Marine Issues Committee Special Publication Number 9

Assessment of Tidal Restrictions Along Hants County's Highway 215: Opportunities and Recommendations for Salt Marsh Restoration

by Tony M. Bowron and Allison Fitzpatrick

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ISBN 0-9683068-6-1

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The authors wish to thank their funding source:
North American Fund for Environmental Cooperation (NAFEC)

Cover photo by Tony M. Bowron.
The photo is of the downstream end of the large double concrete culvert at Rainy Cove. This picture was taken approximately three hours before the high tide.

The photographs displayed within the report taken by Tony M. Bowron and Allison Fitzpatrick.

Site drawings by Allison Fitzpatrick and reproduced from 1:10000 air photographs.

National Library of Canada Cataloguing in Publication Data

Bowron, Tony M., 1974-
Assessment of tidal restrictions along Hants County's Highway 215: opportunities and recommendations for salt marsh restoration

(Marine Issues Committee special publication; no. 9)
Includes bibliographical references.
ISBN 0-9683068-6-1

1. Salt marshes--Nova Scotia--Hants. 2. Coastal zone management--Nova Scotia--Hants. I. Fitzpatrick, Allison, 1976- II. Ecology Action Centre III. Title. IV. Series.

QH106.2.N68B693 2001 333.91'8153'0971635 C2001-903347-8

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Acknowledgements

The Salt Marsh Restoration Project would like to thank those who helped make this report possible:

- The Parker River Clean Water Association, Massachusetts, for developing the original audit methodology and allowing for its modification and use by groups such as ours.
- The members of the Bay of Fundy Ecosystems Partnership (BoFEP) Salt Marsh and Restricted Tidal Systems Working Group for adapting the Parker River Methodology for use in the Bay of Fundy, and for developing the field data sheets.
- Shayne McQuaid and Darren Hiltz of the Department of Fisheries and Oceans Habitat Division for their time, input and equipment.
- Dr. Derek Davis for his expertise, support and advice throughout the project and with the preparation of this report.
- The members of the Noel Shore Wildlife Protection Association for their patience, participation and support.
- Elizabeth Pugh, Denis Rushton and Dave Kelly with the Nova Scotia Department of Transportation & Public Works for their interest and support.
- The members of the salt marsh project steering committee for their assistance with this report and for their support and guidance throughout the entire project.

Equipment provided by:

DALHOUSIE University

Fisheries and Oceans Canada / Pêches et Océans Canada

Habitat Management Division, Oceans Sector

Nova Scotia Museum of Natural History

This work was carried out with the aid of a grant from the North American Fund for Environmental Cooperation.

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1.0 INTRODUCTION

Like any healthy salt marsh, the salt marshes found throughout the Bay of Fundy provide the principal food source for marine organisms, control mosquito populations, provide habitat for wildlife, help control flooding, provide shoreline stabilization and improve water quality. As tidal flow to a salt marsh is reduced or cut off, the influence of freshwater flow will increase, terrestrial vegetation and animals may begin to encroach upon the area transforming it into a freshwater system or the area may become dry land. The destruction of salt marshes and their tidal streams is not simply a local concern since it is highly possible that marine productivity is adversely affected by such changes in function of coastline ecosystems. The salt marshes along the upper Bay of Fundy once occupied a large portion of the coastline, yet today it is estimated that salt marsh area has been reduced by upwards of 85% through a variety of human activities (MacKinnon and Scott 1984). These activities, some of renowned cultural significance and dating back several hundred years, include dyking, ditching and road construction.

In this project, carried out by the Ecology Action Centre (EAC) with funding from the North American Fund for Environmental Co-operation, a focus was placed on the identification of the adverse effects that tidal crossings such as bridges, culverts and aboiteaux have had on salt marshes along Highway 215 in Hants County, Nova Scotia. The methodology used for the project was adapted from the Parker River Clean Water Association's *Tidal Crossing Handbook* (Purinton and Mountain, 1998), with adjustments made to compensate for the large tides in the Bay of Fundy (see Appendix D for examples of the data sheets used). Tides, which travel up the Bay of Fundy every 12½ hours as a result of gravitational and centripetal forces between the earth, moon and sun, have an average range between high and low tide of 12 metres and a recorded high tide of 16.2m, the highest in the world.

Triassic red beds are the predominant geologic feature forming the Bay of Fundy however the area under consideration lies mainly to the south of the Portapique Mountain Fault and consists of Carboniferous beds with Triassic deposits in some areas. The tidal marshes in the area formed along the emerging coastline as the soft Bay beds eroded into sediment and accumulated in sheltered and protected areas. Cordgrasses grow abundantly in these areas and help trap sediment deposited by the incoming tides in the expanding marsh (Davis and Browne 1997b).

2.0 METHODOLOGY

A preliminary visual assessment of the bridges, culverts and aboiteaux along Highway 215 (Appendix A) was carried out in the spring of 2001, to determine which crossings were potentially restricting tidal flow. In July of 2001, based on the degree of tidal restriction and the size of the potential restoration area, four crossings identified as being potentially restrictive in the preliminary assessment were revisited for further data collection during a spring tide event. Using a tripod, bubble level and metric measuring rod, water levels near the culvert both upstream and downstream were measured from specific reference points. Measurements were taken prior to and after high tide at regular time intervals. Using the Parker River Clean Water Association methodology, the two data sets were manipulated so that they could be compared and their values plotted on the same graph as tidal levels (refer to Appendix E for an example of the spreadsheet template).

Theoretically, non-restrictive crossings should have similar upstream and downstream tidal levels throughout the monitoring period indicating that water was able to move freely through the opening at all times. Those that are restrictive will have upstream and downstream tidal levels that differ at any time by more than ten centimetres.

3.0 RESULTS

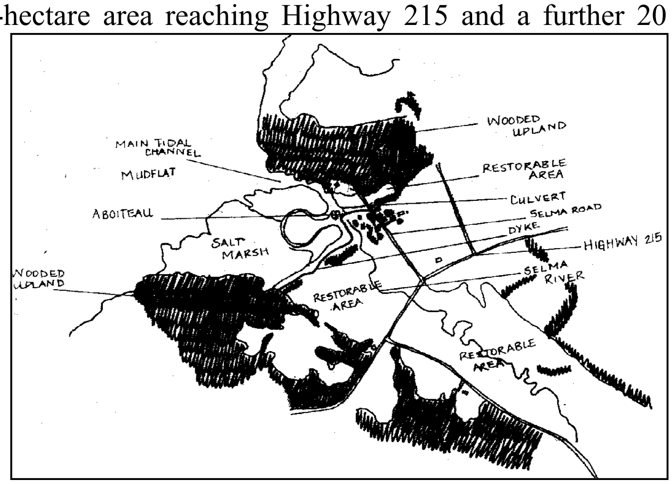
The results of the data collection and analysis for the four sites revisited during the spring tide event follow. The site analyses also contain recommendations on how to achieve restoration of the historic hydrology of the area of interest. The raw data sheets for each of these sites are contained in Appendix C. For a summary of all sites visited during the preliminary visual assessment please refer to Appendix B of the report.

3.1 SELMA (N4C)

Aerial Photo 92234-59

3.1.1 Site Description

Located in the community of Selma, the culvert of interest crosses a dirt road that braches off of Highway 215. The small culvert is constructed of wooden block with a non-functioning clapper gate on the downstream end. An area upstream of the culvert of less than one hectare receives tidal flow, however beyond this area there are numerous trees and cattails indicating that this area is inundated with freshwater runoff only. Downstream, the channel, which flows through the culvert, is a branch of the main tidal channel of the Selma River. The river terminates at a dyke protecting a 14-hectare area reaching Highway 215 and a further 20 hectares beyond the highway.



The dyke, maintained by the Department of Agriculture and Fisheries, runs for a distance of 500 metres from the unpaved road to an upland wooded area and contains a fully functional double aboiteau located where the Selma River meets the dyke. Present on the downstream end of the culvert, and seaward of the dyke is a functioning salt marsh stretching the length of the dyke and ~300m seaward.

Left: main tidal channel, dyke and double aboiteau at low tide.

Right: culvert inlet on the downstream side at low tide. Note the bank slumping and sediment deposition on the marsh surface and in the stream channel.

3.1.2 TIDAL ANALYSIS

FIGURE 1: SELMA TIDAL ANALYSIS

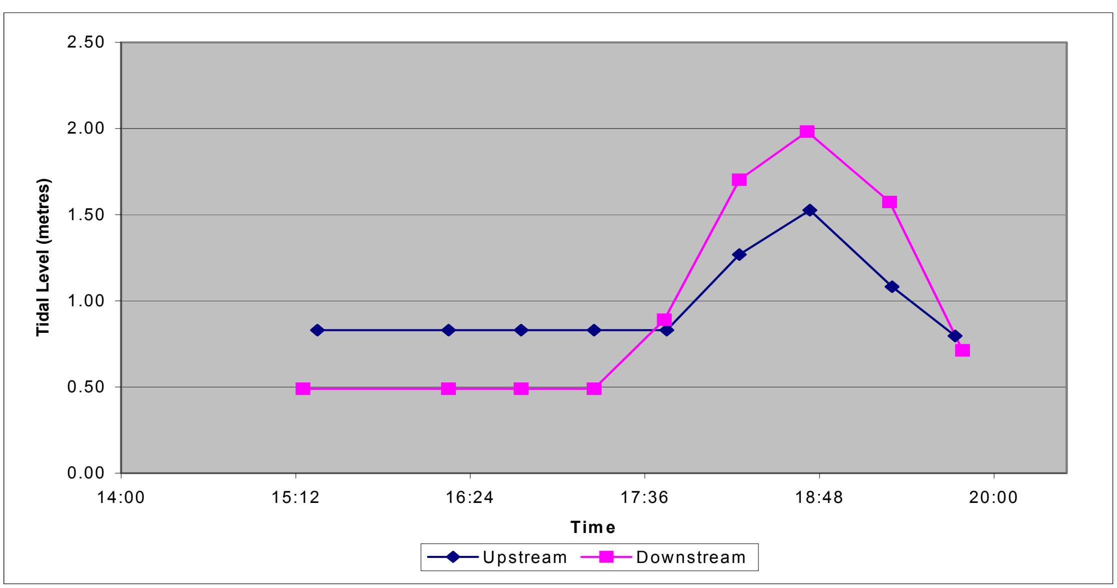


Figure 1 provides evidence of a restrictive tidal crossing as the two curves although similar in shape do not lie on top of each other. This occurs because the upstream invert is located above the channel bed, trapping water as the tide drops below the culvert and during low tide, hence a curve that peaks at high tide and is flat for the remainder of the measurements. In addition, the larger tidal range on the downstream end indicates that culvert size is also causing a restriction. This was observed as the tide rose and the culvert became submerged, flooding the downstream channel and surrounding banks.

TABLE 1: SELMA TIDAL DATA

Upstream			***Downstream***		
Time	**Raw Data**	**Change**	**Time**	**Raw Data**	**Change**
15:21	3.047	**0.829**	15:15	3.848	**0.490**
16:15	3.047	**0.829**	16:15	3.848	**0.490**
16:45	3.047	**0.829**	16:45	3.848	**0.490**
17:15	3.047	**0.829**	17:15	3.848	**0.490**
17:45	3.047	**0.829**	17:44	3.448	**0.890**
18:15	2.608	**1.268**	18:15	2.635	**1.703**
18:44	2.350	**1.526**	18:43	2.355	**1.983**
19:18	2.795	**1.081**	19:17	2.764	**1.574**
19:44	3.080	**0.796**	19:47	3.625	**0.713**
Tidal Range	0.730			1.493	
Range Ratio	0.49				

3.1.3 RECOMMENDATIONS

The installation of a larger, better-positioned culvert would allow for increased tidal inundation and the restoration of an area of 2-3 hectares.

Although the site was revisited to assess the area upstream of the small wooden culvert for possible salt marsh restoration, the area behind the dyke with its large restoration area reaching back to and beyond Highway 215 is of significant interest. Opening the aboiteau, which currently blocks the Selma River and protects the dyked area which is not and has not been used for agricultural purposes for many years, shown by the mature trees growing on the land, would allow for the restoration of tidal flow to the Selma River and the restoration of nearly 40 hectares of salt marsh and tidal fresh water marsh habitat. To successfully implement this recommendation, a properly sized and placed culvert would need to be installed beneath Highway 215 where it crosses the river channel to allow tidal flow up the Selma River to reach the entire 40 hectare restoration area.

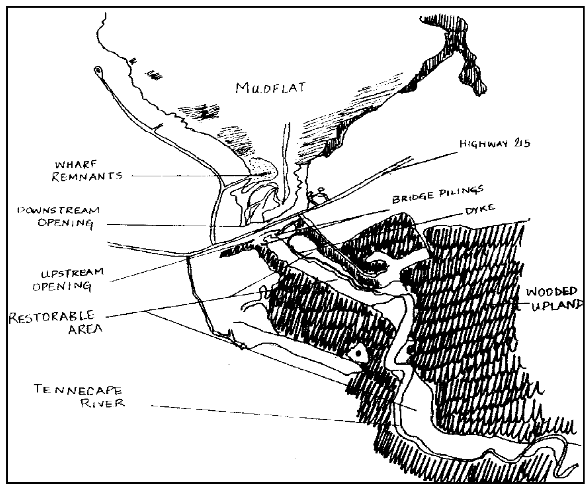
3.2 TENNECAPE (N14C)

Aerial Photo 92333-55

3.2.1 SITE DESCRIPTION

Located in the community of Tennecape, the tidal crossing is a large concrete double culvert situated beneath a small causeway that crosses the Tennecape River. Upstream of the crossing the Tennecape River is 75m wide when it meets the roadbed, with the culvert located to the left of the mouth of the river. Trees and freshwater plants are located below the high water mark as well as concrete pilings of a former bridge that historically spanned the river. Remnant dykes run along the edge of the river indicating that saltwater did flood the area at one time. Currently, the dykes do not appear to be maintained and no evidence of agricultural activities in the area is visible. From aerial photographs an area of 20 hectares is visible that has the potential to be restored to salt marsh.

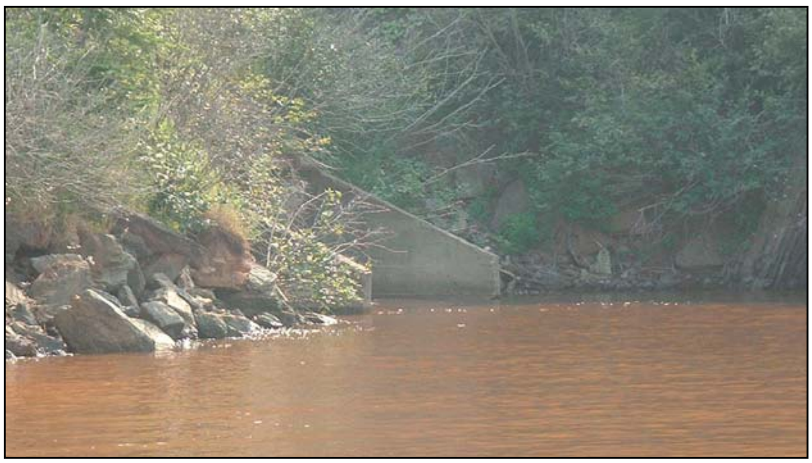
At three hours prior to high tide on the downstream side of the crossing, a mudflat stretches 500 metres into the Minas Basin with low marsh grasses growing along the fringe. Pooling of saltwater is occurring at the base of the culvert, which is situated with its invert three metres above the pool bed and leading to erosion of the surrounding bedrock.



Large volumes of freshwater flow steadily from beneath the roadbed in many locations on the downstream side. These locations are submerged at high tide and a small amount of saltwater travels beneath the road upstream as indicated by bubbles and a steady stream of saltwater from the roadbed.

Left: downstream view of the culvert three hours before high tide. The water visible in the foreground to the left is the result of freshwater flow from under the roadbed.

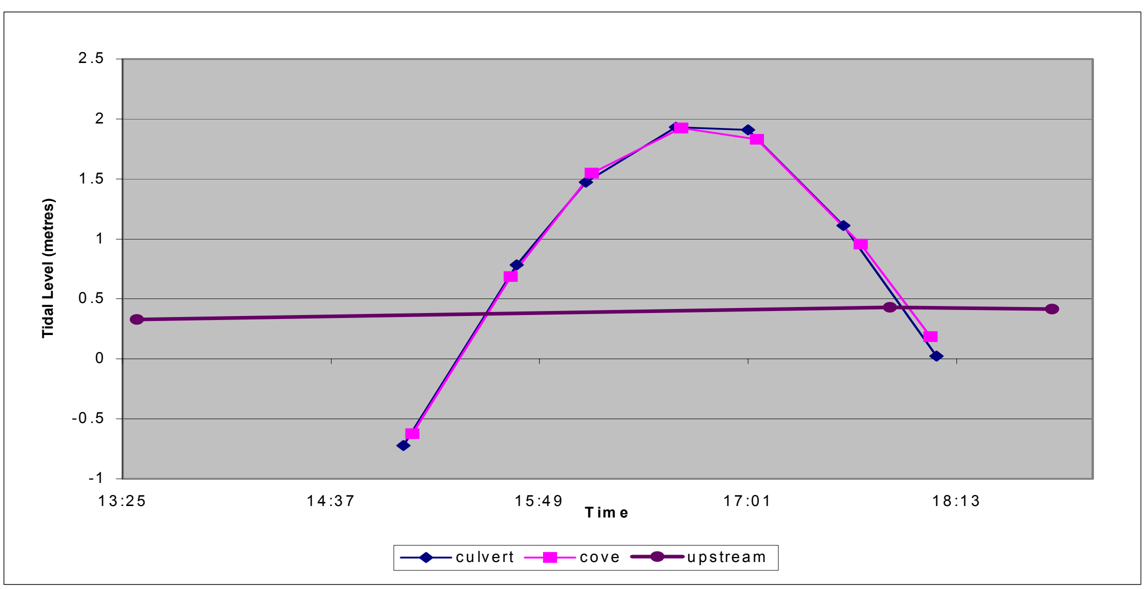
Right: Water hitting the roadbed on the upstream side. Culvert is located, as indicated by the white circle, behind the trees in the background



Left: The downstream culvert opening at high tide (4:35pm). The water level was even with base of the culvert but did not flow through the culvert.

3.2.2 TIDAL ANALYSIS

FIGURE 2: TENNECAPE TIDAL ANALYSIS



Previous observation of this crossing during a spring tide event, combined with the lack of evidence on the upstream side of the culvert of saltwater passage, indicated that very little saltwater actually passes through the culvert. Investigation of the culvert on this day, revealed a distinctive debris line from the previous high tide within the culvert. It was assumed that if saltwater did not pass through the culvert on the previous high tide that it was not likely to do so on this occasion.

Measurements were taken at two locations downstream from the road - near the culvert and in the outer cove - and show very little difference in tidal range (table 2), indicating that there are no natural restrictions on the downstream approach to the culvert. Data collected on the upstream side of the culvert at the edge of the river shows a slight increase in water level at high tide. Bubbles at the edge of the road and water flowing from the roadbed indicate that this increase is due to a combination of saltwater moving upstream under the road and freshwater backup. It should be noted and stressed that the increase in water level on the upstream side is not due to flow through the culvert, as this did not occur at any point during the monitoring.

TABLE 2: TENNECAPE TIDAL DATA

Upstream			***Downstream-culvert***			***Downstream-cove***		
Time	**Raw Data**	**Change**	**Time**	**Raw Data**	**Change**	**Time**	**Raw Data**	**Change**
13:30	0.1333	**0.328**	13:35			13:35		
17:50	0.2328	**0.428**	14:35			14:30		
18:46	0.2205	**0.416**	15:02	4.400	**-0.720**	15:05	4.291	**-0.623**
			15:41	2.897	**0.783**	15:39	2.981	**0.687**
			16:05	2.206	**1.474**	16:07	2.119	**1.549**
			16:36	1.750	**1.930**	16:38	1.744	**1.924**
			17:01	1.771	**1.909**	17:04	1.839	**1.829**
			17:34	2.570	**1.110**	17:40	2.710	**0.958**
			18:06	3.658	**0.022**	18:04	3.481	**0.187**
			18:32			18:35		
			Tidal Range	2.650			2.547	

3.2.3 RECOMMENDATIONS

Tidal flow is almost completely restricted in this site due to improper positioning of the culvert in relation to the river channel. The culvert experiences almost no tidal flow at high tide while a steady flow of freshwater and some saltwater travels beneath the road. Although the culvert itself is likely sufficient in size to ensure proper tidal exchange, the placement of the culvert ensures that it experiences flow only during periods of extreme high water repositioning of the culvert so it is centred and flush with the base of the channel would once again allow saltwater to flow upstream. Repositioning will also ensure that water does not continue to flow beneath the road, potentially weakening the base of the causeway.

The replacement of the causeway, with the construction of a bridge over the Tennecape River as was the previous crossing, would be the ideal solution for this location allowing for free non-restrictive movement of water and species at all times.

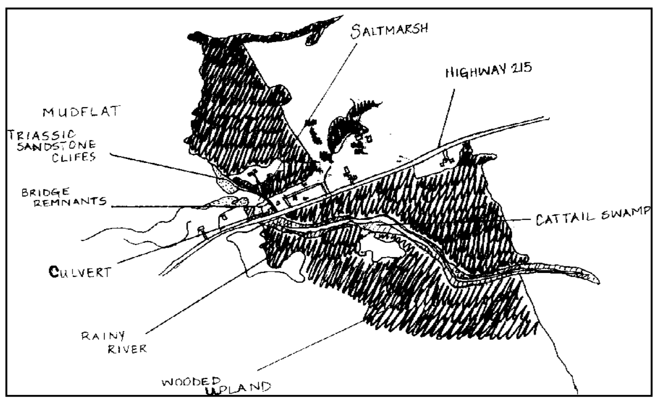
3.3 RAINY COVE (N16C)

Aerial Photo 92391-6

3.3.1 SITE DESCRIPTION

Located in the community of Pembroke at Rainy Cove, the crossing is a large concrete double culvert situated beneath the highway were it crosses the Rainy River. The culvert is situated on an angle with the road rather than perpendicular. On the upstream side of the culvert freshwater plants including cattails and flowering trees are abundant along the banks of the river and are visible further upstream on aerial photographs. A possible restoration area of approximately 10 hectares is visible upstream on the photographs as well.

Downstream, the culvert invert is situated two metres above the base of the channel with freshwater flowing constantly through it from upstream. Pooling is occurring at the base of the downstream invert causing erosion of the banks on the downstream approach as well as beneath the culvert. On the approach to the culvert, remnants of a wooden bridge jut into the channel from both of the banks. On the seaward side and to the right of the bridge remnants exists a small salt marsh and channel leading to a corrugated culvert running beneath a small dirt road. This one lane dirt road leads further out in cove where there are Triassic sandstone cliffs containing plant and animal fossils.

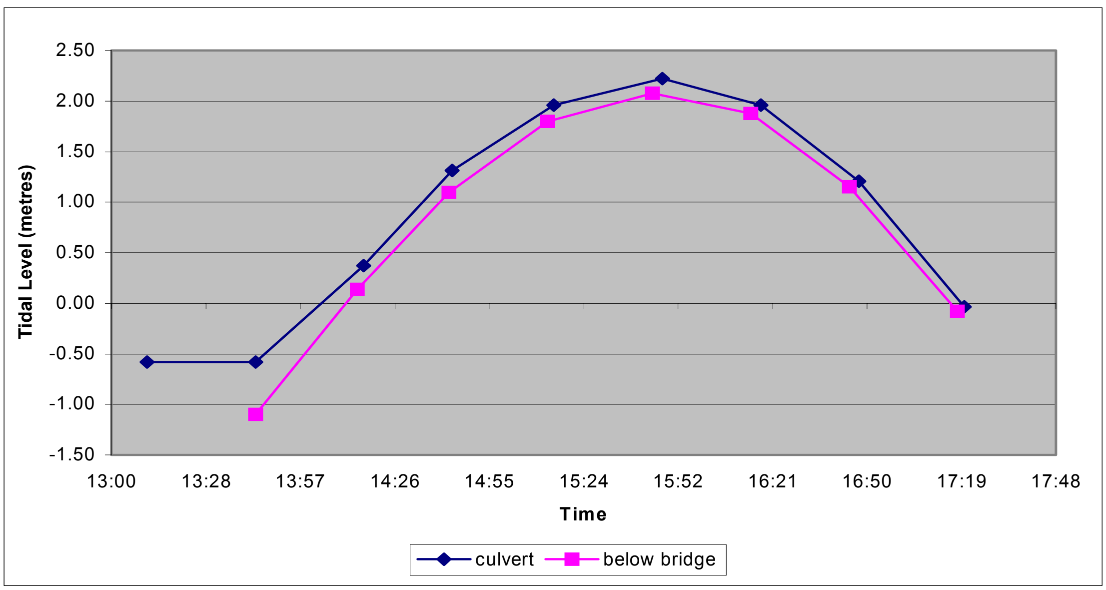


Right: culvert one hour prior to high tide, note the bridge remnants and small flooded salt marsh in the foreground.

Left: culvert at high tide (3:45pm); water just barely reaches the underside of the base of the culvert. A small amount of freshwater continues to flow out of one side of the culvert.

3.3.2 TIDAL ANALYSIS

FIGURE 3: RAINY COVE TIDAL ANALYSIS



Upstream measurements were not taken for this site due to the fact that water did not enter the culvert at any point during the spring tide event; and the lack of evidence upstream of saltwater intrusion. The data in table 3 and the plots in figure 3 are of measurements taken at two downstream locations (near the base of the culvert and beyond the old bridge) to check for restriction due to the bridge remnants. Although the tidal range at the culvert is less than that below the bridge structure, this should not be cause for concern because there is no lag time between the two locations, and the differences in tidal levels are quite small.

TABLE 3: RAINY COVE TIDAL DATA

Downstream-culvert			*Downstream-below bridge*		
Time	**Raw Data**	**Change**	**Time**	**Raw Data**	**Change**
13:11	4.171	**-0.582**			
13:44	4.171	**-0.582**	13:44	4.554	**-1.099**
14:17	3.215	**0.374**	14:15	3.317	**0.138**
14:44	2.278	**1.311**	14:43	2.359	**1.096**
15:15	1.629	**1.960**	15:13	1.658	**1.797**
15:48	1.370	**2.219**	15:45	1.379	**2.076**
16:18	1.630	**1.959**	16:15	1.577	**1.878**
16:48	2.383	**1.206**	16:45	2.303	**1.152**
17:20	3.621	**-0.032**	17:18	3.535	**-0.080**
Tidal Range	2.801			3.175	

3.3.3 RECOMMENDATIONS

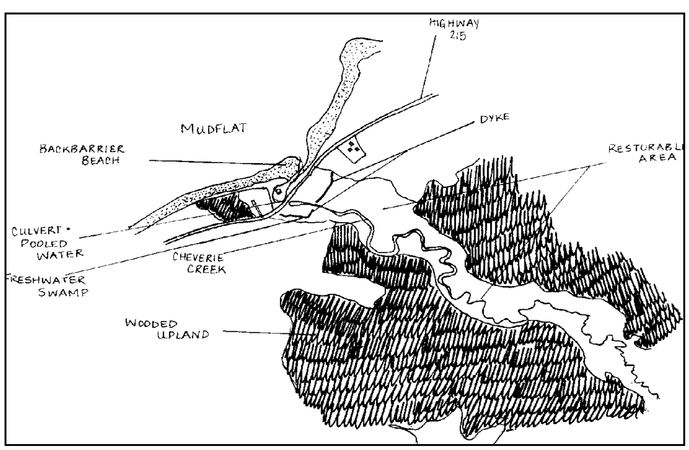
Since the area upstream from Highway 215 is essentially completely restricted from saltwater flow due to the culvert location, repositioning of the culvert is necessary to remedy this problem. The culvert is on an angle with respect to the perpendicular to the road, and is situated approximately 2m above the base of the river channel. In addition to cutting off all saltwater flow upstream, pooling is occurring at the base of the culvert, leading to erosion of the banks near and beneath the culvert. The culvert size should be sufficient to allow for adequate flow, so we recommend that it be lowered until it is even with the base of the river and angled correctly with the run of the river.

3.4 CHEVERIE CREEK (N21C)

Aerial Photo 92317-22

3.4.1 SITE DESCRIPTION

Located in the community of Cheverie, the crossing is a one and a half metre wide double wooden block culvert situated beneath a small causeway crossing Cheverie Creek. The culvert is in disrepair on both ends, most likely due to ice and other debris striking the structure. Saltwater does pass through the culvert to flood an area of approximately 4 – 5 hectares. An old dyke system is visible running parallel to the causeway; however, it does not appear to be maintained. The dyke continues to significantly influence the hydrology upstream by restricting saltwater flow to some areas and



trapping freshwater in others. From the aerial photographs, a total of 30 hectares would benefit from culvert replacement and habitat restoration work.

Downstream, water pools at the culvert with a small fringe marsh forming on the sides of the pool. A rocky, barrier beach is forming on the approach to the pool and is subsequently diverting water flowing away from the culvert downstream. Near the culvert, material from the road is sliding and being washed down the bank into the river channel.

Left: downstream culvert three hours prior to high tide. Debris is present on banks and pooling of freshwater is occurring at the base of the culvert.

Right: upstream at high tide (5:25pm); dykes are present on either side of the flooded area. Culvert is situated to the left of the photo and restorable area extends left, right and back beyond the range of the photo.

3.4.2 TIDAL ANALYSIS

FIGURE 4: CHEVERIE CREEK TIDAL ANALYSIS

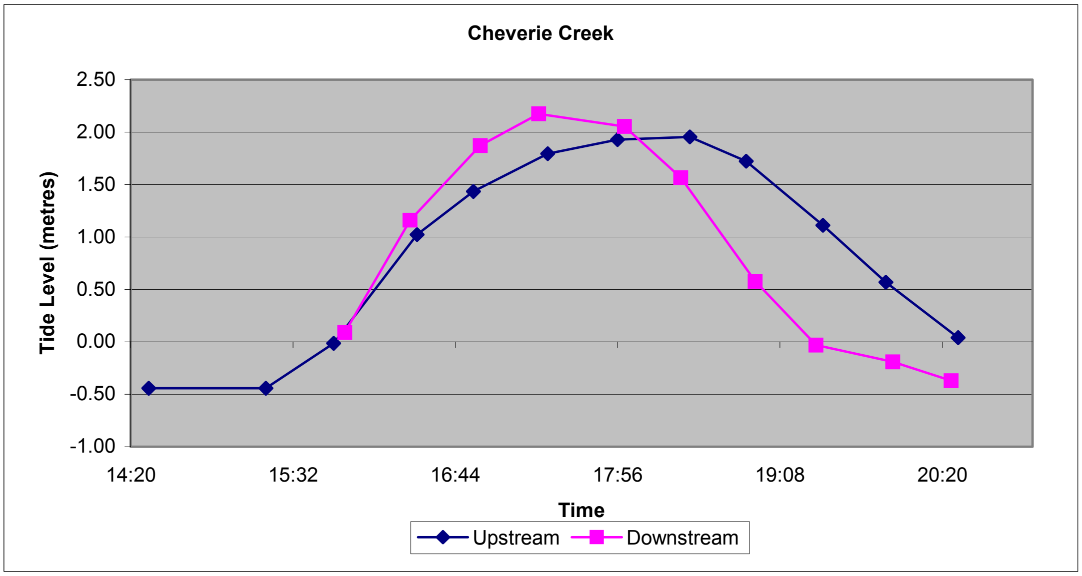


Figure 4 indicates that the culvert, although allowing for tidal flow to the upstream side, is insufficient in size and is not providing adequate flow. The difference in time for the upstream and downstream sides to reach peak levels, referred to as lag, and the difference in the tidal levels indicate that the culvert is not sufficient for the location. Both the upstream and downstream culverts were completely submerged an hour and a half prior to high tide leading to dangerous undertows on the downstream side and a large whirlpool at the upstream end of the culvert during the falling tide. After high tide, as the downstream end began to drop, the upstream end continued to rise as water was still being forced upstream through the culvert. Three hours after high tide both the upstream and downstream levels were dropping, however they were not yet at the levels observed three hours prior to high tide.

TABLE 4: CHEVERIE CREEK TIDAL DATA

Upstream			***Downstream***		
Time	**Raw Data**	**Change**	**Time**	**Raw Data**	**Change**
14:28	3.581	**-0.442**	14:25		
15:20	3.581	**-0.442**	15:25		
15:50	3.154	**-0.015**	15:55	4.270	**0.089**
16:27	2.116	**1.023**	16:24	3.198	**1.161**
16:52	1.705	**1.434**	16:55	2.487	**1.872**
17:25	1.345	**1.794**	17:21	2.185	**2.174**
17:56	1.210	**1.929**	17:59	2.306	**2.053**
18:28	1.185	**1.954**	18:24	2.793	**1.566**
18:53	1.415	**1.724**	18:57	3.783	**0.576**
19:27	2.027	**1.112**	19:24	4.390	**-0.031**
19:55	2.570	**0.569**	19:58	4.551	**-0.192**
20:27	3.098	**0.041**	20:24	4.730	**-0.371**
Tidal Range	2.396			2.545	
Range Ratio	0.94				

3.4.3 RECOMMENDATIONS

Enlargement of the culvert is necessary to increase tidal flow upstream and to eliminate the lag between the upstream and downstream ends. Placement of the culvert is also of concern as the barrier beach that is forming may eventually cut off all flow to the culvert and cause water to flood the road. We are aware that the causeway is a popular stopping spot for tourists as it faces Cape Blomidon so replacement of the entire causeway with a bridge is not a viable solution. The replacement of the existing culvert with a larger culvert, or even a small bridge, would increase tidal flow significantly, reduce the dangerous currents and would not require replacement of the entire causeway. Removal of the dykes in place, which do not appear to have any agricultural function, would also allow saltwater to flow more fully over the original marsh surface and eliminate the freshwater flooding that currently occurs in the area.

4.0 GENERAL CONCLUSION AND RECOMMENDATIONS

The reclamation of large areas of coastal salt marsh from the sea and conversion of it to agricultural land through the construction of dykes equipped with aboiteau, is a process that has important cultural and historical significance throughout the BoF. It is a practice that has resulted in the trading of marine productivity for terrestrial productivity. The more recent construction of tidal crossings, such as causeways and roadways with poorly sized and improperly placed culverts and bridges, have also contributed significantly to the amount of tidal river and salt marsh habitat lost around the Bay. This is something that is both preventable and repairable.

Along Highway 215, twenty-one tidal crossings were identified as being tidal in nature through a preliminary visual assessment (appendix B). Of the twenty-one, four culverts of particular interest were chosen for further study, based on the size of their potential restoration areas and the degree of tidal restriction at the site. Monitoring of the sites during a spring tide event allowed for the flow of water through the culvert to be observed when tides were at their highest. Each of the four sites revisited for further analysis proved to be restrictive to some degree and consequently are compromising the health of the river system and salt marsh upstream of the culvert. Eventually, this leads to a complete conversion of salt marsh areas to freshwater systems, a situation that has occurred upstream of the Tennecape and Rainy River causeways. Culvert repositioning, enlargement and repair are some suggested solutions that would allow for increased tidal flow to marsh areas, fish passage upstream and the eventual restoration of the former salt marsh and tidal river ecosystem.

By collaborating with various government agencies, including the Department of Transportation and Public Works, Department of Agriculture and Fisheries, Department of Natural Resources, Department of Environment and Labour and the Department of Fisheries and Oceans Canada, the EAC plans to choose a site and begin the actual restoration process in the coming year. The culvert located across Cheverie Creek is the preferred site to begin hydrological and salt marsh restoration due to the large potential restorable area, the imminent necessity and the relative ease with which the culvert could be replaced. The Tennecape and Selma sites are also of particular interest, due to the size of the potential restorable areas at both locations, the safety of the roadway at Tennecape, and the maintenance of a dyke that is no longer necessary at Selma. Rainy Cove, of the four sites, is the one with the least potential for restoration work. The restorable area at this site is much smaller than the others and without a safety or repair factor present, as is the case with the Tennecape and Cheverie sites, the amount of money and work involved to reposition the culvert renders this site unviable given the return.

Prior to the restoration of any site, a habitat survey and baseline data collection (especially of the hydrological conditions) is required. The establishment of the baseline for the area allows one to measure and document the conversion of the area from a freshwater or a brackish system to salt marsh, and to monitor the appearance and proliferation of saltwater species in the marsh. Good data the on existing and historical (if possible) hydrological conditions is crucial to the designing of a successful restoration plan. Establishment of the baseline does not need to be complicated or expensive and will be of considerable use if an Environmental Impact Assessment is required before a restoration project is carried out.

A recommendation for consideration in the future is the expansion of this tidal crossing survey to encompass the remainder of the Minas Basin shoreline. The Conservation Council of New Brunswick, for the past two years, has been conducting a survey of restrictive tidal crossings in the upper BoF on the New Brunswick side of the Bay. The ultimate outcome of this work, both by the Conservation Council and the EAC, should be a completed inventory of all restrictive tidal crossings for the entire upper Bay feeding into salt marsh and tidal river restoration projects.

Further information on salt marshes, the impacts of tidal restrictions and barriers, salt marsh restoration and this project can be obtained by contacting the EAC. Publications such as this one, *Community and Social Considerations in Salt Marsh Restoration Work in Nova Scotia* and *Getting Dirty: the Why and How of Salt Marsh Restoration, Proceedings of the Salt Marsh Restoration Workshop* are EAC publications which contain a considerable amount of information on these topics and are available through the Centre.

5.0 GLOSSARY

Aboiteau/Aboiteaux(pl.) **-** A small wooden tunnel with a hinged door inside, built into a dyke; the door swings open to let fresh water drain out and closes to keep out the tide; modern versions in reconstructed dykes [and highway crossings] use square logs or concrete, long sluices with multiple (often 3) waterways, and bronze, steel or Armco gates (Hustvedt 1987 in Wells 1999).

Barrier **–** obstacle…that prevents communication, success, etc. (Sykes 1978); any physical structure built into, through or over a waterway (stream, creek, river, estuary) that changes, possibly irreversibly, the physical (e.g. sedimentation, water circulation), chemical (e.g. salinity, oxygen, trace elements), biological (e.g. fish behaviour) or ecological (e.g. production) characteristics of that waterway (Wells 1999).

Causeway **-** Raised road across low or wet place or piece of water (Sykes 1978).

Cordgrass **-** Salt marsh or smooth cordgrass (*Spartina alterniflora*), with its flat smooth blades, is the dominant plant of the low marsh and in places flooded by the tides. Cordgrass is able to survive in areas of the marsh flooded by saltwater because of its regulatory system that enables the plant to be under water for part of the tidal cycle each day, and to excrete salt through the leaf edges. The root system of the cordgrass helps stabilize the marsh mud and provides habitat and food for other plants and animals.

Creation **–** Refers to establishing wetland functions on an area where a wetland never existed.

Culvert **-** An underground channel constructed of a wooden block, concrete or corrugated metal structure intended to carry water across a road in either direction. A number of culverts in the study area were constructed with tide gates enabling the culverts to function as aboiteau.

Dyke or dike **–** embankment, long ridge, dam, against flooding, especially one of those in Holland against sea; causeway; barrier, obstacle, defense (Sykes 1978).

Ecological Restoration **-** Ecological restoration is the process of assisting the recovery of an altered or degraded ecosystem to a self-sustaining condition that resembles that which existed prior to alteration. Efforts to restore salt marsh habitat may include the removal of a dyke, enlarging a culvert, opening a tidal gate or the plugging of drainage ditches.

Invert **-** The base or bottom of a culvert

Range Ratio **-** The ratio between the upstream and downstream tidal ranges for a tidal crossing. Theoretically, the crossing ratio for a non-restrictive crossing should equal one

Rehabilitation/Enhancement **–** These two terms are often used interchangeably. They refer to the enhancement of specific intrinsic functions, the addition of desirable features and the suppression of undesirable natural functions and characteristics of a habitat. Efforts to rehabilitate or enhance a habitat typically concentrate on the repair and substitution of specific features of the habitat with little reference to the original, natural form and function of the habitat. The natural habitat is replaced by a different, but no less valuable one.

Reclamation – The term used to describe the practice of dyking salt marshes for the purpose of creating viable agriculture land and which is defined as "…make wasteland fit for cultivating, esp. by draining it…" (Barber 1998).

***Spring Tide* -** A tide occurring just after the new and full moon each month, in which there is the greatest difference between high and low water. Not related to the season, but rather to the phenomenon where the water "springs" higher than normal.

***Tidal Barrier* -** A physical obstruction (e.g. dyke, dam) constructed in or across a tidal water body that completely restricts the tidal flow in all or part of the water body above and/or below the obstruction (Wells 1999).

***Tidal Range* -** The change in tide level between low tide and high tide measured at a given location.

Tidal Restriction –A physical obstruction (e.g. culvert, bridge) constructed in or across a tidal body that reduces tidal flow in all or part of the water body above the obstruction.

6.0 REFERENCES AND SUGGESTED READINGS

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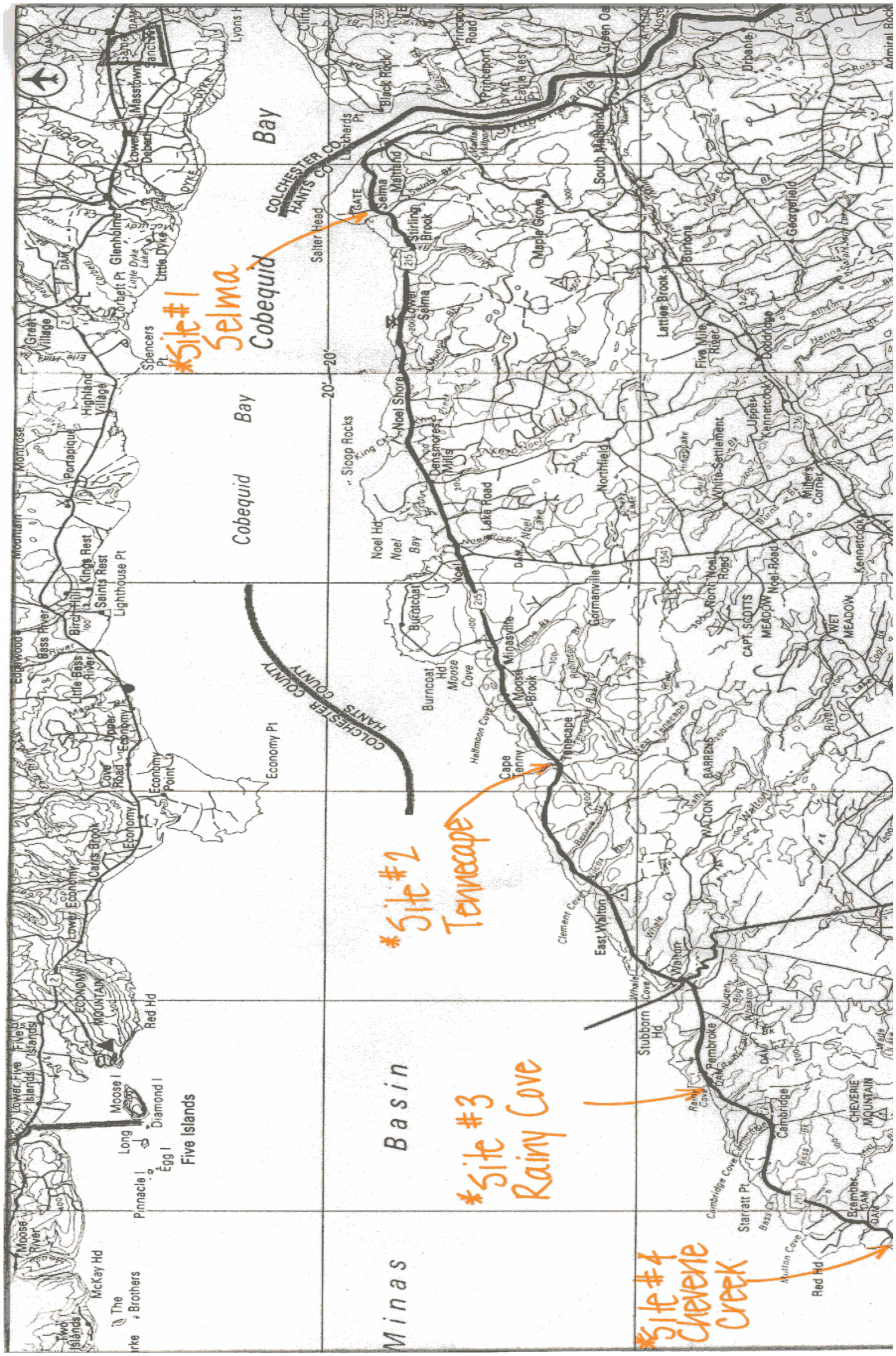
APPENDIX A – MAP OF HIGHWAY 215



APPENDIX B – SUMMARY OF TIDAL CROSSINGS ALONG HIGHWAY 215

Crossing Code	Classification	Material	Sm/Med/Lg	Complete/Partial/ No Restriction	Restorable Area	Fish Passage(?) Yes/No	Corrective Action (Refer to Codes)	GPS Coordinates
N1A - Five Mile River	Aboiteau	concrete/ steel	small	partial		no	RA OA	N 44°15"00.6 W63°27"48.8
N2A - Five Mile River	Aboiteau	concrete/ steel	small	complete		no	EO RA	N 45°15"06.8 W63°28"10.8
N3B - Maitland	Bridge	wood	medium	partial		yes	RS EO	N 45°19"03.4 W63°29"49.9
N4C - Selma	Culvert	wood	small	partial	(<5 ha) small	yes-limited	LC EO	N 45°19"18.5 W63°32"31.2
N5B - Sterling Brook	Bridge	steel	large	no restriction	N/A	yes	NR GR OM	N 45°18"39.8 W63°33"37.3
N6C Sterling Marsh	Culvert	wood	small	partial	small	yes-limited	LC SC OM	N 45°18"41.3 W63°33"54.6
N7B - Mungo Brook	Bridge	wood	large	no restriction	N/A	yes	NR	N 45°18"46.9 W63°37"58.0
N8C - Kings Creek	Culvert	wood	medium	partial/complete	small	yes-limited	EO LC	N 45°18"36.1 W63°40"16.0
N9C - Noel Marsh	Culvert	wood	small	complete	small	no	LC	N 45°17"57.3 W63°43"42.1
N10C - Noel Marsh	Culvert	concrete	small	partial	small	no	LC EO	N 45°17"57.3 W63°44"42.1

Codes:NR-not restrictive GR-in good repair RA-replace aboiteau OA-open aboiteau
RS-repair structure RC-repair/replace culvert SC-site clean-up FP-install fish passage
LC-lower culvert EO-enlarge opening OM-situated on marsh of interest

Crossing Code	Classification	Material	Sm/Med/Lg	Complete/Partial/ No Restriction	Restorable Area	Fish Passage Yes/No	Corrective Action (Refer to Codes)	GPS Coordinates
N11B - Noel River	Bridge	steel/wood	medium	no man made restriction	N/A	no	FP	N 45°17"45.9 W63°44"29.3
N12C - Lighthouse Ln	Culvert	wood	small/med	partial	N/A	yes-limited	GR	N 45°18"02.8 W63°45"09.0
N13A - Moose Cove	Aboiteau	concrete/ wood	medium	complete	(5-15 ha) Medium	no	EO OA OM	N 45°17"44.4 W63°48"19.1
N14C - Tennecape	Culvert	concrete	large	complete	(>15 ha) Large	no	LC EO FP OM	N 45°15"59.7 W63°52"26.5
N15B - Walton River	Bridge	concrete/ steel	large	no restriction	N/A	yes	NR	N 45°13"44.1 W64°00"19.8
N16C - Rainy Cove	Culvert	concrete	large	complete	Small	no	LC FP	N 45°13"15.4 W64°04"09.0
N17B - Bass Creek	Bridge	wood	large	no restriction	N/A	yes	RS SC	N 45°11"55.3 W64°08"00.4
N18B - Mill Brook	Bridge	concrete/ steel	small	no restriction	see N20C	yes		N 45°10"20.6 W64°09"13.4
N19C - Mill Brook	Culvert	wood	small	partial/complete	see N20C	no	RC FP	N 45°10"20.6 W64°09"13.4
N20C - Mill Brook	Culvert	concrete	medium	partial	Large	yes-limited	GR EO	
N21C - Cheverie Creek	Culvert	wood	small	partial	Large	yes-limited	RS RC EO OM	N 45°09"32.6 W64°10"12.9

small crossing: <2m **Codes**:NR-not restrictive GR-in good repair RA-replace aboiteau OA-open aboiteau
medium crossing: 2-4m RS-repair structure RC-repair/replace culvert SC-site clean-up FP-install fish passage
large crossing: >4m LC-lower culvert EO-enlarge opening OM-situated on marsh of interest

*** Each site is assigned a code e.g. N1A: The first letter indicates the area of study, Noel Shore (N). The second digit is the sequential number of the site. The third letter indicates the type of crossing (A-aboiteau, B-bridge, C-culvert).*

Crossing Summaries: Visual Assessments

Crossings and marshes of interest for restoration and/or rehabilitation are underlined.

N1A – Steel gate of the aboiteau has broken off allowing for limited tidal flow through the culvert. Allowing the culvert to remain open is recommended.

N2A – Aboiteau is functioning properly, completely restricting tidal flow upstream. Removal of the tidal gate would restore tidal flow upstream.

**N1A and N2A drain and flood the same area; restoring flow through the culverts would restore a small area with little adverse affects on the adjacent Ducks Unlimited impoundment, roadway or upland.

N3B – Old wooden bridge in disrepair, sides are beginning to collapse and bank is eroding.

N4C – discussed in report.

N5B – Medium sized metal bridge in good repair

N6C – Small wooden block culvert partially restricting tidal flow due to its size and debris present in the channel. Culvert could be enlarged and lowered to increase tidal flow but the affected area is small.

N7B – Wooden block bridge structure in good repair. Does not appear to be restrictive.

N8C – Double wooden block culvert partially restricting tidal flow. Culvert should be enlarged and invert lowered to allow for tidal flow at both low and high tide. It is likely that agricultural activities seaward of this crossing has reduced flow such that the tidal prism would not reach much beyond the culvert even if size and placement were altered.

N9C – Double wooden block culvert present along the upper edge of a very large community marsh, and at the tidal extreme.

N10C – Small, round concrete culvert situated within 50m of crossing N9C along the upper edge of the same community marsh.

N11B – Medium sized wood and steep bridge. Tidal flow is not occurring upstream of the bridge, however this is due to a natural bedrock barrier downstream of the crossing.

N12C – Wooden block culvert in good repair with some rip-rap at the inlet. Culvert is restrictive due to its size, but location of road, near the tidal extreme, is such that the restriction is not significant (in terms of area). Crossing should be monitored to ensure that debris does not build up and block what flow is passing through the culvert.

N13A – Combination wood and concrete culvert/aboiteau with vinyl inlay. Area upstream of aboiteau is not being actively farmed at present and a larger opening would allow for even better and more desirable flow. This site is of interest for the restoration of tidal flow and salt marsh habitat, however, it was not looked at detail at this time due its proximate to actively utilized agricultural lands.

N14C – discussed in report.

N15B – Large steel and concrete bridge that allows for sufficient tidal flow. Rip-rap and wooden debris which has accumulated in the river bed should be removed to prevent restriction in the future.

N16C – discussed in report.

N17B – Large wooden bridge with some supports that need to be repaired however structure does allow for sufficient tidal flow.

N18B – Small concrete, steel and wooden block bridge located along upper edge of marsh. Bridge is in good repair and experiences little tidal flow.

N19C – Located near site N18C, small wooden culvert in disrepair located at upper edge of marsh area and at or above tidal reach.

N20C – Medium concrete culvert located on dirt road off Highway 215, restricting tidal flow to a marsh area of 10 hectares which N18B and N19C border on. Increase in the size of culvert would allow for increased tidal exchange to the area.

N21C – discussed in report.

APPENDIX C – RAW DATA SHEETS

Selma River N4C
Tennecape River N14C
Rainy Cove N16C
Cheverie Creek N21C

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name: *Tony Bowron* **Date:** *08/05/01* **Time:** *12:33pm*

Location: *Selma* **Restriction Severity:** *Partial Restriction*

GPS Coordinates: *N 45° 19"18.5 W63° 32"31.2* **Crossing code:** *N4C*

Weather: [Check Environment Canada web site] Wind velocity and direction: *10-15km/hr west*

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide *2:15pm 13.7m* Low tide *8:15am 0.3m* Mean high tide for area [in metres]:

Crossing characteristics [circle one]: Bridge ***Culvert*** – corrugated cement steel PVC ***wooden block***

Crossing condition [circle one]: Is original design intact? ***Yes*** No. Describe condition if in need of repair: *Bank erosion from road/entire side downstream. Top of culvert starting to collapse.*

Width of road [in metres]: *11/2 lane dirt road* **Length of opening** [in metres]: *1m*

Describe dominant land use or features: Above the crossing: *mix of fresh with salt marsh, woods, property on right.*

Below the crossing: *dyke, outer marsh*

Restoration potential, if restricted: Area with restoration potential [in hectares] *~5 acres*

Type of restoration work [circle one]: Culvert repaired ***Culvert replaced*** Culvert installed Bridge installed Bridge widened
Other *lower culvert, enlarge opening. Fortify road to prevent erosion and washing of the material into the channel and marsh.*

Photographic record checklist: Crossing upstream ___ Crossing downstream ___ Landscape upstream ___ Landscape downstream ___ Dominant plants upstream ___ Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___ Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening* (channel widens as it approaches main channel)	~1.5 m	~ 1.5 m
Opening diameter	~1m	~1m
Opening height (invert is higher than stream bed on both sides)	~1 m	~ 1 m
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)	2 – 3 m	2 – 3 m

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	Upstream (Yes No)	Downstream (Yes No)
Bank slumping **erosion around opening downstream	Yes	Yes
Scour Pools	Yes	Yes
Current channel appears divergent from original channel	No	No
Other: channel likely due to culvert construction and freshwater outflow		Debris in channel

Flow restriction assessment:

Evidence of flow restriction	Upstream (Yes No)	Downstream (Yes No)
Smooth flow (water level quite low but steady flow out)	Yes	Yes
Turbulent flow	No	No
Slack (still) water	No	No
Eddies, swirling water	No	No
Flow direction	Upstream	Downstream
Choose one: straight; angular; reversed	straight	straight
Water level variance	Yes	No
Is there a visible difference in water level on each side of the crossing?	X	

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle] : **<u>Yes</u>** No

Obvious plants	Upstream Yes No	Downstream Yes No
Cordgrass: Spartina alterniflora	Yes (limited)	Yes
Salt marsh hay: Spartina patens	Yes (limited)	Yes
Cattails	Yes	No
Phragmites	No	No
Other?????	fresh marsh plants	Yes (other salt marsh plants)

Tidal Barriers Audit: Phase 2 Measurement

Name: *Selma River*

GPS Coordinates: *N45°19"18.5 W63°32"31.2* **Crossing code:** *N4C*

Crossing characteristics [circle one]: Bridge; ***Culvert*** corrugated concrete steel PVC ***wooden block***

Visit #1. **Date:** *July 26, 2001*

Weather: [Check Environment Canada web site] Wind velocity and direction: ____
Sunny with cloudy periods
Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]
Brief periods of light rain.
Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide *6:15pm ~13.9m* Low tide ~*12:15pm ~.7m*

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time (high tide = 0)	Actual time	Upstream (in m)	Actual time	Downstream (in m)
0 - 3	3:21pm	3.047	3:15pm	3.848
0 - 2	4:15pm	3.047	4:15pm	3.848
0 - 1.5	4:45pm	3.047	4:45pm	3.848
0 - 1	5:15pm	3.047	5:15pm	3.848
0 - .5	5:45pm	3.047	5:44pm	3.448
0	6:15pm	2.608	6:15pm	2.635
0 + .5	6:44pm	2.350	6:43pm	2.355
0 + 1	7:18pm	2.795	7:17pm	2.764
+ 1.5	7:44pm	3.080	7:47pm	3.625
0 + 2				
0 + 3				

Observations:

Three days after spring tide event.

Culvert:
Downstream invert -.5m above channel base
Width 1.1m
Height .6m

Upstream invert - .1m above channel base
Width 1m
Height 1m

Reference Point:
Height of tripod - 98cm
-Reference point located on side of road, ~10m from culvert, same point used for both upstream and downstream measurements.
-Measurement line begins on streambed in front of culvert for both upstream and downstream and moves up bank as the tide rises.

Observations:
-Channel of interest is a branch off of the main tidal channel that runs through the outer salt marsh. The main channel intersects a large dyke at a functioning aboiteau. The aboiteau is a large double-gated structure allowing for the drainage of the dyked land upstream of the dyke.
-The culvert was construct with a clapper gate on the downstream end that has been locked in the open position. Uncertain whether this is by design or due to the shifting and settling of the structures wooden siding. Given the position of the gate, it appears to be by design.
-The main tidal channel is full of water one full hour before high tide.
-Culvert opening is completely submerged at high tide.
-The marsh surface near the downstream end of the culvert (where the marsh borders on the dirt road) has an elevation that is visible higher than the marsh surface further out from the road. This is likely due to a combination of materials being depositing here by the tide as it encounters the road, and the washing of road materials on the marsh. This raise in surface elevation likely has an impact on the amount of water that reaches the road back and passes through the culvert. Also affected by this would be the rate of drainage of the area near the road and upstream of the culvert. The area upstream of the culvert and immediately downstream of the crossing experiences complete drainage while the channel and marsh surface a mere 20ft. from the culvert is still full.
-Main channel at the aboiteau is still full at 7:45pm, an hour and a half after high tide.

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name: *Tony Bowron* ***Date:*** *15/06/01* **Time:** *10:41am*

Location: *Tennecape* **Restriction Severity:** *Complete Restriction*

GPS Coordinates: *N 45° 15"59.7 W63° 52"26.5* **Crossing code:** *N14C*

Weather: *[Check Environment Canada web site] Wind velocity and direction:* *15km/hr* west

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide *8:20am 11.7m*

Low tide *2:55pm 3m* Mean high tide for area [in metres]:

Crossing characteristics [circle one]: Bridge ***Culvert*** – corrugated ***cement*** steel PVC wooden block

Crossing condition [circle one]: Is original design intact? ***Yes*** No. Describe condition if in need of repair: *Road is being undercut by water. Rock base under opening (seaside) eroding. Loss of support*

Width of road [in metres]: *2 lane* **Length of opening** [in metres]: *5m*

Describe dominant land use or features: Above the crossing: *river valley, old bridge, old parts of dyke, area flooded.*

Below the crossing: *coastal inlet, marsh, beach, cliffs*

Restoration potential, if restricted: Area with restoration potential [in hectares] *~22 acres*

Type of restoration work [circle one]: Culvert repaired ***Culvert replaced*** Culvert installed ***Bridge installed*** Bridge widened Other - *culvert placement diverts flow, no saltwater flow, too high, too off-centre. River is undercutting embankment. Install bridge near centre of causeway.*

Photographic record checklist: Crossing upstream ___ Crossing downstream ___ Landscape upstream ___ Landscape downstream ___ Dominant plants upstream ___ Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___ Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening*.	+100m	+100m
Opening diameter	6m	6m
Opening height	2m	2m
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)	>30m	30m

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	Upstream (Yes No)	Downstream (Yes No)
Bank slumping	Yes	Yes
Scour pools	Yes	Yes
Current channel appears divergent from original channel	Yes	Yes
Other **culvert no where near river; no flow at all through culvert		fw flow out from bank

Flow restriction assessment:

Evidence of flow restriction	Upstream (Yes No)	Downstream (Yes No)
Smooth flow **culvert placement allows only for flow through culvert at extreme water level conditions	no flow	no flow
Turbulent flow	No	No
Slack (still) water **FW pooling at base of causeway	Yes	No
Eddies, swirling water **water is undercutting road.		
Flow direction	Upstream	Downstream
Choose one: straight; angular; reversed (no flow through culvert, but straight flow through base of causeway)		X (Straight)
Water level variance	Yes	No
Is there a visible difference in water level on each side of the crossing?	X	

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle] : **Yes** No

Obvious plants	Upstream Yes No	Downstream Yes No
Cordgrass: Spartina alterniflora	No	Yes
Salt marsh hay: Spartina patens	No	Yes
Cattails **all freshwater	Yes	No
Phragmites	No	No
Other?????	FW marsh plants	Beach & marsh plants

Tidal Barriers Audit: Phase 2 Measurement

Name: *Tennecape*

GPS Coordinates: *N45°15"59.7 W63°52"26.5* **Crossing code:** *N14C*

Crossing characteristics [circle one]: Bridge ***Culvert*** corrugated ***concrete*** steel PVC wooden block

Visit #1. **Date**: *July 24, 2001*

Weather: [Check Environment Canada web site] Wind velocity and direction: ____
Sunny, slight onshore breeze
Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]
No rain
Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide *4:35pm 14.2m* **Low tide** ~*10:30am ~0m*

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time (high tide = 0)	Actual time	Upstream (in m)	Actual time	Downstream (in m)
0 – 3	1:35pm	no flow through	1:35pm	no readings
0 – 2		no flow through	2:35pm 2:30pm	no readings
0 - 1.5		no flow through	3:02pm 3:05pm	4.400 4.291
0 – 1		no flow through	3:41pm 3:39pm	2.897 2.981
0 - .5		no flow through	4:05pm 4:07pm	2.206 2.119
0		no flow through	4:36pm 4:38pm	1.750 1.744
0 + .5			5:01pm 5:04pm	1.771 1.839
0 + 1			5:34pm 5:40pm	2.570 2.710
+ 1.5			6:06pm 6:04pm	3.658 3.481
0 + 2			6:32pm 6:35pm	>4.5 >4.5
0 + 3				

Observations:

One day after spring tide event

Culvert:
Width ~6.6 m
Height ~ 2.5 m
Culvert has a structural support divide running down the centre of the structure dividing into two channels.

Reference Point:
Height of tripod - 93cm

-The downstream reference point was chosen ~50m to the right of the culvert on roadway bank. The vegetation cover on the bank indicated that it was above the high/high tide level.
-Took measurements along two lines: one along bank ~15m from the culvert (right side of the culvert), and the second more towards the middle of the cove, along a line marked by the Tennecape Road sign and a large boulder along the shore. The boulder was not visible at this tide.
-Based on previous observations of this crossing during an earlier spring tide, it was anticipated that no saltwater passage would occur through the culvert. To determine if any change in water level occurred upstream during the monitoring period, measurements were taken using a wooden stake placed in the bank at the waters edge at the beginning on upstream side.

Observations:
-At three hours before high tide, water is still a considerable distance from the shore and beyond range/reason for measure.
-At low tide, the undercutting of the causeway bed is visible as a considerable amount of freshwater can be seen flowing out of the base of road at numerous points. Freshwater flow through the culvert is likely to occur only at extreme high water/runoff periods. Observation of this crossing following a heavy run reveals that the difference between the extreme high water levels of freshwater is considerable higher than the normal, low water level for the river. The majority of freshwater that crosses the roadway occurs through the roadbed rather than through the culvert.
-It was observed that as the tide level reached and surpassed the points where freshwater was flowing out from the roadbed that freshwater continued to flow out for a time as evidenced by bubbles.
-At a point nearing the time of high tide and for a period after, the flow of water under the causeway actually switched. Freshwater began to back up on the upstream side of the causeway and saltwater actually began to flow under the road. Salt water could be seen flowing out of the roadbed at an approximate height of .5 m above the level of freshwater at several points as well as bubbles at others indicated flow below the water level.

Upstream Measurements:
1:30pm - 13.33cm
5:50pm - 23.28cm
6:46pm - 22.05cm

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name: *Tony Bowron* ***Date:*** *15/06/01* **Time:** *11:47am*

Location: *Rainy Cove* **Restriction Severity:** *Complete Restriction*

GPS Coordinates: *N 45° 13"15.4 W64° 04"09.0* **Crossing code:** *N16C*

Weather: [Check Environment Canada web site] Wind velocity and direction: *15km/hr west*

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide *8:20am 11.7m*
Low tide *2:55pm 3m* Mean high tide for area [in metres]:

Crossing characteristics [circle one]: Bridge ***Culvert*** – corrugated ***cement*** steel PVC wooden block

Crossing condition [circle one]: Is original design intact? ***Yes*** No. Describe condition if in need of repair:
No Fish Passage, No Tidal Exchange

Width of road [in metres] *2 lanes* **Length of opening** [in metres]: *5-6m*

Describe dominant land use or features: Above the crossing: *river valley, flood plain, no SW flow.* Below the crossing: *remnants of old bridge potentially restricting flow, coastal inlet, salt marsh and beach, flats*.

Restoration potential, if restricted: Area with restoration potential [in hectares] *~8 acres*
Type of restoration work [circle one]: Culvert repaired ***Culvert replaced*** Culvert installed Bridge installed Bridge widened
Other - ***culvert needs to be lowered, invert far too high above channel bed.***

Photographic record checklist: Crossing upstream ___ Crossing downstream ___
Landscape upstream ___Landscape downstream ___ Dominant plants upstream ___
Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___
Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening*.	10m	30m
Opening diameter	6m	5-6m
Opening height	42m	42m
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)	15m	20m

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	**Upstream (Yes No)**	**Downstream (Yes No)**
Bank slumping ***stream bed is even with upstream invert*	No	No (rock bank)
Scour pools	No	Yes
Current channel appears divergent from original channel	No	No (water falls)
Other ***old bridge structure narrows channel*	No	Pooling

Flow restriction assessment:

Evidence of flow restriction	**Upstream (Yes No)**	**Downstream (Yes No)**
Smooth flow	Yes	Yes
Turbulent flow		Yes (water fall)
Slack (still) water	Yes	Yes
Eddies, swirling water		Yes
Flow direction	**Upstream**	**Downstream**
Choose one: straight; angular; reversed		X (Straight)
Water level variance	**Yes**	**No**
Is there a visible difference in water level on each side of the crossing?	X (elevation very different)	

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle] : **Yes** No

Obvious plants	**Upstream Yes No**	**Downstream Yes No**
Cordgrass: *Spartina alterniflora*	No	Yes
Salt marsh hay: *Spartina patens*	No	Yes
Cattails	Yes	No
Phragmites		No
Other????? ***fresh water swamp*	FW marsh plants, trees	Beach & marsh plants goldenrods, roses

Tidal Barriers Audit: Phase 2 Measurement

Name: Rainy Cove

GPS Coordinates: N45° 13"15.4 W64° 04"09.0 **Crossing code:** N16C

Crossing characteristics [circle one]: Bridge; **Culvert** corrugated ***concrete*** steel PVC wooden block

Visit #1. **Date:** July 23, 2001

Weather: [Check Environment Canada web site] Wind velocity and direction: ____
Sunny, very light onshore breeze
Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]
No rain
Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide 3:45pm ~14.4m Low tide ~9:40am ~-.4m

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time (high tide = 0)	Actual time	Upstream (in m)	Actual time	Downstream (in m)
0 - 3	1:22pm	no flow through	1:11pm	4.171
0 - 2		no flow through	1:44pm	4.171 4.554
0 - 1.5		no flow through	2:17pm 2:15pm	3.215 3.317
0 - 1		no flow through	2:44pm 2:43pm	2.278 2.359
0 - .5		no flow through	3:15pm 3:13pm	1.629 1.658
0		no flow through	3:48pm 3:45pm	1.370 1.379
0 + .5			4:18pm 4:15pm	1.630 1.577
0 + 1			4:48pm 4:45pm	2.383 2.303
+ 1.5			5:20pm 5:18pm	3.621 3.535
0 + 2				
0 + 3				

Observations:

Day of the spring tide.

Culvert:
Width ~6.6 m
Height ~ 2.5 m
Culvert has a structural support divide running down the centre of the structure dividing into two channels.

Reference Point:

Height of tripod - 87cm

-The reference point selected on top of old bridge surface on the seaward side of the culvert
-Downstream, measurements were taken along two lines, one located near the culvert, the other located further downstream beyond the old bridge.
-Based on previous observations of this crossing during an earlier spring tide event, it was anticipated that no saltwater passage would occur through the culvert. Tidal debris along downstream bank combined with the lack of evidence on the upstream side of the culvert, supported the theory that water would not pass through the culvert and therefore an upstream reference point was not necessary.

Observations:
-Freshwater flowed steadily from the culvert and a salinometer reading of the water pooling at the base of the culvert and flowing out the channel was fresh in nature.
-The old bridge embankments which do confine the tide channel and prevent even flow of water as it approached the road bank, does not significantly restrict the flow of water reaching the road bank.
-It is likely that the old bridge embankments act as a buffer, reducing the force of the water before it reaches the road.
-The level of water did reach the large corrugated culvert under the dirt road leading to the beach but did not pass very far beyond it. The location of the dirt road is such that it borders on the point were the elevation of the land increases.

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name: *Tony Bowron* ***Date:*** *15/06/01* **Time:** *12:38pm*

Location: *Cheverie Creek* **Restriction Severity:** *Partial Restriction*

GPS Coordinates: *N 45° 09"32.6 W64° 10"12.9* **Crossing code:** *N21C*

Weather: [Check Environment Canada web site] Wind velocity and direction: *15km/hr west*

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide *8:20am 11.7m*
Low tide *2:55pm 3m* Mean high tide for area [in metres]:

Crossing characteristics [circle one]: Bridge ***Culvert*** – corrugated cement steel PVC ***wooden block***

Crossing condition [circle one]: Is original design intact? ***Yes No***. Describe condition if in need of repair: *Partial function, both ends in disrepair (impact damage)*

Width of road [in metres] *2 lanes* **Length of opening** [in metres]: *2-4m (when repaired)*

Describe dominant land use or features: Above the crossing: *flood plain*
Below the crossing: *marsh, cobble beach, coastal inlet, road runs across outer edge of inlet.*

Restoration potential, if restricted: Area with restoration potential [in hectares] *~25 acres*
Type of restoration work [circle one]: Culvert repaired ***Culvert replaced*** Culvert installed ***Bridge installed*** Bridge widened Other - *larger culvert/bridge. Placement should be adjusted.*

Photographic record checklist: Crossing upstream ___ Crossing downstream ___ Landscape upstream ___ Landscape downstream ___ Dominant plants upstream ___ Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___ Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening*.	6m	
Opening diameter	2-4m	?
Opening height	?	?
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)	?	?

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	Upstream (Yes No)	Downstream (Yes No)
Bank slumping	Yes	Yes
Scour pools	Yes	Yes
Current channel appears divergent from original channel	Yes	Yes
Other *(lots of debris on both banks = high energy, pooling)*	Major pooling	

Flow restriction assessment:

Evidence of flow restriction	Upstream (Yes No)	Downstream (Yes No)
Smooth flow	Yes	Yes
Turbulent flow	No	No
Slack (still) water	Yes	Yes
Eddies, swirling water	No	No
Flow direction	**Upstream**	**Downstream**
Choose one: straight; angular; reversed		X (Straight)
Water level variance	**Yes**	**No**
Is there a visible difference in water level on each side of the crossing?	X	

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle]: **Yes** No

Obvious plants	Upstream Yes No	Downstream Yes No
Cordgrass: *Spartina alterniflora*	Yes	Yes
Salt marsh hay: *Spartina patens*	Yes	Yes
Cattails	Yes	No
Phragmites	No	No
Other?????	FW marsh plants	Beach & marsh plants

Tidal Barriers Audit: Phase 2 Measurement

Name: <u>*Cheverie Creek*</u>

GPS Coordinates: <u>*N45° 09"32.6 W64° 10"12.9*</u> **Crossing code:** <u>*N21C*</u>

Crossing characteristics [circle one]: Bridge; ***Culvert*** B corrugated concrete steel PVC **wooden block**

<u>**Visit #1**</u>. **Date:** <u>*July 25, 2001*</u>

Weather: [Check Environment Canada web site] **Wind velocity and direction**: ____
<u>*Sunny, slight onshore breeze.*</u>
Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions**[from station?]
<u>*No rain*</u>
Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide <u>*5:25pm ~14m*</u> Low tide ~<u>*11:25am ~.3m*</u>

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time(high tide = 0)	Actual time	Upstream (in m)	Actual time	Downstream (in m)
0 - 3	2:28pm	3.581	2:15pm	no measurement
0 - 2	3:20pm	3.581	3:25pm	no measurement
0 - 1.5	3:50pm	3.154	3:55pm	4.270
0 - 1	4:27pm	2.116	4:24pm	3.198
0 - .5	4:52pm	1.705	4:55pm	2.487
0	5:25pm	1.345	5:21pm	2.185
0 + .5	5:56pm	1.210	5:59pm	2.306
0 + 1	6:28pm	1.185	6:24pm	2.793
0 + 1.5	6:53pm	1.415	6:57pm	3.783
0 + 2 0+2.5	7:27pm 7:55pm	2.027 2.570	7:24pm 7:58pm	4.390 4.551
0 + 3	8:27pm	3.098	8:24pm	4.730

Observations:

Two days after spring tide event.

Culvert:
Downstream
Height- 1.5m
Width (top) - ~4.9m
Freshwater level at 2:25pm-1.1m in reference to culvert invert

Upstream
Height - .87m
Width (top) - 2.99m
Freshwater level at 2:30pm- .65m in reference to culvert invert

Culvert is a double chambered wooden block culvert. Both ends are in disrepair, likely due to ice damage.

Reference Points:
-The downstream reference point was adjacent to roadway along edge of the beach to the left of the culvert (opposite to the picnic area)
-The reference line was selected from the centre of the culvert and running up the bank towards to road surface.
-At low tide, water level is ~.3m below the top of the culvert.

-The upstream reference point was similar to the downstream side, facing up river to the right of the culvert above the highest debris line on a small pile of rocks, near the insertion of the old dyke with the road bank.
-The measurement line ran up the bank from centre of the culvert.

Observations:
-The was considerable much evidence of rip-rap from road bank washing/sliding into channel bed at both ends of the culvert.
-Rocky beach, barrier beach/rock forming along outer cove and gradually diverting and cutting off flow to/from culvert and a large pool has formed at the downstream end of the culvert.
-Small fringe marsh along upper edges of pool and along channel
-At low tide, height of the water in the culvert is less on the seaward side.
-The river channel appears diverted from its original location, but this is most likely due to historical dyking along river channel than the construction of the roadway and the location of the culvert.
-The upstream area does experience saltwater flooding to a limited degree (presence of spartina along channel bank and saltwater debris along the upstream banks of the river.
-An old network of dyking is still affecting the hydrology upstream - dykes are preventing flooding of some areas, while holding water in others (freshwater marsh, bulrushes, cattails)
-A farmer was cutting hay in field adjacent to the river but upslope of the potential flood area. The lower edge of the farmed field grades in to a freshwater swamp behind a dyke that prevents. Spartina is visible along both sides of this dyke indicating that some saltwater is crossing this dyke.

-The salt wedge reached the culvert at 3:34pm.
-Water passed the top of the culvert at 3:41pm.
-At 5:55pm, one half hour after high tide, downstream water level dropped .3m, however upstream continued to rise another .15m.

APPENDIX D - BLANK DATA SHEETS

Tidal Crossings Audit Data Sheet: Phase I Visual Assessment
Tidal Barriers Audit Data Sheet: Phase II Measurement
Tidal Barriers Audit Data Sheet: Dykes

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name:________________________ Date:_______________ Time: ______________

Location:____

GPS Coordinates: ________________________ Crossing code: _________________

Weather: [Check Environment Canada web site] ____________________________________
Wind velocity and direction: ____

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?] ___________________________

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide__ ________________ Low tide ______________________. Mean high tide for area [in metres]: _______________________

Crossing characteristics [circle one]: Bridge; Culvert B corrugated concrete steel PVC wooden block

Crossing condition [circle one]: Is original design intact? Yes No. Describe condition if in need of repair: ____
____

Width of road [in metres] ____________________ **Length of opening** [in metres]:___________

Describe dominant land use or features: Above the crossing:______________________
____
____
Below the crossing:____
____
____

Restoration potential, if restricted: Area with restoration potential [in hectares] _______
____
____

Type of restoration work [circle one]: Culvert repaired Culvert replaced Culvert installed Bridge installed Bridge widened Other _______________________________________
____
____

Photographic record checklist: Crossing upstream ___ Crossing downstream ___
Landscape upstream ___Landscape downstream ___ Dominant plants upstream ___
Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___
Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening*		
Opening diameter		
Opening height		
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)		

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	Upstream (Yes No)	Downstream (Yes No)
Bank slumping		
Scour pools		
Current channel appears divergent from original channel		
Other		

Flow restriction assessment:

Evidence of flow restriction	Upstream (Yes No)	Downstream (Yes No)
Smooth flow		
Turbulent flow		
Slack (still) water		
Eddies, swirling water		
Flow direction	**Upstream**	**Downstream**
Choose one: straight; angular; reversed		
Water level variance	**Yes**	**No**
Is there a visible difference in water level on each side of the crossing?		

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle] : Yes No

Obvious plants	Upstream Yes No	Downstream Yes No
Cordgrass: *Spartina alterniflora*		
Salt marsh hay: *Spartina patens*		
Cattails		
Phragmites		
Other?????		

Tidal Barriers Audit Data Sheet: Phase 2 Measurement

The primary tool for determining whether a crossing is restrictive is the Visual Assessment (Phase 1). Measurements of tidal crossings will be made where it is uncertain whether there is a restriction, or where there is a need for more information about the degree of restriction (Phase 2). Measurements will be made over approximate 6-hour period, from three hours flood tide to three hours ebb tide. Ideally, measurements will be made during the highest tides of the month (spring tide). This should capture a "worst case" normal -- as opposed to abnormal scenario - which would most likely demonstrate restricted flow if there is any. It is important to determine whether the restriction is ongoing or periodic. If possible, the site should be visited twice under different tidal conditions to make this assessment.

Name:_______________________________**GPS Coordinates:**_____________________

Crossing code: ___________________

Crossing characteristics [circle one]: Bridge Culvert B corrugated concrete steel PVC wooden block

Visit #1. **Date:** __________________

Weather: [Check Environment Canada web site]:_______________________________

Wind velocity and direction: ____________________

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?] ____________

Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide ____________ Low tide ____________

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time (high tide = 0)	Actual time	Upstream (in cm)	Actual time	Downstream (in cm)
0 - 3				
0 - 2				
0 - 1.5				
0 - 1				
0 - .5				
0				
0 + .5				
0 + 1				
0 + 1.5				
0 + 2				
0 + 3				

Tidal Barriers Audit Data Sheet: Dykes

The priority for assessment is dykes no longer maintained by the Department of Agriculture. Assessment of dykes should be carried out from high tide plus or minus two hours [????]

Name:___________________________**Date:**__________________**Time:** _______________

Weather: [Check Environment Canada web site]
Wind velocity and direction: _______________________

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]
____

Tide conditions [height and time as recorded in tide book, adjusted for area]: **High tide** _______________ **Low tide** _______________________ **Mean high tide for area** [in metres]: ____________________

Dyke name/location: ____

GPS coordinates: _________________________ **Dyke code**: ________________**Elevation:** ________________

Aboiteau_______________________ **name/location:** ____________________________________

GPS coordinates:___________________________________ Aboiteau code:___________

Length [in metres]: ___________________**Width at base** [in metres]: _________________

Original purpose of dyke: ____
____

Current use: On top of dyke: ____
Landward:____
Seaward: ____

Degree of restriction: Dyke - Total _______ Partial _______ Aboiteau - Total _____ Partial _____

Comments: ____
____
____

Breaches, weak points: GPS coordinates ____

Tidal channels blocked by dyke: Name ___________________________ GPS coordinates ____
Name____________________________________GPS coordinates _____________________

Name___________________________________GPS coordinates _______________________
Name ______________________________________ GPS coordinates ____________________

Land ownership [number of properties in each category]: Private _______ Crown _________ Non-profit ____

Land area behind dyke [in hectares]: __________________

Vegetation comparison:
Is there a significant difference in vegetation landward and seaward of the dyke? [circle] : **Yes No**

Obvious plants	**Landward Yes No**	**Seaward Yes No**
Cordgrass: *Spartina alterniflora*		
Salt marsh hay: *Spartina patens*		
Cattails		
Phragmites		
Other?????		

Photographic record checklist: Aerial photo of area ______ Breaches/weak points _________ Aboiteau ____ Landscape seaward ________ Landscape landward _________

Potential for restoration: ____

____

Comment____

____

____

Contacts made with respect to this dyke/aboiteau:

____

____

Other:

APPENDIX E – SPREADSHEETS USED FOR DATA ANALYSIS

	A	B	C	D	E	F
	Upstream			Downstream		
1	Time	Raw Data (m)	Change (m)	Time	Raw Data (m)	Change (m)
2			-(B2-TH)+AVERAGE($B$2:$B$10)			-(E2-TH)+AVERAGE($E$2:$E$10)
3			-(B3-TH)+AVERAGE($B$2:$B$10)			-(E3-TH)+AVERAGE($E$2:$E$10)
4			-(B4-TH)+AVERAGE($B$2:$B$10)			-(E4-TH)+AVERAGE($E$2:$E$10)
5			-(B5-TH)+AVERAGE($B$2:$B$10)			-(E5-TH)+AVERAGE($E$2:$E$10)
6			-(B6-TH)+AVERAGE($B$2:$B$10)			-(E6-TH)+AVERAGE($E$2:$E$10)
7			-(B7-TH)+AVERAGE($B$2:$B$10)			-(E7-TH)+AVERAGE($E$2:$E$10)
8			-(B8-TH)+AVERAGE($B$2:$B$10)			-(E8-TH)+AVERAGE($E$2:$E$10)
9			-(B9-TH)+AVERAGE($B$2:$B$10)			-(E9-TH)+AVERAGE($E$2:$E$10)
10			-(B10-TH)+AVERAGE($B$2:$B$10)			-(E10-TH)+AVERAGE($E$2:$E$10)
11	Tidal Range	MAX(B2:B10) -MIN(B2:B10)			MAX(E2:E10) -MIN(E2:E10)	
12	Range Ratio	+B11/E11				

***TH = height of the tripod (m)

	A	B	C	D	E	F
	Upstream			Downstream		
1	Time	Raw Data (m)	Change (m)	Time	Raw Data (m)	Change (m)
2	15:21	3.047	0.829	15:15	3.848	0.490
3	16:15	3.047	0.829	16:15	3.848	0.490
4	16:45	3.047	0.829	16:45	3.848	0.490
5	17:15	3.047	0.829	17:15	3.848	0.490
6	17:45	3.047	0.829	17:44	3.448	0.890
7	18:15	2.608	1.268	18:15	2.635	1.703
8	18:44	2.350	1.526	18:43	2.355	1.983
9	19:18	2.795	1.081	19:17	2.764	1.574
10	19:44	3.080	0.796	19:47	3.625	0.713
11	Tidal Range	0.730			1.493	
12	Range Ratio	0.490				

***TH = 0.98 m

About the Ecology Action Centre's Marine Issues Committee

The Ecology Action Centre (EAC) works to encourage a society in Nova Scotia which respects and protects nature and also provides environmentally and economically sustainable solutions for its citizens.

The EAC relies on education, advocacy, and action to bring about change. Each year we respond to hundreds of information requests, maintain one of the best environmental libraries in the Maritimes, publish a quarterly magazine called *Between the Issues*, offer informed analysis of current issues, and initiate community development and environmental projects in areas such as wetlands restoration, forestry, marine conservation and transportation issues. The EAC has recently been listed in the Globe and Mail as one of Canada's top ten charities "worthy of support".

The goal of the Marine Issues Committee has been and remains "To promote marine conservation and sustainable ocean-based livelihoods in Nova Scotia." We try to pursue this goal in an informed and conscientious manner. Our geographical focus is primarily the Gulf of Maine and the Atlantic Coast of Nova Scotia. The EAC chose to work on marine issues because of the many threats facing the oceans and until recently the relatively small number of conservation groups addressing these threats. The coastal waters off Nova Scotia are home to the greatest concentration of biodiversity in Atlantic Canada and are of significant historical, cultural and economic importance to the region.

The program of the Marine Issues Committee has six areas of interest: 1.) to promote sustainable fisheries management; 2) to support transition to community based management; 3.) to increase our knowledge and protection of benthic habitat in Atlantic Canadian waters; 4.) to challenge the further expansion of the oil and gas industry in Atlantic Canada with respect to its impact on the oceans and the atmosphere; 5.) to generate interest in the coastal and marine environment of the Scotian Shelf and Gulf of Maine and to protect and restore coastal habitats; 6.) to reduce and prevent the introduction of marine invasive species into Atlantic Canadian waters.

Support the Marine Issues Committee by joining the Ecology Action Centre. Clip and mail the form below or contact us by phone (902-429-2202), fax (902-422-6410), e-mail (eac_hfx@istar.ca) or visit our website (http://ecologyaction.ca/).

ECOLOGY ACTION CENTRE

I want to join Ecology Action Centre and help protect our Ocean

- ☐ $30.00/year Regular
- ☐ $50.00/year Contributing
- ☐ $75.00/year Supporting
- ☐ $120.00/year Sustaining
- ☐ $30.00/year Gift membership
- ☐ $15.00/year Student, Senior Citizen, Unemployed

Name ____

Address: ____

Phone: _____________ Fax: _____________ E-mail: ______________________

I understand that all payments are tax deductible and will be receipted promptly.

Mail to: Ecology Action Centre, 1568 Argyle St. Suite 31
Halifax, NS B3J 2B3 p(902) 429-2202 f(902) 422-6410