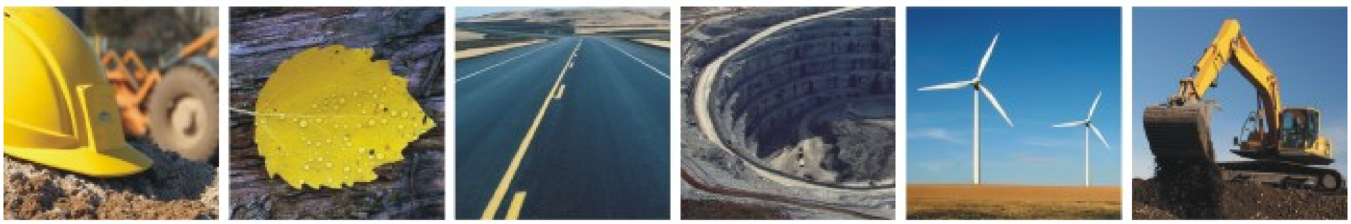
GOVERNMENT OF NUNAVUT, DEPARTMENT OF COMMUNITY & GOVERNMENT SERVICES

AIRPORT COMMUNITY ROAD WASHOUT
CORAL HARBOUR, NUNAVUT



REPORT

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1.0 INTRODUCTION

During the week of June 30, 2012 with spring snow melt and rain occurring, the Airport Community Road was washed out in two places northwest of the Fuel Storage Facility Tank Farm in Coral Harbor, Nunavut. The Government of Nunavut, Department of Community & Government Services (DCGS) requested EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company (EBA) to provide engineering services to prepare a report for different remediation options for the washout areas located on the Airport Community Road in Coral Harbour, Nunavut. The scope of work is defined in the Request for Proposal (RFP) issued by the DCGS on October 26, 2012 and the Proposal prepared by EBA on October 29, 2012:

- Review Owner's drawings and background information,
- Visit the site, and compile data available from the local people familiar with the history and flows during the site visit, and locate a suitable aggregate source.
- Assessment of the existing drainage infrastructure located near the Fuel Tank Station,
- Delineate catchment boundary using the existing topographic map, and estimate the peak design flows based on snow melt and rainfall Intensity Duration Frequency (IDF) data for different return periods using computer model XP SWMM,
- Hydrologic and hydraulic analyses for the catchment using XP SWMM model to assess the hydraulic capacity of the existing structures (Washouts 1 and 2),
- Prepare a report showing conceptual design for different options including preliminary construction costs and life cycle costs.

2.0 EXISTING DOCUMENTS

Several documents were reviewed to understand the existing conditions on site. The Community & Government Services Kivalliq Regional Projects Division prepared a report on the Airport Community Road Washout at Coral Harbour, Nunavut (Appendix A) that identifies the washout issue. With the spring snow melt occurring and moderate levels of rain for two weeks, water levels rose, and drained to the lowest elevation in the area located adjacent to the Fuel Storage Facility. Two existing 1000 mm diameter Corrugated Metal Pipe (CMP) culverts crossing the road did not have the capacity to effectively accommodate the peak flow, and the existing road washed out in two areas. The Airport Community Road was unusable for a week while the areas washed out were repaired. The Mayor indicated that the road washing out has been an issue four times in the last six or seven years confirming the inadequacy of the existing culvert system.

Coral Harbour is located on Southampton Island at the mouth of Hudson Bay. Looking at the topographic map of Coral Harbour (Figure 1), there is a large area draining from north to south towards Hudson Bay. The Post River cuts north to south through the catchment area, but the river becomes divided north of the Hamlet.

The geology, topography, and drainage adjacent to the Hamlet are also discussed in the Route Location Southampton Island N.W.T. report prepared by Airphoto Analysis Associates for the Department of Indian Affairs and Northern Development in April 1971 (Appendix B). The 1971 report was prepared to present alternative highway and power line routes using air photo interpretation but it offers few comments that may be relevant to this Coral Harbour Airport Community Road Washout report.

Geology:

- Precambrian rock upland (bedrock consisting of Precambrian granite and granite gneiss bedrock) and Palaeozoic sedimentary rock lowland.
- Foliation trends in a north-south direction and common in the Southeast area.
- Eskers and small glacial moraines have been deposited in the Southeast area, with isolated lows filled with glacial tills containing sands, silts, clays, and numerous boulders.
- Limestone can be found near the airstrip in river channels. Western and Northern areas have glacial moraines and glacial outwash deposits that may be an available source of granular material. Deposits of sands and silts can be found between ridges.

Topography and Drainage:

- The Post River has one or two channels for summer flow but other channels are utilized during the spring snow melt. The report noted that some channels may be frozen from the previous autumn, and runoff is accommodated in new channels. This creates a diffuse drainage system that is not consistent from year to year.
- Aerial photography taken August 14, 1969 showed three wash-out areas. The photos indicated that the washouts were 30, 100, and 120 feet in width and as deep as 2-3 feet.
- Watershed area was difficult to confirm but it was estimated at 129 square miles (33,410 ha).
- Due to permafrost, little infiltration of surface water is expected.
- If the rainfall peak discharge (1109 ft^3/s) and snow melt peak discharges (2320 ft^3/s) coincided, the maximum flow of the Post River near the sea would be 3400 ft^3/s (96.3 m^3/s). A design flow of 3500 ft^3/s (99.1 m^3/s) is recommended.

In addition to the 1971 report, a design brief for a Water Supply System design was done by Thurber Consultants Ltd. in September 21, 1979 for Coral Harbour that investigated the feasibility of several potential reservoir sites (Appendix C). In addition to an air photo interpretation, a field investigation and laboratory testing was carried out that included samples from a local borrow source 6 km west of the Hamlet on the airport road and several boreholes completed in April 1979 within ponds/lake areas. The areas north and west of the Hamlet are characterized by linear bedrock ridges aligned in an approximate north-south direction, and Coral Harbour is situated mainly on Precambrian granite gneiss. In the trough areas, where rock is not exposed, it is usually filled with fine grained sediments and brown fibrous peat up to 0.46 m deep. Local depressions in these troughs have shallow ponds throughout most of the year. Since surface drainage drains south towards the Coral Harbour Inlet, some of the channels between the bedrock ridges are covered with a slow moving water during snow melt. It also mentions washout outs at specific channel crossings along the airport road including the bridge crossing of the Post River.

The last report that was reviewed was a geotechnical evaluation done for the design of an ice arena in the Coral Harbour Area in September 1985 by Thurber Consultants Ltd (Appendix D). Five areas just west and north of the fuel storage facility were analysed through air photo and a visual site inspection, and different foundation types and construction of fills were discussed for the five areas. Like the previous reports, the 1985 report mentions how the area was once covered by glaciers and once the glacial ice retreated, it left fine grained marine sediments ranging from sand to clay between rock ridges and cobbles and boulders ranging from 0.5m to 2.0m between the fine marine sediments and the bedrock surface. Ample sources of granular material were found to occur in the Coral Harbour area but a source for concrete aggregate was difficult to find. It also mentions that the area is covered with moss and other vegetation to some extent. Of particular interest, it notes that Coral Harbour is within the zone of continuous permafrost, and the maximum active layer was estimated to be 1 to 2 metres.

Finally, Environment Canada information was reviewed for temperatures, rainfall, and snowfall at Coral Harbour, and Table 1 shows some of the relevant information.

Table 1 – Environment Canada Data for Coral Harbour (Canadian Climate Normals - 1971-2000)

Extreme Maximum (°C)	23.3
Extreme Daily Rainfall (mm)	33.1
Extreme Snow Depth (cm)	109
Maximum Hourly Wind Speed (km/h)	89
Below 0°C (Degree Days)	4877.4
Above 0°C (Degree Days)	679.9

3.0 SITE INVESTIGATION

Between November 12th to 18th, 2012, Mr. Jagadish Kayastha, P.Eng. from EBA met with Mr. Bryan Purdy, P.Eng. of DCGS on site at the Hamlet of Coral Harbour for a visual inspection of the washout areas, examining existing drainage infrastructure along the Airport Community Road, and consultation with the Mayor and other locals.

3.1 Site Conditions

Although the ground was covered in snow during the visit, the trip was useful in understanding the existing drainage infrastructure on site, and other site conditions. The different culverts and bridge structures were located using a GPS handheld device and the locations were plotted on Figure 2 with the diameters identified. The high point of the road is approximately 3.2 km west of the town and the road runoff drains towards an isolated low area adjacent to the fuel tank area with other elevated areas like the cemetery along the stretch of road. Coral Harbour is located on an elevated area since culverts at Crossings 11 and 12 are also lower than the Hamlet, and when the washouts occurred in June 2012, the flooding area isolated the Hamlet, and prevented ingress and egress from the Hamlet. Since there is a fuel pipeline mounted on supports running east out of the Fuel Tank area and south along the edge of the Hamlet, the flow velocity and energy through this area may call for additional measures such as rip rap to avoid damage to the pipeline and its foundation.

Crossings 1 to 7, Crossing 8 located at Washout 1, and Crossing 9 located at Washout 2 flow north to south. The culvert at Crossing 6 was installed in a high area but was done to control flow through the Yellow Bridge after the 2012 spring flood. Crossings 11 to 12 flow east to west but when Washout 1 and Washout 2 occurred, the flows reversed. The culvert ends extended approximately 2-2.5m from the top of the road, and appeared to be in acceptable condition but there was localized scouring around the area and no rip rap at the inlet and outlet of the culvert structures. There were cobbles and boulders located along the road during the site visit and communication with a local Contractor identified a rip rap material source located 400 m before the Kirchoffer Bridge. Granular material on site does not appear to be an issue after consulting with the Hamlet Senior Administrative Officer (SAO) and other locals. There are three granular borrow pits within 15 kilometers of the Hamlet that can be considered for road repair. The gradations and material types may have to be verified during detailed design.

During the site visit, it was noted that the edges of the road did not have a gentle slope when tying into existing ground. After speaking with the SAO, it was determined that the steep slopes was due to inadequate construction time to complete. When the road was repaired after the wash out, the construction crew did not have enough time to reconstruct the side slopes due to the long stretch of road and other commitments in the Hamlet before the ground froze.

3.2 Meeting With Local Officials

Meeting minutes were taken during the meeting with EBA, DCGS, the Mayor, the SAO, former Mayors, and senior elder in attendance. (Appendix E).

4.0 HYDROLOGIC AND HYDRAULIC ANALYSIS

The main goal of hydrologic and hydraulic analysis was to obtain (i) peak runoff from the given catchment due to rainfall and snow melt from spring flooding, (ii) the hydraulic capacity of the existing hydraulic structures for the given watershed area, and (iii) the design for the hydraulic structures for Crossings 9 and 10 so that there is no road overtopping in the event of spring flooding in future. The following assumptions were made for the hydraulic assessment of the existing structures.

- The longitudinal bed slope is 0.1%;
- The assessed hydraulic capacity is estimated without any road over topping;
- Culvert pipe diameters and the bridge opening is based on information provided by the Hamlet of Coral Harbour office, Nunavut; and
- Culverts entrance type is projecting from the fill.

Using the HY-8 (version 6.0) computer program, the flow capacity has been assessed for the existing hydraulic structures along the Airport Community Road between the cottage junction (high point) and the entrance into the Hamlet, as shown on Figure 2.

HY-8 Versions 6.0 was developed by Philip L. Thompson and was provided to the Federal Highway Administration (FHWA) USA for distribution. HY-8 is a computerized implementation of FHWA-endorsed culvert hydraulic analysis approaches and can be simply used for the following purposes:

- Hydraulic design of Highway Culverts;
- Hydraulic design of energy dissipaters for Culverts and Channels;
- Effects of inlet geometry on hydraulic performance of Box Culverts; and
- Hydraulic loss coefficients for Culverts.

4.1 Existing Conditions

Section 4.1 provides the hydraulic capacity assessments using the HY-8 model for the existing culverts and bridge.

Table 2 shows a summary of the hydraulic capacity of the existing crossing structures, and Sections 4.11 to 4.18 describe the analysis in more detail.

Table 2: Hydraulics Characteristics of the Existing Culverts and Bridge

Hydraulic Structures	**Length** (m)	**Slope** (%)	**Total Flow** (m^3/s)	**Headwater** (m)*
Crossings 1, 2 and 3: 1000 mm CMP	12	0.1	5.0	3.5
Crossing 4: 8 Barrels of 1200 mm CMP	12	0.1	20.0	3.7
Crossing 5: 2 Barrels of 1200 mm CMP	12	0.1	5.0	3.7
Crossing 6: 1200 mm CMP	12	0.1	3.0	4.0
Crossing 7: Yellow Bridge (8.5m x 2.5 m opening)	6	0.1	40.0	4.0
Crossing 8: 600 mm CMP	12	0.1	0.6	3.2
Crossing 9: Washout 1: 1000 mm CMP	12	0.1	3.0	4.0
Crossing 10: Washout 2: 1000 mm CMP	12	0.1	2.4	3.5
Total			79	

*Note: The headwater level elevation shown assumes the invert elevation is 2.0 m.

There is neither inlet and outlet control of the existing culverts and nor any effects from high tides.

4.1.1 Crossings 1, 2 and 3

Crossings 1, 2 and 3 located after the cottage junction road (high point) along the Coral Harbour Airport Community Road are single corrugated metal pipe (CMP) structure of 1000 mm diameter. The combined hydraulic capacity of these three culverts is estimated at 5.0 m^3/s with headwater elevation at 3.45 m as shown on Figure 3.

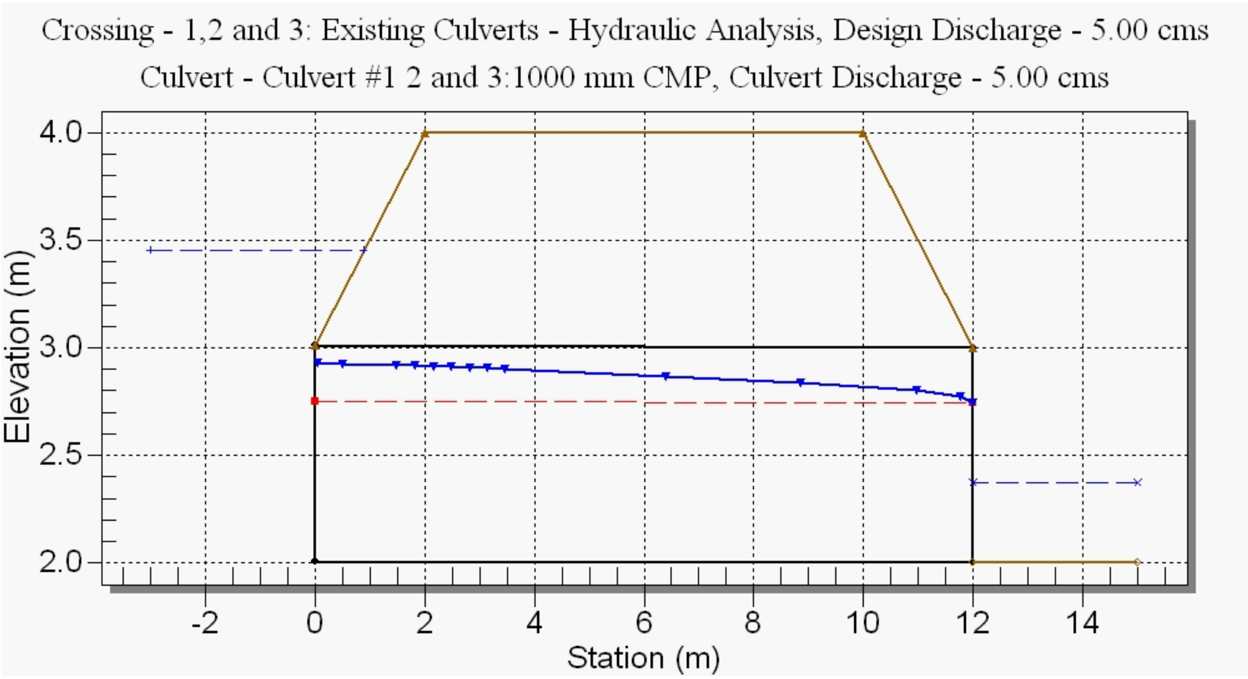

Figure 3: Culvert profile showing headwater and its flow capacity

4.1.2 Crossing 4

Crossing 4 consists of 8 barrels of 1200 mm CMP installed parallel without any spacing between the pipes. Total hydraulic capacity of these eight culverts is estimated at 20.0 m^3/s with a headwater elevation at 3.65 m as shown on Figure 4.

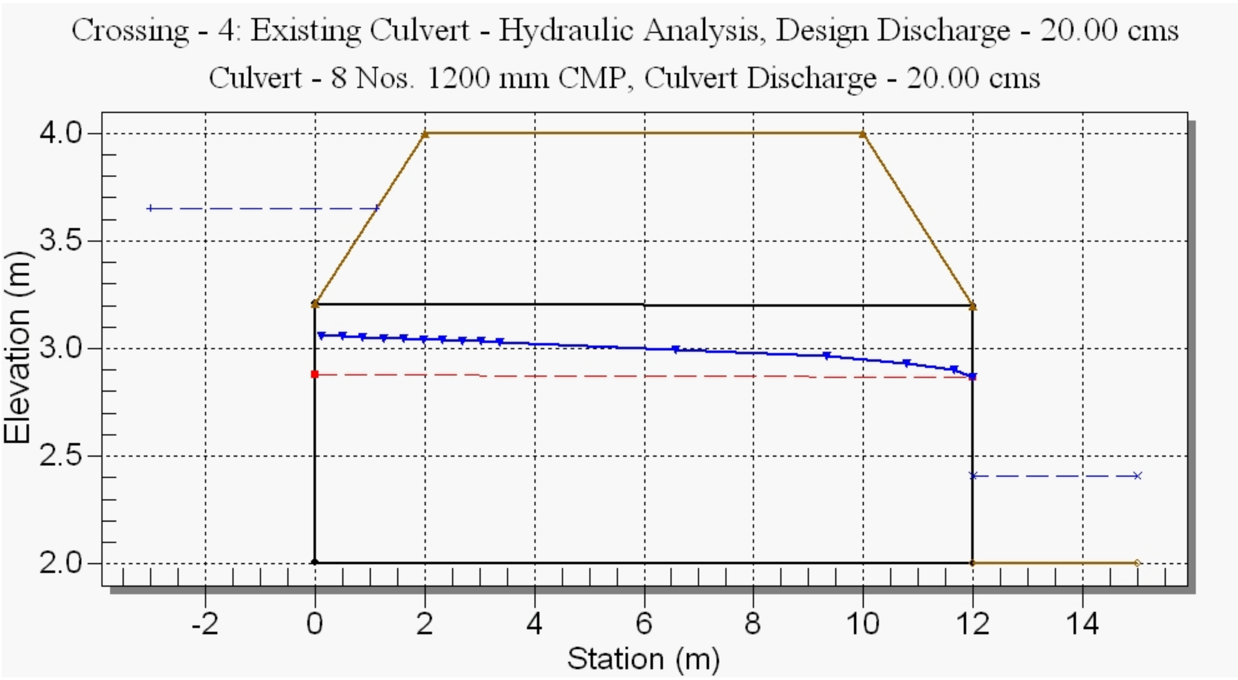

Figure 4: Culvert profile showing headwater and its flow capacity

4.1.3 Crossing 5

Crossing 5 consists of two parallel barrels of 1200 mm CMP with 1.0 m spacing. Total hydraulic capacity of these three culverts is estimated at 5.0 m^3/s with a headwater elevation at 3.65 m as shown on Figure 5.

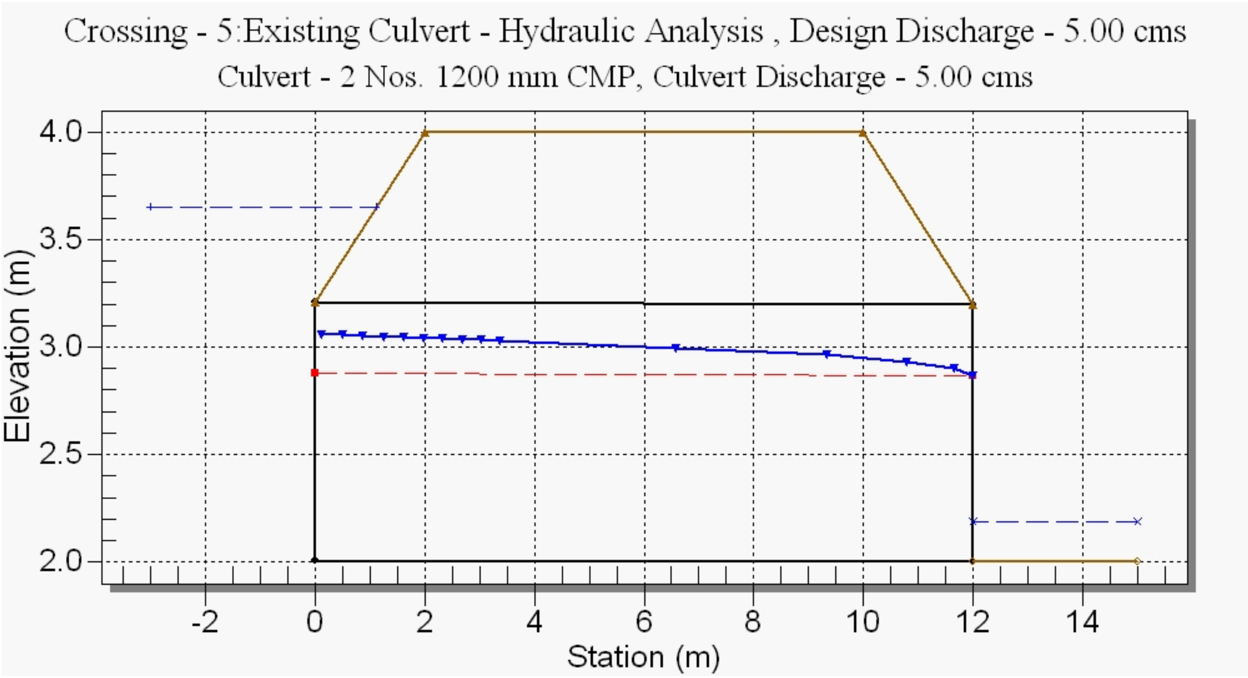

Figure 5: Culvert profile showing headwater and its flow capacity

4.1.4 Crossing 6

Crossing 6 consists of one barrel of 1200 mm CMP. Total hydraulic capacity of the culvert is estimated at 3.0 m^3/s with a headwater elevation at 4.02 m as shown on Figure 6.

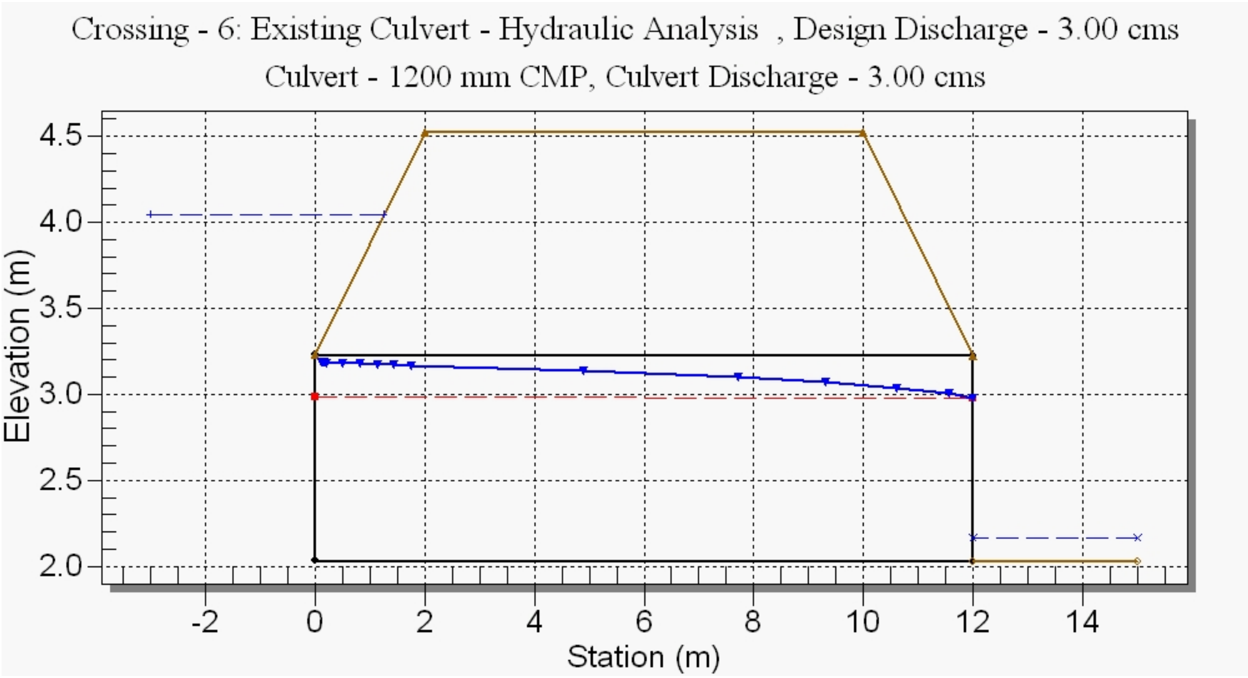

Figure 6: Culvert profile showing headwater and its flow capacity

4.1.5 Crossing 7:

Crossing 7 is the Yellow Bridge with a clear opening of approximately 8.5 m span and 2.5 m rise with rock gabion basket abutments. Road top width is approximately 4.5 m with steel handrail of 0.8 m high. Total hydraulic capacity of the bridge is estimated at 40.0 m^3/s with a headwater elevation of 4.2 m and free board of 0.25 m as shown on Figure 7.

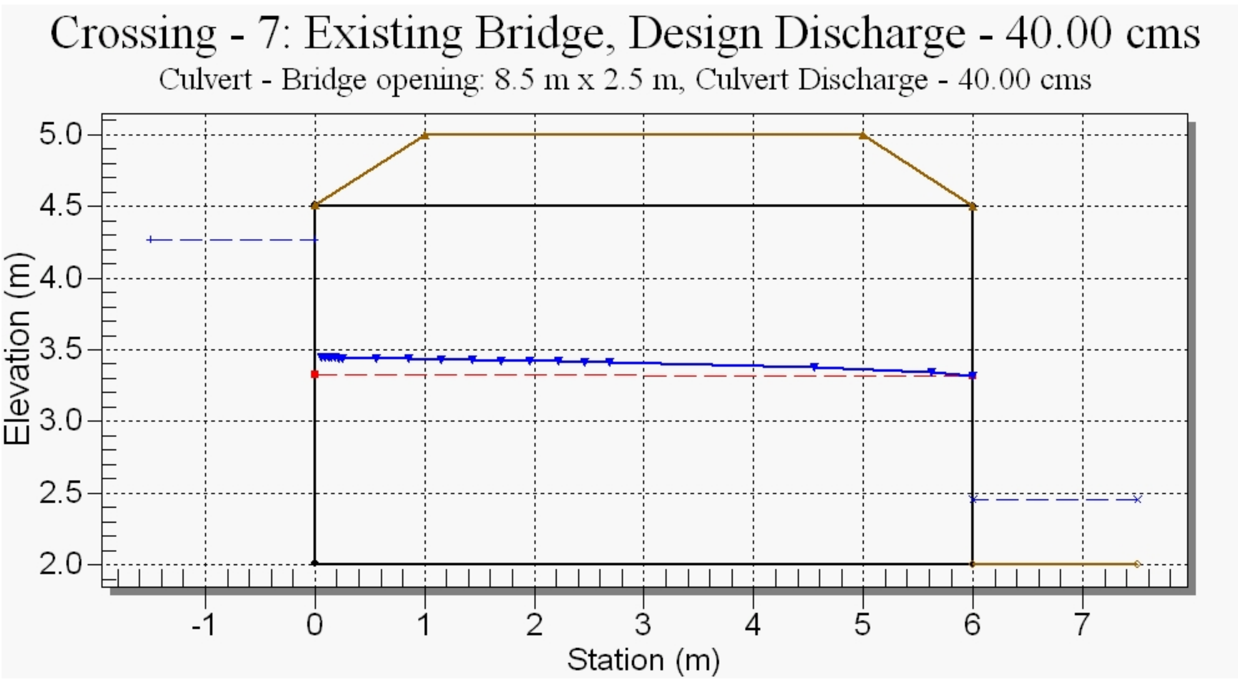

Figure 7: Culvert profile showing headwater and its flow capacity

4.1.6 Crossing 8

Crossing 8 consists of one barrel of 600 mm CMP. Total hydraulic capacity of the culvert is estimated at 0.6 m^3/s with a headwater elevation at 3.2 m as shown on Figure 8.

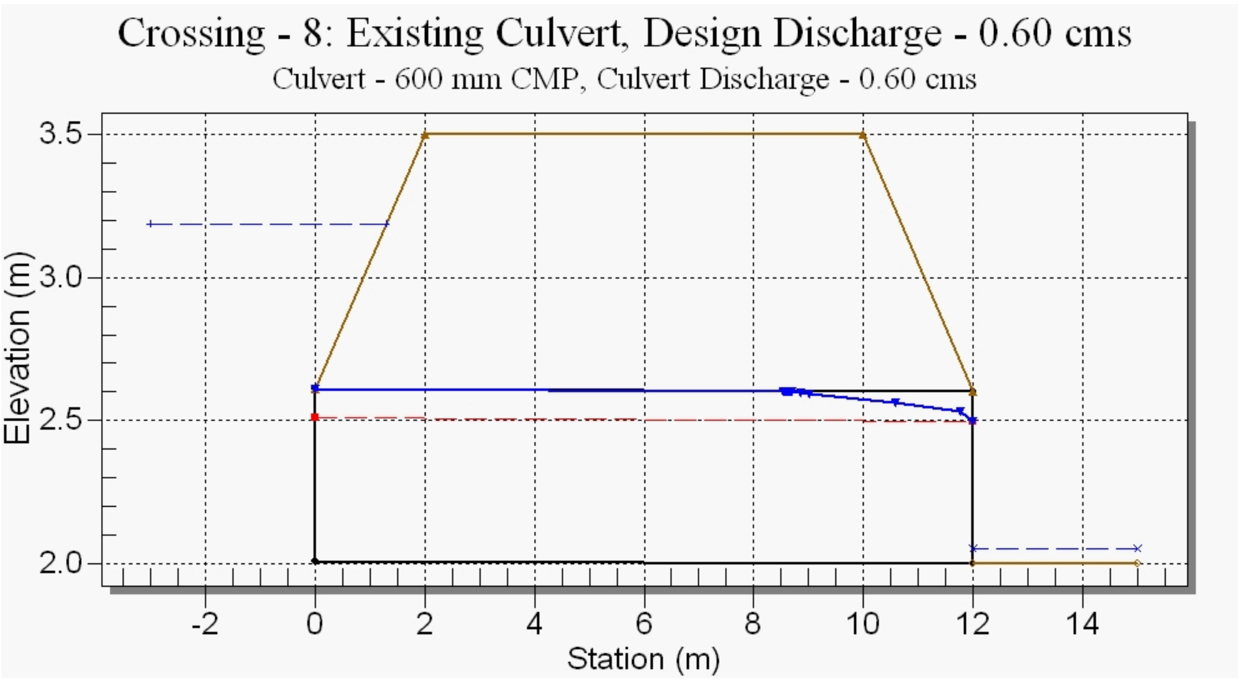

Figure 8: Culvert profile showing headwater and its flow capacity

4.1.7 Crossing 9

Culvert 9 consists of 1 barrel of 1200 mm CMP. Total hydraulic capacity of the culvert is estimated at less than 3.0 m^3/s with a headwater elevation at 4.0 m as shown on Figure 9. Spring flood in June 2012 washed out about 30 m stretch of road on the right side of the culvert as shown on Figure 10.

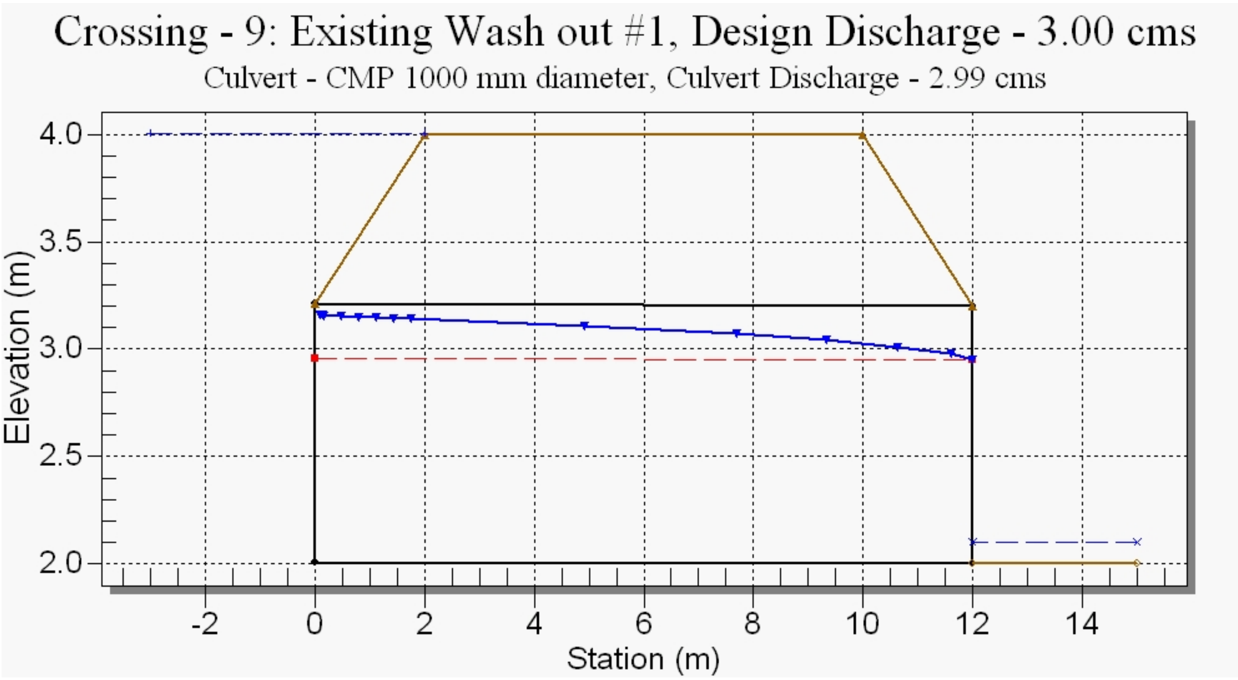

Figure 9: Culvert profile showing headwater and its flow capacity

4.1.8 Crossing 10

Crossing 10 consists of one barrel of 1200 mm CMP. Total hydraulic capacity of the culvert is estimated at less than 2.4 m^3/s with a headwater elevation at 3.5 m as shown on Figure 10. The spring flood in June 2012 washed out about a 50 m stretch of road on the right side of the culvert as shown on Figure 11.

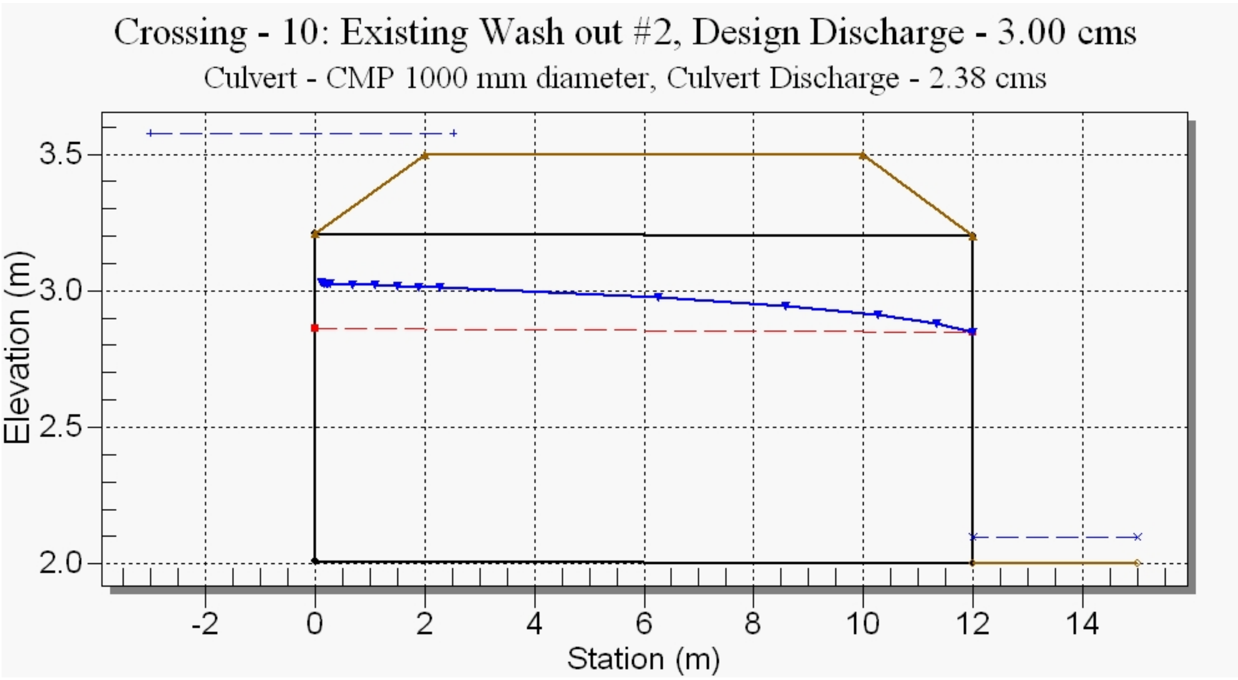

Figure 10: Culvert profile showing headwater and its flow capacity

4.2 Post-development Condition

The storage and melting of snow plays an important role in the watershed response of the Post River in Coral Harbour, Nunavut. The reliable prediction of the rate of snow melt and release of water from a snow pack are a per-requisite to the efficient design and operation of the existing hydraulic structures such as culverts and bridges.

Hydrologic analysis of the Post River watershed at post-development condition was carried out using XP SWMM hydro dynamic model. The analysis was done using the following criteria applicable to cold climate:

- Snowmelt;
- Rain-on-snow; and
- Frozen ground with 85% imperviousness ratio during spring flooding season.

An extreme flood event, such as a combination of rain-on-snow and spring snowmelt event, which produces high runoff volume with the 85% frozen ground condition, was considered for this analysis. The existing road is about 3 km long between the high point and the entrance of the Coral Harbour Hamlet, and acts as a weir during the peak snow melt and rain condition. This condition creates a ponding area of up to 128 ha upstream of the road, and generates 128 ha-m storage volume because of the limited hydraulic capacities of the culverts and bridge structures along the road as shown on Figure 11. The ponding will not typically over-top under the design snowmelt and or rain-on-snow events alone. Hydrologic and hydraulics analysis using XP SWMM model is given below.

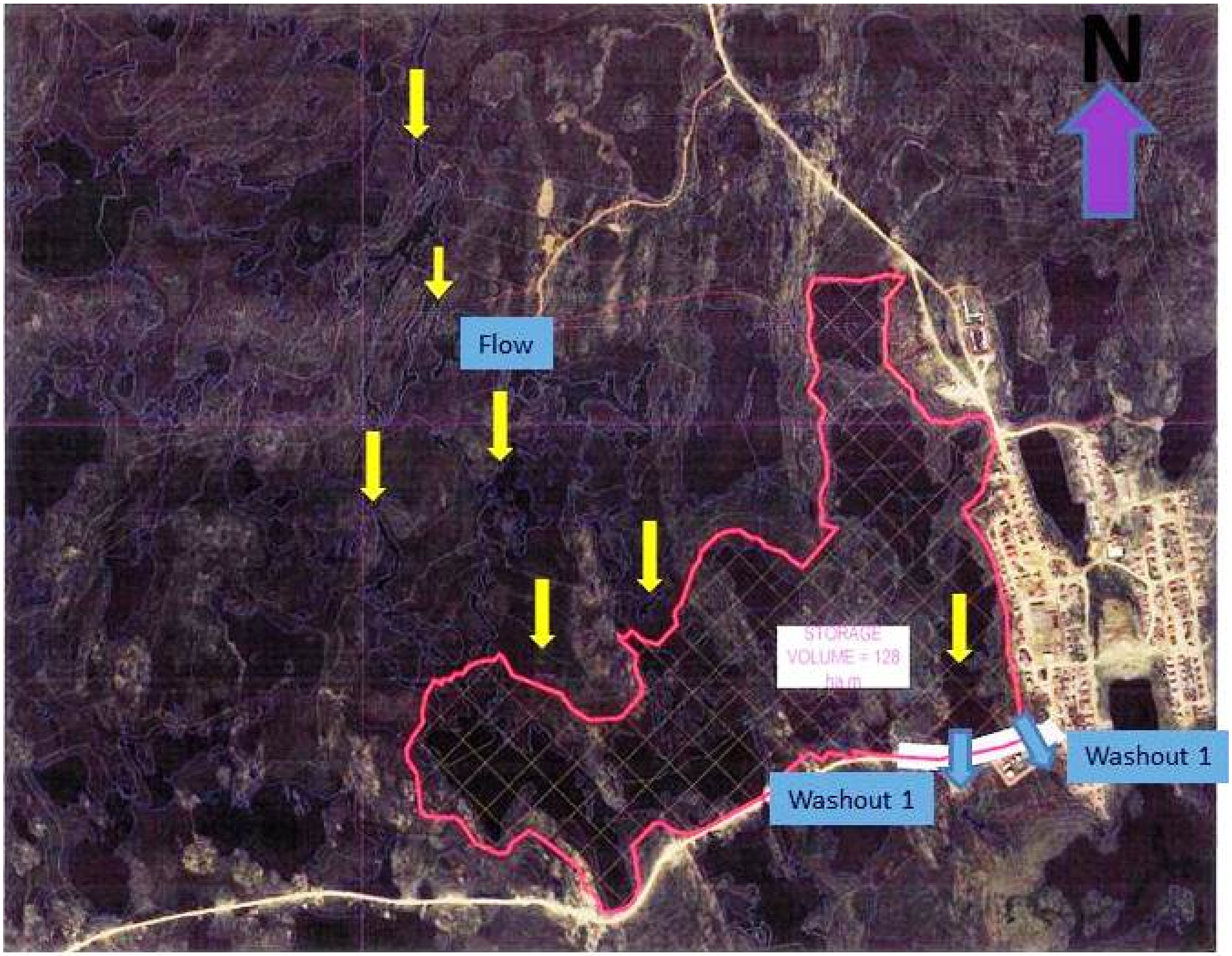

Figure 11: Ponding area during spring flooding.

Drainage evaluations were carried out to calculate design flows for two proposed culvert locations near the road washouts, based on the total required flow capacity, and subtracting the current flow capacities for the existing bridge and culvert structures (Crossings 1 to 8).

4.3 XP SWMM Model

XP-SWMM is a dynamic rainfall-runoff simulation model that is based on the US Environmental Protection Agency's original Storm Water Management Model (SWMM), with a computerized graphical interface provided by XP Software. The model, which is used for a single events or continuous simulation, generates local run-off hydrographs using rainfall data and watershed characteristics and can route the runoff through a system of pipes, ponds, and channels. The model can account for detention in ponding areas, backflow in pipes, surcharging of manholes, as well as tail-water conditions that may exist and affect upstream storage or pipe flows. This model can also analyze snowmelt runoff using the Degree-Day method, which is a simple method of calculating snowmelt assuming the snowmelt is related only to the average or maximum air temperature and snowmelt factor. Large snow piles produce the highest melt rate during spring flooding in Coral Harbour. The historical record high temperature during the month of June is 23.3°C (June 30, 1973). Similarly, the maximum recorded wind speed in June is 89 km/hour.

Flows caused by rain-on-snow events fall on relatively impervious soils because of frozen ground conditions during early and or late spring season. The maximum recorded precipitation recorded by Environment Canada during June is 33.1 mm on June 17, 1978, which is equivalent to the 10 year Chicago storm event for 24 hours duration as per the IDF curve available from the Cape Dorset Airport, Nunavut. Figure 12 shows rainfall intensity generated from Intensity-Duration-Frequency (IDF) parameters for the 10 year Chicago storm event for 24 hours duration. The adjusted IDF parameters used are given below.

$a = 107.326 \qquad b = 9.025 \qquad c = 0.593$

Total design storm amount for the 10 year storm event is 34.4 mm.

4.3.1 Single Event-based Hydrologic Analysis

Estimates of peak flow are necessary for evaluating conveyance facilities and estimating storm storage capacity. All hydrologic processes including snowmelt, evaporation, infiltration, and surface ponding were modeled using XP-SWMM. An event-based hydrologic model, which simulates design rainfall event plus snowmelt, was used to assess the drainage study of the existing snow disposal site. A 10 year Chicago design rainfall for 24 hours duration with infiltration defined by Green-Amp equation were used as input parameters for computing storm runoff hydrographs. Figure 12 shows the temporal distribution of the rainfall, which is characterized by storm peak of 18.7 mm/hour intensity. The longer duration (i.e., 24-hour) storm is usually the controlling type of storm for the design of hydraulic conveyance structure, where both peak discharge and total runoff volume are important considerations.

Snowmelt adds significant runoff volume to a hydrograph and this is more significant in Coral Harbour due to its south exposed large watershed area with very little vegetation (Tundra area). Therefore, a snowmelt factor of 0.15 mm per hour per degree Celsius, based on 23.3°C surface temperature and 1.5 m average snow depth are assumed as model input parameters.

Estimating watershed runoff in areas of seasonal or a long term snow cover requires a snowmelt algorithm to be part of the modeling system. In recent years, advances in computing speed have made possible the implementation of more one-dimensional snowpack models and distributed model techniques. XP SWMM hydrodynamic model, a single event simulation with degree-day temperature index method was used in the Post River hydrologic analysis of runoff calculation due to combination of rain and snow melt. The temperature index degree-day method uses the following equation:

M = Cd (Ta – Tb) (1)

Where, M = snowmelt (mm per day),
Cd = degree-day melt coefficient (mm per degree C per day),
Ta = air temperature (degree C),
Tb = base temperature at which melt will occur, normally 00 C.

As shown on the above equation, air temperature is the single most reliable index to snow melt. Since snow melt does not occur with temperature below freezing, the temperature data are commonly converted to degree-days above some base, usually the freezing point. According to local officials and based on spring flooding history for last ten years, the worst case scenario of flooding due to both rain and snow melt combination in Coral Harbour occurs during the end of June.

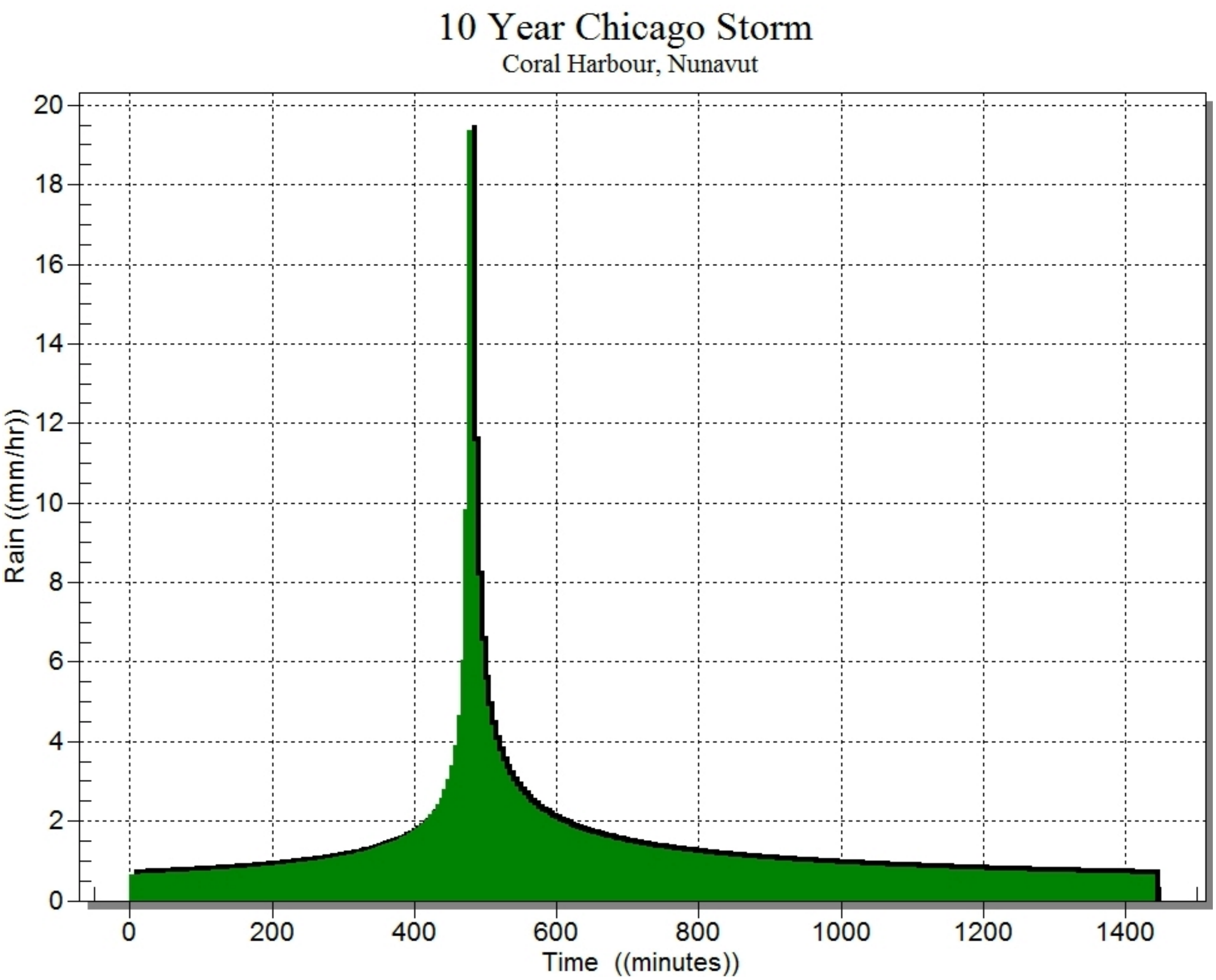

Figure 12: Hyetograph for the 10 year Chicago storm event, Coral Harbor, Nunavut

The Post River drainage area comprises 30,350 ha and the elevations of the Airport Community Road washout locations in the vicinity of the town and the highest watershed elevation are 2.5 m and 520 m, respectively within the river stretch of about 52 km length. The average watershed slope is 0.8%. Since surface air temperature is an inverse function of elevation, the rate of snow melt decreases with elevation. An assumption of mean daily surface air temperature drops about 1 Celsius degree per 100 m increase in elevation had been considered and therefore, a maximum air temperature of 18^0 C was used instead of 23.3^0 C in model input parameters. Also, according to officials, there is typically no residual snow left within a two kilometre radius of the washout areas at the end of June and therefore, the assumption of the effective snow covered area of 60% which contributes to the snow melt runoff was used. Another input parameter for the snow melt runoff is wind speed. However, the analysis was done with a single event simulation, and the monthly wind speed does not affect the snow melt runoff estimation.

The combination of the extreme rainfall and the maximum recorded adjusted temperatures were used as the model input parameters in the XP SWMM single event simulation for 24 hours period. As the Intensity Duration Frequency (IDF) curve for the Coral Harbour airport is not available, Cape Dorset airport IDF curve with rainfall data from 1971 to 1990 was used to estimate rainfall runoff. This airport is situated at same latitude and elevation as that of Coral Harbour airport and about 300 km east of Coral Harbour.

4.3.2 Model Results

The estimated peak flow of 126 m^3/s was obtained from XP SWMM model based on a combination of the 10-year storm event with storm duration 24 hours and the snowmelt with respect to the maximum recorded temperature of 23°C. The Hyetograph and combined hydrograph obtained from the XP SWMM model run is shown on Figure 13.

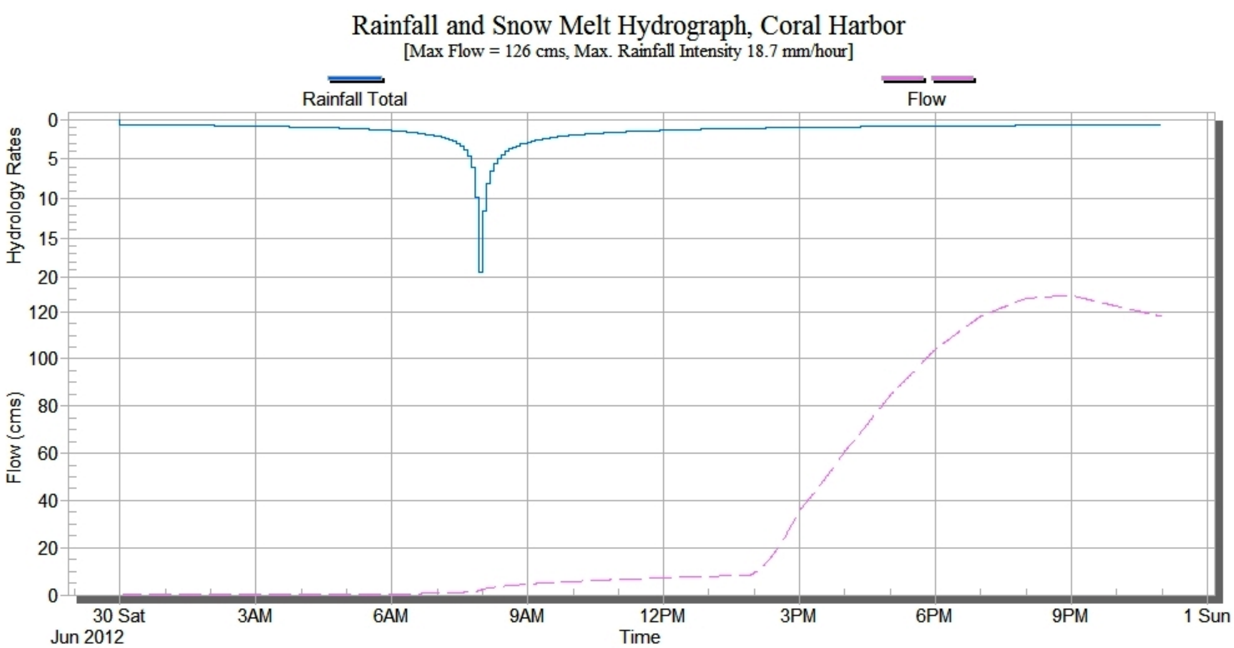

Figure 13: Hyetograph (10 year storm event, 24 hours duration) and Hydrograph from XP SWMM model run during snow melt.

Total peak flow obtained from the watershed is separated into two components as culvert flow and bridge flow as shown on Figures 14 and 15.

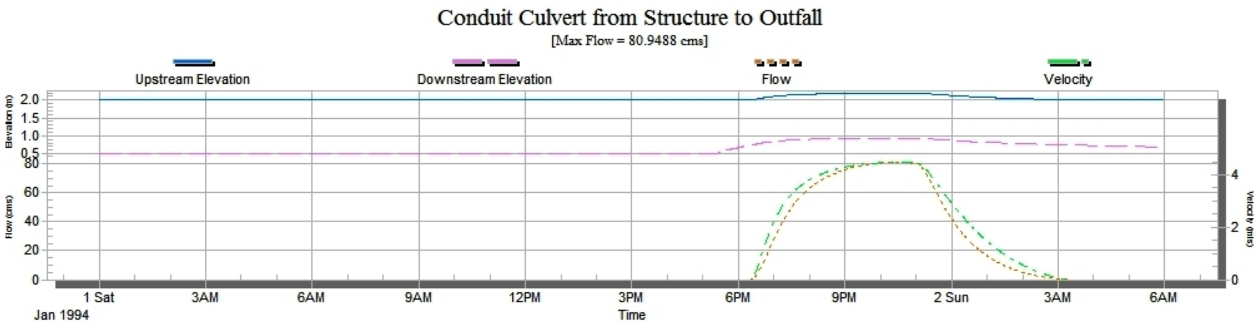

Figure 14: Hydraulics characteristics of the culvert during snow melt and rainfall.

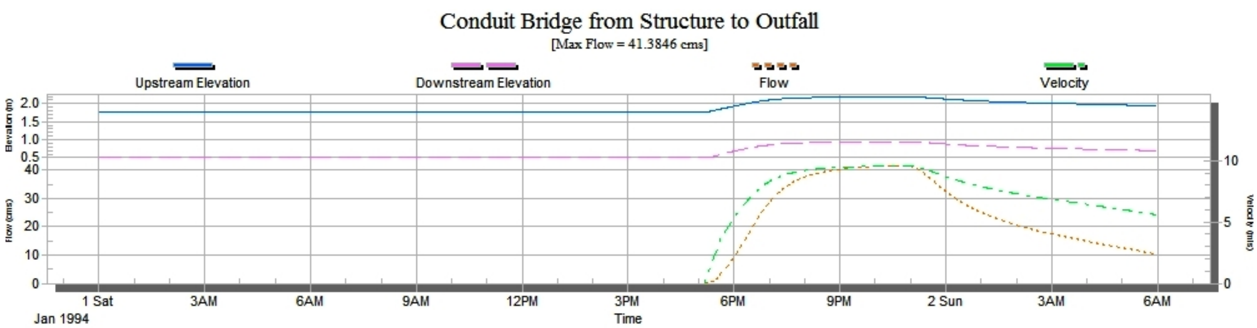

Figure 15: Hydraulics characteristics of the bridge during snow melt and rainfall.

The existing culverts and bridge structures can handle 73.6 m^3/s and the remaining flow of 52.4 m^3/s will be handled by proposed hydraulic structures at Crossings 9 and 10, respectively as discussed in Section 4.4.

4.4 Design Options

Three options were looked at to meet the 52.4 m^3/s capacity shortfall required at Crossings 9 and 10. The following three design options explain the hydraulics structures requirements at Crossings 9 and 10.

4.4.1 Design Option 1

Option 1 provides a combination of bridge and culvert structures at Washouts 1 and 2, respectively. The proposed bridge structure at Crossing 9 is similar to the existing yellow bridge with hydraulic capacity of 40 m^3/s and a free board of 0.5 m during spring flooding condition as shown on Figure 16.

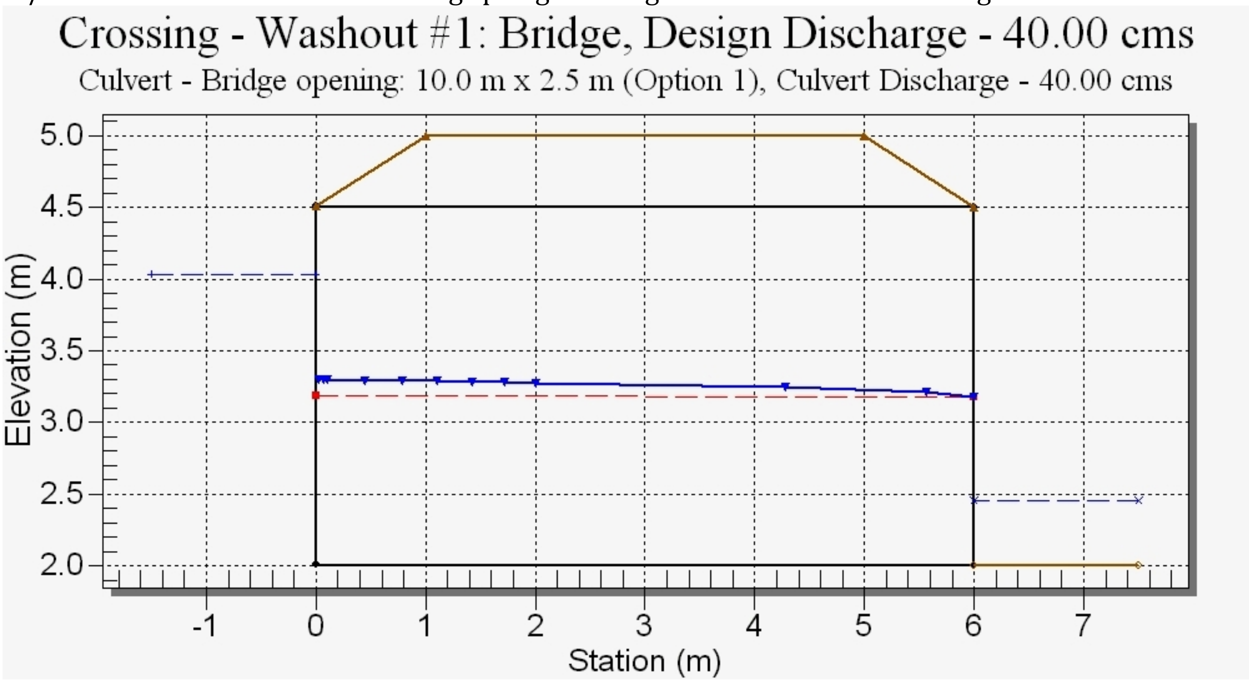

Figure 16: Bridge option at washout 1 location.

The proposed culvert structure at Crossing 10 is the corrugated metal pipe (CMP) of 1500 mm diameter. Four barrels of these CMP can handle 12.5 m^3/s flows with a headwater of 1.6 m as shown on Figure 17. The culvert length is 12 m and sloped at 0.1%. Rip-rap protection is required at both inlet and outlet of the structure.

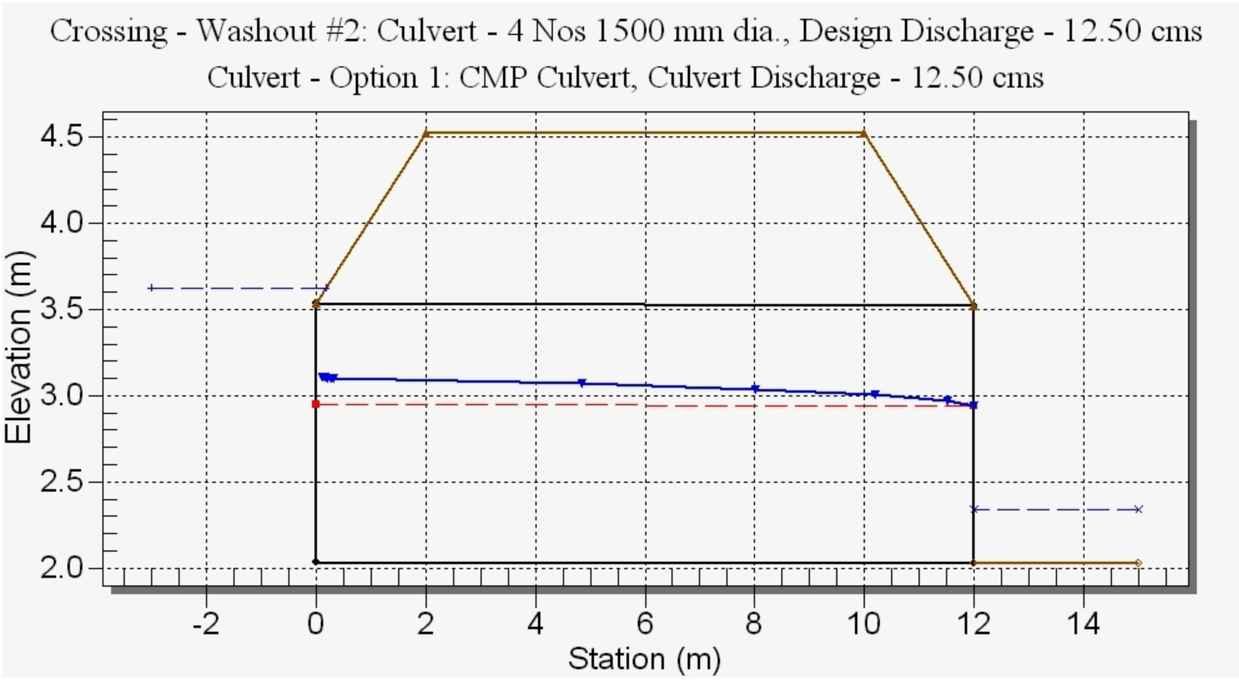

Figure 17: Bridge option at Washout 1 location.

4.4.2 Design Option 2

Hydraulic structure for Option 2 is a concrete box culvert of opening size 2400 mm span and 1800 mm rise. Total flow of 52.4 m^3/s is distributed equally to both Crossing 9 (Washout 1) and Crossing 10 Washout 2). Therefore, each crossing needs three barrels of concrete box section of 2400 mm x1800 mm which can handle 26.2 m^3/s flows at headwater 1.95 m as shown on Figures 18 and 19. The culvert length is 12 m and sloped at 0.1%. Rip-rap protection is required at both inlet and outlet of the structure.

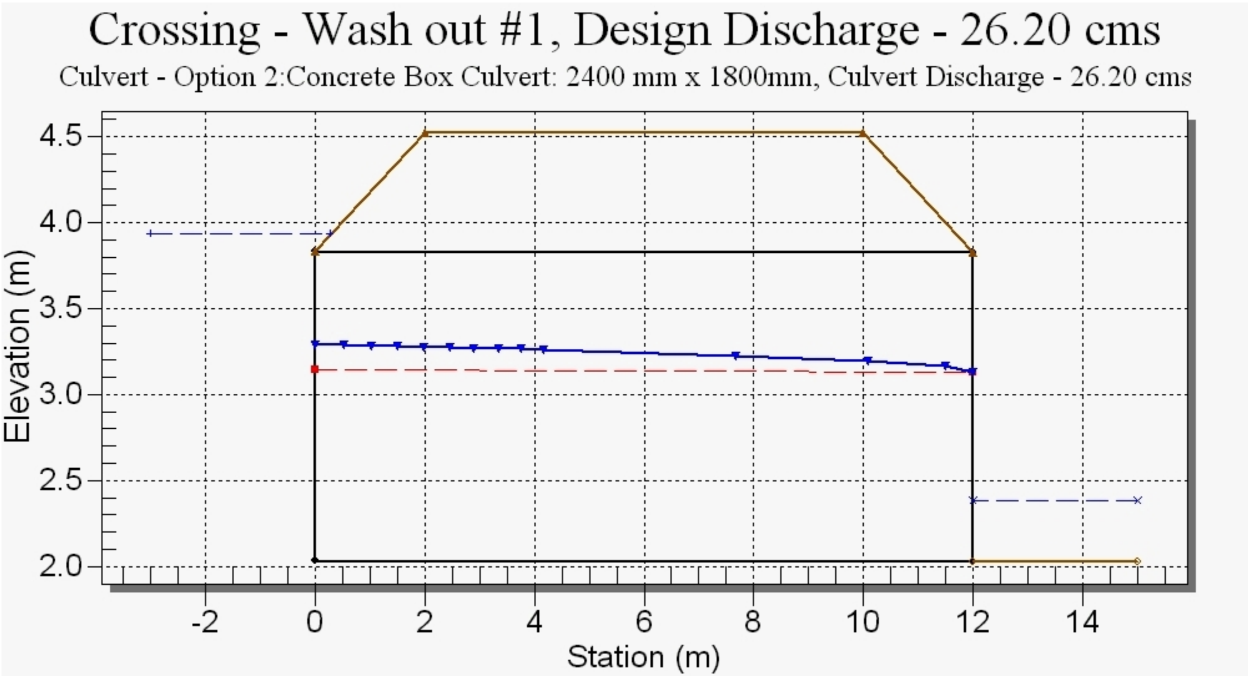

Figure 18: Bridge option at Washout 1 location.

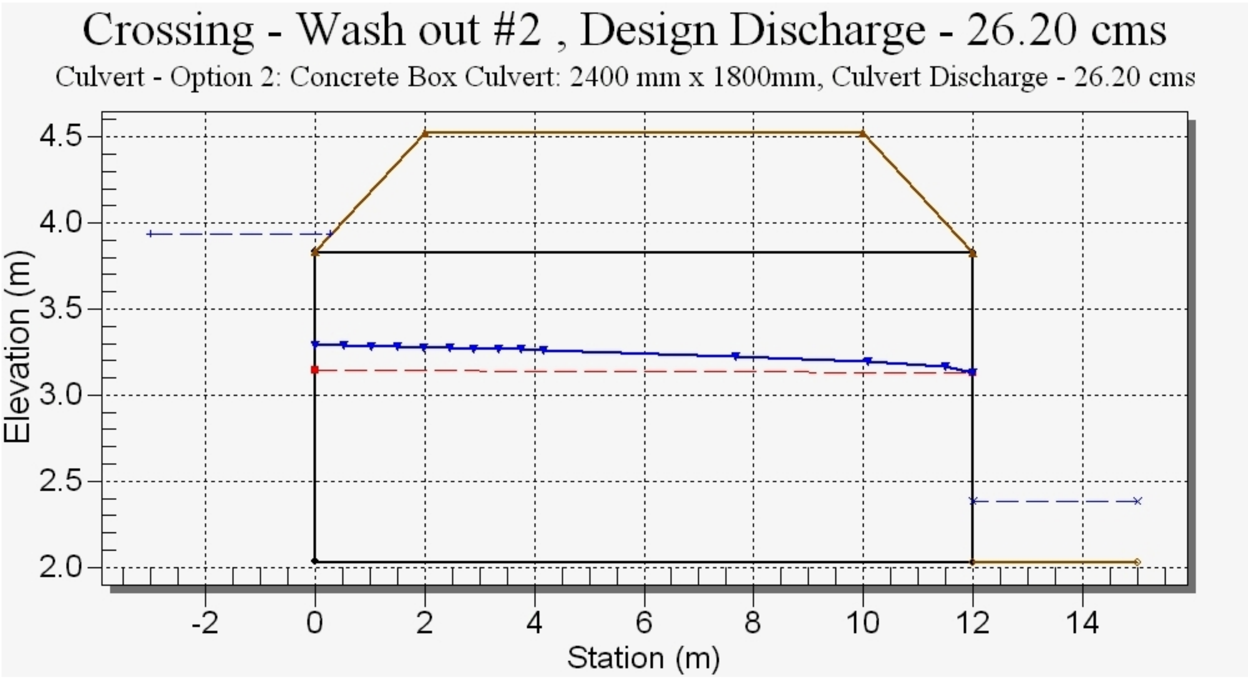

Figure 19: Bridge option at washout 1 location.

4.4.3 Design Option 3

Hydraulic structure for Option 3 is a steel box culvert of opening size 6400 mm span and 1800 mm rise. Total flow of 52.4 m^3/s is distributed equally to both Crossing 9 (Washout 1) and Crossing 10 (Washout 2). Therefore, each crossing with a single steel box section of 6400 mm by 1800 mm can handle 26.2 m^3/s flows at headwater 2.1 m as shown on Figures 20 and 21. The culvert length is 14 m and sloped at 0.1%. Rip-rap protection is required at both inlet and outlet of the structure.

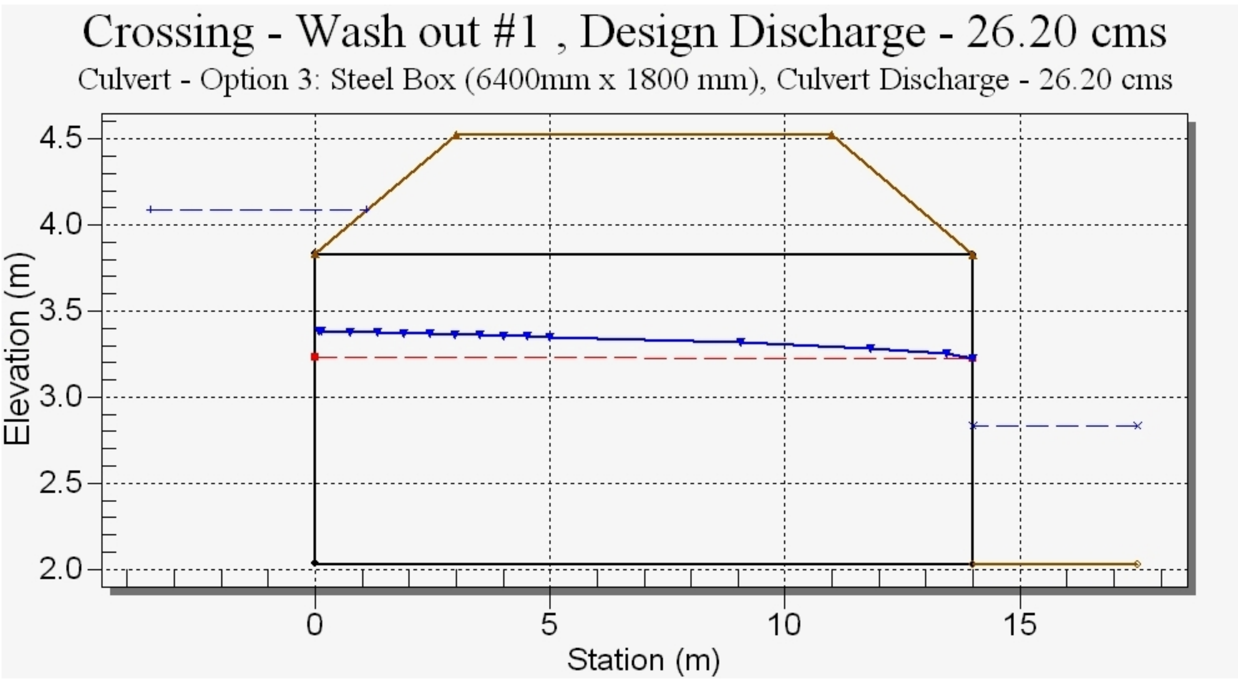

Figure 20: Bridge option at Washout 1 location.

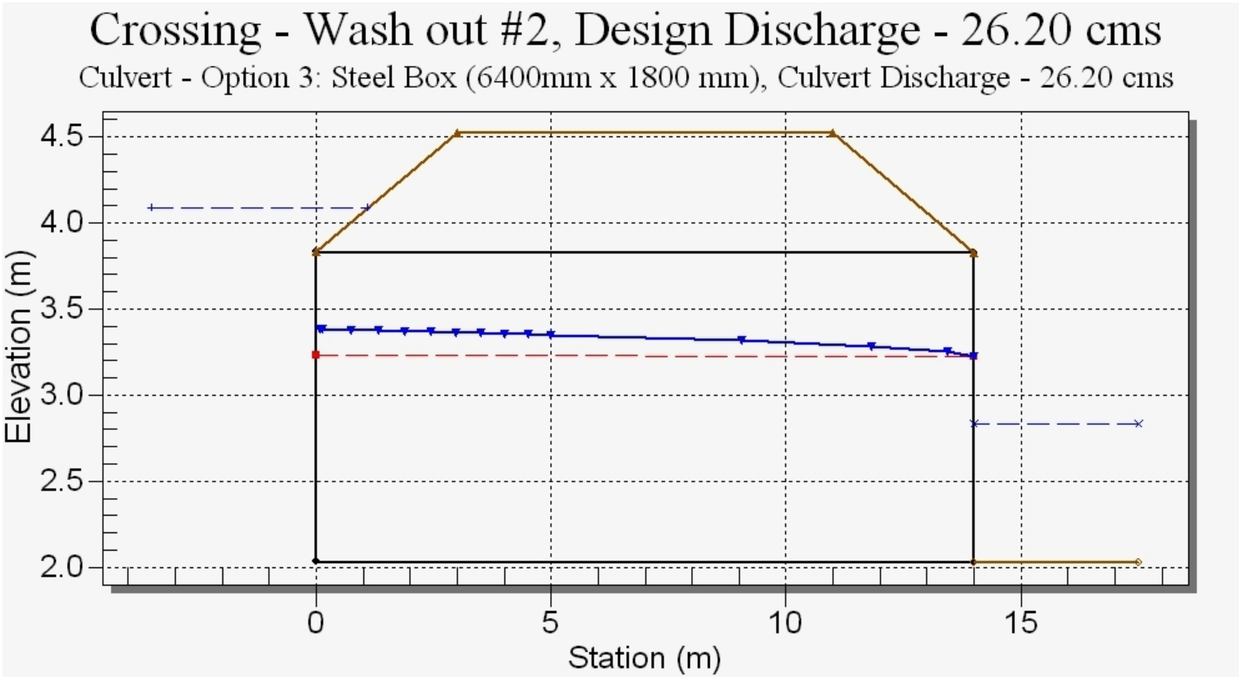

Figure 21: Bridge option at Washout 1 location.

5.0 CONSTRUCTION COST

After the hydraulic and hydrologic analysis, three crossing infrastructure options were selected to meet the capacity required at Washout 1 and Washout 2 (Crossing 9 and Crossing 10). All these options involve removal of the existing 1.0 m diameter CMP culvert at Crossing 9 and 10, and rip rap placement on inlets and outlets. The preliminary construction costs are summarized in Table 3 and the construction cost breakdown can be viewed in Appendix F.

Table 3 – Three Options for Increasing Capacity of the Drainage Infrastructure at Coral Harbour

	Drainage Infrastructure at Washout 1 (Crossing 9)	Drainage Infrastructure at Washout 2 (Crossing 10)	Construction Cost (Includes 35% Contingency)
Option 1	Bridge With an Opening of 10m width and 2.5m Height	4- 1500mm Diameter CMP Pipe	**$ 1,014,660**
Option 2	3 – 2400mm x 1800mm Concrete Box Culvert	3 – 2400mm x 1800mm Concrete Box Culvert	**$ 1,133,595**
Option 3	6400mm x 1800mm Bridge Plate Box Culvert	6400mm x 1800mm Bridge Plate Box Culvert	**$ 655,290**

There are local contractors in town, and some of the available equipment on site includes an excavator, dozer, wheel loader, grader, and double axel tandems. A local contractor was contacted about unit rates for granular material, Jivko Engineering Ltd was contacted about rough bridge costs, Armtec was consulted about CMP culvert pricing, and Inland Pipe Limited was consulted about concrete box culvert pricing. Shipping prices for the culverts were completed using rates from the 2012 sealift fee schedule.

The preliminary construction cost assumes the following:

- This cost estimate is prepared for 2012 planning and budgetary purposes only and is based on concept designs, and does not constitute a guarantee on the project cost. The actual cost will be determined by the detailed design, tendering and construction processes.
- Preliminary material selection (See Appendix G for culvert types). Material and sizing selection is preliminary and will need to be confirmed during final design. Factors that will change the material selection includes traffic loading, existing soil conditions, coating types for CMP culverts, sizing of concrete footing required for the bridge plate box culvert, etc.
- Prices for supply and installation of culverts were based on a breakdown of 40% labour and 60% materials. Bridge costs are very approximate.
- A local supply of granular material and rip rap is available on site (quarry of new material not required).
- No road build-up was assumed and the existing grades on the Airport Community Road were assumed adequate to provide a minimum of 0.5m depth of cover for the new pipe culverts.

5.1 Life Cycle Cost Analysis

The operational and maintenance costs for the culverts and bridges were estimated over the course of the service life, and discounted to calculate the present value of the future costs, as shown in Table 4. The discount rate (excluding inflation) is assumed to be 6% based on Public Works Canada.

Table 4 – Life Cycle Costs for the Three Options

	Construction Cost (Includes 35% Contingency) - Rounded	Estimated Service Life	Operational and Maintenance (O&M) Costs	Present Value of Construction Cost and O&M Costs
Option 1	$ 1,010,000	Bridge: 43 Years Round CMP Culvert: 50 Years	Annual: $3,200/year; Deck Replacement ($90,000) for Bridge at 20 Years	$ 1,090,000
Option 2	$ 1,130,000	Concrete Box Culvert: 75 Years	Annual: $4,000/year	$ 1,200,000
Option 3	$ 660,000	Bridge Plate Box Culvert: 50 Years	Annual: $4,000/year	$ 720,000

Although the initial construction cost is highest for Option 2, it also has the highest service life of the three options. A bridge has an average service life of 43 years in Canada, according to Statistics Canada, and the service lives for the metal pipe culverts and concrete box culverts are based on conservative values taken from industry standards.

The operational and maintenance costs are approximate and would vary from year to year depending on the work that would need to be completed. For bridge operations, two bridges at Coral Harbour had their decks replaced in 2010 due to damage caused by grader blades and snow ploughing machines.

6.0 RECOMMENDATIONS

Option 3, 6400mm x 1800mm bridge plate box culverts located at washout area 1 and 2, were determined to have adequate capacity and the lowest construction cost based on the analysis carried through the concept design report. However, the construction cost is preliminary and detailed design will need to be carried out to refine the pricing and design details. Work going forward should take into consideration the following:

- Since the Hamlet of Coral Harbour is in the region of continuous permafrost, consideration will have to be given to designing drainage infrastructure in permafrost zones during detailed design. The construction cost may be more depending on the depth of embedment for bridges, sub-excavation of frost susceptible material, etc.
- A geotechnical study is recommended to better understand in-situ conditions and types of granular material on site.
- Due to the lack of adequate concrete aggregate as mentioned in the 1985 report done at Coral Harbour, pre-cast foundations for the bridge plate box culvert in Option 3 and pre-cast concrete box sections were assumed in Option 2. The transportation of precast concrete may be challenging and effort should be provided in ensuring the concrete is not damaged during transport.
- A topographic survey of the road and pipe culverts and bridge structures is recommended to better understand the slopes of the pipe, amount of granular material required, and drainage along the road. Depending on the detail of survey required, it is estimated to be around $30,000 or more for survey.
- The existing culverts on site do not have rip rap around the inlets and outlets. Consideration for this should be investigated to prevent scouring at these areas.
- Since all three options discussed in this report involve increasing the flow of water at Washout areas 1 and 2 and there is a fuel pipeline downstream of the washout 2 area, an energy dissipater structure such as rip rap may be required adjacent to the fuel pipeline to control the velocity of the water. The estimated velocity at the outlet is about 3.0 m/s.
- Also, an appropriate size of rip-rap along the bridge plate box culvert foundation and river bed within the box section is required to protect scouring as the flow velocity is about 3.0 m/s.
- A real time flow monitoring during snow melt season is recommended and the flow data to be used for model calibration prior to construction of the proposed culverts. This work should be considered during detailed design.

7.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Sincerely,
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FIGURES