sewer Systems

Follow-up for storm sewer systems has the same objective, content and schedule as described for sanitary sewer systems (Section 13.2.4.5).

Dykes and Aboiteaux

Follow-up for dykes and aboiteaux, which will verify the effectiveness of mitigation, will involve visual inspection to ensure that the upstream dykes and aboiteaux that were restored in Stage I are functioning properly. This follow-up will occur annually for the first 5 years and then be transferred to NB Department of Agriculture, Forestry and Aquaculture. If dykes and aboiteaux are not functioning, then adaptive management will be used to either repair or modify the dykes and aboiteaux or find an alternative solution (i.e., compensation for loss of agricultural lands). No other follow-up is required.

Other Infrastructure

Evaluation of mitigation measures to protect the former Moncton Landfill from erosion will be accomplished through a Follow-up Program. The Follow-up Program will continue seasonal inspection of erosion protection measures at the landfill as described in Stage II (Section 13.2.3) for the first 5 years after Project Option construction. If erosion does not occur, the City of Moncton will incorporate inspection into its normal programs.

13.2.4.6 Road Transportation Network

As no negative environmental effects are predicted for the Project Options and no mitigation is recommended for the Road Transportation Network, long-term follow-up is not required. Follow-up for the evaluation of the environmental effects assessment for flooding of roads is described in Section 13.2.4.14 (Flooding).

13.2.4.7 Vessel Traffic and Navigation

No mitigation is required for Vessel Traffic and Navigation. Follow-up will determine the accuracy of the environmental effects assessment predictions and will consist of annual examination of the cross-sectional data collected as described in Section 13.2.4.1 to determine if river width and depth is sufficient to permit vessel traffic and navigation within the Assessment Area at all times of the year.

13.2.4.8 Land Use and Value

Follow-up to determine the effectiveness of mitigation for dyked agricultural lands is described in Section 13.2.4.5. Therefore, follow-up for Land Use and Value will evaluate the accuracy of the environmental effects assessment predictions. Every five years the market value of property along the river will be compared with the market value of equivalent properties in the Assessment Area to determine the effect of the river on the value of properties adjacent to it. If
a decrease in market value for waterfront property is realized, then adaptive management will mitigate this loss (e.g., compensation).

13.2.4.9 Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons

There is no specific mitigation proposed for Current Use of Land and Resources for Traditional Purposed by Aboriginal Persons, nor are there any negative environmental effects predicted by the environmental effects assessment. Follow-up of predictions will occur through follow-up of other VECs (i.e., Fish and Fish Habitat, Terrestrial and Wetland Environment), and an effort will be made to communicate these results to the Aboriginal Community.

13.2.4.10 Tourism

Follow-up for Tourism will include continuation of the annual survey of tourists in downtown Moncton to determine if changes to the river (e.g., increase in tidal bore), as a result of the selected Project Option, has an effect on the number and activities of tourists coming to the GMA (survey described in Section 13.2.2.10). The size of the tidal bore will be monitored annually through visual inspection, and cross-sectional data at the Moncton bend in the river (a control point for the tidal bore) will be analyzed to determine if erosion is occurring as predicted (follow-up of cross-sectional data described in Section 13.2.4.1). As no mitigation is proposed, the purpose of the Follow-up Program for Tourism is to verify predictions made in the environmental effects assessment.

13.2.4.11 Recreation

The Follow-up Program for Recreation will verify the accuracy of the environmental effects assessment predictions. Annual follow-up in the spring will determine if recreational trails along the river maintain continuity or are flooded. If they are flooded, adaptive management will determine if mitigation (i.e., seasonal closure or relocation of trails) is necessary. If after 5 years trails remain functional, follow-up will cease. Follow-up will also include annual surveys of boater and anglers to determine the effects of the Project Option on recreational activities and fisheries on the river.

13.2.4.12 Labour and Economy

The Follow-up Program for Labour and Economy will evaluate predictions of the environmental effects assessment and the effectiveness of its proposed mitigation. Follow-up for commercial fisheries will continue the annual collection of catch data for commercial lobster and scallop fisheries in the Bay of Fundy and eel fisheries in the Petitcodiac River system, as described in Section 13.2.2.12. If after 10 years it is determined that there is a substantial reduction in harvest levels in the potentially affected areas relative to the control location elsewhere in the Bay of Fundy that can be attributed to the implementation of the Project Option, then compensation will be provided. As noted in Section 12.1.11.1, the value of the potentially affected lobster resource is currently between $85,000 and $175,000 annually. Compensation for each fishery would be negotiated, if required, based on the level of environmental effects in the affected area. Data developed in the baseline Follow-up Program (Section 13.2.2.12) will provide a benchmark for the evaluation of the need for and magnitude of compensation.
The Project Options will result in a positive environmental effect on the commercial shad fishery due to reduction in sedimentation and improved tidal exchange. Verification of hydrodynamic and sedimentation trends will be accomplished through follow-up of the physical characteristics of the Petitcodiac River estuary (Section 13.2.4.1).

Follow-up for river-based tourism (as described in Section 13.2.4.10) will evaluate the predictions of the environmental effects assessment and determine the effects of the Project Option on tourism to the economy.

13.2.4.13 Heritage and Archaeological Resources

No mitigation is proposed for Heritage and Archaeological Resources and no negative environmental effects are predicted (Section 9.12.4). Follow-up will verify the accuracy of these predictions and will proceed as described in Section 13.2.4.1 to determine if the river channel affects pre-causeway shorelines. If so, adaptive management will be used to mitigate the potential environmental effects on archaeological resources (e.g., monitoring by a licensed archaeologist).

13.2.4.14 Public Health and Safety

Vehicular Accidents

Long-term follow-up of vehicular accidents is not required, as there are no negative environmental effects predicted as a result of the Project Options and no mitigation proposed (Section 9.13.4.1).

Non-vehicular Accidents and Unplanned Events

Long-term follow-up of non-vehicular accidents and unplanned events will evaluate the effectiveness of mitigation measures and predictions of the environmental effects assessment. Assessment of annual strandings in the river and its tributaries for the first 5 years after construction will determine the effectiveness of signage and boating safety education mitigation. Follow-up will end after this period, unless adaptive management requires its continuation. Follow-up of water supply for emergency fire fighting will determine if water or other substances (e.g., chemical fire retardants) are available to fight forest fires. This follow-up will take place for the first 5 years after construction, following any forest fires that occur in the Assessment Area.

Groundwater Quality and Quantity

Long-term follow-up of groundwater quality and quantity is not required, as there are no negative environmental effects predicted as a result of the Project Options, no mitigation proposed, and a low likelihood for potential environmental effects to occur (Section 9.13.4.3).

Contaminated Effluents and Redistribution of Contaminants

Follow-up for contaminated effluents and redistribution of contaminants is described in part in Section 13.2.4.3 (Sediment and Water Quality) and in part in Section 13.2.4.5 (Other Infrastructure – former Moncton Landfill erosion protection).
Human Disease Vectors

No mitigation is proposed and the environmental effects assessment predicts that there will be no negative environmental effects of the Project Options for human disease vectors (Section 9.13.4.5). As such, no follow-up is required. If at a later time the risk of the West Nile Virus is realized in the Assessment Area, the proper authorities will assess the situation.

Flooding

Follow-up of flooding in the Assessment Area will verify predictions of the environmental effects assessment (Section 9.13.4.6) and Modelling Component Study (AMEC, 2005b). Evaluation of cross-sectional data (Section 13.2.4.1) will provide the information necessary to determine channel conveyance, which is the basis for potential flood risk.

13.2.5 Reporting Schedule

If channel evolution and mitigation effectiveness occurs as predicted, reporting of the results of Stage I and Stage II Follow-up Programs will occur simultaneously 1-2 months after completion of Stage II. If follow-up determines that a problem exists, adaptive management in consultation with provincial and federal regulators will be initiated immediately and result in a new strategy for development of the Project Option, as applicable. Results of Stage I and II follow-up will be used to further develop the detailed implementation plan for Stage III.

Reporting of Stage III will occur annually for the first 5 years. If follow-up determines that environmental effects assessment predictions and mitigation are proceeding as expected, the reporting schedule will decrease to once every 3 years. The results of this follow-up will be used as part of the adaptive management strategy to be employed for this Project.

13.3 Economics Considerations Summary

A Follow-up Program will be implemented to meet the requirements of both the Guidelines and CEAA, and will be consistent with the implementation strategy described in Chapter 7 for each Project Option. The overall objective of the Follow-up Program is to facilitate the successful implementation for the selected Project Option so that it meets the Project Objectives.

In Stage I, follow-up will focus on the collection of baseline data (if required and not already available) to be used as a benchmark for follow-up of environmental effects assessment predictions. Data collection includes cross sections of the upstream channel, tourist surveys in the GMA, and the assembly of catch data for commercial lobster, scallop and eel fisheries.

Follow-up in Stage II will verify the accuracy of short-term modelling predictions for development of the river channel, through the seasonal measurement of cross sections along the length of the river. Follow-up will also verify the effectiveness of mitigation measures implemented in Stage I before the gates were opened (i.e., upstream dyke restoration, former Moncton Landfill erosion protection, watermain relocation, embankment and channel bottom protection, and upstream channel excavation). Tourism surveys and commercial fisheries catch data will continue to be collected/assembled throughout Stage II.
Stage III follow-up will verify the effectiveness of mitigation measures and the accuracy of environmental effects assessment and modelling predictions. Follow-up will focus on physical characteristics of the Petitcodiac River estuary as they relate to the following VECs: Fish and Fish Habitat, Terrestrial and Wetland Environment, Municipal Services and Infrastructure, Vessel Traffic and Navigation, Tourism, Labour and Economy, Heritage and Archaeological Resources and Public Health and Safety. In addition, follow-up will include the collection of sediment and water quality data, air photo interpretation to determine changes in wetland and mudflat areas, evaluation of riverfront property market values, communication with the Aboriginal Community, collection of river based tourism, boating and angling survey data, inspection of trails adjacent to the river, continued assembly of commercial fisheries data, evaluation of boater stranding statistics and forest fire fighting resources and visual inspection of mitigation measures (i.e., watermain relocation, upstream dyke restoration, former Moncton Landfill erosion protection and embankment protection).

Assuming channel evolution and mitigation effectiveness occurs as predicted, reporting of Stage I and II follow-up results will occur one to two months after completion of Stage II, and reporting of Stage III follow-up will occur annually for five years and decrease to once every 3 years thereafter. The Follow-up Program focuses on an adaptive management approach to verify the conclusions and the effectiveness of mitigation, and will be used to update the EMP in the unlikely event of unanticipated changes to the river or failure of mitigation measures.
14.0 SUMMARY AND CONCLUSIONS

14.1 Purpose of EIA

Construction of the Petitcodiac River causeway between 1966 and 1968 resulted in a number of challenges with respect to fish passage. Even though a fishway was included in the control structure as part of the authorization to construct the causeway, the fishway proved ineffective and subsequent modifications to the fishway and gate management failed to provide a solution to the fish passage issues for all fish species requiring passage upstream and downstream of the causeway. Following a variety of reports and actions, and based on the Niles Report (Niles, 2001) recommendations, it was resolved that an EIA was necessary to evaluate potential Project Options to address the fish passage and other ecosystem issues. A modelling workshop was organized by EC and DFO in March 2002 to address the issues associated with modelling of the Petitcodiac River and identify the path forward for modelling the Petitcodiac River estuary in order to facilitate this EIA per the recommendations of the Niles Report. NBDSS was appointed as the Proponent and a harmonized federal-provincial EIA was established with the issuance of joint Guidelines. The AMEC Study Team was retained in November 2002 to conduct the EIA.

14.2 Scope of EIA

This EIA evaluated four Project Options to determine if they met the Project Objectives. The Project Objectives are to achieve a long-term solution to fish passage and other ecosystem issues related to the causeway, including tidal exchange, sediment transport and other physical processes and biophysical functions (e.g., wetlands, populations of flora and fauna, fish habitat, etc.). The fish passage Project Objective (the unimpeded and safe movement, upstream or downstream, of fish between aquatic habitats required for their life cycle) was the principal purpose of this EIA. Other ecosystem issues were for the most part directly related to the same environmental effects that caused the fish passage issues. The potential environmental effects of those Project Options that meet the fish passage Project Objective were specifically assessed. The environmental effects of those Project Options are compared to the Status Quo and pre-causeway conditions, and elements of full cost accounting are used to assist in the comparative analysis.

The conduct of the EIA has involved ongoing, thorough, and multi-faceted consultation (including meetings, open houses, workshops, direct communication and an internet website) with the public, stakeholders and regulatory authorities and meetings with the Aboriginal Community. Issues not previously identified in the Guidelines were documented and addressed in the EIA. Thirteen VECs were selected for the EIA, comprising a range of biophysical, socio-cultural and economic aspects of the environment that may be affected by the Status Quo and Project Options:

- Atmospheric Environment;
- Fish and Fish Habitat;
- Terrestrial and Wetland Environments;
• Municipal Services and Infrastructure;
• Road Transportation Network;
• Vessel Traffic and Navigation;
• Land Use and Value;
• Aboriginal Land and Resource Use;
• Tourism;
• Recreation;
• Labour and Economy;
• Heritage and Archaeological Resources; and
• Public Health and Safety.

14.3 Evaluation of Project Options

The Status Quo is not a Project Option as it does not meet the Project Objectives. It is included in this EIA for comparison purposes only. The Project Options that have been considered are:

• Project Option 1—replacing the fishway.
• Project Option 2—gates open during peak migration.
• Project Option 3—gates open permanently.
• Project Option 4—replace the causeway with a partial bridge.

The existing fish passage issues have been reviewed and found to include a number of impediments to fish passage. These include predation, difficulties in negotiating the fishway, gate management, DO barriers, seasonal sediment plug that extends several kilometres downstream of the causeway, and upstream of the causeway and headpond the water level elevation is lower than highest tide providing no attraction flow for fish. An exhaustive evaluation of fisheries facilities in New Brunswick, Canada and elsewhere in the world was conducted to identify potential fishway solutions. It was evident that the issues associated with the causeway fish passage facility were difficult to overcome. Technologies that have been applied at other facilities are not applicable to the Petitcodiac River fish passage facility. This is mainly due to the unique characteristics of the Petitcodiac River (low and highly variable rate of freshwater flow, high tidal range and high suspended sediment concentrations) and the variety of fish species requiring migration. Examination of the facilities revealed that none examined could provide fish passage, upstream or downstream, for all of the fish species requiring passage at the causeway (Atlantic tomcod, rainbow smelt, gaspereau (both alewife and blueback herring), brook trout, American shad, American eel, sea lamprey, Atlantic sturgeon and Atlantic salmon). It was therefore concluded that a new fishway or further enhancement to the gate management strategy is not feasible to provide upstream and downstream passage for these fish species. Hence, Project Option 1 did not meet the fish passage Project Objective of providing unimpeded and safe movement of fish upstream or downstream, between aquatic habitats required to complete their life cycle.

Although it may appear that peak migration may occur in the spring and fall, it is evident that considerable upstream and downstream migration is also occurring in the summer and winter.
Opening the gates in the spring and fall only would not provide passage opportunities for all of the identified fish species requiring migration at the causeway and therefore Project Option 2 does not meet the fish passage Project Objective. Project Option 2 is also burdened with other issues such as continued sediment accumulation in the headpond, ice-jamming at the gate piers and the summer and winter headpond would be brackish and unsuitable for freshwater fish species.

Project Options 3 and 4 both meet the fish passage Project Objective as they allow free tidal exchange and the movement of fish species that require passage.

14.4 Project Description and Implementation Strategy

Design Criteria for the Project Options were developed in addition to the main Project Objective of safe and unimpeded passage of fish so that these Project Options could meet the other ecosystem issue Project Objectives as well. These criteria included:

- reversing the current infilling trend within the river both upstream and downstream of the causeway;
- the protection of species regulated by SARA or the New Brunswick Endangered Species Act;
- free passage of ice;
- protection of wetland area that provides water quality treatment for the former Moncton Landfill immediately downstream of the causeway and the integrity of the landfill itself; and
- design life of at least 100 years, including consideration of a sea level rise of 88 cm in the next 100 years.

Project Option 3 involves the removal of all gates and all but one center pier at the location of the existing gates and provides an opening of 68 m. Project Option 4A involves construction of a 170 m-long bridge downstream of the existing gates and the removal of the entire gate and fishway structure to provide an opening of 72 m. Project Option 4B involves a new bridge, 280 m long downstream of the existing gates that would afford a range of potential openings from 72 to 225 m. Project Option 4C involves a 315 m long, bridge in the central portion of the causeway, providing a river channel width of 225 m.

Mitigation strategies have been built into the design of the Project Options so that the Design Criteria and Project Objectives can be met. These strategies include erosion and scour protection along critical riverbank locations and the former Moncton Landfill. Compensation for affected facilities or operations (e.g., sea cadet, Tri Community Marina) is included. Most importantly however, as a remedial project aimed at providing a solution to fish passage and other ecosystem issues, the Project Options have been designed to reverse the infilling and issues related to the reduction of the tidal prism that are the principal "ecosystem issues" identified in the Project Objectives.
A three-staged implementation strategy has been developed for each Project Option:

- Stage 1—Design, construction and communication prior to opening the existing gates;
- Stage 2—Open existing gates; and
- Stage 3—Construct the structure required for the preferred Project Option.

Stage 3 involves the following:

- for Project Option 3, remove piers and fish passage facility and replace/construct bridge deck;
- for Project Option 4A, construct a new bridge downstream of the causeway and remove the piers and fish passage facility;
- for Project Option 4B, construct a new bridge downstream of the causeway and remove the control structure and a portion of the causeway; and
- for Project Option 4C, construct the cofferdams and temporary bypass, create an opening in the central portion of the causeway, and construct a new bridge).

This precautionary approach will ensure that the Project is implemented successfully and that predictions made in this EIA are verified through monitoring of the evolution of the channel before irreversible decisions are made for the next stage.

14.5 Description of Anticipated Changes to the River

Hydrodynamic and sediment transport modelling is a tool to assist in predicting change. Modelling, trend analyses, interviews with people knowledgeable about the river and the expertise of the AMEC Study Team, was used to assist in describing the future anticipated changes to the River under a series of scenarios that enveloped the original Project Options.

Under the Status Quo, the channel downstream of the causeway will continue to infill. The tidal volume will continue to decrease. Equilibrium is not anticipated to occur for another 70 years. It is anticipated that tidal elevations in the Moncton area will increase by about 0.2 m due to infilling. Flooding risk under open water conditions will increase under the Status Quo due to infilling both upstream and downstream of the causeway. Current DO problems downstream of the causeway will continue and likely worsen with the Status Quo. Existing ice jamming and channel narrowing will continue and worsen under the Status Quo.

Project Options 3 and 4 (i.e., 4A, 4B, 4C) will reverse all of these problems identified for the Status Quo. Full tidal exchange will occur up to Salisbury and the headpond will be lost. The channel will increase in width and depth and the tidal prism will increase, more for Project Option 4 than Project Option 3. Flooding risk will be reduced due to improved conveyance capacity. DO problems will be alleviated due to the increased dilution.

14.6 Environmental Effects Assessment

A comprehensive environmental effects assessment was conducted of the Status Quo and the Project Options that meet the Project Objective on each of the 13 VECs. The environmental
effects were evaluated for each VEC including the required mitigation. Mitigation of the Status Quo was not described as it is not a Project Option. Table 14.1 summarizes the results of the environmental effects assessment showing whether or not the potential residual environmental effects are significant (S), not significant (NS) or positive (P). The Project Options 3, 4A, 4B and 4C did not have different overall conclusions and are presented as one column.

The Status Quo will not meet the Project Objectives and the Status Quo will result in significant negative environmental effects on most VECs, and no overall positive environmental effects on a VEC-by-VEC basis. These significant environmental effects are primarily related directly or indirectly to sedimentation and the loss of the tidal prism and channel conveyance. These significant environmental effects are those that have led to need for the EIA and to a large extent, determined the Project Objectives (i.e., restore fish passage and other ecosystem issues). The Status Quo does have some positive environmental effects (i.e., recreational smallmouth bass fishery, vacant land value increase adjacent to the headpond, employment and business opportunity, float plane access on headpond, fire protection). These tend to lessen the significant negative environmental effects but clearly not to the extent that would render other negative environmental effects not significant, overall.

Overall, the Project Options would result in several positive environmental effects. Most importantly, these Project Options meet the Project Objectives. Fish passage will be restored for the nine species that require passage through the consequent changes to the Petitcodiac River estuary. Other ecosystem issues (i.e., tidal exchange, sediment transport and other physical processes and biophysical functions) are similarly addressed. The Project Options will result in some negative environmental effects that are not significant due to their limited magnitude, extent, duration, frequency and/or reversibility and in consideration of planned mitigation. Key mitigation includes shoreline erosion protection downstream of the causeway, embankment protection at the former Moncton Landfill immediately downstream of the causeway, protection of the riverbank along the Riverview walking trails, modifications to recreational boating infrastructure or compensation, and restoration and maintenance of agricultural dykes and aboiteaux above the headpond. The Project Options included a comprehensive environmental management strategy that will ensure sound design, construction and operational practices, and an adaptive management approach based on a precautionary implementation strategy and the associated Follow-up Program.

14.7 Effects of the Environment on the Project

The aspects of the environment that may cause a change in the design or construction of the Project Options and the Status Quo include the following: sediment transport process; tidal prism; weather; flooding; ice; climate change and earthquake activity.

Good engineering planning and design always involves consideration of effects of the environment on a project and the planning and engineering design for the Project Options are no exception. The mitigation (e.g., riprap of erodible shorelines) for potential effects of the environment on the Project are inherent in the planning and engineering design presented in this EIA Report. In addition, Stage 1 of the Project Options implementation plan will further
### Table 14.1 Summary of Environmental Effects Assessment

<table>
<thead>
<tr>
<th>Valued Environmental Component</th>
<th>Sub-component</th>
<th>Status Quo</th>
<th>Project Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atmospheric Environment</strong></td>
<td>Climate</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Air Quality</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Odour</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Sound Quality</td>
<td>NS</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Fish and Fish Habitat</strong></td>
<td>Sediment Quality</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Water Quality</td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Fish/Aquatic Animal Species</td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td></td>
<td>Fish Species at Risk</td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Invasive Fish Species</td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Fish Habitat</td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Terrestrial and Wetland Environment</strong></td>
<td>Wetlands</td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Wildlife and Vegetation</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Migratory Birds</td>
<td>P</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Mudflat Productivity</td>
<td>NS</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Managed Areas</td>
<td>P</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Municipal Services and Infrastructure</strong></td>
<td>Water Distribution Systems</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Sanitary Sewer Systems</td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td></td>
<td>Storm Sewer Systems</td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td></td>
<td>Dykes and Aboiteaux</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Other Infrastructure</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Road Transportation Network</strong></td>
<td></td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Vessel Traffic and Navigation</strong></td>
<td></td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Land Use and Value</strong></td>
<td></td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons</strong></td>
<td></td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td><strong>Tourism</strong></td>
<td></td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td><strong>Recreation</strong></td>
<td></td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td><strong>Labour and Economy</strong></td>
<td></td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td><strong>Heritage and Archaeological Resources</strong></td>
<td></td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Public Health and Safety</strong></td>
<td>Vehicular Accidents</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Non-vehicular Accidents and Unplanned Events</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Groundwater Quality and Quantity</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Contaminated Effluents and Redistribution of Contaminants</td>
<td>S</td>
<td>NS-P</td>
</tr>
<tr>
<td></td>
<td>Human Disease Vectors</td>
<td>NS</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Flooding</td>
<td>S</td>
<td>P</td>
</tr>
</tbody>
</table>

S = Significant, NS = Not Significant, P = Positive
define the mitigation for construction and operation of the Project Options and monitoring and follow-up, as described in Chapter 12, will further minimize the likelihood of a substantive effect of the environment on the Project Options from occurring.

In consideration of the likely effects of the environment on the Project Options and the proposed mitigation (including monitoring and follow-up), the residual effects of the environment on the Project Options are determined to be not significant.

By contrast, the Status Quo will continue to result in a changing environment due to sedimentation and reduction in tidal exchange. This will in some instances result in an effect of the environment on the Status Quo that is significant (e.g., increased flooding risk due to decline in channel conveyance, climate change related sea level rise made worse).

14.8 Cumulative Environmental Effects Assessment

The assessment of cumulative environmental effects builds on the environmental effects analysis of the Status Quo and Project Options. Once established, the environmental effects of the Status Quo and Project Options must overlap with those of other past, present and future actions. The environmental effects assessment and analysis of the effects of the environment on the Status Quo and Project Options very clearly establish the cumulative environmental effects of past and present actions, including the contribution of the causeway to date. The cumulative environmental effects of the Status Quo and Project Options are evaluated in respect of four main categories of future actions: global, land use, economic and cultural.

Evaluation of these cumulative environmental effects has demonstrated that the cumulative environmental effects of past, present and future actions that overlap with those of the Status Quo and Project Options is consistent with those identified in the environmental effects assessment and assessment of the effects of the environment on the Project. Future actions including other future development projects (e.g., City of Moncton Assomption Boulevard Phase II and Vaughan Harvey Boulevard Extensions) do not contribute in substantive ways to cumulative environmental effects.

Importantly, the Status Quo contributes substantively to cumulative environmental effects that are significant. These include the persistence of Fish and Fish Habitat issues that are significant (i.e., not meeting the fish passage Project Objective), and also:

- sedimentation and ice blocking outfall flapgates and drainage ditches downstream of the causeway;
- increased flooding of roads;
- sedimentation further reduces navigability;
- increased flooding will result in property damage and increased insurance premiums;
- the loss of opportunity for land and resource use for traditional purposes by the Aboriginal Community;
- the loss of a natural estuary and the tidal bore and related tourism opportunity;
- the loss of some recreational fisheries;
the loss or reduction of some commercial fisheries (e.g., American shad); and
increased flooding risk and public safety and human health risk due to recreational contact.

By contrast in meeting the Project Objectives, the Project Options contribute to positive cumulative environmental effects due to changes to the Petitcodiac River estuary that afford the restoration of fish passage and the overall ecosystem benefits (tidal exchange, sediment transport and other physical processes and biophysical functions). Mitigation planned for the Project Options mitigate potential cumulative environmental effects and no specific mitigation is required to address cumulative environmental effects beyond those measures.

14.9 Economic Considerations

The benefits and costs of the causeway to date, and out into the future with the Status Quo and Project Options that meet the Project Objectives have been considered. Capital and operating costs have been characterized for the Status Quo and Project Options. Other economic considerations associated with the causeway to date (i.e., intangibles or benefits and costs that are difficult to attach “hard costs” to), Status Quo and Project Options have been qualitatively and, where feasible, quantitatively analyzed.

To date, the causeway has resulted in a number of benefits and costs that resulted in several significant negative environmental effects and some positive environmental effects. On the whole, it can clearly be concluded that the costs of the causeway have from a benefit and cost perspective, not been favorable. This is particularly true when one considers the fact that these negative significant environmental effects would not have occurred if a bridge had been constructed rather than a causeway, although maintenance of agricultural dykes and aboiteaux upstream of the causeway would have been required.

The original causeway construction cost between $18,000,000 and $24,000,000 in 2004 dollars. Similar costs would have been expended to build a bridge. The capital and operating cost of the Status Quo going forward from 2005 are on the surface relatively small for maintenance and operation of the gates, and occasional major repairs (i.e., $666,800 every 15 years). What must be factored into the Status Quo are the undefined but substantial costs associated with elevated flood risk that will result in increased magnitude and frequency of flooding and/or increased insurance rates (likely in the tens of millions of dollars). Importantly, it is estimated that the cost of sewage treatment improvements to address current water quality issues alone is in the order of $36,400,000. As such, the direct and indirect costs of the Status Quo in future would be well in excess of $36,400,000.

However, due to anticipated changes in regulatory requirements for municipal wastewater, it is possible that at some time in the future improved treatment may be required at the GMSC wastewater treatment facility regardless of the presence or absence of the causeway. If this were to occur, then the direct costs of improvement (estimated at $36,400,000) would not be attributable to the Status Quo.

The capital and operating cost of the Project Options is summarized in Table 14.2.
The avoided future costs of sewage treatment alone under the Status Quo clearly offset the cost of implementing Project Options 3 and 4A and a substantial portion of Project Options 4B and 4C. The costs of Project Options 4B and 4C would likely be fully or almost entirely offset by future avoided costs of the Status Quo when the avoided cost of flood protection, damage, or property insurance are factored in, along with other identified costs.

The Status Quo on the whole has many costs associated with the significant negative environmental effects predicted, but in addition, there are the consequences of ongoing violation of the *Fisheries Act* that have not been quantified as part of this study. Conversely, the Project Options in meeting the Project Objectives will overall result in many benefits that on the whole will result in even greater net benefits (e.g., tourism, commercial and recreational fishing, navigation, etc.).

Although the predicted environmental effects of the Project Options are similar, overall, Project Option 4C will result in the greatest amount of benefits from a full cost accounting perspective. This is due to Project Option 4C resulting in the greatest reduction to flood risk, and the closest return to the pre-causeway environmental conditions. However, Project Option 4C has substantially higher costs than the other Project Options (approximately $50 million more then Project Option 4B). Project Options 3/4A will result in less extensive (but the same type) benefits then Project Option 4C, while Project Option 4B will result in benefits between that of Project Options 4C and 3/4A, pending the selected channel width. A detailed flood risk analysis and wetland specific modelling would be required to better qualify and quantify these differences.

### 14.10 Follow-up Program

A Follow-up Program will be implemented to meet the requirements of both the Guidelines and CEAA, and will be consistent with the implementation strategy for each Project Option. The overall objective of the Follow-up Program is to support the successful implementation for the selected Project Option so that it meets the Project Objectives.

In Stage I, the Follow-up Program will focus on the collection of baseline data (if required and not already available) to be used as a benchmark for follow-up of the environmental effects assessment predictions. Data collection includes cross sections of the upstream channel excavation, tourist surveys in the GMA, and the assembly of catch data for commercial lobster, scallop and eel fisheries.

#### Table 14.2 Capital and Operating Costs of the Project Options*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Project Option 3</th>
<th>Project Option 4A</th>
<th>Project Option 4B</th>
<th>Project Option 4C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-total Stage 1</td>
<td>$18,430,000</td>
<td>$20,390,000</td>
<td>$20,390,000</td>
<td>$21,610,000</td>
</tr>
<tr>
<td>Sub-total Stage 2</td>
<td>$3,120,000</td>
<td>$3,960,000</td>
<td>$5,080,000</td>
<td>$7,000,000</td>
</tr>
<tr>
<td>Sub-total Stage 3</td>
<td>$12,530,000</td>
<td>$17,600,000</td>
<td>$29,140,000</td>
<td>$78,660,000</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$34,080,000</td>
<td>$41,950,000</td>
<td>$54,610,000</td>
<td>$107,270,000</td>
</tr>
</tbody>
</table>

*all values in 2004 CDN dollars and include 25% contingency (see Table 12.2.1 for detail)
Follow-up in Stage II will verify the accuracy of short-term modelling predictions of changes to the river channel, through the seasonal measurement of cross sections along the length of the river. Follow-up will also verify the effectiveness of mitigation measures implemented in Stage I before the gates were opened (i.e., upstream dyke restoration, former Moncton Landfill erosion protection, watermain relocation, embankment and channel bottom protection and channel excavation upstream of causeway to facilitate initiation of the erosion process). Tourism surveys and commercial fisheries catch data will continue to be collected/assembled throughout Stage II.

Stage III follow-up will verify the effectiveness of mitigation measures and the accuracy of environmental effects assessment and modelling predictions. Follow-up will focus on physical characteristics of the Petitcodiac River estuary as they relate to the following VECs: Fish and Fish Habitat, Terrestrial and Wetland Environment, Municipal Services and Infrastructure, Vessel Traffic and Navigation, Tourism, Labour and Economy, Heritage and Archaeological Resources and Public Health and Safety. In addition, the Follow-up Program will include: collection of sediment and water quality data; air photo interpretation to determine changes in wetland and mudflat areas; evaluation of river front property market values; communication with the Aboriginal Community; collection of river-based tourism, boating and angling survey data; inspection of trails adjacent to the river; continued assembly of commercial fisheries data; evaluation of boater stranding statistics and forest fire fighting resources; and visual inspection of mitigation measures (i.e., watermain relocation, upstream dyke restoration, former Moncton Landfill erosion protection and embankment protection).

The Follow-up Program focuses on an adaptive management approach to verify the conclusions and the effectiveness of mitigation, and in the unlikely event of unanticipated changes to the river or failure of mitigation measures, be used to update the EMP before each construction stage is implemented.

14.11 Overall Conclusion

The Status Quo and Project Options 1 and 2 do not meet the Project Objectives, whereas Project Options 3 and 4 with modifications do.

Project Option 3 is the least costly to build and operate, but has the narrowest opening (44.2 m) and does not have the enhanced benefits of Project Options 4B and 4C (increased sediment erosion and tidal exchange).

Project Option 4A is more costly than Project Option 3, but provides a wider opening (72 m) that will create a river channel more like the pre-causeway river channel.

Project Option 4B affords a greater degree of flexibility should predicted sediment erosion and increased tidal exchange be found to be less than predicted under Project Options 3 or 4A. Project Option 4B can have the widening in the causeway opened beyond that in Project Options 3 and 4A (up to 225 m), if necessary, but could avoid that cost if not necessary. Project Option 4B could be constructed in phases with the initial phase involving removal of the control
structure, followed by subsequent phased removal of portions of the causeway, thus deferring some of the capital cost while at the same time achieving an optimal opening width.

Project Option 4C is the most costly Project Option and has inherent construction risks (dredging or cofferdam failure and proximity to the former Moncton Landfill immediately downstream) that are much greater than the other Project Options. However, Project Option 4C does result in a river channel that most closely resembles the pre-causeway river channel.

From a full cost accounting perspective, the benefits associated with the Project Options are similar, with Project Option 4C having slight more extensive benefits than the others. However, Project Option 4C is substantially more costly and environmentally risky, and this additional cost likely outweighs the additional benefits associated with it. Project Option 4B has benefits that approach Project Option 4C, at substantially less cost and risk. Project Options 3/4A offer the least cost but also have the least benefits. The overall costs of all of the Project Options would be partially offset by the avoided costs associated with the Status Quo.
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Colepit, Garry, New Brunswick Department of Transportation
Copp, Graham, President of Alma Fishermen’s Association. Alma
Cormier, Dan. Tri-Community Marina
Dadswell, Michael. Ph.D. Acadia University Biology Department.
Gary Griffin, Petitcodiac Riverkeeper.
Hache, Denis, Fisheries and Oceans Canada, Stewardship Section, Moncton, New Brunswick.
Hooper, William. New Brunswick Department of Natural Resources.
Hussey, Eric. Sea Cadets, Moncton
Knockwood, Joe. Member Fort Folly First Nation
Knockwood, Mary. Member Fort Folly First Nation
Landry, Richard. P.Eng., Director of Environmental Planning and Management, City of Moncton
LeBlanc, Daniel, Executive Director of Petitcodiac Riverkeeper.
MacKenzie, Blair. NB Power
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Walker, Jordan. Planning Supervisor, Enbridge Gas New Brunswick
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FIGURES
APPENDIX A
Gate Management Plan
Fisheries and Oceans Canada and
New Brunswick Department of Transportation

Gate Management Plan to Improve Fish Passage Opportunities
at the Petitcodiac River Dam and Causeway

April 01, 2005 to March 31, 2006

Introduction

The trial gate experiment of 1998 and 1999 provided the Departments with information and data on the issue of fish passage. In both years, for extended periods of time during the experiment, the gates were operated such that a minimum of one gate was kept open on a rising tide up to the point where the tidal water elevation was the same as the headpond freshwater elevation. Similar gate management was conducted in November and early December 1999 to optimize adult salmon upstream migration. This was done without impacting the infrastructure or civil works and without further negative impact to fish, fish habitat or the fisheries.

A Gate Management Plan was approved by Fisheries and Oceans Canada for the periods of October to December 1999, February 2000 to March 31, 2001, April 1, 2001, to March 31, 2002, April 1, 2002, to March 31, 2003, April 1, 2003, to March 31, 2004, and April 1, 2004, to March 31, 2005. Those gate management plans were implemented and monitored by NBDOT where DFO and NBDSS monitored fish passage opportunities and presence of fish. This monitoring and DFO expertise on fish passage and fish behaviour allowed this Department to conclude that the improved gate management is providing superior fish passage opportunity to that provided by the two previously approved fishways.

Based on this conclusion and in view of the possibility that there may not be free flow through the gates in 2005/2006, the Department of Transportation and Fisheries and Oceans Canada agreed on the following temporary procedures to optimize fish passage opportunities. This agreement is limited by the following conditions:

- That saltwater introduction into the headpond would be in the same order of magnitude as what would occur if the two fishways were in operation.
- That water level in the headpond would be consistent with the status quo (prior to 1999) range of headpond water level variations.
Gate Management Plan for April 1, 2005, to March 31, 2006

This Gate Management Plan to improve fish passage opportunities at the Petitcodiac River causeway is for the period of April 1, 2005, to March 31, 2006.

Improvement to Fish Passage Opportunity

Smelt Migration

Upstream and downstream smelt migration normally occurs at night from mid-April to the end of May. NBDOT will advise Fisheries and Oceans Canada of smelt arrival and will immediately implement the smelt gate management plan. This will normally occur during relatively high freshwater flow and will be done by opening a minimum of one gate for a minimum of 4 hours prior to the expected maximum high tide provided water flows of the Petitcodiac River are sufficient to maintain the headpond levels within normal range.

The closure of the gate(s) will not begin until the tide is at least at the same elevation as the headpond elevation. When the maximum high tide is at about the same as the headpond elevation, the gates will be kept open for another hour. Under low maximum high tide, the headpond will be lowered as much as possible to the maximum predicted high tide elevation. Under this condition, the gate(s) will again remain open until an hour after the tide peaks.

The stop log fishway located downstream of gate number 5 will not be installed, but the vertical slot fishway will be open for the duration of the smelt migration.

If the gates need to be open for more than 5 hours per night, the operator will open them sooner than described on the rising tide. This is to prevent flushing smelt out of the headpond.

Shad, Striped Bass, Gaspereau

Expected upstream migration is during May and June daylight hours. The vertical slot fishway will remain opened after the end of the smelt upstream migration. The following gate management will be implemented:

One or more gate(s) will be opened for approximately 4 hours prior to predicted maximum high tide. The duration and the number of gate(s) that will be opened will be at the discretion of the gate operator and will depend on the freshwater input into the headpond in the preceding hours. The gate(s) will be opened during daylight hours. The gate(s) will be manipulated differently for different maximum high tide scenarios.

- Large high tide (maximum high tide higher than 6.3 metres)
  The headpond is kept as close as possible to elevation 6.1 metres.
  The closure of the gate(s) begins once the tide reaches the headpond elevation.
• Medium high tide (maximum high tide elevation between 5.5 and 6.3 metres)
  The headpond is kept as close as possible to maximum high tide elevation.
  The gate(s) is/are kept opened from 4 hours prior to maximum high tide as a
  minimum, to 1.0 hours after maximum high tide.

• Neap high tide (maximum high tide elevation is lower than 5.5 metres)
  The headpond will be lowered as much as possible to the expected maximum
  high tide elevation.
  The gate(s) will be kept open for at least 4 hours prior to maximum high tide and
  for a minimum of 1.0 hours after maximum high tide if the headpond can be
  lowered to the maximum high tide elevation. Otherwise, the closure of the
  gate(s) will not begin until after the tide reaches the headpond elevation.

Salmon Smolt Downstream Migration

Salmon smolt downstream migration normally occurs from mid-May to the end of June
during night-time. Smolt downstream migration will be monitored by DFO on other inner
Bay of Fundy salmon rivers. This information will be used to advise NBDOT district
office of the smolt migration. NBDOT will immediately implement the following gate
management plan. Gate manipulation will promote night-time downstream migration to
reduce bird predation and to follow smolt behaviour.

A number of gate(s) as required will be opened at night on a receding tide only.
The gate(s) will be opened to promote a rapid drawdown “flushing” of the headpond
similar to what was done for smolt migration in the last two weeks of May 1998.
The headpond will be allowed to fluctuate between elevations 6.1 to 4.5 metres.

Smolt passage through the headpond will benefit from the fluctuation, and smolt survival
and acclimation to saltwater will benefit from the large outflow of freshwater into the
Petitcodiac River estuary.

Potential Conflict between Shad, Striped Bass, Gaspereau and Salmon Smolt
Migration

Freshwater flow in June may not be sufficient to operate the gates on a daily basis to
promote fish passage as described above. Should freshwater flow not be sufficient,
NBDOT district office will contact DFO Habitat Management immediately to resolve fish
passage priorities. Operating the gates for fish passage every second or third day or
prioritizing species depending on extent of passage or peak migration period will be
considered.

Gate Operation for the Summer Period

For fish passage consideration, summer is defined as the low flow period starting at the
end of the blueback herring upstream migration, normally occurring at the end of June
and ending with the first large freshwater flow normally occurring in late September or
early October.
The stoplog fishway located downstream of gate number 5 will not be installed and the vertical slot fishway will be closed for this period. This will be done to conserve whatever little freshwater is flowing into the headpond. Conserving freshwater flow as described should help bring the headpond to its “normal” level relatively quickly after the end of the spring fish migration. This should also help NBDOT to optimize mud management and should at the same time improve fish passage opportunity.

Surface water flow measurements over the last 4 decades indicate that low flows smaller than 5 cums (cubic metres per second) are the norm for this time period. The low flow for 2001 was in the order of 1 cums. Flows of this magnitude occurred from Mid-July to late October 2001, resulting in a low headpond elevation and high downstream mud elevation.

**Gate Management**

If there are no juvenile fish present, the gate(s) will be operated as required for mud and headpond management.

The gate plan is based on previous fish monitoring studies. The gates will be operated as described below for the downstream migration of juvenile Gaspereau for the period of July 21 to August 31 inclusively. The gate(s) will be operated to keep the headpond between elevations 5.0 to 6.1 metres.

- At night time, open one or more gate on an outgoing tide when the predicted maximum tide is higher or the same elevation as the headpond.
- The gates will not be opened when the maximum predicted tides are lower than the prevailing headpond elevation.
- The gate opening will start when the tide is at the same elevation the headpond.
- The gate will be opened for a minimum of 2 hours.
- Gate manipulation for mud flushing only is not allowed during this time period. NBDOT will call a meeting if they believe that mud flushing is required above and beyond what is accomplished by gate opening for fish migration.

NBDOT will immediately call a meeting with DFO to assess the gate operation plan if the headpond water surface elevation gets to be lower than elevation 5.4 metres and cannot be raised as a result of sustained low flow conditions.

**Adult Salmon Upstream Migration**

The gate management specific to salmon will be as described for shad, striped bass and Gaspereau and will be implemented from the end of summer as described above to the end of migration, which is believed to occur prior to mid-December. The gates will be managed up to that date unless ice conditions or other valid considerations do not allow it.

NBDOT in Moncton will contact DFO Habitat Management should they believe that it be necessary to terminate gate management for salmon migration prior to December 15.
Other Species

It is expected that other species of concern such as eel and trout will be provided with better fish passage opportunities as part of the overall fish passage gate management plan.

Fish Passage During the Winter Months

Tomcod upstream spawning migration may take place from early December to early February, with spawning occurring under the ice in January to February. As a result, the vertical slot fishway will remain open until February 15.
APPENDIX B
Report on Site Visit to Cardiff, Wales Fish Passage Facility
Report on Visit to Cardiff Wales

Purpose of Visit: To collect information about the Cardiff Bay Barrage and Fishpass
Dates of Visit: December 10-12, 2003
Visitor: Greg Gillis – AMEC Project Manager

Introduction

The AMEC Petitcodiac River EIA team learned of a fish passage facility (fishpass) in Cardiff Wales that is physically located in an area that has similarities to the location of the Petitcodiac Causeway. The construction of the Cardiff Bay Barrage commenced in 1994 and was completed in 1999. The Barrage was constructed downstream of the confluence of the River Taff and the River Ely within the tidal range of the Severn Estuary.

Preliminary information on the Cardiff Bay facilities was presented in Maritime and Water Engineering, Special Issue, Cardiff Bay Barrage, Proceedings of the Institution of Civil Engineers, June 2002, Vol. 154. Following review of the information in this journal, contact was made with managers of the facility in Cardiff. Information exchange lasted about one month following which it was decided that a visit by a member of the AMEC Study Team to the Cardiff facility would be beneficial. The goal of the visit was to understand the approach to fish passage that is used in Cardiff in order to determine if any of the information could assist fish passage at the causeway on the Petitcodiac River.

Greg Gillis from AMEC visited Cardiff on December 9, 2003. During the visit he met with several individuals from the Cardiff Harbour Authority including:

- Mr. Roger Thorney, Operational Manager for the Barrage,
- David Lowe, Operational Manager, Environment and
- Stuart Jones, Barrage Team Leader.

The personnel from the Authority were very helpful in providing information on the facility. In addition to information provided during the visit, other information was provided subsequently in letters or email. The information presented in this report was taken from the documents provided, as well as from information gained during discussions with the Cardiff personnel.

The major similarities between the Cardiff and the Petitcodiac River situations include:

a) The Cardiff Bay Barrage and Fish Passage Facility are located along the Severn Estuary, which has a large tidal range that is slightly lower than that of the Bay of Fundy.

b) The common mouth of the Taff and Ely rivers is located in the lower middle of the Severn Estuary, and the Cardiff Barrage is in the lower portion of the tidal range of the rivers.
c) The Barrage has created an upstream impoundment similar to that on the Petitcodiac River.

d) The elevation of the peak of the highest tides is higher than that of the upstream impoundment.

Differences between the two situations include:

a) The Cardiff Fish Passage Facility is designed to pass only Atlantic salmon and sea run brown trout. Other species rarely, if ever, pass through the facility, while a requirement of the Petitcodiac River Causeway EIA is to ensure that all options meet fish passage requirements (upstream and downstream) for a wide variety of species and sizes of fish.

b) The normal suspended solids level in the Severn (and in the vicinity of the barrage) - approximately 1200 milligrams per litre (mg/l) is much lower than in the Petitcodiac River Estuary – approximately 30,000 mg/l.

c) The combined freshwater discharge from the Taff and Ely Rivers is about 10 times that of the Petitcodiac River, and the flows are more evenly distributed throughout the year. (Please refer to Table 1, attached.)

**History of the Cardiff Bay Barrage**

Cardiff was once a thriving seaport with a regular schedule of international shipping. Since the Second World War, and associated with the decline of the Welsh Coal fields, the port has been in a state of decline with major portions of the docks having been abandoned. This resulted in urban decay in the centre of the city. Several attempts at urban re-development, including construction of office towers and housing developments, did little to reverse this trend. The Secretary of State for Wales established the Cardiff Bay Development Corporation in 1987 to address this issue. The task was to spearhead the regeneration of 1,100 hectares of South Cardiff and adjoining Penarth – the old docklands area of the city. The resulting plan became the second largest regeneration scheme in Europe. The mission statement for the program was: “to put Cardiff on the international map as a superlative maritime city which will stand comparison with any such city in the world, thereby enhancing the image and economic well-being of Cardiff and Wales as whole.”

The plan involved the attainment of a series of targets including:

- creating a superlative maritime environment by building a barrage across the mouth of Cardiff Bay and thus providing a 200 hectare freshwater impoundment and 12 km of continuous waterfront;
- re-uniting the city and its waterfront by means of an new boulevard and rapid transit system;
- providing 373,000 sq m of office accommodations;
- providing 465,000 sq m of Industrial space;
- providing 6000 new homes (25% being social housing); and
- the establishment of a link road to South Cardiff.
The plan to turn Cardiff Harbour into a freshwater impoundment was designed to facilitate its use by recreational boats, while maintaining commercial shipping at the docks that were still functioning. The plan involved the erection of a Barrage, at a cost of £125 Million (approximately $250 Million Canadian) across a portion of the harbour to separate the freshwater and seawater. Associated site remediation, installation of transportation infrastructure, and landscaping and environmental improvements brought the total estimated public investment to approximately £513 million ($1 billion Canadian). Private investment associated with the renewal project was £1.14 billion as of 2000.

The primary revenue source for the Cardiff Bay Development Corporation was Public Sector Funding (est. £444 Million) followed by £56 Million in proceeds from sale of lands. Government grants and Interest and Rebates totalled £9 and £4 Million respectively. The project has resulted in industrial development in the area as well as new housing, both social housing and exclusive housing.

The elevation chosen for the surface of the impounded freshwater bay (the Bay) was set below that of the highest tides to take the greatest advantage of the existing docks. A system of locks was constructed to allow the passage of recreational vessel traffic between the Severn Estuary and the Bay. A staff of 15 people works on a 24-hour rotation to operate the boat locks and sluices, as well as to provide for security. Every day, a staff member inspects the fish pass to conduct routine maintenance such as debris removal. The downstream channel is dredged every six months. The volume of dredged material in each dredging event is approximately 70,000 to 80,000 cubic metres. This material is dumped in the Severn Estuary approximately 4 km seaward from the Barrage.

Photo 1. Cardiff Bay Barrage Viewed from the Estuary (foreground)

The construction of the Barrage encountered a number of environmental challenges. The Barrage impounded the estuary of the Taff and the Ely Rivers, which have important runs of anadromous fish including Atlantic salmon and brown trout. The construction of
the barrage prevented the free movement of these fish and also resulted in a loss of 200 hectares of marine fish habitat. Because of this, an Act of Parliament was required to approve the project subject to a number of provisions the maintenance of dissolved oxygen levels in the Bay at 5 milligrams per litre or greater through the entire water column, and the provision of upstream fish passage for Atlantic salmon and trout. The dissolved oxygen level is maintained by means of artificial aeration. A unique fishpass was incorporated in the development to attempt to achieve acceptable levels of fish passage. Included in the initial capital cost of the development was £6 million for the construction of the fishpass. The cost of running the fish passage facilities, locks and routine barrage maintenance is approximately £5 Million ($10 Million Canadian) per year.

Following are descriptions of the major water control components of the Cardiff redevelopment project including the barrage, the locks and the fish passage facility.

**The Barrage**

Cardiff Bay is the estuary for the Taff and Ely Rivers, the two main rivers in South Wales. The tidal range in the area is up to 14 m, which in the past at low water resulted in the exposure of extensive mud flats that limited development of the waterfront. The barrage that was constructed to separate the freshwater impoundment from the Severn Estuary is an 800 m long embankment constructed from sand and rock along with a 300 m long concrete section containing the locks, sluices, bridges, fish passage facilities and control building. The embankment on the Bay side is landscaped to provide a linear park, while rock stone armour protects the seaward side of the barrage.

**Sluice Gates**

Cardiff has a history of flooding, the result of combined high river flows and spring tides. Following the urban renewal project, the consequences of flooding in the Bay would be more severe due to the value of the newly installed infrastructure, including industrial, commercial and recreational development. Sluice gates were installed in the barrage and are operated to limit the risk of flooding.

There are five sluice gates, designed to close during high tides to prevent seawater from entering the freshwater Bay, and to maintain a preferred water level in the Bay. Each sluice gate can discharge up to 250 cubic meters per second. An on-site staff of 5 engineers maintains the gates. The gates can be operated as overflow or underflow structures, depending on the wishes of the operator. The normal mode of operation is overflow that minimizes turbulence in the approaches to the fish passage facility.
Electricity for operating the facilities can be supplied from either end of the Barrage. Three on-site generators can supply complete back-up power. To help manage water flows, discharges and levels, telemetry links supply information from gauging stations on the Taff and Ely Rivers. The Barrage has level sensors, which record both Bay and tide levels in the estuary. In case of malfunction here are two back-up sensors for each side of the Barrage.

**Locks and Bridges**

There are 3 locks, each 40 m long, in the Barrage. Two locks are 8 m wide, and one is 10.5 m wide. The lock gates are 16 m high. There is 24-hour access for vessels to the lock gates, which are operated from the Barrage Control room, that is staffed 24-hours per day / 365 days per year. There are three Bascule Bridges that can be raised to allow ship passage through the Barrage. Each bridge weighs 88 tonnes and works by means of a cantilever system that is powered by an electrically driven hydraulic pump.

**Fish Passage**

Under the agreement with the regulatory authorities, 1000 fish must move upstream annually through the fish passage facility. If fewer than 100 fish annually move through the fishpass, a financial penalty is paid. The migrating fish are counted at a weir located at Blackwell in the River Taff (upstream of the impoundment). In addition, a video monitoring system that incorporates a series of cameras is situated in the bottom of a section of the fish pass. The system is being used to accurately count the migrating fish, as well as to identify the species of fish that are using the fishpass.

The initial fishpass facility failed to work properly, and as a result it was renovated. A detailed description of the fishpass follows. Plan and profile views of the facility are provided in Figure 1 (attached).
1. The Cardiff Bay fishpass allows adult Atlantic salmon, sea run brown trout and occasionally juvenile eels to move from the ocean into Cardiff Bay, which is a freshwater impoundment created by a dam (barrage) across the mouth of the confluence of two major rivers. (A comparison of the mean monthly flow of the rivers is compared with that of the Petitcodiac River in Table 1.) A species called the sand smelt, which is analogous to our rainbow smelt, cannot use the fishpass. Its numbers are undoubtedly diminished by a lack of access to spawning grounds, although a limited number of smelt gain access to the bay through the boat locks.

2. The lower portion of the fishpass is a pool-and-weir fishway. Flows in the pool-and-weir portion of the fishpass are maintained at 2.5 m$^3$/s whenever the sea level is below Bay level. Three 0.5 m wide vertical slots provide access for fish into the fishpass. A cable pulls leaf gates upward from the bottom into the entrance slots to maintain optimal water levels (and water column cross sectional area) over the top of the leaf gates resulting in an exit velocity of 1.5 to 2 m/second.

3. The elevation difference between the floors (as well as the tops of the weirs) of adjacent pools in the main fishway is 45 cm. The pools are 8 m wide and 3 m long. The pools drown out in succession as the leaf gates at the entrance rise to block the rising tide. This creates an ever-lengthening concrete walled canal.

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1 In fishway terminology, the entrance is at the lower end where the fish enter. The exit is at the upper end.
4. At the top end of the pool-and-weir fishway, there are two steep-pass (Denil) fishways. One is used to pass fish when the Bay level is higher than that of the estuary. The other is used when the tide is higher than the level of the Bay.

![Photo 4. Denil Portion of the Fishpass](image)

Photo 4. Denil Portion of the Fishpass

5. When the Bay is higher than the estuary, a separate pipe provides water by gravity flow to the lower pools of the pool-and-weir fishway. This augments the discharge from the entrance slots, without increasing flow down the pool and weir system, and attracts fish into the fishpass.

6. When the tide rises high enough that the pool-and-weir fishway and the first steep-pass become “tide-locked” (sea level higher than that of the Bay), a gate at the exit (top end) of the steep-pass closes to prevent salt water entering the freshwater impoundment. At this state of the tide, water is pumped to the second pool from the exit end of the pool-and-weir fishway to maintain flow in the lower end of the fishpass. Water is also pumped to the second steep-pass fishway that becomes accessible to fish when a gate opens. This gives access for fish from the pool-and-weir channel to an upper pool. At the exit end, there is a blind weir that fish swim over and are sluiced into the impoundment. (A blind weir is a horizontal header pipe that acts as a weir. Water is discharged from the top of the pipe with 80% of the water flowing down the steep-pass, and 20% back into the Bay. The 20% back-flow transports the fish into the impoundment.).

7. The entire system is under the control of a computerized Process Logic Controller (PLC). The PLC can be over-ridden to allow manual control.
8. After water is discharged from the fishpass entrance slots and the adjacent sluice gate #5, the flow enters a stilling basin (See Photo 2), which is essentially a concrete box with sidewalls of differing heights (steps). When the velocity of the flow over the lowest wall becomes too great, a second wall is over-topped, and when the velocity of the flow over this wall becomes too great, the third wall is over-topped. In this way, fish gain entrance to the chamber from which they can access the fishpass at a large range of flows and flow velocities.

During low river flows, the operators have difficulty operating the fishpass. There were significant mechanical failures with inlet leaf gate operation in the first year (2000), and therefore difficulties in maintaining the desired discharge velocity of 1.5 to 2.0 m/s at the fishway entrance.

**Fisheries Management and Its Effectiveness in the Taff/Ely Basin**

The Cardiff Bay Development Corporation (CBDC) stocks hatchery smolts annually in order to compensate for the impact of the Barrage on fish migration. As a worst case, it was anticipated that the Barrage would result in reduction of returns by about 35%. To compensate for anticipated reduced returns, two-year old salmon smolts were stocked - 10,000 fish were stocked prior to Barrage construction and 50,000 fish (since raised to 60,000) after construction.

The mean return of tagged adult salmon resulting from smolt stocking before construction was 0.66%. Returns of salmon from smolts tagged in 1998 that returned in 1999, the last pre-impoundment year, were 0.29%. An additional 0.02% multi-sea-winter fish from the 1998 release returned in 2000 for a total return from the 1998 year-class of 0.31%. In the year 2000, the year following the completion of the Cardiff Bay Barrage
and impoundment (impounded on November 4, 1999), the return rate of adult salmon from tagged smolts was 0.25%. (A good return would be in the order of 3%)

Angler catch per unit effort for salmon in 2000 was 0.19 fish per angler-day compared with 0.15 fish per angler-day in the pre-construction and construction period (1992 to 1999). Sea trout catch per unit effort in 2000 was also 0.19 fish per angler-day compared with 0.45 fish per angler-day in the pre-construction and construction period (1992 to 1999).

Fish trapping at Blackweir index trap on the River Taff captured 0.097 salmon per hour in the pre-construction and construction period from 1991 to 1999 (2,159 fish in 22,342 hours of trapping). This can be compared with 0.035 fish per trap-hour (574 fish in 16474 hours) for the post-impoundment period of 2000 to 2003 (See Table 2, below). Trapping took 0.108 sea trout per trap-hour (2,410 fish in 22,342 hours) in the pre-impoundment period, and 0.067 per trap-hour (1,104 trout in 16474 hours) in the post-impoundment period (See Table 2, below).

Adult salmon and sea trout were tracked in the estuary using a combined hydroacoustic / radio tag system. The fish were obtained from the Taff and Ely rivers feeding the Bay (i.e. they had already managed to pass the barrage and enter the river once). The tracking demonstrated that the fish were easily confused, and few successfully re-entered the system from the estuary.

There is also concern about the effect of the system on the downstream migration and survival of post-spawned Atlantic salmon and sea trout (kelts). Seven kelt were tracked using the tagging system after the fish spawned in 2000. In addition, three previously tagged salmon were known to have entered the Bay. Only one was detected in the marine environment after the period of downstream kelt migration. If downstream post-spawning migration is in fact a problem, it would have serious consequences in the case of trout in which repeat spawners provides a significant portion of the egg deposition.
Table 1. Comparison of Mean Monthly Flows between the Taff/Ely Rivers and the Petitcodiac River

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Monthly Flows (m$^3$/s)</th>
<th>Petitcodiac River at Petitcodiac</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rivers Taff/Ely</td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>29.6</td>
<td>5.5</td>
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<tr>
<td>February</td>
<td>36.1</td>
<td>5.03</td>
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<td>18.3</td>
<td>11.5</td>
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</tr>
<tr>
<td>December</td>
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<td>8.65</td>
</tr>
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</table>

Table 2. Catch Statistics from the Blackweir Index Trap on the River Ely

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase</th>
<th>Total Trap Hours</th>
<th>Salmon Catch</th>
<th>Salmon CPUE$^1$</th>
<th>Sea Trout Catch</th>
<th>Sea Trout CPUE</th>
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Mean CPUE, '91-'99 (Pre and During Construction)

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Mean CPUE, '00-'03 (Post Construction)

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<td>CPUE</td>
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1. CPUE: Catch per Unit Effort
Figure 1. Drawings Depicting the Cardiff Bay Fishpass