Petitcodiac River Causeway project

Stage 2 Follow-up Program
Year 3 Results

Executive Summary

Submitted to:

New Brunswick Department of Transportation & Infrastructure

Fredericton, New Brunswick

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1.0 INTRODUCTION

1.1 PURPOSE

This document is a summary of the results of Year 3 of the Stage 2 Follow-up Program (S2FUP) for the Petitcodiac Causeway Project (the "Project"). Year 3 results are compared to baseline conditions established during the Stage 1 Follow-up Program with respect to predictions and conclusions contained in the Environmental Impact Assessment (EIA) and provide a measure of the effectiveness of mitigation measures undertaken in Stage 1. The predictions and conclusions contained in the EIA are generally focused on conditions that will be present following completion of Project Option 4B (the bridge); therefore it is not possible to verify these during Stage 2 of this three stage Project. This document focuses on how the environmental effects observed during Year 3 of Stage 2 are trending as compared to the EIA predictions and conclusions specific to Stage 3 and beyond. The document focuses on the findings and conclusions relevant to the six Valued Ecosystem Components (VECs, see Section 1.3).

For a comprehensive description of background, methodology, references, and a more complete presentation of the results the reader is encouraged to refer to the main report, which is available from the New Brunswick Department of Transportation and Infrastructure by contacting the Communications Director: Judy Cole, at 506.453.5634.

1.2 FOLLOW-UP PROGRAM OBJECTIVES

The S2FUP objectives are to:

- Examine trends in environmental conditions for selected VECs to determine how environmental conditions are trending in regards to the environmental effects predictions in the EIA.
- Verify the effectiveness of mitigation measures to protect physical works installed during Stage 1.
- Provide an early indication of any unexpected change in environmental conditions.
- Improve understanding of environmental cause and effect relationships.

1.3 SCOPE

The S2FUP focuses on six VECs:

- Physical Characteristics of the Petitcodiac River and Estuary
- Tourism
- Commercial Fisheries
- Archaeology
- Public Health and Safety
- Engineered Environmental Protection Works

In addition to these six VECs, the monitoring of fish passage was formally included in the Follow-up Program for Year 3.

1.4 REGULATORY CONTEXT

The EIA required a Follow-up Program that would satisfy the objectives presented above. The S2FUP is a key component of the Environmental Management Plan (EMP), and is required as per Condition of EIA Approval (4). The S2FUP is divided into stages that correspond with the Implementation Plan, as per Condition of EIA Approval (5), and has been and will continue to be submitted to the New Brunswick Department of Environment and Local Government (NBDELG) for review and approval when required. The S2FUP is also required under the *Canadian Environmental Assessment Act* (*CEAA)* as a condition of the *CEAA* Screening undertaken by Fisheries and Oceans Canada (DFO). A Technical Review Committee (TRC), comprised of federal and provincial agency and department representatives, presided over the EIA process. The TRC was co-chaired by NBDELG, and DFO acting as the federal lead Responsible Authority. A similar TRC, chaired solely by NBDELG with input from DFO, was assembled to preside over the implementation of the Project.

2.0 PHYSICAL CHARACTERISTICS

2.1 OBJECTIVES

The objective of this component is to monitor and measure changes to the Petitcodiac River (hereinafter River), the Petitcodiac Estuary (Estuary), and the Upper Bay of Fundy after gate opening in order to understand effects on width, depth, and other physical characteristics as compared to baseline conditions.

2.2 RESULTS

2.2.1 Satellite Imagery

During Year 3 of Stage 2 the satellite imagery component focused on two tasks:

- the acquisition of satellite images captured at low tide, during cloud-free conditions and corresponding to either the spring season or major precipitation events; and

- the continued exploration of the quantification of total suspended sediments (TSS) in the Upper Bay of Fundy using remotely sensed data.

The satellite imagery data and the associated daily discharge records indicate that Year 3 physical characteristics are comparable between Stage 1 and Stage 2, with respect to the extent of the visible sediment plume emanating from the mouth of the River into the Upper Bay of Fundy. These observations on the water surface sediment plume do not necessarily support the EIA predictions that accumulated sediment in the River will likely and ultimately be transported into the middle Bay of Fundy, but rather appear to be limited to the Upper Bay of Fundy and mostly in Shepody Bay. The visible surface water plume contains the finer fraction of transported sediments and which would delineate the maximum possible extent of transported sediment. The heavier and larger fraction of sediment will likely be transported over a shorter distance and closer to the mouth of the River than that for fine sediments that would be contained in the surface water.

2.2.2 Aerial Photography

Aerial photographs were obtained during Year 3 on October and November of 2012. Both images were taken near low tide so that the mudflats were exposed. A special flight was made on November, 2012 to provide detailed LiDAR data for the reach from immediately downstream of the causeway to the railway bridge near Salisbury. The information from this flight provided a means of obtaining contours at an interval of 2.0 m, and was used to map the mudflats adjacent to the main channel above the water level. In addition, oblique non-geo-referenced photographs were taken from a small aircraft during three flights in February and March 2012 to assess the ice processes in the Estuary. The results are summarized as follows:

Immediate vicinity of the control structure: The upstream channel is well developed and the mudflats are well established.

Immediately downstream of the Gunningsville Bridge: The north bank located about 1500 m downstream from the Gunningsville Bridge is building out into the main channel; however, the overall channel geometry is relatively stable. Much of the change in the channel platform in this area occurred during the first six months after the gates were opened.

Near the GMSC outfall: The west bank has eroded laterally in the order of 20 to 30 m±; however, the outfall has remained stable as it is protected by riprap. The lower portion of the east bank has eroded laterally in the order of 40 to 60 m± and has actually cut off some of the small tributary streams which were present. The mudflats on the upper east side of the channel have grown appreciably and small drainage channels have become established on the surface. The flood channel is enlarging - attributed to the increased tidal inflow.

10.5 km downstream of the causeway: The flood channel continues to enlarge and migrate upriver.

2.2.3 Cross-sections

All references to “right” or “left” are taken as looking upstream.

2.2.3.1 Upstream of the Causeway

- **At km 1.1:** As of November 5-6, 2012 extensive mudflats have developed on both sides of the channel to elevation +6.0 to 6.4 m±, a rise of 3.5 to 5.0 m since May 21, 2009. By May 2012, the channel width at elevation 4.0 m has narrowed from about 440 m on May 21, 2009 to about 150 m in May 9, 2012. By May 9, 2012, the lowest elevation on the section was -1.0 m compared to an elevation of +1.0 m in May 2009. The thalweg position moved about 220 m toward the centre of the section over this period.
- **At km 6.1:** (just downstream of Turtle Creek) At this section the channel bottom has varied between elevation 1.0 m and -1.0 m± depending on the season. Mudflats have formed on the

left to an elevation of 6.2 m± increasing in height by about 2.8 m since May 2009. The River channel width at elevation 4.0 m has narrowed from greater than 230 m in May 2009 to about 120 m in May 2012.

- **At km 15.2:** Mudflats have formed on the left bank to elevation 6.0 m± with a depth of deposition of about 2.0 m. The main channel width remains relatively unchanged at 110 m± even though the mudflats have developed adjacent to the main channel.

2.2.3.2 Downstream of the Causeway

- **At km 0.9:** The bed elevation formerly experienced a large seasonal change in this portion of the Estuary. Before the gates were opened the thalweg at this section could vary as much as 8 m during a year. The seasonal accumulation of silt has been substantially reduced at this section following the opening of the gates. At the same time the channel width, at an elevation of 2.0 m, has increased by about 20 m on the right side up to November 17, 2012.
- **At km 5.1:** The seasonal accumulation of silt in the bed has been greatly reduced and the section has widened on the left side by about 26 m at an elevation of 2.0 m.
- **At km 7.3:** (Chartersville area) The channel bed has dropped in elevation by about 1.5 m between November 18, 2009 and November 17, 2012. The left side bank has widened by about 75 m at an elevation of 2.0 m. This section is near the outfall from the GMSC treatment plant. Monitoring of the bank erosion near the outfall is continuing
- **At km 10.5:** This section has widened on the right side by about 350 m at an elevation of 2.0 m. The seasonal accumulation of silt is substantially less than that prior to the gate opening. This section is located in a zone where separate ebb flow and flood flow channels are developing.
- **At km 19.5:** (about 4 km upstream of Stoney Creek) The left bank at an elevation of 2.0 m has widened by about 30 m, whereas the right bank has not changed to any significant degree.
- **At km 35.9:** (Hopewell Cape) This section on November 17, 2012 is very similar to that of November 18, 2009 indicating that there has been no net change in this section since the gates were opened.

2.2.3.3 Upper Bay of Fundy

- **At km 39.2:** (Calhoun Flats) Most of the change occurred from the centre of the section to the left bank looking upstream where a deposition of about 1.1 to 1.5 m occurred over a length of about 800 m.
- **At km 42.8:** (Grand Anse) The bed level in the central portion of the section (Middle Ground area) has risen about 0.5 to 2 m over a width of about 2500 m. This rise in the bed level is attributed to the net erosion of sediment from the Estuary upstream of Hopewell Cape, which is being transported down and is now depositing in the upper part of Shepody Bay.
- **At km 48.8:** (Daniels Flats) A deposition of about 3 m over a width of 1000 m in the deepest part of the Bay is occurring.
- **At km 55.9:** The purpose of this survey was to compare the current bathymetry with the bathymetry obtained by the Canadian Hydrographic Survey in 1965. The sections are similar except for two mounds: a small mound and a larger mound extending over a distance of about 1200 m in the central portion of the section. The average height of the larger mound in the 1965 survey compared to that for the 2012 survey was about 2.0 m. It is concluded that sediment deposited on the bed in this vicinity was transported upstream in response to the closure of the Estuary at the causeway in 1968.

2.2.4 Channel Profiles Along the Estuary

2.2.4.1 Thalweg Profiles

The thalweg profile represents the lowest elevations along the length of the Estuary and provides a means of assessing areas where water may pond during periods of low tide and low flow from the land.

Estuary: Since the gates were opened the thalweg elevation has dropped a maximum of about 3.0 m from 5 to 25 km downstream of the causeway and has risen a maximum of about 2.0 m from 32 to 35.9 km downstream.

"Mud Plug": The thalweg level has stabilized in the reach associated with the "mud plug" zone, 250 m to 780 m upstream of the control structure. The maximum change in the elevation of the thalweg, over the period December 2010 to May 2012, in this area is in the order of 1.0 m. This relatively stable zone may undergo some adjustment if the abandoned water main is removed or when it no longer acts as a control. During February 2012, the evidence of the presence of the water main was clearly visible from the control structure during low tide. The obstruction caused by the abandoned water main limits the outflow from the lower several kilometres of the reach upstream of the causeway during periods of low tide and there is evidence that large chunks of ice grounded in this area.

Scour Hole: The maximum depth of the scour hole, with reference to the initial bed level, was 5.5 m on May 17-18, 2011. This is about 0.1 m deeper than that for November 23, 2011. Any additional scour in the future at this site should be relatively small. The peak tidal inflows are not likely to increase over time.

Immediately downstream of the control structure, the structure was built with a concrete apron extending 18.0 m downstream of the ends of the piers. The original design recognized that the structure had to pass high flows from the land in the order of 1000 m3/sec. Once the gates were opened, the tidal outflows were in the order of 1000 to 1500 m3/sec twice a day.

The Year 3 surveys indicate that the scour hole is becoming stabilized. The repeated hydrographic surveys upstream of the control structure show that the tidal volume is decreasing over time because of the sediment deposition in the developing mud flats. Based on these observations, it is expected that the peak tidal outflows will decrease over time. As a consequence, it is predicted that the depth of the scour hole downstream of the control structure should not increase to any significant degree over time.

2.2.4.2 Tidal Flats

Most of the tidal flat development is taking place between the control structure and the confluence of Turtle Creek. The typical mudflat elevation was 6.3 m on November 6-7, 2012, that is about 0.2 m above mean high tide elevation of 6.1 m (geodetic). These data indicate that the rate of increase in the surface elevation of the developing mudflats is decreasing with time.

In the long term, the plan form of the channel could change in the area between the causeway and Turtle Creek if ebb flow and flood flow channels begin to diverge. The enlarged ebb flow - flood flow channel could move laterally into the newly deposited sediments that form the tidal flats upstream of the causeway. This process, if it occurred, would increase the tidal storage upstream of the control structure.

2.2.4.3 Channel Width Relationships

In order to assess the changes in the channel both upstream and downstream of the causeway, width at elevations 2.0 m and 4.0 m were measured.

Upstream of the Control Structure: In general, the channel width at elevation 4.0 m has decreased appreciably over time after the gates were opened. The greatest changes occurred in the first 6 km upstream. the channel width in this reach at elevation 4.0 m on May 9, 2012 were about 50 percent of that before the gates were opened. It is in this reach that the major tidal flats have developed in response to the opening of the gates.

Downstream of the Control Structure: The channel width at elevation 2.0 m increased along the first 19.5 km downstream with very little change after that point. The greatest increase in width at elevation 2.0 m occurred between 5.0 km 14.1 km downstream of the control structure. The greatest changes are indicated at a location 10.5 km downstream. Although the channel appears to have increased by over 100 percent at this location, it is related to the development of separate ebb flow and flood flow channels. The changes at locations of 7.3 km and at 14.1 km are more representative of the maximum channel widening between the causeway and Hopewell Cape. At these sites the channel widening is in the order of 30 to 50 percent of the width before the gates were opened. At elevation 4.0 m, the major changes are similar to that for the widths at elevation 2.0 m except for the section at 31.1 km which shows a narrowing of about 10 percent between November 8, 2010 and October 17, 2012.

2.2.5 Bottom Sediment Samples

2.2.6 Suspended Sediment Sampling and Current Profiling at the Gunningsville Bridge

Sub-surface Current Velocities: For the early fall event, the velocities measured in Year 3 are in agreement with recorded velocities during previous years with a slight increase in the peak velocity during the flooding tide that reached 2.86 m/s. These slight velocity increases suggest that a fully stable condition may not be reached yet and changes are still occurring. Overall, the current measurements confirm the predictions of the EIA. At this point it is difficult to predict if the maximum velocities that can be reached in the channel in the next few years will be much higher than the velocities measured in previous events, which ultimately will affect the sediment erosion and deposition regime along the River.

Total Suspended Solid (TSS) Measurements: In Year 3, TSS concentrations increased when compared to the previous years of Stage 2, reaching similar concentrations than the comparable event during Stage 1, with the highest peak occurring during the arrival of the tidal bore. TSS concentrations were similar to the previous year; however, a significant increase in concentrations was measured during the arrival of the tidal bore as well as during the ebbing tide, and this is likely a direct consequence of an increase in water current velocities. The availability of more suspended sediments during 2012 when compared to previous years can be attributed to different factors, including higher velocities and flow rates with a corresponding increase in sediment concentrations.

Suspended Sediment Transport: In Year 3, the transport of suspended sediment increased in the upstream direction when compared to previous years, which were showing a decreasing trend in upstream sediment movement. This is mostly due to an increase in TSS concentrations and a further increase in current velocities that were measured in the channel. In terms of the sediment transport regime, the higher amounts of suspended sediment that traveled upstream created a net balance in the upstream direction. Additionally, during this event the peak suspended sediment mass amounts were approximately 15 times higher than the sediment mass estimated during the same event in 2011. The sediment transport regime is similar to what it was observed during Year 2, suggesting that the hydrodynamic conditions are stabilizing with similar current velocities, TSS concentrations and therefore sediment transport amounts.

2.2.7 Ground-level Observations

As a general observation, no discernable changes in the shoreline at the lower portions of the Estuary were noted in 2012.

Upstream of the control structure rapid siltation has occurred, most evident by the increase in elevation of the mudflats in the former headpond area. In the spring of 2010 all incoming tides flooded the former headpond; however, due to sediment deposition in these low energy areas, the elevation of these mudflats has increased from an average 3.5 m at the time the gates were opened to an estimated 6.3 m by the fall of 2012. As a result lower tides no longer cover the mudflats. The rate of silt deposition on the mudflats had decreased by the fall of 2012 as a result of the less frequent flooding.

The pattern of silt deposition and erosion in the Estuary at the near head of tide at the former railway bridge has repeated seasonally over the 2010 to 2012 period.

Conditions of the River and tributaries downstream of the control structure during the winter of 2012 appeared to be similar to that of past winters with respect to the build-up and passage of ice. Tributaries such as Halls Creek, Jonathan Creek, Mill Creek, Weldon Creek, and Stoney Creek experienced a significant build-up of shorefast ice, resulting in a narrowing of the channel. Similarly, the upper portions of the River downstream of the control structure narrowed as in past winters due to the formation of shorefast ice. Above the control structure significant narrowing of the River occurred as a result of both the build-up of shorefast ice and the presence of stranded ice deposited by incoming tides. For much of the winter of 2012 the River upstream of Turtle Creek was frozen over.

Ice passage did not cause any significant problems for the control structure, although NBDTI did carry out de-icing of the gates as a precautionary measure in late February 2012.

The riprap protection placed during Stage 1 and most recently placed in the fall of 2011 continues to perform as designed and is preventing erosion.

2.2.8 Sediment Deposition, Erosion and Net Accumulation

For Year 3 the hydrographic data were supplemented by a LiDAR survey upstream to capture the elevation of the mudflats upstream of the causeway which are no longer accessible by boat. Downstream the edges of the channel were tied in by field surveys on the marshes.

The following estimates are provided for changes in volume during the monitoring period:

- **Upstream of the Causeway** - Between April 14, 2010 and November 2012 approximately 6.0 million cubic metres (m^3) of silt accumulated in the former headpond mainly in the form of mudflats which have now reached an elevation of 6.2 to 6.5 m±. In addition to the permanent infilling, about 2.0 to 2.5 million m^3 of sediment moves into the upstream area in the summer and is eroded out in the subsequent fall or spring.
- **Causeway to Hopewell Cape** - Between April 14, 2010 and November 2012 a net erosion of approximately 43.5 million m^3 has occurred in this reach. The most active widening of the River seems to be in the reach Dieppe to Upper Dover.
- **Shepody Bay** – The net difference between the total estimated erosion downstream and infilling upstream should approximate the deposition in Shepody Bay. The volume changes in Shepody Bay over the period April 14, 2010 to November 17, 2012 indicate reasonable agreement between the computed and measured volume of material deposited. The data collected to date shows that the Estuary responded very rapidly to opening the gates, with about two thirds of the changes taking place in the first 7 to 8 months.

2.2.9 Estuary Volume and Tidal Prism

Upstream of the causeway, when the gates were initially opened, the tidal prism increased immediately by about 20.4×10^6 m^3 (pre gate opening value) due to the increased tidal volume in the former headpond. This decreased, by November 2012, to about 14.4 x 106 m^3 due to channel narrowing and mudflat build-up. Erosion downstream of the causeway since the gates were opened now approximates 21×10^6 m^3 in the tidal zone, giving a combined total increased tidal prism of 35.4×10^6 m^3 or 14% greater than pre-gate opening value. In addition, a further 20×10^6 m^3 of erosion has occurred below the low tide level downstream of the causeway.

3.0 TOURISM

3.1 OBJECTIVES

The objective of this component is to estimate the environmental effects of the Project on tourism.

3.2 RESULTS

The following observations summarize the overall results of each of the three years of Stage 2:

- the average number of visitors who viewed the tidal bore at Boreview Park increased each year from an average of 37 visitors per day in 2010, to 41 per day in 2011, to 59 per day in 2012;
- the average visitor group size has remained fairly consistent at 2.9 persons per group;
- most visitors (80%) to Boreview Park were from outside of the Province;

- most visitors (87%) were at Boreview Park principally to view the tidal bore;
- most visitors (83%) said they would return to Boreview Park to view the tidal bore; and
- almost all visitors (97.2%) indicated that they would recommend visiting Boreview Park to view the tidal bore to others.

In 2011 and 2012 supplementary visitor count surveys were conducted from the boardwalks at Chateau Moncton and the Riverview Chocolate River Station. These surveys indicate that while most visitors (54.2%) view the tidal bore from Boreview Park, it is apparent that many view the bore from other points in the Greater Moncton Area (GMA): 29.7% at Chateau Moncton, and 16.1% at the Chocolate River Station.

The survey results for the three years of Stage 2 indicate that visitation to Boreview Park to view the tidal bore has increased each year. Visitation during Stage 2 has increased by 75% over that of Stage 1. The tidal bore has become a popular tourism attraction for visitors from outside of the Province, as well as within the GMA. After three years of Stage 2, the survey results appear to be consistent with the EIA prediction that the Project would have a positive environmental effect on tourism.

4.0 COMMERCIAL FISHERIES

4.1 OBJECTIVES

The objective of this component is to determine how the Project affects commercial fisheries landings; specifically lobster and scallop in the Upper Bay of Fundy. The eel fishery in the Estuary was compensated for loss of fishing opportunity.

4.2 RESULTS

4.2.1 Sediment in Lobster Traps

Year 3 lobster sediment data were collected for September and November 2012. The reporting of detailed numbers for year-to-year comparison of the percentage of traps that contain sediment would be of little value for the following reasons:

- Commercial fishermen avoid areas where they know that sediment deposition is common.
- Fishermen try not to drag traps across the bottom during retrieval.
- Reporting of sediment in the traps is up to the fisherman retrieving them and the availability of the technician at the time.

It is suspected that the reporting of sediment in traps is not conducted with enough scientific rigour to have confidence in the precise number of traps that contained sediment in 2012 or prior to this. In addition, lobster traps are not designed to monitor sediment deposition.

4.2.2 Sediment Plume Delineation

The results of the Year 3 satellite image analysis of surface sediment plumes in the Upper Bay of Fundy did not suggest any noticeable change in sediment plume distribution. The qualitative assessment of TSS conditions demonstrate that an initial increase in suspended sediment loading likely occurred immediately following gate opening and which is trending towards equilibrium. Images captured later in Stage 2 illustrate relative suspended sediment levels that were comparable to the overall sediment plume characteristics observed in Stage 1. TSS concentration values for the Upper Bay of Fundy are predominantly between 15 and 35 mg/L. These results were validated by both *in-situ* TSS data and by quantified suspended sediment data using MERIS satellite data and a sensor-specific algorithm.

The calculation of sediment load estimates using the TSS quantification results for Stage 1 and Stage 2 imagery suggested that surface water sediment loads decreased relatively rapidly over the area known as the Middle Ground compared to the rate of sediment load decrease in Chignecto Bay. This trend was observed in both Stage 1 images and in the single Stage 2 image. The sediment load analysis also confirmed the boundary location for the effects of sediment transport from the River and Cumberland Basin at low tide. At this region and beyond, it is suggested that sediment transport effects at low tide are the result of ocean conditions in the Bay of Fundy.

4.2.3 Lobster

Overall the Catch Per Unit Effort (CPUE) of legal lobsters in commercial traps during Stage 2 (2010 through 2012) in both the control and exposure areas has increased or has remained similar to the CPUE of legal lobsters in Stage 1. Year 3 CPUE data suggest the following:

Out-of-season program:
Exposure zone - a decrease to a level similar to or slightly lower than the baseline rate. Control zone - similar to the pre-causeway rate, but did show a bump in 2012 to a point at which the rates were very similar in the exposure and the control zones. Since CPUE is being used as a surrogate for “commercial landings” in evaluating the potential effects on the fishery from the removal of the causeway, the results indicate no discernible negative effects.

Sub-legal lobsters:
Fall: Exposure zone - slightly downward since the baseline year, but essentially flat since the start of Stage 2. Control zone - slightly downward since baseline year, and downward from 2010 through 2012.
Spring: Exposure zone - down from baseline year and down from initial Stage 2 year of 2010, but the same as 2011. Control zone - similar to the baseline year, but down from 2011.
Out-of-season: Exposure zone - down from baseline year, but up from 2011. Control zone - up from the baseline year, but down from 2011. These results indicate the control zone in 2012 was producing more juvenile lobsters than the exposure zone, whereas the production was approximately the same pre-causeway opening.

Water temperatures were consistently higher in 2012 than all other years. Increased temperatures in spring 2012 were especially pronounced in the control zone, but elevated temperatures in fall 2012 (until late November) were present in both control and exposure zones. It is unlikely that depth dictated these temperature trends because depth was fairly consistent across the years. Additionally, despite greater and more variable depths in the exposure zone, the same temperature pattern was observed. During the spring, temperatures were higher in the exposure zone than the control zone in all years (except for part of 2012).

4.2.4 Scallop

In Years 2010 to 2012 there was no statistical difference in meat weight at shell height between the control zone and the exposure zone. This suggests that scallop meat weight at shell height was similar in the control and exposure areas before the opening of the gates, as well as after the opening. The results of the S2FUP to date do not identify a negative effect of the Project on the scallop fishery.

5.0 ARCHAEOLOGICAL AND HERITAGE RESOURCES

5.1 OBJECTIVES

The objectives of this component are to ensure all areas of potential archaeological interest are identified, and, where necessary to mitigate risk to archaeological and heritage resources.

5.2 RESULTS

The Year 3 activities included a visual survey of 40 areas by a permitted archaeologist and the limited mitigation of four archaeological sites. The survey included: 13 areas along the headpond identified as having potential for considerable erosional activity; 24 of the 27 registered archaeological sites identified in 2009-2010; an archaeological site on Outhouse Point; the boardwalk area at Halls Creek; and, a newly identified wooden cultural feature. As a result of the visual survey, 12 registered archaeological sites were identified as being partially exposed and/or negatively impacted, and two previously unrecorded sites were identified along the shoreline of the River. Both of these newly registered sites are historic shoreline wooden structural remnants. Of the 12 negatively impacted sites, eight were assessed as not requiring mitigative action.

Of the four archaeological sites that were assessed as requiring mitigation measures, one was reburied and three were partially excavated and reburied. One feature was dendrochronologically dated to 1740 and appears to be contemporaneous with the nearby Acadian aboiteau sluice feature. Dendrochronology analysis of a previously collected sample (2011) from an in situ aboiteau feature with a sluice structure built from milled wood dated to 1946, while a sample collected in 2012 dated to 1890. This feature was very likely constructed in the early 1900s prior to the MMRA program (1950s). An in situ portion of an aboiteau, complete with multiple layers of brush matting and a sluice with a clapet at the shoreline exit point was dated from 1870 to 1920.

6.0 SURFACE WATER QUALITY

6.1 OBJECTIVES

The objective of this component was to obtain interim surface water quality data following gate opening, to give an indication of how the environment is trending towards EIA predictions.

6.2 STAGE 2 FOLLOW UP PROGRAM PLAN MODIFICATIONS

The results of the S2FUP in Years 1 and 2 demonstrated a substantial net reduction to overall bacteria levels in the Estuary, particularly in the downstream reach from the Gunningsville Bridge to Hopewell Cape suggesting that the surface water quality is trending towards the predictions contained in the EIA. However, some limitations to the previously implemented methods were observed, with refinements occurring in each sampling year. As a result of the evaluations completed in Year 1 and Year 2, and in consultation with provincial regulators, the water sampling program for Year 3 was revised as indicated below. A complete description of methods is available in the main report.

- Enterococci analysis was discontinued from the program and BacH analysis was added. E.coli analysis was continued as in past sampling events.
- The number of sampling events was increased from one summer wet event to three seasonal events (spring, summer and fall) to characterize a greater diversity of hydraulic conditions.
- In order to eliminate distance from the source as a variable, a 12-hour sampling event (duration of one tide cycle) was conducted from the Gunningsville Bridge. This was completed concurrent to the Fall multi-station sampling event and acoustic Doppler current profiler monitoring at the bridge.
- water samples were collected from existing structures alongside or crossing the Petitcodiac River (Belliveau Village Wharf, Gunningsville Bridge, Turtle Creek Bridge on Highway 112, and Salisbury Rail Bridge).

6.3 DISCUSSION OF RESULTS

Evaluation of this program requires that surface water quality be reported to the NBDELG for determination of acceptability based on their selected Criteria. As such, following each year of Stage 2, NBDELG was consulted to review the results and discuss refinements to the sampling methods consistent with the evolving understanding of the use of bacterial indicators in high suspended sediment environments.

Any comparison between Stage 1 and Stage 2 data should be done qualitatively and cautiously because of the different hydraulic regimes. This is also true when comparing between Year 3 and other years in Stage 2 or Stage 1 as a result of on-going refinements to the sampling methodology, which included changes in sampling station locations, and sample collection methods. The EIA predictions regarding bacteria levels (E. coli only) were specific to comparison of Stage 3 with Stage 1 (baseline) data. Therefore, no attempt should be made to verify the EIA predictions with these Stage 2 data beyond the qualitative comparison of the current data trends.

The addition of the fall 12-hour sampling at the Gunningsville Bridge in Year 3, and concurrent sampling with the ADCP monitoring, revealed much insight into changes in bacteria concentrations throughout a tide cycle. It was observed that bacteria counts vary greatly throughout the tide cycle, and more strongly correlate to water velocity than to dilution, where periods of high velocity just following the tidal bore and with the ebbing tide resulted in the highest concentrations. Similar trends were observed in TSS concentrations at the Gunningsville Bridge, which suggests that sediment re-suspension influences both TSS and bacteria concentrations, especially at stations with higher volumes of sediment (i.e., Gunningsville Bridge, Turtle Creek, and the former stations at Boundary Creek and Outhouse Point).

In response to concentrations being observed at unpredicted times, beginning in Year 2, BacH was added to the program to better understand the origin of the E. coli that was observed in the Estuary. The analysis of other BacH and other Bacteroidales determined that the source of measured E.coli concentrations were of human origin (i.e., BacH was present along with E. coli at most stations under most conditions). The use of BacH, coupled with the addition of the second station at Boundary Creek in Year 2, also demonstrated that the GMSC is likely the primary source of E. coli observed throughout the Estuary. In Year 3, BacH sampling was continued to examine the relationship between BacH and E. coli. The results of E. coli and BacH multi-station sampling were statistically compared using regression analysis, which showed a reasonably strong correlation between the two parameters. The analysis of both E. coli and BacH during the fall 12-hour sampling event also revealed very similar patterns with the concentrations of both bacteria correlating with flow velocity. As a result of these comparisons, E. coli and BacH appear to be similarly suitable indicators for tracking and estimating sewage-related bacterial concentrations in the Estuary.

6.4 CONCLUSIONS

The results of the Surface Water Quality sampling events clearly indicate that there are many factors that contribute to water quality, including bacteria counts, in the Estuary. The 12-hour sampling conducted at the Gunningsville Bridge, indicates that bacteria counts vary greatly throughout a tidal cycle and that the multi-station sampling methodology was not able to fully control for hydraulic conditions. Further, the nature of the Project is such that the environmental conditions were significantly changed between Stages, particularly upstream of the causeway. Attempting to determine which factors are responsible for water quality conditions is problematic given the complexity of the system, the limitations of the available data, and knowledge of how bacteria behave in suspended sediment-rich systems.

Regardless, there is sufficient evidence to support some trends. Most importantly, the overall levels of E. coli have greatly decreased in the system, which is consistent with predictions contained in the EIA. The 12-hour sampling program indicates bacteria counts are strongly correlated to the presence of TSS caused by the re-suspension of suspended sediments in the water column. This may explain the results of past sampling programs where a correlation existed between turbidity and bacteria, while a weak relationship existed between salinity and bacteria levels.

Effluent from the GMSC and other sources control the total number of bacteria, but the channel volume (assimilative capacity) and residence time of the Estuary is the dominant factor controlling bacteria counts. While Stage 2 has resulted in an increase to the channel volume downstream of the causeway, the upstream migration of sediments and the average tide levels being less than the elevation of the former headpond has reduced the channel volume upstream.

Through the continued use of BacH in Year 2 and Year 3 and comparison to E. coli, it has been determined that both parameters are suitable indicators for tracking and estimating sewage-related bacterial concentrations in the Estuary.

7.0 ENGINEERED ENVIRONMENTAL PROTECTION WORKS

7.1 OBJECTIVES

The objective of this component was to ensure that erosion protection installed at the former Moncton landfill, the Greater Moncton Sewage Commission (GMSC) outfall, along the Riverview riverfront, along the Moncton riverfront near Westmorland Street, and along the Chateau Moncton shoreline performed as required.

7.2 RESULTS

7.2.1 Armoured Areas

Inspections of all erosion protection measures were completed throughout Years 1 to 3 of Stage 2. In Year 3 no significant changes to existing erosion protection were noted at any locations.

7.2.2 Dykes and Aboiteaux

The dykes and aboiteaux generally appeared to be functioning properly in Year 3, preventing estuarine water from impacting the protected areas and allowing surface water to drain as planned. Drainage will be monitored as part of on-going inspections to assess if mitigation is required to improve drainage. Ground surveys were also completed during 2012 as part of on-going monitoring to assess the physical condition of the dykes and aboiteaux, although at a reduced frequency.

Maintenance activities on the dykes, aboiteaux and marshes are conducted by the NB Department of Agriculture Aquaculture and Fisheries (NBDAAF). In 2012, NBDAAF conducted:

- soil testing, conditioning and reseeding as required,
- clearing inlet and outlets of aboiteaux,
- ditching and land forming,
- access road upgrades and fencing.

7.2.3 Traffic Circle Drainage Improvement and Starter Dyke

During Year 3, water within the drainage channel was found to continue to flow correctly and no new issues were identified. The rubber seal within the flap gate identified in Year 2 was replaced in October 2012 and appears to be functioning well.

7.2.4 Additional Erosional Areas

The following erosional areas adjacent to existing infrastructure were identified during Year 1. These areas were inspected bi-weekly or monthly as part of the on-going Year 3 inspections:

- downstream from existing rip-rap at the GMSC;
- southern shoreline immediately upstream of the causeway;
- between Chateau Moncton and Roger's Building; and

- upstream of Chateau Moncton adjacent to, and underneath boardwalk.

Erosion protection placed at the GMSC outfall: During Year 2 it was observed that the rate of erosion in this area decreased. No significant changes were observed in Year 3. As such, no additional erosion protection is deemed necessary at the current time.

Causeway intake channel: At this time, there appears to be no risk to infrastructure due to the observed erosion in this area, and no mitigation has been recommended.

Supporting cribwork located under the Moncton riverfront boardwalk, upstream of Chateau Moncton: Results of monitoring undertaken in Year 3 revealed that the erosion protection in this location is functioning as expected.

8.0 FISH PASSAGE

8.1 Introduction

In the EIA, fish passage monitoring was recommended for Stage 3 only. This was to include verification of an open channel at all seasons capable of allowing fish passage in a manner similar to pre-causeway conditions; and the seasonal surveying of fish communities above the causeway to demonstrate the presence of the fish species that require passage for life cycle purposes. The presence of nine targeted fish species would confirm the effectiveness of the fish passage opportunities.

However, when the EIA was written it was assumed that the duration of Stage 2 would be one to two years and that monitoring for fish passage would begin in Stage 3, or approximately three years after the opening of the gates. With Stage 2 extending beyond the 2nd year and continuing for an indeterminate amount of time, a verification of fish passage is warranted. The Stage 3 fish passage verification and monitoring program that was informally conducted in Years 1 and 2 of Stage 2, was formally included in Year 3 of the S2FUP.

8.2 Fish Passage Results

Upstream fish passage was monitored by means of the fish trap that was installed just below the head-of-tide at Salisbury. Although it was dedicated to capturing fish moving upstream into the freshwater environment, the trap was also partially effective at capturing downstream-migrating fish that had been temporarily moved in an upstream direction by the tide.

In 2010 and 2011, the presence of the following diadromous species in the Petitcodiac River was confirmed through sampling at the fish trap in Salisbury:

- Blueback herring,
- Alewife,
- American eel,
- Striped bass,

- Tomcod,
- Brook trout,
- American shad (one individual), and
- Atlantic salmon.

Large Atlantic sturgeon were seen at the Salisbury train bridge just downstream of the trap, and spawning sea lampreys were abundant in the River. A shad that was captured was determined to be an immature stray fish that was captured two months after the spawning season had ended. Atlantic salmon that were observed were juvenile fish (smolts) that were leaving the River and were brought into the trap by the rising tide.

Gaspereau continued to be the species that dominated the capture at the trap in 2012. The trap was installed later than it had been in 2010 or 2011 to avoid being over-run with gaspereau, and indeed, the catch rate for this species in 2012 was only one half of what it was in 2010. The two major re-colonizing species that were noted in 2011 were the striped bass, which started using the upper Estuary and lower freshwater reaches of the River as nursery areas, and the tomcod. The numbers of captured striped bass increased almost five times from 2011 in 2012 (158 to 706), and the numbers of tomcod decreased from 1,316 to 774.

Other notable differences in catch numbers were, for American eels, 388 up from 118 in 2011, and smallmouth bass, 15, down from 48 in 2011. In general the same species were observed in 2012 though no adult Atlantic salmon or American shad were captured in 2012.

9.0 OVERALL CONCLUSION

The results of Year 3 of the S2 FUP indicate that the mitigation measures put in place in Stage 1 are functioning as designed. The findings and conclusions relevant to the seven Valued Ecosystem Components indicate trending, from an environmental and socio-economic perspective, in a direction consistent with the predictions and conclusions contained in the EIA. However, it will not be possible to make a definitive statement in this regard until the completion of Project Option 4B.