APPENDIX B

HYDROLOGY STUDY

HYDROTECHNICAL EVALUATION OF THE PROPOSED HIGHWAY 104 BYPASS ANTIGONISH, NOVA SCOTIA

PROJECT NO. 02029

REPORT TO

JACQUES WHITFORD ENVIRONMENT LIMITED

ON

HYDROTECHNICAL EVALUATION OF PROPOSED HIGHWAY 104 BYPASS ANTIGONISH, NOVA SCOTIA

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1.0 INTRODUCTION

Hydro-Com Technologies Limited, acting at the request of Jacques Whitford Environment Limited has performed a hydrotechnical evaluation of an area in and around Antigonish, Nova Scotia as part of the Class II Environmental Assessment required for the proposed Nova Scotia Department of Transportation (NSDOT) Highway 104 Bypass of this area.

This report has been prepared solely for the project described above and contains a description of our methodologies, findings, and conclusions.

2.0 METHODOLOGY

The objective of the evaluation was to provide a general hydrologic, hydraulic, and water quality description of all surface water bodies in the vicinity of the proposed project. The scope of work for this evaluation consisted of the following components:

- review of the available mapping to assess the general site drainage patterns and to identify any significant watercourses,
- perform a site investigation and assessment of all the significant watercourses where they are crossed by the proposed highway bypass,
- determine the impacts to drainage, flooding, and water quality associated with the proposed highway bypass,
- provide an estimate of the effects of climate change on the regional hydrology, and
- provide a letter report on all of the findings including any recommendations.

3.0 EXISTING ENVIRONMENT

This section describes the hydrotechnical aspects of the existing environment at the proposed crossing sites, and is intended as a straightforward presentation of the information upon which subsequent analyses or interpretations are based. Information for each of the watercourses that will be crossed by the proposed alignment of the Highway 104 Bypass was collected through the review of available mapping, the performance of site inspections of all the watercourse crossings of the proposed alignment identified on the available mapping, and where applicable, site inspections of the watercourses identified at the crossing of the existing Highway 104. This section presents the relevant information collected from the various sources, while the interpretation of this information is presented in subsequent sections.

The surface water drainage patterns were reviewed based on; the 1:10,000 NSDOT alignment mapping, 1:50,000 topographic mapping (Maps 11 E/8, 11 E/9, 11 F/5, and 11 F/12, Nova Scotia), and the following 1:10,000 Nova Scotia orthographic series maps:

11 E/09 - W2
11 E/09 - W4
11 F/12 - U1
11 F/12 - U2
11 F/12 - U3
11 F/12 - R3
11 F/12 - R4

Initial investigation of the study area and the NSDOT mapping identified the following nineteen (19) watercourses (chainages shown in brackets refer to the mapping produced by the Nova Scotia Department of Transportation and/or chainage stakes located during the site inspections):

Un-named (0+100)
Un-named (0+275)
Un-named (0+600 to 0+850)
Un-named (1+400)
Un-named (2+075)
Un-named (2+420)
Un-named (2+600)
Un-named (3+910)
Un-named (4+150)
Un-named (5+490)
West River (5+700)
Un-named (6+950)
Un-named (8+150)
Un-named (9+160)
Un-named (10+250)
South River (11+150)
Un-named (12+350)
Un-named (13+600)
Un-named (14+580)

A hydrotechnical evaluation of the South River crossing (11+150) was not performed as this location has been previously studied ("Highway 104 Antigonish South River Impact Study" by Neill and Gunter Limited, 2001). Site inspections for the watercourses identified above (at the crossing locations of the proposed bypass alignment and if applicable at the existing Highway 104) were performed by Messrs.

Arisz, M.Sc.E., P.Eng, and Sharpe, M.Sc.E., P.Eng. of Hydro-Com Technologies Limited on August 26 and 27, 2002. The following sections describe the drainage patterns and basin characteristics for each of these watercourses.

Please note that the basin characteristics and field observations in the following sections are based on the existing drainage patterns (pre-construction). Any modifications to the drainage basins into and around the watercourses due to the construction of the proposed bypass roadway may affect the size of required hydraulic structures.

3.1 Un-named (0+100)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104. As the proposed highway 104 bypass road is situated at the same location as the existing highway 104, the existing watercourse structure was investigated. The 1:10,000 scale mapping for this watercourse shows no residential or commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 1 and 2, Appendix A, refer):

- The structure is comprised of a rectangular timber cribwork culvert (approximately 1.8 m H by 1.5 m W) which is in good condition.
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom upstream was comprised of rocks and gravel.
- The channel bottom downstream was comprised of dark soil and organics (indicating low flood flows).
- No high water marks or ice scarring were observed at the site.
- Main channel is poorly defined (indicating flows are likely intermittent).
- Channel upstream and downstream is vegetated with grasses (indicating low flood flows).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- It appears that this culvert is for local drainage and may receive surface flows from the existing highway 104 roadway.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 1 - Un-named (0+100)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.205 km^2
Drainage Length [Channel Length]	0.74 km [0.59 km]
Average Basin Slope	3.3 %
Approximate Slope at Crossing Location	2.6 %
% Lakes	0.0 %

3.2 Un-named (0+275)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104. As the proposed highway 104 bypass road is situated at the same location as the existing highway 104, the existing watercourse structure was investigated. The 1:10,000 scale mapping for this watercourse shows no residential or commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 3 and 4, Appendix A, refer):

- The structure is comprised of a concrete culvert (0.75 m diameter) which is in good shape, however, the last section of pipe downstream is separated and undercut.
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom upstream was comprised of dark soil and organics (indicating low flood flows).
- The downstream end of the culvert is located approximately 0.60 m (2') above the channel bottom.
- No high water marks or ice scarring were observed at the site.
- Main channel is poorly defined (indicating flows are likely intermittent).
- Channel is vegetated with grasses.
- It appears that this culvert is for local drainage and may receive surface flows from the existing highway 104 roadway.
- Evidence of high flows in pipe (staining), therefore system may be “flashy”.

The following table presents the basin characteristics that were obtained from1:10,000 scale mapping.

Table 2 - Un-named (0+275)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.070 km^2
Drainage Length [Channel Length]	0.47 km [0.32 km]
Average Basin Slope	4.9 %
Approximate Slope at Crossing Location	12.3 %
% Lakes	0.0 %

3.3 Un-named (0+600 to 0+850)

The watercourse at the proposed crossing collects surface flows from a large area south of the existing highway 104 and includes input from the watercourse described in section 3.4 (Un-named, 1+400). As the proposed highway 104 bypass road is situated at the same location as the existing highway 104, the existing watercourse structure was investigated. The 1:10,000 scale mapping for this watercourse shows some residential properties (on Addington Forks Road) within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 5 through 8, Appendix A, refer):

- The watercourse is an existing wetland habitat located adjacent to the existing highway 104 with a culvert under the roadway located at approximately 0+750.
- The existing structure is comprised of a timber cribwork culvert (1.5 m H by 1.2 m W) in fair condition (slight sagging of roof in the middle of the culvert).
- No flow was observed in the culvert at the time of the inspection.
- No high water marks or ice scarring were observed at the site.
- Upstream wetland habitat is significant size.
- Channel is highly vegetated upstream and downstream (indicating flood flows with small magnitudes).
- Terrain is relatively flat upstream and downstream.
- Standing water depth at time of inspection was between 0.10 to 0.30 m.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 3 - Un-named (0+600 to 0+850)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	1.140 km^2
Drainage Length [Channel Length]	1.64 km [1.34 km]
Average Basin Slope	1.5 %
Approximate Slope at Crossing Location	~0.5 %
% Lakes	0.0 %

3.4 Un-named (1+400)

The watercourse at the proposed crossing collects surface flows from a small area between trunk 4 and the existing highway 104. As the proposed highway 104 bypass road is situated at the same location as the existing highway 104, the existing watercourse structure was investigated. The 1:10,000 scale mapping for this watercourse shows some residential and commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 9 and 10, Appendix A, refer):

- The existing structure is comprised of a square timber cribwork culvert (1.2 m by 1.2 m) in good condition.
- No flow was observed in the culvert at the time of the inspection.
- No high water marks were observed at the site.
- Channel upstream is vegetated with grasses (indicating flood flows with small magnitudes).
- It appears that this culvert is for local drainage and may receive surface flows from the existing highway 104 roadway.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 4 - Un-named (1+400)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.112 km^2
Drainage Length [Channel Length]	0.22 km [0.21 km]
Average Basin Slope	4.9 %
Approximate Slope at Crossing Location	3.8 %
% Lakes	0.0 %

3.5 Un-named (2+075)

The watercourse at the proposed crossing collects surface flows from; an area north of trunk 4, between trunk 4 and highway 104, and between highway 104 and Addington Forks Road. This watercourse is not crossed by the proposed 104 bypass roadway but would be crossed by a proposed off-ramp. An investigation of this watercourse was therefore performed at the existing crossing of the Addington Forks Road. The 1:10,000 scale mapping for this watercourse shows residential properties within the watershed upstream of the proposed crossing (note that some residences on Addington Forks Road will be moved for the proposed highway).

The following observations were made during the site investigation (Photographs 11 and 12, Appendix A, refer):

- The existing structure is comprised of two (2) offset corrugated steel culverts (0.750 m diameter) in fair condition.
- No flow was observed in the culverts at the time of the inspection.
- No ice scarring was observed at the site.
- Channel upstream and downstream is vegetated with grasses (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- High water mark indicated by rust line located at half depth of upper culvert.
- The lower culvert was approximately half full of silt and sand.

The following table presents the basin characteristics that were obtained from1:10,000 scale mapping.

Table 5 - Un-named (2+075)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.243 km^2
Drainage Length [Channel Length]	0.79 km [0.79 km]
Average Basin Slope	1.1 %
Approximate Slope at Crossing Location	1.2 %
% Lakes	0.0 %

3.6 Un-named (2+420)

The watercourse at the proposed crossing collects surface flows from an area south of the existing highway 104 and east of Addington Forks Road as well as the drainage from the watercourse described in section 3.5 (Un-named, 2+075). The 1:10,000 scale mapping for this watercourse indicates that there are both residential and commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 13 through 15, Appendix A, refer):

- Terrain is relatively flat without a well defined floodplain.
- No flow at the time of inspection.
- Channel width approximately 1.5 to 2.0 m.
- Stable rock size, d_{50}, approximately 0.10 m.
- Positive chainage bank at proposed crossing location is fairly steep.
- Negative chainage bank at proposed crossing location is shallow.
- No evidence of erosion in the floodplain.
- No evidence of ice scour or scarring, however, believe this location to have ice jamming potential.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 6 - Un-named (2+420)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.395 km^2
Drainage Length [Channel Length]	1.19 km [1.19 km]
Average Basin Slope	1.5 %
Approximate Slope at Crossing Location	2.7 %
% Lakes	1.0 %

3.7 Un-named (2+600)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104. The 1:10,000 scale mapping for this watercourse indicates that there are no residential properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 16 and 17, Appendix A, refer):

- Main channel is not defined (indicating flows are likely intermittent).
- Channel is vegetated with grasses (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- No flow at the time of inspection.
- No hydrotechnical concern.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 7 - Un-named (2+600)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.139 km^2
Drainage Length [Channel Length]	0.45 km [0.19 km]
Average Basin Slope	3.5 %
Approximate Slope at Crossing Location	3.0 %
% Lakes	0.0 %

3.8 Un-named (3+910)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104 and west of trunk 7. The 1:10,000 scale mapping for this watercourse shows some residential properties (Tamara Drive subdivision) within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 18 and 19, Appendix A, refer):

- Channel upstream and downstream is vegetated with grasses (indicating flood flows with small magnitudes).
- No flow at the time of inspection.
- Channel width approximately 1.0 m (man-made ditch with a dirt bottom).
- No hydrotechnical concern.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 8 - Un-named (3+910)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.127 km^2
Drainage Length [Channel Length]	0.72 km [0.12 km]
Average Basin Slope	2.9 %
Approximate Slope at Crossing Location	2.5 %
% Lakes	0.0 %

Existing Structure Inspection

A site inspection was performed on the structure which conveys flows from this watercourse crossing and the watercourse crossing described in section 3.9 (Un-named, 4+150) under the existing Highway 104. The following observations were made during the site inspection (Photographs 20 through 22, Appendix A, refer):

- The structure is comprised of a square timber cribwork culvert (0.9 m by 0.9 m) in a fair to poor condition (slight lean to structure).

- Little or no flow was observed in the culvert at the time of the inspection.
- Standing water in the culvert approximately 0.45 m at upstream end.
- The downstream end of the culvert was mostly submerged at the time of the inspection.
- A storm culvert was located draining to the downstream side of this structure.

3.9 Un-named (4+150)

The watercourse at the proposed crossing collects surface flows from an area south of the existing highway 104. The 1:10,000 scale mapping for this watercourse indicates that there are residential properties within the watershed upstream of the proposed crossing (trunk 7, and Tamara Drive).

The following observations were made during the site investigation (Photographs 23 through 26, Appendix A, refer):

- Proposed crossing is located at same spot as an existing dirt road which has an existing structure.
- Existing structure at upstream end is comprised of two (2) offset corrugated steel culverts (0.6 m diameter).
- High water marks of upstream culverts indicated by rust line located at half depth of upper culvert.
- Existing structure at downstream end is comprised of a cut-off oil tank.
- Channel downstream appears to have been man-made.
- Channel upstream is highly vegetated (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain.
- No flow at the time of inspection.
- Channel width approximately 3.0 m downstream.
- Standing water depth at time of inspection was approximately 0.30 m.
- No evidence of erosion in the floodplain.
- No evidence of ice scour or scarring.
- Inspection of a structure (corrugated steel culvert, 0.6 m diameter) located under a drive-way approximately 40 m upstream of proposed crossing indicated some overtopping.

The following table presents the basin characteristics that were obtained from:10,000 scale mapping.

Table 9 - Un-named (4+150)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.493 km^2
Drainage Length [Channel Length]	1.27 km [0.98 km]
Average Basin Slope	2.0 %
Approximate Slope at Crossing Location	1.3 %
% Lakes	0.0 %

3.10 Un-named (5+490)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104 and west of the Kell Road. The 1:10,000 scale mapping for this watercourse indicates there are residential properties within the watershed upstream of the proposed crossing (Kell Road).

The following observations were made during the site investigation (Photograph 27, Appendix A, refers):

- Main channel is poorly defined (indicating flows are likely intermittent) and appears to be local drainage only.
- Channel is highly vegetated with grasses and moss (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- No flow at the time of inspection.
- No hydrotechnical concern.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 10 - Un-named (5+490)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.366 km^2
Drainage Length [Channel Length]	0.94 km [0.88 km]
Average Basin Slope	2.4 %
Approximate Slope at Crossing Location	0.8 %
% Lakes	0.0 %

3.11 West River (5+700)

The watercourse at the proposed crossing collects surface flows from a significantly sized watershed that extends to the James River (north of the existing highway 104) and to Donny Brook (south of the existing highway 104). The 1:50,000 and 1:10,000 scale mapping for this watercourse indicates that there is a large number of residential and commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 28 through 31, Appendix A, refer):

- Good flow at the time of inspection (unmeasured).
- Channel width approximately 25 m.
- Water depth at time of inspection was approximately 0.30 m at the centre of the channel.
- Stable channel with stable rock size, d_{50}, approximately 0.075 m.
- Negative chainage bank at proposed crossing location is fairly steep.
- Floodplain exists upstream of crossing location on negative chainage side with competent vegetation (indicating no significant flows or ice movement).
- Floodplain exists at crossing location on positive chainage side with competent vegetation.
- Alignment of proposed highway is perpendicular to channel.
- No evidence of erosion in the floodplain.
- No evidence of ice scour or scarring.
- No high water marks located at proposed crossing location.
- Due to the width of the crossing and the steep bank on the negative chainage side, recommend a bridge structure at this location.

The following table presents the basin characteristics that were obtained from 1:50,000 scale mapping and confirmed using 1:10,000 scale mapping.

Table 11 - West River (5+700) Basin Characteristics Upstream of Proposed Crossing	
Parameter	**Value**
Drainage Area	330.6 km^2
James River Drainage Length [James River Channel Length]	32.35 km [31.07 km]
Ohio River/Donny Brook Drainage Length [Ohio River/Donny Brook Channel Length]	43.37 km [41.59 km]
James River Average Basin Slope	0.89 %
Ohio River/Donny Brook Average Basin Slope	0.51 %
Approximate Slope at Crossing Location	~0.33 %
% Lakes	0.56 %

3.12 Un-named (6+950)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104 and east of Beech Hill Road. The 1:10,000 scale mapping for this watercourse shows that there are some residential properties within the watershed upstream of the proposed crossing (at existing highway 104).

The following observations were made during the site investigation (Photographs 32 through 34, Appendix A, refer):

- Main channel is well defined and incised approximately 0.5 m (indicating good flows).
- Channel is steep at proposed crossing location
- No flow at the time of inspection.
- Channel width approximately 0.9 m.
- Stable rock size, d_{50}, approximately 0.05 m with some larger moss covered rocks.
- Floodplain not well defined and vegetated on both sides of channel.
- No evidence of ice scour or scarring.
- System may be “flashy”.

The following table presents the basin characteristics that were obtained from1:10,000 scale mapping.

Table 12 - Un-named (6+950)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.207 km^2
Drainage Length [Channel Length]	0.81 km [0.53 km]
Average Basin Slope	4.2 %
Approximate Slope at Crossing Location	3.5 %
% Lakes	0.0 %

Existing Structure Inspection

A site inspection was performed on the structure which conveys flows from this watercourse under Beech Hill Road (located downstream of the proposed crossing location). The following observations were made during the site inspection (Photographs 35 through 37, Appendix A, refer):

- The structure is comprised of a corrugated steel culvert (0.9 m diameter) in fair condition.
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom both upstream and downstream was comprised of dark soil and organics (indicating low flood flows).
- High water mark in culvert indicated by rust line at approximately 40% depth.
- This structure also receives flows from an area north of highway 104 which travels under the highway via a timber cribwork culvert (0.6 m by 0.60 m). This culvert was found to be in poor condition with the downstream culvert section having failed

3.13 Un-named (8+150)

The watercourse at the proposed crossing collects surface flows from a large area south of the existing highway and east of Beech Hill Road as well as the drainage from the watercourse described in section 3.14 (Un-named, 9+160). The 1:10,000 scale mapping for this watercourse shows some residential or commercial properties within the watershed upstream of the proposed crossing (at existing highway 104).

The following observations were made during the site investigation (Photographs 38 and 39, Appendix A, refer):

- No visible flow at the time of inspection.
- Channel width approximately 8.0 to 10.0 m .
- Water depth at time of inspection was between 0.3 and 0.6 m.
- Channel bottom comprised of silts and sands (indicating low flood flows)
- Both positive and negative chainage banks at proposed crossing location are fairly steep, with positive chainage side clear-cut up to edge of watercourse (potential for erosion and sediments into watercourse).
- No evidence of ice scour or scarring.
- Wide channel and steep banks therefore recommend a span structure or bridge for this crossing location.
- A riffle section is located approximately 60 m downstream of the proposed crossing location.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 13 - Un-named (8+150)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	3.153 km^2
Drainage Length [Channel Length]	3.71 km [3.49 km]
Average Basin Slope	2.3 %
Approximate Slope at Crossing Location	1.2 %
% Lakes	0.0 %

Existing Structure Inspection

A site inspection was performed on the structure which conveys flows from this watercourse under the existing Highway 104 (located downstream of the proposed crossing). The following observations were made during the site inspection (Photographs 40 and 41, Appendix A, refer):

- The structure is comprised of a cast in place concrete culvert (1.8 m by 1.8 m) in good condition.
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom upstream was comprised of dark soil and organics (indicating low flood flows).
- The channel was well vegetated both upstream and downstream of the structure, with a good wetland habitat located immediately upstream of the structure.
- Recommended increased sediment control at the proposed crossing location to minimize any impact on the downstream wetland.

3.14 Un-named (9+160)

The watercourse at the proposed crossing collects surface flows from a small area around the existing highway 104. The 1:10,000 scale mapping for this watercourse indicates that there are both residential and commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 42 and 43, Appendix A, refer):

- Main channel is poorly defined (indicating flows are likely intermittent).
- Channel is vegetated with grasses and moss (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- No flow at the time of inspection.
- No hydrotechnical concern.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 14 - Un-named (9+160)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.219 km^2
Drainage Length [Channel Length]	0.66 km [0.35 km]
Average Basin Slope	5.3 %
Approximate Slope at Crossing Location	1.8 %
% Lakes	0.0 %

3.15 Un-named (10+250)

The watercourse at the proposed crossing collects surface flows from a small area south of the existing highway 104. The 1:10,000 scale mapping for this watercourse shows no residential or commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 44 and 45, Appendix A, refer):

- Main channel is well defined and incised approximately 0.5 m (indicating good flood flows).
- No flow at the time of inspection.
- Channel width approximately 1.0 m .
- Channel is steep at the proposed crossing location.
- Stable rock size, d_{50}, approximately 0.15 m.
- Both positive and negative chainage banks at proposed crossing location are fairly steep.
- System may be “flashy”.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 15 - Un-named (10+250)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.148 km^2
Drainage Length [Channel Length]	0.65 km [0.28 km]
Average Basin Slope	6.4 %
Approximate Slope at Crossing Location	6.7 %
% Lakes	0.0 %

Existing Structure Inspection

A site inspection was performed on two (2) structures located downstream of the proposed crossing; the first structure conveys flows under the existing Highway 104 while the second structure conveys the flows under a secondary road. The following observations were made during the site inspection (Photographs 46 through 49, Appendix A, refer):

Existing Highway 104 Structure

- The structure is comprised of a cast in place concrete culvert (1.2 m by 1.2 m) on the upstream end, with a section of corrugated steel culvert (1.35 m diameter) at the downstream end.
- Rust mark on downstream end culvert indicates low flows, however, tar coating on inside of pipe has worn to the half pipe depth (indicating potential "flashy" flows).
- Channel at upstream end of structure comprised of large rock, d_{50} approximately 0.05 m with some larger rocks (0.1 m) located in the ditch alongside the existing highway.
- Steep banks off existing highway 104 both upstream and downstream of structure, with signs of erosion and large rock.

Secondary Road Structure

- The structure is comprised of a cast in place concrete arch culvert (2.25 m H by 1.2 m W).
- The floor of the structure is deteriorating which may allow flows to travel underneath the structure.
- No flow was observed in the culvert at the time of the inspection.

3.16 Un-named (12+350)

The watercourse at the proposed crossing collects surface flows from a small area north of the existing highway 104. The 1:10,000 scale mapping for this watercourse shows no residential properties within the watershed upstream of the proposed crossing. The proposed crossing location was not inspected, however, the existing culvert located downstream under a secondary road was.

The following observations were made during the site investigation (Photographs 50 through 52, Appendix A, refer):

- The existing structure under the secondary road is comprised of a timber cribwork culvert (0.9 m by 0.9 m) on the upstream side, with a cast in place concrete culvert (0.9 m by 0.9 m) on the downstream side.
- No flow was observed in the culvert at the time of the inspection.
- Main channel upstream is poorly defined (indicating flows are likely intermittent).
- Culvert appears to be for local drainage only.
- Erosion measures including rip-rap placed downstream of structure between secondary road and existing highway 104.
- Storm sewer culverts enter ditch between roads from both directions.
- The existing structure under highway 104 is comprised of a concrete culvert (1.2 m diameter) on the upstream side, with a timber cribwork culvert (0.75 m by 0.75 m) on the downstream side.

The following table presents the basin characteristics that were obtained from1:10,000 scale mapping.

Table 16 - Un-named (12+350)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.108 km^2
Drainage Length [Channel Length]	0.42 km [0.42 km]
Average Basin Slope	~3.0 %
Approximate Slope at Crossing Location	1.9 %
% Lakes	0.0 %

3.17 Un-named (13+600)

The watercourse at the proposed crossing collects surface flows from a small area north of the existing highway 104. The 1:10,000 scale mapping for this watercourse shows no residential or commercial properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (No photographs available):

- Main channel is poorly defined (indicating flows are likely intermittent).
- Channel is vegetated with grasses and moss (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- No flow at the time of inspection.

The following table presents the basin characteristics that were obtained from 1:10,000 scale mapping.

Table 17 - Un-named (13+600)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.062 km^2
Drainage Length [Channel Length]	0.30 km [0.06 km]
Average Basin Slope	1.3 %
Approximate Slope at Crossing Location	~0.5 %
% Lakes	0.0 %

Existing Structure Inspection

A site inspection was performed on the structure which conveys flows from this watercourse under the existing Highway 104 (downstream of the proposed crossing). The following observations were made during the site inspection (Photographs 53 through 55, Appendix A, refer):

- The structure is comprised of a cast in place concrete culvert (0.6 m by 0.6 m).
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom upstream was comprised of dark soil and organics (indicating low flood flows).
- No high water marks or ice scarring were observed at the site.

3.18 Un-named (14+580)

The watercourse at the proposed crossing collects surface flows from a small area south of existing highway 104. As the proposed highway 104 bypass road is situated at the same location as the existing highway 104, the existing watercourse structure was investigated. The 1:10,000 scale mapping for this watercourse shows no residential properties within the watershed upstream of the proposed crossing.

The following observations were made during the site investigation (Photographs 56 and 57, Appendix A, refer):

- The structure is comprised of a cast in place concrete culvert (0.6 m by 0.6 m).
- No flow was observed in the culvert at the time of the inspection.
- The channel bottom upstream was comprised of dark soil and organics (indicating low flood flows).
- Staining due to groundwater infiltration was observed at the downstream end of the culvert.
- No high water marks or ice scarring were observed at the site.
- Channel upstream is vegetated with grasses (indicating flood flows with small magnitudes).
- Terrain is relatively flat without a well defined floodplain (indicating flood flows with small magnitudes).
- No evidence of ice scour or scarring.

The following table presents the basin characteristics that were obtained from1:10,000 scale mapping.

Table 18 - Un-named (14+580)
Basin Characteristics Upstream of Proposed Crossing

Parameter	Value
Drainage Area	0.236 km^2
Drainage Length [Channel Length]	1.00 km [0.71 km]
Average Basin Slope	2.2 %
Approximate Slope at Crossing Location	~1.0 %
% Lakes	0.0 %

4.0 IMPACT ASSESSMENT, MITIGATION AND MONITORING

Since surface water supplies are sensitive to environmental effects resulting from development activities, any major development in a watershed can pose a potential water quality hazard. Surface water resources are hydraulically linked to groundwater resources and aquatic habitat. Surface water quality can be directly affected by the volume and quality of groundwater flowing to the surface water; while conversely, surface water quality and quantity may affect groundwater quality and quantity. Construction activities may alter existing overland drainage patterns and result in the transport of suspended solids to the nearest stream or wetland.

The key environmental issues for surface water resources from a linear development include:

- interference with drainage,
- interference with the local flood regime, and
- degradation of the water quality of surface water resources.

4.1 Drainage

The potential interference with the local drainage by the construction and operation of the proposed new highway may consist of the blockage or alteration of existing drainage patterns or the creation of new drainage channels over previously undisturbed terrain.

Based on the field inspection, all of the watercourses along the proposed road alignment are well defined with all of the existing local drainage concentrated through the channels. However, since the majority of the watercourses have small drainage areas, the additional drainage area from the proposed highway (road surface, median, ditches, etc.) becomes significant (see areas and volumes of runoff in Table 19, section 4.3.2). Therefore the design of the structures should account for the additional drainage area and associated flows.

4.2 Flooding

The potential interference with the local flood regime by the construction of the proposed new highway would consist of the initiation or aggravation of local flooding (especially at watercourse crossings that: have large drainage basins, steep channel slopes, and have significant floodplains). None of the proposed crossing locations showed signs of active ice movement (ice scour, erosion, scarring, significant debris in channel) and there is limited development in or near the floodplain of most watercourses that could be affected. However, several of the crossing locations were assessed as having the potential for ice or debris jam which may endanger the stability of the roadway embankment. Based on the field inspections, the following watercourses were identified as being “flashy” (due to steep

channel at crossing, large stable rock) and/or had steep banks at the crossing with no floodplain. These sites would have the potential for the initiation of an ice or debris jam especially with the additional flows from the proposed highway.

- Un-named 0+275
- Un-named 2+420
- Un-named 8+150
- Un-named 10+250

4.3 Water Quality

The potential impacts of the construction and operation of the proposed new highway on the water quality of local surface water resources may consist of the entrance of sediment laden runoff or runoff containing contaminants (salt and/or hydrocarbons) into watercourses. The entrance of sediment laden runoff from the roadway right-of-way into watercourses is expected to primarily occur during construction, while the entrance of runoff containing contaminants is expected to occur primarily during the operation of the highway (sanding and salting operations during the winter and spring seasons and oil and gasoline drips from traffic on the proposed roadways).

4.3.1 Sediment Laden Runoff

The potential for the entrance of sediment laden runoff is minimal in the majority of the watercourses as the general terrain outside of the floodplain and riparian zone is relatively flat. However, steep banks were found at the following crossing locations which could lead to sediment laden runoff entering the watercourses;

- Un-named 2+420
- West River 5+700
- Un-named 8+150
- Un-named 10+250

Note that the steep bank on the positive chainage side of the watercourse at Un-named 8+150 was found to be clear-cut all the way to the watercourse edge. This lack of natural vegetation could lead to increased amounts of bank erosion and sediment load entering the watercourse. In addition, a good wetland habitat exists downstream of this crossing location (upstream of the existing structure under highway 104) which could be adversely affected by sediments.

The use of standard erosion and sediment control measures is expected to adequately mitigate the effects of sediment laden runoff on nearby surface water sources of watercourses. However, it is recommended

that the watercourses identified above as having steep banks (especially the watercourse at Un-named 8+150) should have an augmented level of erosion and sediment control measures.

4.3.2 Runoff Containing Contaminants

To assess the significance of surface runoff from the proposed new highway, the annual volume of surface runoff from the proposed driving surface within each watercourse was estimated and compared to the mean annual flow in each of the impacted watercourses. The annual volume of surface runoff from the proposed driving surface was estimated using: a design road width of 60.0 m (includes roadway surface, median area, and roadside ditch), lengths of highway draining to each watercourse (assuming highway will follow the natural topography), a mean annual precipitation amount of 1,200 mm/year (MacLaren Atlantic Limited, 1980), and a runoff coefficient of 1.0, since all precipitation on the highway driving surface ends up as surface runoff. The mean annual flow in each of the watercourses was estimated using the drainage area (as measured from the 1:50,000 scale mapping) and a mean annual runoff of 900 mm/year (MacLaren Atlantic Limited, 1980). The results from the assessment are presented in Table 19.

Based on the results presented in Table 19, the volume of runoff from the driving surfaces of the proposed new highway ranges between 0.05 and 56.6 % of the mean annual flow in the impacted watercourses. Only those locations identified as having a runoff volume to mean annual runoff greater than 10 % are believed to have a potential impact on the water quality of a watercourse. A total of 13 watercourses are identified in Table 19 as satisfying this criteria. Therefore, the sensitivity of the aquatic habitat downstream of these crossings to the above water quality impacts should be reviewed.

Table 19 - Surface Runoff Estimates and Comparison					
Crossing (Location)	**Roadway Area (m^2)**	**Annual Runoff (m^3)**	**Watershed Area (km^2)**	**Annual Flow (m^3)**	**%**
Un-named (0+100)	24,000	28,800	0.205	184,500	15.6
Un-named (0+275)	12,000	14,400	0.070	63,000	22.9
Un-named (0+600 to 0+850)	93,000	111,600	1.140	1,026,000	10.9
Un-named (1+400)	36,000	43,200	0.112	100,800	13.1
Un-named (2+075)	36,000	43,200	0.243	218,700	19.8
Un-named (2+420)	18,000	21,600	0.395	355,500	6.1
Un-named (2+600)	27,000	32,400	0.139	125,100	25.9
Un-named (3+910)	9,000	10,800	0.127	114,300	9.4
Un-named (4+150)	36,000	43,200	0.493	443,700	9.7
Un-named (5+490)	42,000	50,400	0.366	329,400	15.3
West River (5+700)	126,000	151,200	330.638	297,574,000	0.05
Un-named (6+950)	36,000	43,200	0.207	186,300	23.2
Un-named (8+150)	156,000	187,200	3.153	2,837,700	6.6
Un-named (9+160)	48,000	57,600	0.219	197,100	29.2
Un-named (10+250)	24,000	28,800	0.148	133,200	21.6
Un-named (12+350)	30,000	36,000	0.108	97,200	37.0
Un-named (13+600)	18,000	21,600	0.062	55,800	56.6
Un-named (14+580)	42,000	50,400	0.236	212,400	23.7

5.0 CLIMATE CHANGE ASSESSMENT

The following climate information is extracted from a background paper titled "Water Sector: Vulnerability and Adaptation to Climate Change" which was presented during a Canadian Society of Civil Engineering conference held in Moncton, New Brunswick, 11 to 12 May, 2000. This document was prepared with support from the Climate Change Action Fund, National Resources Canada with authors from Global Change Strategies International Inc. (GCSI) and the Atmospheric Environment Service, Environment Canada.

The above document discusses the climate trends associated with an increase in the global mean temperature due to increased greenhouse gases in the atmosphere (particularly carbon dioxide, CO_2). The trends are based on General Circulation Models or Global Climate Models (GCM's) that have been developed in Canada, U.S.A., U.K., and Germany. These models anticipate that the concentration of CO_2 in the atmosphere will double between the year 2000 and the year 2050. The following relevant statements that were extracted from the document are presented below:

- For a doubled CO_2 atmosphere, by the second half of the coming century, temperature increases for summers, over Canada, as projected would average about 4 °C. For winter months (Dec, Jan, Feb) increases of 6 °C or more are projected for most of central Canada, with slightly lower values in the east and west.
- A winter precipitation increase of 0 to 20% is projected for Atlantic Canada.
- In summer only small increases in precipitation are projected for Atlantic Canada.
- Nationally, precipitation has increased 1.7% of the mean per decade over the period 1948 to 1985.
- No analyses of Canadian data are available of trends in very short duration (minutes to hours) heavy rain events which cause city street flooding, sewer overflows, erosion and flash floods, and landslides, but some analyses of heavy one-day events have been undertaken. These show that there has been an increase in precipitation in heavy events in Atlantic Canada.
- Model results indicate that there will be an increased frequency of heavy one-day rains in a doubled CO_2 climate, with return periods halved, e.g. a 20 year return period rainfall becomes a 10 year event.
- The Canadian GCM indicates that in a doubled CO_2 world, the number of weak to moderate winter storms in the northern hemisphere would decrease but the number of very severe storms would increase.
- If the frequency of short duration high precipitation intensities increase as projected, then greater soil erosion and sedimentation is likely, and more pollutants will be washed into rivers and lakes due to urban runoff.

The above information, in particular the change in the return period of storm events, should be considered during the design of the watercourse structures.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the field observations that were performed as part of this study, and assuming normal standards are used during the design of the hydraulic structures (this includes addressing the high risk for the initiation of an ice or debris jam at the identified watercourses and the accommodation of increased storm flows due to highway runoff and global warming), no significant hydraulic changes are expected either during or after construction of the new highway.

Based on experience with erosion and sediment control measures in Eastern Canada, it is recommended that these measures be designed to function to the applicable water quality limits during a 1 in 2 year return period storm event. Structures are designed to withstand a 1 in 100 year return period event without incurring significant damage.

Smaller culverts are based on a 1 in 100 year return period under worst case conditions (frozen ground conditions). For 100 Series Highways, a minimum cross culvert size of 900 mm diameter is used, which often is considerably larger than the design requires.

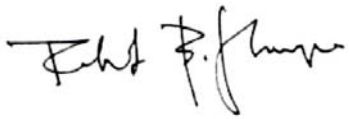
For larger structures, including bridges, the design is based on a 1 in 100 year event without incurring significant damage. Consideration is also given to the width of the existing watercourse, upstream and downstream structure dimensions, fish passage requirements, anticipated increases in runoff, and field observations that includes comments from local residents and NSTPW maintenance field staff on the capacity of existing structures under recent 1:100 storm events.

Due to the wide channel width and the steep negative chainage bank that exists at the West River (5+700) crossing, it is recommended that a free-spanning structure be considered at this location. As the crossing at Un-named 8+150 is a good habitat and steep banks also exist at this location, it is recommended that a spanning structure (arch-span culvert, bridge, etc.) be considered at this location.

The percentage of runoff containing contaminants to the mean annual runoff at 13 of the watercourse crossings were greater than 10 % indicating a potential impact on the aquatic habitat downstream of these location. It is recommended that the aquatic habitat downstream of these locations be reviewed to assess the requirements for contaminant mitigation measures at the crossing.

7.0 SIGNATURE

This report is an accurate reflection of the field conditions noted during the site inspection performed on August 26 and 27, 2002 by Messers Arisz, M.Sc.E., P.Eng., and Sharpe, M.Sc.E., P.Eng. of Hydro-Com Technologies Limited.



Robert B. Sharpe, M.Sc.E., P.Eng.

REFERENCES

MacLaren Atlantic Limited. 1980. Regional Flood Frequency Analysis for Mainland Nova Scotia Streams

Appendix A

Site Photographs

Photograph 1 – Un-named 0+100
Existing timber culvert upstream side

Photograph 2 – Un-named 0+100
Local drainage culvert to upstream side

Photograph 3 – Un-named 0+275
Existing concrete culvert upstream side

Photograph 4 – Un-named 0+275
Existing concrete culvert downstream side

Photograph 5 – Un-named 0+600 to 0+850
Existing timber culvert upstream side at 0+750

Photograph 6 – Un-named 0+600 to 0+850
Existing timber culvert upstream side at 0+750

Photograph 7 – Un-named 0+600 to 0+850
Existing timber culvert downstream side at 0+750

Photograph 8 – Un-named 0+600 to 0+850
Existing timber culvert downstream side at 0+750

Photograph 9 – Un-named 1+400
Existing timber culvert downstream side

Photograph 10 – Un-named 1+400
Existing timber culvert upstream side

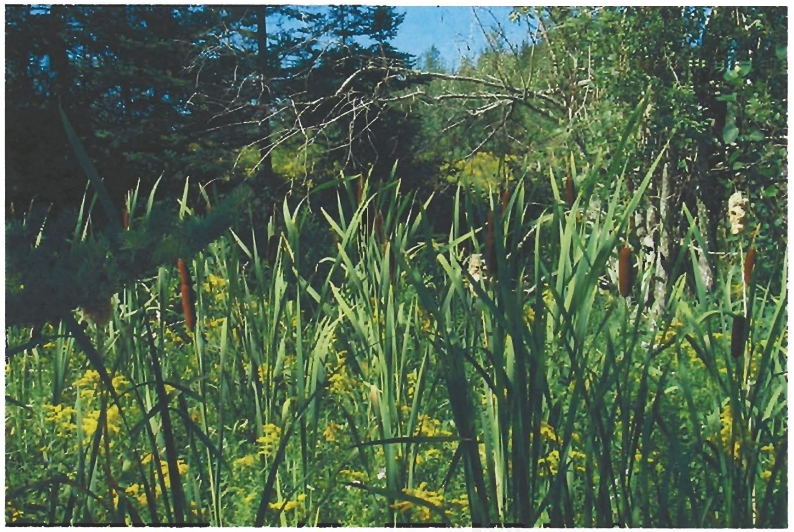
Photograph 11 – Un-named 2+075
Existing culverts upstream side

Photograph 12 – Un-named 2+075
Existing culverts downstream side

Photograph 13 – Un-named 2+420
Channel at crossing location looking downstream

Photograph 14 – Un-named 2+420
Channel at crossing location stable rock

Photograph 15 – Un-named 2+420
Channel at crossing location looking upstream



Photograph 16 – Un-named 2+500
At crossing location looking upstream

Photograph 17 – Un-named 2+500
At crossing location looking downstream

Photograph 18 – Un-named 3+910
Channel at crossing location looking upstream

Photograph 19 – Un-named 3+910
Channel at crossing location looking downstream

Photograph 20 – Existing structure at highway 104
(downstream of un-named 3+910 and 4+150) u/s side

Photograph 21 – Existing structure at highway 104
(downstream of un-named 3+910 and 4+150) d/s side

Photograph 22 – Existing structure at highway 104
(downstream of un-named 3+910 and 4+150) storm culvert

Photograph 23 – Un-named 4+150
Existing culvert at crossing upstream side

Photograph 24 – Un-named 4+150
Existing culvert at crossing downstream side

Photograph 25 – Un-named 4+150
Existing culvert at crossing looking downstream

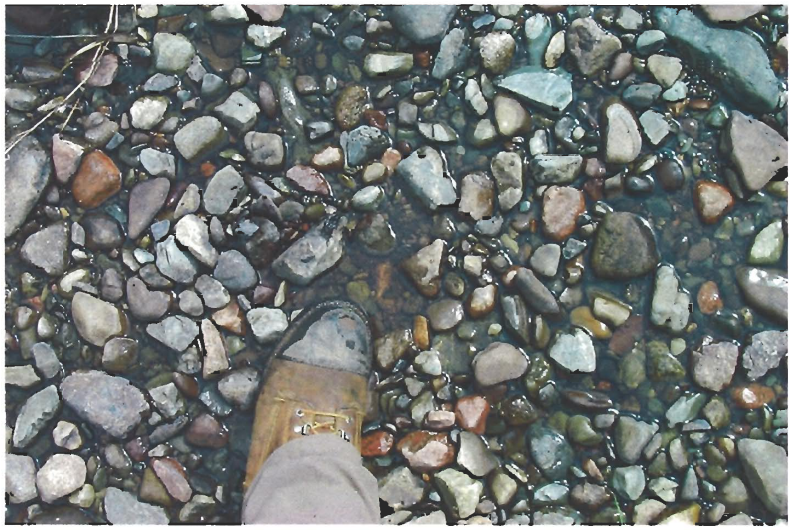
Photograph 26 – Un-named 4+150
Culvert under driveway upstream of crossing location

Photograph 27 – Un-named 5+490
Channel at proposed crossing location

Photograph 28 – West River 5+700
At proposed crossing location looking upstream

Photograph 29 – West River 5+700
Stable Rock at shallow channel

Photograph 30 – West River 5+700
At proposed crossing location looking downstream



Photograph 31 – West River 5+700
Stable Rock at bank

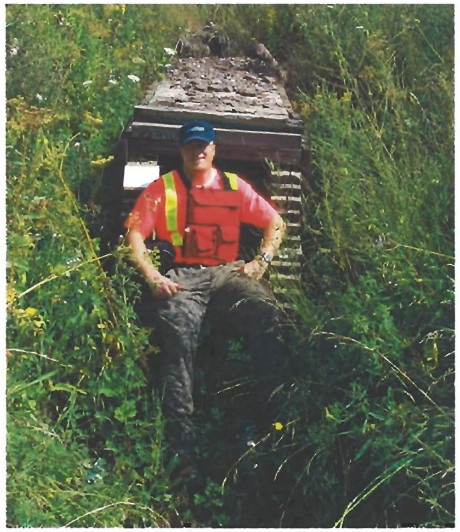
Photograph 32 – Un-named 6+950
At proposed crossing location looking upstream

Photograph 33 – Un-named 6+950
At proposed crossing stable rock in channel

Photograph 34 – Un-named 6+950
At proposed crossing location looking downstream

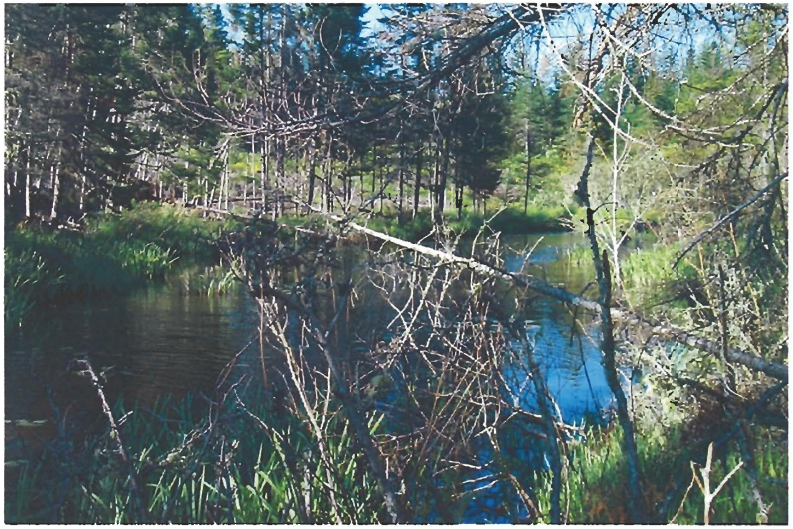
Photograph 35 – Existing Structure at Beech Hill Road
(downstream of un-named 6+950) upstream side

Photograph 36 – Existing Structure at Beech Hill Road
(downstream of un-named 6+950) downstream side



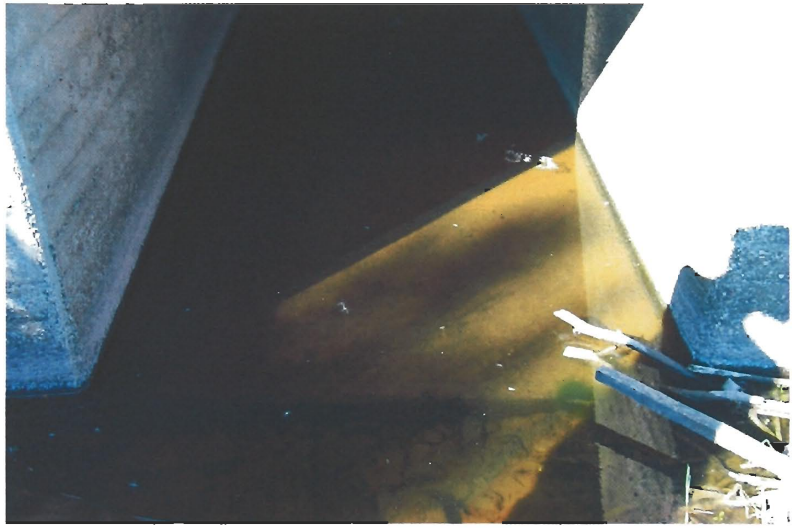
Photograph 37 – Existing Structure under highway 104
(downstream of un-named 6+950) downstream side

Photograph 38 – Un-named 8+150
At proposed crossing location looking upstream



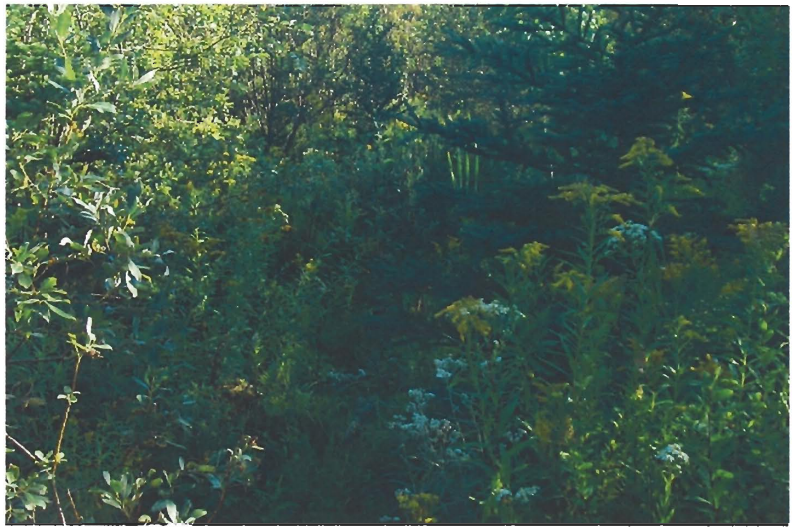
Photograph 39 – Un-named 8+150
At proposed crossing location looking downstream

Photograph 40 – Existing structure under highway 104
(downstream of un-named 8+150) upstream side



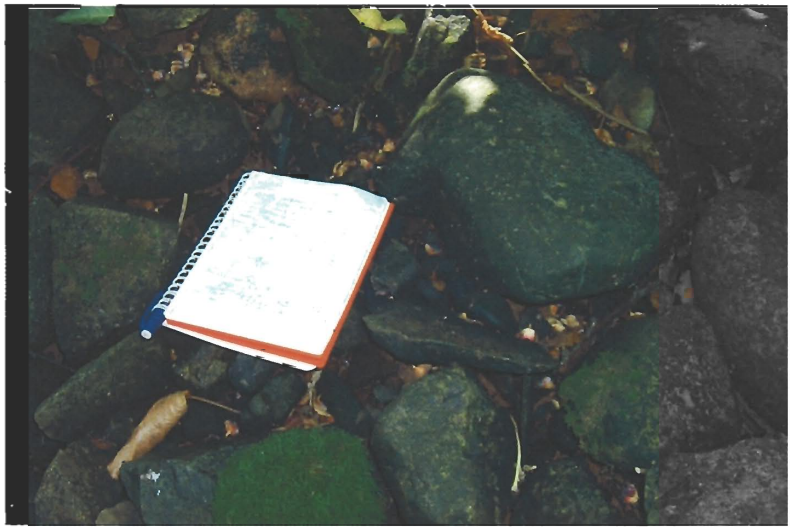
Photograph 41 – Existing structure under highway 104
(downstream of un-named 8+150) upstream side

Photograph 42 – Un-named 9+160
At proposed crossing location looking upstream



Photograph 43 – Un-named 9+160
At proposed crossing location looking downstream

Photograph 44 – Un-named 10+250
At proposed crossing location looking upstream



Photograph 45 – Un-named 10+250
At proposed crossing location stable rock

Photograph 46 – Existing structure under highway 104
(downstream of un-named 10+250) downstream side

Photograph 47 – Existing structure under highway 104
(downstream of un-named 10+250) upstream channel

Photograph 48 – Existing structure under highway 104
(downstream of un-named 10+250) upstream side

Photograph 49 – Existing structure under secondary road (downstream of un-named 10+250) downstream side

Photograph 50 – Existing structure under highway 104 (downstream of un-named 12+350) upstream side

Photograph 51 – Existing structure under secondary road (downstream of un-named 12+350) downstream side

Photograph 52 – Existing structure under secondary road (downstream of un-named 12+350) upstream side

Photograph 53 – Un-named 13+600
Existing structure at proposed crossing, upstream side

Photograph 54 – Un-named 13+600
Existing structure at proposed crossing, downstream side

Photograph 55 – Un-named 13+600
Looking downstream

Photograph 56 – Un-named 14+580
Existing structure at proposed crossing, upstream side

Photograph 57 – Un-named 14+580
Existing structure at proposed crossing, downstream side