Yukon Community Services

ISSUED FOR USE

FLOOD ASSESSMENT AND ABATEMENT OPTIONS STUDY
MARSH LAKE AND UPPER LIARD

V13201069

August 2008

EBA Engineering Consultants Ltd.
p. 867.668.3068 • f. 867.668.4349
Calcite Business Centre • Unit 6, 151 Industrial Road • Whitehorse, Yukon Y1A 2V3 • CANADA

EXECUTIVE SUMMARY

EBA Engineering Consultants Ltd. (EBA) was engaged by Yukon Community Services to undertake a Flood Assessment and Abatement Options Study of the Marsh Lake and Upper Liard areas. Major support for the study was provided by EBA's Vancouver office including Hay & Company Consultants (Hayco), a Division of EBA. Additional support was provided by the KGS Group (Winnipeg) regarding the assessment of flood damages. Survey services were provided by Challenger Geomatics Ltd.

The study was initiated as a result of floods in 2007 which caused extensive flood damage to the Marsh Lake area south of Whitehorse where record flood levels occurred. A large emergency response was organized to combat the rising flood water which peaked on August 13. The flooding at Upper Liard, west of Watson Lake, was less severe and limited to 7 homes on the east bank of the Liard River north of the Alaska Highway.

The purpose of the flood study was to assess the flood hazard at the Marsh Lake and Upper Liard areas including an assessment of potential damages faced by these communities for a range of floods with return periods from 20 to 200 years.

The flood hazard assessment included a review of the project hydrology in order to establish design floods and corresponding flood levels at the two project areas. At Marsh Lake, a wind-wave analysis was undertaken in order to establish design waves and associated wave run-up conditions for design of bank protection options. Dyke crest design levels together with riprap and underlayer gradations were established for the Army Beach, South McClintock and Swan Haven sites. Options to mitigate the flood risk were subsequently developed including conceptual designs and cost estimates to complete the works. Dyke designs included 12 typical cross sections at surveyed locations along the lake shoreline. Road upgrades were included as part of the flood mitigation works at the Army Beach and South McClintock sites. It is proposed that roads be raised a minimum of 0.3 m above the 200-year lake level. At Swan Haven, the development is well above Marsh Lake flood levels and erosion of the shoreline is the only concern.

Flood mitigation options at Upper Liard are of a preliminary nature due to lack of survey data. Flood levels have been estimated at the highway bridge; however, a hydraulic model of the river is required to establish the design profile upstream of the bridge. The May 29, 2008 assessment of the left bank dyke works at Upper Liard has revealed these works to be more substantial than shown on the McElhanney topographic plan.

The impact assessment of flood damages at Marsh Lake was based on field work carried out in December 2007 by KGS Group staff together with survey data for the main floor building elevations. Damages were estimated based on property assessment rolls and flood damage data developed elsewhere in North America. The damage estimates were based on graphical relationships linking the inundation flood level to the resulting flood damage as a percentage of the assessed value of the buildings. At Marsh Lake the flood damages were estimated to range from $1,354,000 to $1,966,000. The flood damage estimates for Upper Liard were less precise due to a lack of current survey data. Flood damage estimates for Upper Liard ranged from $644,000

to $1,281,000. The assessment by the KGS Group indicates the proposed Marsh Lake flood protection works to be marginally justifiable in terms of benefit/cost analysis.

Regulatory approval strategies were also prepared as part of this study including YESAA requirements. General requirements are presented and a refined plan can be prepared once a decision is made on which option will be adopted for final design.

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLES

FIGURES

TABLE OF CONTENTS

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 GENERAL

This study was initiated as a result of recent record flood levels, during the summer of 2007, at two separate sites in Yukon, namely the Marsh Lake and Upper Liard basins.

At Marsh Lake, part of the Southern Lakes near the headwaters of the Yukon River, residential properties experienced serious flooding along Army Beach Drive and the South McClintock roads. Flood levels eclipsed all previous records and affected about 40 properties, mostly year-round residences located within commuting distance from Whitehorse. An emergency was declared and a large scale flood response was organized to combat the rising waters. Over 250,000 sand bags were placed by hundreds of volunteers and Yukon Government personnel. Temporary dykes were constructed and large pumps were brought in from Vancouver to clear the floodwaters.

The response at Upper Liard, west of Watson Lake, was much less and flooding was only monitored in this area. We understand that in June 2007 about 7 homes were flooded in the Liard area on the north side of the Alaska Highway Bridge and on the east side of the river. A similar flood threat developed in 2008, however, peak flood levels on May 30th were 1.02 m lower than in 2007. An emergency response was undertaken with some limited sandbagging on the left bank just upstream of the bridge.

1.2 BACKGROUND INFORMATION

1.2.1 Marsh Lake

Marsh Lake is part of the catchment for the Whitehorse Rapids Hydro plant and is regulated for part of the year. The Lewes Dam control structure is located about 11 km downstream of the outlet from Marsh Lake and has provided control in one form or another since the 1920s. Originally built to provide flushing flows during ice break-up on the Yukon River, it was rebuilt in 1969 as a water control structure for the Whitehorse Rapids Generating Facility. A completely new structure was built in 1974.

Ron Gee (Yukon Energy) reported that the control gates at this structure are fully open by May 15th each year and it operates uncontrolled throughout the annual flood period. Control resumes when the water level in Marsh Lake drops below the full supply level (656.234 m). The stored water augments winter flows at the generating plant when electrical demand is greatest. Plans to raise the controlled maximum level during winter months have been suggested but would not affect the uncontrolled operation during the flood season. Therefore, the Lewes Dam control structure does not appear to be a factor in the Marsh Lake flood situation.

It was noticed that Bennett Lake, which flows into Marsh Lake, peaked only 0.103 m higher than Marsh Lake during the 2007 flood event. Peak water levels were 657.448 m

(Geodetic datum) at Bennett Lake on August 13, whereas Marsh Lake peaked at 657.345 m on August 13 and again on August 20. Rick Janowicz (Yukon Environment) reported that flow sometimes reverses and flow goes into Bennett Lake. At higher levels it is essentially one body of water. If additional controls were put into the upper lake system it might be possible to reduce extreme flood levels in Marsh Lake.

This possibility was discussed with Ron Gee and he confirmed that control structures have been considered at several lakes within the system including Tagish, Tutshi and Atlin; however, they would not store water under flood conditions so no flood abatement would be possible. They would only consider controlling post flood flows for winter flow augmentation.

In a recent study by Northwest Hydraulic Consultants (February 2008) it was concluded that the starting water level in Marsh Lake during the spring has no significant impact on the peak level in the summer. This study found that 40% of the water in the system comes from Atlin Lake, 21% from Bennett Lake, 18% from Tagish Lake, 5% from Marsh Lake and the remainder (16%) from other water sources. As the Bennett and Tagish Lakes have flooding issues as well, Atlin Lake is probably the best candidate for storage regulation in the system. It is not known what impact such regulation might have on reducing extreme flood levels on Marsh Lake.

1.2.2 Upper Liard

The Upper Liard site is approximately 10 km due west of Watson Lake at the Alaska Highway crossing. A number of homes are situated in close proximity to the river bank, particularly along the west bank of the river which is on the outside of a large bend in the river. The east or inside bend of the river has lower bank elevations and is therefore more prone to flooding. Flood levels peaked on June 8, 2007 at 609.219 m (Geodetic datum) at the gauge at the bridge and resulted in the evacuation of several residents along the east side of the Liard River, north of the highway.

1.3 STUDY OBJECTIVES

The project objectives, at the onset of this study, were to map and identify the extent of the flood prone residential areas at both Marsh Lake and the Upper Liard site, based on a range of flood return periods from 25 to 200 years. This range was subsequently modified to include floods with return periods of 20, 50 and 200 years based on a realistic assessment of the topographic information available. Flood damage impacts were prepared for the above range to enable flood damages to be estimated versus flood stage and/or flood frequency. The purpose of this assessment was to allow potential flood reduction benefits to be compared against flood mitigation costs as a means of determining the optimal level of protection to be provided to these areas and also to determine if flood mitigation was economically viable, meaning a benefit: cost ratio greater than one.

The various flood mitigation options and erosion protection measures were to be presented in April 2008 to enable a coordinated and consistent approach to future flood and erosion protection efforts and to allow residents time to plan and implement appropriate measures in advance of the next flood season in the summer of 2008.

1.4 AUTHORIZATION

This study was authorized by Jeff Boehmer, P.Eng. with Yukon Community Services (YCS). The project was awarded to EBA Engineering Consultants Ltd. Whitehorse office with major support from EBA's Vancouver office including staff from Hay & Company Consultants, a division of EBA, plus additional support from the KGS Group, based in Winnipeg.

1.5 STUDY TEAM

The study team for this project included the following:

EBA Engineering Consultants (EBA)

- Richard Trimble, P.Eng., Senior Geotechnical Engineer, Project Manager
- Jack T. Dennett, P.Geo., Senior Project Geologist
- Chadwyck P. Cowan, P.Eng., Senior Project Engineer
- Patricia Randell, B.Sc., M.Sc. (Candidate), Assessment and Regulatory Specialist, Whitehorse Environmental Group
- Bengt Pettersson, B.Sc., M.A., Project Director, Whitehorse Environmental Group
- Dr. Adrian Chantler, P.Eng., Project Director, Water & Marine Engineering, Senior Reviewer
- Robert Wallwork, P.Eng., Senior Water Resources Engineer
- Dr. Shamsul Chowdhury, Senior Hydrotechnical Engineer
- Edwin Wang, P.Eng., Hydrotechnical Engineer
- Eva Li, EIT, Junior Hydrotechnical Engineer

KGS Group (KGS)

- Rick Carson, P.Eng., Manager Water Resources Services
- Fuad Curi, P.Eng., Water Resources Engineer
- Ambroise Percheron, EIT, Water Resources Engineer

1.6 SITE VISIT AND INITIAL ASSESSMENT

A site visit to the Upper Liard and Marsh Lake areas was undertaken on December 11 - 12, 2007 by Mr. Robert J. Wallwork, P.Eng. (Hayco) accompanied by Mr. Jeff Boehmer, P.Eng. (YCS). The purpose of the site visit was to allow Mr. Wallwork to gain familiarity with the project areas and field conditions. The Upper Liard site was visited December 11 during a snowstorm and the Marsh Lake area was visited the following day under mostly clear, cold conditions. Site time at Upper Liard was limited by the short daylight hours available following the drive from Whitehorse.

1.6.1 Marsh Lake

At the Marsh Lake study area, the shoreline was examined starting at the viewing platform near the Bible Camp on Swan Haven Drive, west of the mouth of the McClintock River. Wave action at high lake levels has eroded the toe of the slope causing the upper bank to fail. The resultant erosion threatens to undermine the wooden viewing platform and stairs down to the lake shore. The erosion extends along about one km of shoreline. Riprap toe protection is likely required for a lower berm built to the flood construction level with a 2H:1V slope facing the lake. Fill could be placed above this level to re-establish the upper bank at a stable slope.

On the other side of the bay at South McClintock Road, the bank has been protected with berms, rock filled gabions, lock-blocks and sandbags. It is understood that the gabions were placed for protection against wave attack and were subsequently raised with sandbags for additional protection. The treatment further east consists of riprap berms, sandbag walls and timber crib walls. It is evident that some homeowners are reluctant to give up lake views/beach use for flood protection. Large openings exist in the flood defences.

The shoreline along Army Beach Road was inspected next and included a wide variety of treatment methods including gabions, riprap, concrete walls, rubber tires, sandbags walls and sandbags used to raise the other wall types. The resulting dyke, using this term loosely, is of varying height, is not watertight, and has openings through it. Further north along the shoreline, the bank is higher and the need for flood protection diminishes. These areas are still subject to erosion damage.

1.6.2 Upper Liard

At Upper Liard, located approximately 12 km west of Watson Lake on the Alaska Highway, the berm along the east (left) bank, upstream of the bridge, was inspected first. Mr. Boehmer indicated the berm was constructed of sand and gravel in the late 1980s; it is now overgrown with vegetation and likely needs to be tied in to high ground at the upper end and extended downstream to the bridge. The crest elevation of the existing berm is unknown and it likely will need to be raised as well. As the ground was covered in deep snow, it was not possible to inspect the banks for signs of erosion.

On the west (right) bank at Upper Liard, the road adjacent the river could probably be raised as a dyke to provide flood protection to the community. It is set back from the river with a tree buffer between. Again, the upstream end would likely need to be wrapped around to tie in to high ground. There is one house on the riverside of the road and this would either have to be raised above the flood construction level or relocated to the west side of the raised road.

1.7 PROJECT INITIATION MEETING

A meeting was held at YCS offices on December 12, 2007 (3:00 p.m. to 4:45 p.m.) following the site visit at Marsh Lake. The meeting was attended by:

Yukon Energy

- Hector Campbell, P.Eng., Director, Resource Planning & Regulatory Affairs

Marsh Lake Community Representative

- Paule Senechal, B.Com., CGA
- Perry Savoie

Yukon Highways and Public Works

- Dan Profeit, Transportation Maintenance

Yukon Government

- Ric Janowicz, Environment, Water Resources
- Jeff Boehmer, P.Eng., Community Services, Community Infrastructure

KGS Group, Speakerphone

- Fuad Curi, P.Eng., Senior Water Resources Engineer

EBA Engineering Consultants Ltd.

- Richard Trimble, P.Eng., Project Manager
- Bob Wallwork, P.Eng., Senior Water Resources Engineer, (Hay & Company Consultants, a division of EBA)

There was a discussion based on the conditions observed during the site visit followed by the approach to be followed for future work including survey requirements.

2.0 GEOTECHNICAL INVESTIGATIONS

Prior to commencing site specific geotechnical evaluations in the Upper Liard and Marsh Lake areas, EBA completed a review of data available in company files. Logs and laboratory test data were located for 31 boreholes and 4 testpits in Upper Liard; and 3 boreholes/10 testpits for Marsh Lake. It was concluded that there was sufficient information in Upper Liard, but that some site specific soil testing would be required in the Army Beach/McClintock Bay areas.

On March 25, 2008, an EBA Technician collected seven soil samples at the locations shown on Figure 2.1. The locations were selected to be representative of the areas where erosion protection would be required, for the purposes of designing adequate filters to protect the natural soils from erosion beneath riprap.

2.1 SUMMARY OF SOIL TESTING

The particle size curves are presented on the attached Aggregate Analysis Report, Appendix E. Six of the seven samples showed consistent soil types (SAND, trace of silt to some silt) with one outlier (SA5) that consists of imported fill. This data is consistent with the other data collected and reviewed as part of this study.

The gradation of the five natural sand samples indicates that the soil would be protected by using Layfield LP8 or heavier non-woven geotextile beneath the riprap. Manufacturer's specifications are also attached, Appendix E.

A conventional riprap underlayer material has also been sized (see Table 5.12), so the use of geotextile would be an alternative to the underlayer material. Underlayer is preferred under wave conditions and for use with blasted riprap.

3.0 SURVEYS

An initial pick-up survey was undertaken by Yukon Government Services (YGS) on November 20-22, 2007 and included roads, ditches, driveways and some building information in the Marsh Lake area. These drawings for the Marsh Lake Flood Control (Project) were provided on seven map sheets at 1:500 horizontal scales with profiles at 1:20 vertical scale. The coverage includes three drawing sheets in the South McClintock area and four drawing sheets covering the south half of Army Beach Drive.

Some additional bathymetric survey data was obtained in the Marsh Lake area in the form of four cross sections arranged perpendicular to the shoreline. This survey was undertaken by Challenger Geomatics Ltd. in late February and early March 2008.

Following our analysis of the project hydrology as presented in the following section, the design flood levels for Marsh Lake were found to be approximately 0.2 m higher than earlier estimates by Yukon Government personnel. As such, the extent of the pick-up survey by YGS was found to be inadequate and more survey was necessary. Challenger Geomatics Ltd. was hired to extend the pick-up survey and also to obtain representative shoreline cross sections throughout the study area to enable bank protection to be designed. This latter survey was commissioned March 20, 2008.

In addition to the above surveys, survey data of main floor building elevations was required in support of the flood damage assessment analysis by the KGS Group. This latter survey was also completed by Challenger Geomatics Ltd. in May 2008 and included extensions to the road profile pick-up at Taylor Road near the intersection with Army Beach Drive.

4.0 HYDROLOGY

4.1 MARSH LAKE FLOOD LEVELS

The water level records for the Marsh Lake hydrometric station (09AB004) were analyzed using the Consolidated Frequency Analysis software, CFA Version 3.1, developed by Environment Canada, to determine the flood levels corresponding to a range of return periods from 2 to 200 years. Records for maximum instantaneous water levels (at the gauge) from 1966 to 2007 were used in the analysis. Records from the four maximum daily flood peaks in the 1950s were omitted from the analysis. Inclusion of these early records, as per the preliminary YG analysis and our own analysis, yielded 200-year flood level estimates that were approximately 0.20 m lower than the subsequent analysis. The Generalized Extreme Value (GEV) frequency estimates appeared to provide the best frequency plot fit and were adopted. Gauge values were converted to Geodetic elevations by adding 653.357 m, the conversion value provided by Environment Canada. These water levels were used in the impact assessments and in the determination of design levels for dyke works.

Results from the above frequency analysis, rounded off to two decimal places, are listed in Table 1. The elevation difference between a 20-year and a 50-year flood is just 0.21 m while the difference between the 50-year and 200-year levels is 0.30 m. The 200-year lake level is just 0.20 m higher than the 2007 record flood level on Marsh Lake (657.34 m). Based on these results, the 2007 flood would have a return period of approximately 80 years.

TABLE 4.1: MARSH LAKE FLOOD LEVEL ESTIMATES

Return Period Years	Gauge Reading m	Marsh Lake Elevation m
2	3.01	656.37
5	3.31	656.67
10	3.50	656.86
20	**3.67**	**657.03**
50	**3.88**	**657.24**
~80	3.986	657.343
100	4.03	657.39
200	**4.18**	**657.54**

4.2 UPPER LIARD FLOOD LEVELS

Flood levels at the Liard River site were developed from the records at the gauge, Liard River at Upper Crossing (10AA001), which is located at the Alaska Highway bridge crossing. Frequency analysis of these records was undertaken using the CFA program and the Log Pearson Type III estimates were deemed to provide the best fit.

At Upper Liard, as at Marsh Lake, we are more interested in the design flood levels rather than the flood discharges so it is necessary to convert flood flow estimates to flood stage values.

The latest Stage Discharge Table, No. 14, was used to convert the flood flows to flood stage. To achieve this it was necessary to develop a power curve fit to the upper end rating curve points as the rating curve was defined only for discharges up to 3000 m^3/s whereas our 200-year flood flow estimate was 3840 m^3/s. The derived power curve formula was:

$$y = 0.152x^{0.4785} \quad R^2 = 0.9995$$

The above formula was developed for discharges (x) in the 1728 m^3/s to 3000 m^3/s range. Gauge values were converted to Geodetic elevations by adding 602.373 m, the conversion value provided by Environment Canada.

The flood frequency estimates (Log Pearson Type III) for the Liard River at Upper Crossing (10AA001) are presented below together with the rating table or rating curve conversion to design water levels.

TABLE 4.2: LIARD RIVER FLOOD LEVEL ESTIMATES AT BRIDGE

Return Period Years	Flood Estimate m^3/s	Flood Stage m	Flood Elevation m	Flood Construction Level
2	1830	5.533	607.91	
5	2370	6.261	608.63	
10	2690	6.652	609.03	
20	**2980**	**6.986**	**609.36**	**609.96**
50	**3340**	**7.378**	**609.75**	**609.75**
100	3590	7.638	610.01	
200	**3840**	**7.888**	**610.26**	**610.86**

The flood construction levels tabulated above assume a 0.6 m freeboard allowance. River profiles upstream and downstream of the bridge are discussed in Section 7.2 together with preliminary flood mitigation measures.

5.0 WIND/WAVE ANALYSIS

5.1 MARSH LAKE AREA WINDS

Historic records of wind data from the Whitehorse Airport Canadian Atmosphere and Environment Service (AES) climate station (Figure 5.1) were examined to determine the most appropriate winds for Marsh Lake.

A wind rose showing the direction and magnitude of the wind at the Whitehorse Airport station for the 54-year record (1953 to 2007) is shown in Figure 5.2. Prevailing winds at the

Whitehorse Airport are primarily from the south and southeast directions, corresponding to the orientation of the valley. The largest storms are from the south and occur in winter.

An extreme event analysis, using the methods described by Goda (1988), was applied to the wind record to determine extreme winds with a range of return periods for the dominant directions. Since the water level in the lake is at its highest during the summer and early fall, for flood protection design purpose, the extreme wind event analysis was conducted only for the wind record between the months of June and November. The results are presented in Table 5.1.

TABLE 5.1: WIND SPEEDS FOR VARIOUS RETURN PERIODS

Return Period (yr)	Wind Speed from Southeast (m/s)	Wind Speed from Southeast (km/hr)
1	11.5	41
10	15.3	55
20	16.4	59
50	17.9	65
100	19.1	69
200	20.2	72

Upon completion of the above analysis of the wind climate, some earlier local wind data were made available by Ron Gee (Yukon Energy) for a site adjacent the Phillips residence at South McClintock Point. This data was compared to the Whitehorse data and a memo was prepared on the results of this analysis (Appendix D). It was concluded that the design wave values derived for the Marsh Lake study by using the Whitehorse Airport data were not underestimated.

5.2 WIND DRIVEN WAVE CLIMATE

A traditional wave hindcast approach, the Jonswap method, as described in the U.S. Army Corps of Engineers (CERC 1977) was conducted to determine wave heights using the wind speed for specific return periods (Table 5.1). This method involves the estimation of such variables as fetch length (14.5 km) and wind duration time (4 hours). The wind speed and direction are assumed to be uniform over the region of interest. In addition, it was assumed that waves generated at the project site are fetch limited. The results are summarized in Table 5.2. Also shown in Table 5.2 is the wind set up with respect to the corresponding storm event.

TABLE 5.2: WIND DRIVEN WAVE AND WIND SETUP FOR VARIOUS RETURN PERIODS			
Return period (yr)	Wave Height (m)	Period (sec)	Wind Setup (m)
10	0.94	3.8	0.05
20	1.01	3.9	0.06
50	1.10	4.0	0.08
100	1.17	4.1	0.09
200	1.24	4.1	0.10

5.3 NEARSHORE WAVE TRANSFORMATION

Determining the wave propagation in Marsh Lake towards the project site is done with detailed modelling, a routine procedure in coastal engineering. Using numerical modelling provides much more accurate estimates of waves than conventional fetch calculations, for little additional effort. To establish the transformation of deepwater waves to the project site the SWAN (Simulating WAves in Nearshore areas) model (Booij et al., 2004) was used. The SWAN wave model incorporates physical processes such as wave propagation, wave generation by wind, white capping, shoaling, wave breaking, bottom friction, sub-surface obstacles, wave set-up and wave-wave interactions.

Bathymetric grids of suitable resolution are required for input to the model. The model grid (Figure 5.3) was generated from the field survey data and from a bathymetry plan obtained from the Yukon Government website. Since no datum information is available for this bathymetry plan, it was assumed that the 0-m contour on this bathymetry plan is at an elevation of 656 m based on available water level data. This level corresponds approximately to the average of the July 1st average lake level (655.47 m) and the average annual maximum lake level (656.39 m). The grid is rotated to follow the orientation of the major axis of the valley, and measures roughly 16 km by 12 km, with each square grid cell measuring 50 m by 50 m.

The wave climate, determined from the wave analysis (Table 5.2), was applied at the south boundary of the model. In addition, the wind field, determined from the wind analysis (Table 5.1), was applied over the model domain to create the wind-generated component of the waves. To determine the design criteria (rock sizes and crest height), simulations were conducted for various combinations of storm events and flood levels. Figure 5.4 shows the model results from a 200 year flood level coinciding with a 10 year storm event. The model results were extracted in the vicinity of the project sites (Sites 1, 2 and 3) to determine the design criteria for the riprap. The results are summarized in Tables 5.3, 5.4 and 5.5.

TABLE 5.3: DESIGN WAVE HEIGHT FOR VARIOUS RETURN PERIODS, 50 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)
10	0.68	2.36	0.53	1.88	0.57	1.92
20	0.72	2.44	0.56	1.94	0.60	1.97
50	0.76	2.55	0.61	2.00	0.64	2.03
100	0.78	2.62	0.63	2.05	0.68	2.08
200	0.82	2.79	0.69	2.19	0.75	2.21

TABLE 5.4: DESIGN WAVE HEIGHT FOR VARIOUS RETURN PERIODS, 100 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)
10	0.70	2.36	0.54	1.89	0.58	1.94
20	0.74	2.44	0.58	1.95	0.61	1.99
50	0.79	2.54	0.62	2.02	0.66	2.05
100	0.81	2.61	0.66	2.07	0.70	2.11
200	0.87	2.79	0.73	2.21	0.78	2.23

TABLE 5.5: DESIGN WAVE HEIGHT FOR VARIOUS RETURN PERIODS, 200 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)	Hs (m)	Tp (sec)
10	0.71	2.37	0.55	1.91	0.59	1.96
20	0.76	2.44	0.59	1.97	0.63	2.01
50	0.81	2.54	0.64	2.04	0.68	2.07
100	0.84	2.60	0.68	2.09	0.72	2.13
200	0.91	2.79	0.76	2.23	0.81	2.25

5.4 WAVE RUN-UP

Wave run-up is a phenomenon in which an in-coming wave crest runs up along the shoreline slope and reaches a maximum water level. The vertical distance between the static water level and the highest point reached by the wave tongue is called the wave run-up. Wave run-up for a permeable structure, such as a riprap revetment, has been calculated based on the methodology described in the Coastal Engineering Manual published by the US Army Corps of Engineers.

Wave run-up levels have been calculated based on 2% exceedance of the incoming waves. The incident wave heights at the three principal sites (Army Beach, South McClintock Point and Swan Haven Drive) are functions of lake water level and wind speed. Based on the significant wave height information, wave run-up levels have been calculated at each of the above sites and this is summarized in Tables 5.6, 5.7 and 5.8 corresponding to Marsh Lake levels with return periods of 50 years, 100 years and 200 years, respectively.

TABLE 5.6: WAVE RUN-UP FOR VARIOUS RETURN PERIODS, 50 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Ru (m)	Hs (m)	Ru (m)	Hs (m)	Ru (m)
10	0.68	1.20	0.53	0.94	0.57	1.01
20	0.72	1.27	0.56	0.99	0.60	1.06
50	0.76	1.34	0.61	1.07	0.64	1.13
100	0.78	1.38	0.63	1.12	0.68	1.20

TABLE 5.7: WAVE RUN-UP FOR VARIOUS RETURN PERIODS, 100 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Ru (m)	Hs (m)	Ru (m)	Hs (m)	Ru (m)
10	0.68	1.23	0.53	0.95	0.57	1.02
20	0.72	1.30	0.56	1.02	0.60	1.07
50	0.76	1.38	0.61	1.08	0.64	1.15
100	0.78	1.42	0.63	1.16	0.68	1.23

TABLE 5.8: WAVE RUN-UP FOR VARIOUS RETURN PERIODS, 200 YEAR WATER LEVEL

Return period (yr)	Site 1		Site 2		Site 3	
	Hs (m)	Ru (m)	Hs (m)	Ru (m)	Hs (m)	Ru (m)
10	0.68	1.24	0.53	0.96	0.57	1.03
20	0.72	1.32	0.56	1.03	0.60	1.10
50	0.76	1.41	0.61	1.11	0.64	1.18
100	0.78	1.46	0.63	1.18	0.68	1.25

5.5 RIPRAP

The size of the riprap required to protect the lake shoreline at the three principal sites was derived using the incident wave height estimates listed in the above tables in conjunction with the methodology described in the Shoreline Protection Manual, published by the U.S. Army Corps of Engineers. Riprap gradation specifications corresponding to each of the three principal sites are listed in Tables 5.9, 5.10 and 5.11 corresponding to Sites 1, 2 and 3, respectively.

TABLE 5.9: RIPRAP TYPE 1 GRADATION FOR SITE 1

MASS (kg)	Percentage Less Than	Nominal Size (mm)
815	100	675
406	60 – 100	535
302	50 – 75	485
203	25 – 50	425 (D_{50})
124	10 – 30	360
91	0 – 20	325
30	0 - 5	225

TABLE 5.10: RIPRAP TYPE 2 GRADATION FOR SITE 2

MASS (kg)	Percentage Less Than	Nominal Size (mm)
465	100	560
226	60 - 100	44
170	50 - 75	400
114	25 - 50	350 (D_{50})
75	10 - 30	305
55	0 - 20	275
21	0 - 5	200

TABLE 5.11: RIPRAP TYPE 3 GRADATION FOR SITE 3

MASS (kg)	Percentage Less Than	Nominal Size (mm)
572	100	600
284	60 - 100	475
211	50 - 75	430
140	25 - 50	375 (D_{50})
104	10 - 30	340
61	0 - 20	285
26	0 - 5	215

TABLE 5.12: FILTER ROCK GRADATION	
Percentage Less Than	Nominal Size (mm)
100	180
70 – 100	100
50 – 70	60
40 – 60	50
30 - 50	30
20 - 40	20
0 - 20	15

The riprap sizes in the above tables are based on an assumed specific gravity for the rock of 2.65. Mass will govern the gradation and the nominal size for the riprap is defined as:

$$D=1000*(W/2650)^{(1/3)}$$

In the above equation, W is the mass in kilograms and D is the nominal rock size in millimetres. It should be noted that the derived rock sizes refer to an effective "cubic" dimension.

All rock material will be rough angular quarried stone of a dense, hard, durable character, free of organic material, and resistant to breakdown by handling.

Filter rock gradations for the three sites are similar and therefore to simplify the construction procedures we have used only one type of filter rock for all three sites.

Riprap and filter rock should both be available from Lloyd Atkinson's quarry at km 1374 of the Alaska Highway, as shown on Figure 2.1

6.0 IMPACT ASSESSMENT OF FLOOD DAMAGES

The impact assessment of flood damages was carried out by the KGS Group (Winnipeg) under the direction of Rick Carson, P.Eng. The field work for this assessment was carried out in late December 2007; however, the main flood damage assessment analysis was delayed until late May 2008 pending completion of the survey information, specifically the main floor building elevations at Marsh Lake. No such information was available at Upper Liard so floor elevations were estimated based on ground elevations.

The report by the KGS Group is included herein as Appendix F and salient features are summarized below. In each area, the potential damages were developed for flood frequencies of 1 in 20 years, 1 in 50 years and 1 in 200 years.

6.1 MARSH LAKE

At Marsh Lake the flood damages were assessed in terms of the flood levels derived by EBA for the 20, 50 and 200-year events, Table 4.1. This damage assessment was based on data for flood damages incurred elsewhere in North America and included direct costs for repair of physical damages to residences, supplementary buildings, building contents and to infrastructure. As well, indirect costs were tabulated including relocation costs, temporary flood protection measures, security, pre-emptive protection and rescue efforts. At Marsh Lake these costs were estimated to range from $1,354,000 to $1,966,000.

Business losses and intangible losses such as stress and anxiety of affected residents were not included.

6.2 UPPER LIARD

At Upper Liard, the damage assessment was less precise due to a lack of current survey data for the land and buildings. It was assumed that the main floors of buildings were one metre above ground elevation. The flood damage estimates at Upper Liard ranged from $644,000 to $1,281,000.

The flood damage versus flood frequency relationship is steeper at Upper Liard, in comparison to Marsh Lake, due to the wider range in river flood levels at Upper Liard, namely 0.90 m, versus the relatively shallow flood level range of 0.51 m at Marsh Lake. This increased depth of flooding translates into substantially higher damages to buildings and contents, which represent the lion's share of the potential damages at each community.

7.0 FLOOD MITIGATION OPTIONS

7.1 MARSH LAKE

At Marsh Lake there are a number of approaches that can be taken to mitigate the flood and erosion damages. These measures include raising roads and driveways above the flood level, constructing cut-off berms, raising buildings and constructing dykes or bank protection along the shoreline to prevent flood and erosion damage to the various properties. Figure 7.1 shows the locations of the surveyed cross sections.

In terms of the shoreline mitigation works, an analysis was carried out based on the wind/wave analysis from Section 5.0. Various combinations of predicted lake flood levels, wind setup and wave run-up were analyzed to determine the combination which gave the maximum design level at each of the three principal sites, namely, Site 1 - Army Beach, Site 2 - South McClintock and Site 3 - Swan Haven Drive. These results are summarized in Table 7.1 below. The wave run-up estimates were based on riprap shore protection constructed on a 2H:1V slope. Wave run-up values are for the 2% exceedance waves. Since 2% of the waves may exceed this height, there is some scope for minor wave overtopping of the designed revetment structure, though it is not expected to cause any significant damage. The 2% exceedance criterion is the standard approach followed for shoreline protection design.

TABLE 7.1: DESIGN CONDITIONS AT SHORELINE SITES				
Location	Lake Level m	Wind Setup m	Wave Runup m	Total m
Site 1	20-yr: 657.03	50-yr: 0.08	50-yr: 1.34	658.45
Site 1	50-yr: 657.24	20-yr: 0.06	20-yr: 1.27	658.57
Site 1	50-yr: 657.24	50-yr: 0.08	50-yr: 1.34	658.66
Site 1	100-yr: 657.39	10-yr: 0.05	10-yr: 1.23	658.67 max.
Site 1: Army Beach – Design Crest Elevation = 658.7 m				
Site 2	20-yr: 657.03	50-yr: 0.08	50-yr: 1.07	658.18
Site 2	50-yr: 657.24	20-yr: 0.06	20-yr: 0.99	658.29
Site 2	50-yr: 657.24	50-yr: 0.08	50-yr: 1.07	658.39 max.
Site 2	100-yr: 657.39	10-yr: 0.05	10-yr: 0.95	658.39 max.
Site 2: South McClintock – Design Crest Elevation = 658.4 m				
Site 3	20-yr: 657.03	50-yr: 0.08	50-yr: 1.13	658.24
Site 3	50-yr: 657.24	20-yr: 0.06	20-yr: 1.06	658.36
Site 3	50-yr: 657.24	50-yr: 0.08	50-yr: 1.13	658.45
Site 3	100-yr: 657.39	10-yr: 0.05	10-yr: 1.02	658.46 max.
Site 3: Swan Haven Drive – Design Crest Elevation = 658.5 m				
Note: The 2007 peak water level on Marsh Lake was 657.343 m				

7.1.1 Flood and Erosion Measures at Army Beach

The flood protection at Army Beach Drive (Site 1) is based on a design crest elevation of 658.7 m as derived in Table 7.1 above. Riprap slope protection was developed for each of the seven cross sections surveyed by Challenger Geomatics. Figure 7.2 shows cross sections 1 and 2 located toward the north end of Army Beach where erosion protection is the only issue. The riprap protection, 0.90 m thick with 0.30 m thick underlayer, is carried 0.50 m below the existing ground level to provide scour protection from the wave action. Figure 7.3 shows cross sections 3 and 4, with erosion being the only issue at cross section 3. At cross section 4, the ground is lower and a dyke section is required to provide both erosion and flood protection to the backshore area. The situation is similar at cross sections 5 and 6, Figure 7.4, where a dyke is required for flood protection. The 200-year water level is only marginally higher than the land at cross sections 4 and 5 such that an impervious core is not required for the dyke. At cross section 7, Figure 7.5, the 200-year lake level exceeds the natural ground level behind the dyke by a significant amount and consequently some impervious material is required to seal the dyke.

It should be noted that the designs shown in Figures 7.2 to 7.5 are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

7.1.2 Flood and Erosion Measures at South McClintock Road

The flood protection at South McClintock Road (Site 2) is based on a design crest elevation of 658.4 m as derived in Table 7.1 above. Cross section 8, Figure 7.5, is located near the east end where the natural ground level behind the dyke is again significantly lower than the 200-year water level. An impervious core is again required for the dyke at this location. The same is true at cross section 9 near the west end of Site 2, Figure 7.6. Again, it should be noted that the designs shown in Figure 7.5 and 7.6 are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

It should be recognized that high flood conditions on Marsh Lake can persist for a month or more such that groundwater levels in backshore areas will increase to match the nearby lake level. Consequently, some seepage is expected in spite of any measures taken to seal the proposed dykes. Temporary pumps will likely be necessary to control this seepage even with dykes in place.

7.1.3 Erosion Protection at Swan Haven Drive

The erosion protection at Swan Haven Drive (Site 3) is based on a design crest elevation of 658.5 m as derived in Table 7.1 above. This section of shoreline has developed steep upper slopes due to wave erosion at the toe of the slopes. The proposed treatment is shown at three locations centred about the viewing platform. Figure 7.6 shows the layout for the protection at cross section 10 where the upper slope is not steep. Figure 7.7 shows a modified layout for the shoreline where the upper slope is undercut. Fill should be used to flatten the upper slope to prevent it from unravelling any further. The fill is stepped back from the outer face of the riprap to provide a buffer from any wave overtopping.

Once again, it should be noted that the designs shown in Figures 7.6 and 7.7 are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

7.1.4 Road and Driveway Upgrades

The existing road network serving the Army Beach and South McClintock areas is subject to flooding during extreme flood events. Figure 7.8 shows the extent of potential road flooding for floods with return periods of 50, 100 and 200 years. This figure has been developed based on the static flood levels listed in Table 4.1. All roads, with the exception of some isolated pockets, are above the 20-year flood event. Therefore the 20-year event does not appear to cause any road flooding apart from some seepage potential.

Alleviating the access restrictions to the properties in times of flood is considered a basic improvement that can be made at a reasonable cost. This will entail raising roads and driveways to the design flood level plus the allowance for freeboard. An allowance for wave conditions is not required as the access roads are well removed from the shoreline and waves should dissipate before reaching the roads. In this case, the flood level for road works is recommended to be some 0.30 m above the 200-year flood level which corresponds to Elev. 657.84 m. Driveways could be raised to a slightly lower standard, say 0.10 m above the 200-year flood level to avoid large grade adjustments on the properties which are generally lower than the roads to begin with. Raising the roads and driveways to these elevations will require adjustments as follows:

- South McClintock Road: average road and driveway adjustments of +0.336 m and +0.412 m, respectively;
- Army Beach Drive: average road and driveway adjustments of +0.373 m and +0.444 m, respectively, plus an adjustment of +0.55 m at Taylor Road

The road length to be raised along Army Beach Drive is approximately 1200 m long beginning at the turning circle at the south end and extending northward to the vicinity of the driveway on lot 70. The road has one additional low spot near the access at the north end; however, the adjustment here is negligible (0.03 m) and could be safely ignored. In addition, 309 m of Taylor Road would also require upgrade to achieve the 200-year flood standard.

Road adjustments at South McClintock Road are 584 m long as shown in Figure 7.8. Some sections of the road were previously upgraded during the 2007 flood event.

A detailed analysis of the road and driveway adjustments is include in Appendix A. Cost estimates for these upgrades are presented in Section 7.3.

7.2 UPPER LIARD

7.2.1 Flood Profile Assessment

The Upper Liard project site currently suffers from a lack of current base mapping information as well as reliable flood profile information to permit dyke grades to be established. Nevertheless, an approximate analysis has been carried out to establish a preliminary flood profile in anticipation of potential flood conditions during the 2008 freshet.

The flood levels at the bridge were initially extrapolated upstream and downstream based on the river slope measured between the river edge terminus of the 604 m and 606 m contours shown on the McElhanney site plan. The river slope between these contours was estimated to be 0.001384. These flood levels, including a 0.6 m freeboard allowance, were developed at flood increments of 0.2 m and marked on the preliminary mapping. The 200-year flood levels are roughly 0.9 m higher than the 20-year flood levels.

It was subsequently noticed that the flood profile upstream of the bridge is likely flatter than the profile downstream of the bridge. There is a spot elevation of 606.7 m in close proximity to the right riverbank at the upstream limit of the McElhanney mapping. The water surface slope between this point and the terminus of the 606 m contour was analyzed and found to be 0.00100. This slope was used to develop flood isograms at 0.10 m elevation increments for the river reach upstream of the 606 m contour limit.

It must be stressed that the river slope derived from the above analysis is only approximate so the derived flood levels should be used with caution. This analysis can be revised once we have better survey data for this area. River cross sections and a HEC-RAS water surface profile analysis are needed to properly estimate the flood levels; however, this is beyond the scope of work for this study.

7.2.2 Right Bank Flood Mitigation

Based on the above flood profile analysis, the right bank (west side) upstream of the bridge is generally high enough except near the upstream end of the riverfront road which is low by up to 0.9 m relative to the preliminary flood profile for the 200-year event. This road can be raised as a dyke to protect the housing development. Low spots are marked on the attached site plan, Figure 7.9, and it appears that about 190 m of the road may require upgrading based on the preliminary flood profile. There appears to be high ground west of the north end of the road which will block overland flows heading toward the community. A single house is on the riverside of the road near the upstream end. While the adjacent road grade is nearly adequate in terms of the 200-year flood profile, it is under by only 0.1 m, it may advisable to move this house to the protected side of the road dyke. Survey information is required to assess the level of risk to this property.

Downstream of the bridge, the right bank is generally high enough with the possible exception of the bank near the buildings furthest downstream, near the 610.2 m flood isogram.

7.2.3 Left Bank Flood Mitigation

The left bank (east side) upstream of the bridge is substantially low for a distance of about 930 m. A gravel berm has been constructed alongside the former riverside road but is generally low throughout its length. A continuous river dyke is required along this river bank and this will require a dyke height of approximately 1.5 m near the bridge, rising to a maximum height of about 2.7 m near the north end, approximately 70 m south of the tie-in to the valley wall. It is noted that overbank flows would travel toward the sag point on the Alaska Highway where there is an existing culvert. During high flood conditions, the floodwaters would pond against the highway embankment and eventually overtop the highway, possibly cutting the highway.

The left bank below the bridge is very low and would be inundated during major floods; however, there is no development so this should not pose a problem.

A typical dyke cross section is shown on Figure 7.10. It was originally proposed to raise the existing access road as a setback dyke which would reduce the velocities near the dyke during flood conditions. The dyke crest would be 4.0 m wide with a gravel surface for road access. The dyke would be faced with riprap and underlayer adequate to protect against velocities to 3.0 m/s. A short 2.0 m wide toe apron would be provided for scour protection against overbank flood flows.

As a result of the left bank dyke inspection May 29, 2008 during our emergency flood assessment at Upper Liard, it was determined that the existing dyke works are more extensive than shown on the McElhanney topographic plan (Figure 7.9) and in fact the low point in the dyke profile is just upstream of the bridge. Incipient flooding develops at a gauge reading of 5.75 m and the peak level on May 30, 2008 was 5.82 m which necessitated only minor sandbagging near the bridge.

Additional surveys and hydraulic profile analysis will be required to properly address the flood mitigation requirements at Upper Liard. This work is beyond the terms of reference for this study.

7.3 COST ESTIMATES

7.3.1 Marsh Lake

Construction cost estimates have been developed for the options described in Sections 7.1.1 to 7.1.4 above. These are class "C" cost estimates (+ or – 30%) and do not include engineering or regulatory approval costs.

South McClintock

The road upgrades at South McClintock involve raising a total length of 584 m of road by an average of 0.336 m to achieve 0.30 m freeboard above the 200-year flood level. Assuming an 8.0 m road width and allowing 1.0 m for the shoulders, we have an effective road width of 9.0 m and the required upgrade translates into a volume of 1770 m^3. This translates into a road upgrade cost of $35,400 at South McClintock assuming $20.00/$m^3$ for gravel supplied and placed.

Driveways at South McClintock would be raised by a lesser amount corresponding to 0.10 m above the 200-year flood level. Assuming a 4.5 m effective driveway width, the total length of driveways to be raised is approximately 382 m. The volume of material to upgrade the driveways is approximately 770 m^3 and this translates into a driveway upgrade cost of $15,400 at South McClintock. Therefore the total cost of upgrading the roads and driveways at South McClintock is estimated at $50,800.

Army Beach

Similarly, the road upgrades at Army Beach Drive involve raising a total road length of 1200 m by an average of 0.373 m which translates into a gravel volume of 4030 m^3, assuming a 9 m overall road width. This works out to a road upgrade cost of $80,600. Taylor Road connects with Army Beach Drive at approximately its mid-point. A total road length of 309 m would require upgrading by an average of 0.55 m which translates into a gravel volume of 1530 m^3 and a road upgrade cost of $30,600 for Taylor Road.

Driveways at Army Beach Drive would be raised in a similar manner to that described for South McClintock with 4.5 m width and a total driveway length of 421 m. The required volume of gravel to upgrade the driveways is approximately 1030 m^3 which corresponds to a driveway upgrade cost of $20,600. The total road and driveway upgrade cost is therefore $131,800 at Army Beach Drive including the connecting Taylor Road.

The total road and driveway upgrade costs are therefore $146,600 and $36,000 respectively, for a combined total cost of $182,600.

The detailed cost breakdown of the riprap bank protection and dyke works at the South McClintock, Army Beach Drive and Swan Haven sites is summarized in Appendix B. These costs, together with the above road and driveway costs are summarized in the following table.

TABLE 7.2: MARSH LAKE COST ESTIMATES

Item	Site 1: Army Beach	Site 2: South McClintock	Site 3: Swan Haven
Road Upgrades	$111,200	$35,400	N/A
Driveway Upgrades	$20,600	$15,400	N/A
Sub-Total	**$131,800**	**$50,800**	**N/A**
Erosion/Flood Prot.			
Excavation	$37,496	$3,772	$13,179
Imported Fill	$94,767	$32,907	$11,602
Riprap	$1,179,690	$152,350	$339,173
Underlayer	$160,688	$23,428	$47,204
Impervious	$12,086	$12,766	
Sub-Total	**$1,484,728**	**$225,223**	**$411,158**
Total	**$1,616,528**	**$276,023**	**$411,158**
Grand Total – All Sites	**$2,303,709**		

7.3.2 Upper Liard

Cost estimates have been prepared for the works on the left bank based on the typical cross shown in Figure 7.10. This section was repeated at 4 other locations spaced along the bank between the bridge and the tie in to high ground at the upstream end. As well, very approximate road upgrade costs have been developed for the right bank. The cost estimate details are shown in Appendix C and are summarized below:

- Left bank setback dyke Sub-total $914,269
- Right bank road upgrade Sub-total $15,390
- Total Cost at Upper Liard $929,659

As mentioned in Section 7.2.3, left bank dyke inspection on May 29, 2008 revealed that the existing dyke works are more extensive than shown on the McElhanney topographic plan and therefore the above estimate for flood mitigation along the left bank is believed to be on the high side. The above estimates are very approximate due to the limited data available.

8.0 REGULATORY APPROVAL STRATEGY

The purpose and objective of this section is to provide a suggested approach for the flood and erosion control options given the context of the Yukon's assessment and regulatory process. This analysis has been broken into two sections, Marsh Lake and Upper Liard, to reflect the review contained in the "Flood Mitigation Options" portion of this report.

8.1 MARSH LAKE

Within the Marsh Lake area three sites were identified for review within the flood assessment, these included Army Beach, South McClintock and Swan Haven. A number of options were presented based on an analysis of the predicted extent of flooding for 20, 50 and 200 year event. Based on the options presented for the Marsh Lake area a separate and discrete regulatory strategy has been developed to provide an optimal approach to assessment and permitting. It should be noted, some options may not require an assessment or authorization. Further some development options may require a better understanding of specific project details in order to formally determine whether an assessment is required. In the absence of specific project details the options presented below indicates where more information may be required and provides a potential regulatory strategy.

8.1.1 Raising of the South McClintock and Army Beach Roads

Under the *Yukon Environmental and Socio-economic Assessment Act* (YESAA) and subsequently the *Assessable Activities, Exceptions and Executive Committee Project Regulations*, a project proponent is provided with activities which will require an assessment if accompanied by a required permit, authorization or grant of interest in land. According to the Regulations Part 6, Item 10:

> "Construction, modification or decommissioning of a public road, including a public road used only in winter"

Will not require an assessment, if, according to the General Exceptions Item 13:

> "Modification of a road if the modification
>
> (a) Is being carried out on the road right of way;
>
> (b) does not increase the length of the road;

(c) does not increase the width of the road by more than 15%;

(d) Is not being carried out within 30 m of a water body; and

(e) Is not likely to involve the release of polluting substances into a water body." (Canada, 2005)

In order to determine if this section of the Regulations would apply to a specific project road design details would need to be known.

The raising of roads and driveways, as identified in the Flood Mitigation Options" section of this report outlines the portions of road in the Army Beach and South McClintock roads which would require an upgrade in elevation. This mitigation is also suggested for the protection of residential driveways. In creating a regulatory strategy it seemed pertinent to separate these two mitigations into separate projects. The separation of these projects keeps with the rules of YESAA for the scoping of projects.

For the upgrading of the Army Beach and South McClintock roads it is suggested that Yukon Government (YG) define the parameters of work to be completed for the elevation change. This information should be used to understand whether the road footprint (i.e. length and width) will be altered or will occur within 30 m of the high-water mark. Of further consideration would be the expected source of any aggregate materials to be used for the upgrade; specifically, whether the material will be extracted from a licensed facility.

The definition of project design will aid in the determination of assessable under YESAA. If an assessment is deemed necessary for the elevation changes to the Army Beach and South McClintock roads the following steps are suggested:

- Preparation and presentation of YG plans for road upgrades to the community through an information session. Ideally this presentation would form part of a larger meeting to identify an overall plan for the area. The presentation of such plans will provide the community with a greater understanding of YG intentions and further allow for questions and concerns to be raised.
- Following public notification the preparation and subsequent submission of an application (Form 1) to the Whitehorse Designated Office should be undertaken. Early discussions with the appropriate assessor are highly recommended prior to submission. These discussions should be used to inform the assessor the upcoming project and to allow the assessor to work with YG to develop a more comprehensive and complete project proposal. This initial work may create efficiency by limiting the need for project clarifications and additional information requests.
- Once the application has been submitted for assessment and has been deemed adequate within the process, any required permit application should also be submitted.

8.1.2 Residential Flood and Erosion Control

This component has been reviewed to include the raising of private driveways and stabilization of banks located on private land. Ordinarily, the work conducted on privately titled land used for residential purposes does not trigger an assessment. However, it is acknowledged that some lots located in the area may require work below the high-water mark and further may be allotted funding from a government agency.

EBA understands from the community meeting held in Marsh Lake on April 22, 2008 that YG is considering the provision of funding for individual lot owners for the purpose of erosion and flood control. Further, EBA also understands that YG has not made a decision or commitment in this regard, nor have any details been provided to suggest whether the funding would be from a territorial or federal agency. It is anticipated that funding would be the main form of YG involvement for works to be conducted on private land. As such a strategy has been prepared in order to accommodate this perceived role.

The following approach has been suggested in order to ensure that residents are able to meet their regulatory requirements while attempting to ease the time and effort required by individuals.

EBA recommends that YG develop a funding application form for residents to complete which would also encompass question regarding project detail. These questions should reflect the detail needed by each regulatory agency (i.e. YG Lands Branch; Yukon Water Board; DFO) to determine whether individual residents will require an assessment. For instance, the residence should be asked to describe the works they intend to undertake; how and when the work would be carried out, whether all work would be completed within the boundaries of their respective titled lots, and other descriptive project questions. The application should be designed to reflect potential project components such as driveway upgrades, shoreline protection, or foundation work.

After each application has been completed regulators would be able to review the applications and determine if the proposed project would require an assessment. Where an assessment and/or permitting are not required government could simply process the application. In situations where an assessment is deemed required additional steps may be undertaken to ease the application process.

YG may wish to consider the completion of a template YESAA Form 1 to which the original funding application could be attached and referenced. This would allow the residents to avoid potential delays in application preparation. It is suggested that where YG intends to create such a template they seek the advice of the Whitehorse Designated Office in advance. This would allow the assessor to present any question they might have and enable YG to seek specified information during the funding application phase.

EBA strongly recommends that Yukon Government engage the community throughout the process.

8.1.3 Flood and Erosion Control Measures at the Army Beach and the South McClintock Areas

As the reviewed option presented the development of a dyke the following section has been prepared to reflect the potential requirement associated with dyke development.

Under the *Assessable Activities, Exceptions and Executive Committee Projects Regulations* the development of a dyke is likely to trigger an assessment under Part 9, Items 9 and 11. Further the expected regulatory circumstance would likely include the need for a YG Department of Energy, Mines and Resources Land Authorization; a Water Licence; and/or a Department of Fisheries and Oceans (DFO) *Fisheries Act Authorization.* Specific permit requirements will be dependent on project details; in this instance may be need to reflect the timing of construction.[1] Based on the expected requirements the following steps have been identified as a recommended regulatory strategy:

- Due to the potential impacts to property value and aesthetics the preparation of an information package and the use of community meetings are suggested. The decision for development of the dykes, specifically the Army Beach dyke, should be based on community acceptance. The success of such a project would likely require access to some properties and potentially the location of the dyke or backfill to be located on private property or land leases. Therefore if this option is selected government should obtain permission from affected land owners prior to commencing an assessment.
- Upon a determination to proceed, Yukon Government should seek to meet and discuss the project with representatives of the Whitehorse Designated Office, YG Department of Energy, Mines and Resources – Lands Branch, YG Water Resources, and DFO. This meeting should be used to present the project conceptually and request the identification of any potential issues or concerns as well as any information which will be required by the differing agencies. Not all listed parties may be regulators for the project; however, all will need to understand the project in order to make a determination.
- Consideration should also be given to meeting with YG Environment, Carcross/Tagish First Nation, Kwanlin Dun First Nation and Ta'an Kwach'an Council as the development may have potential/perceived effects on the Lewes Marsh Wetland Habitat Protection Area or Swan Haven. The Lewes Marsh Wetland Habitat Protection Area is a designated Special Management Area, recognized under the Final Agreements of the listed First Nations and may be considered through the assessment process. (INAC, 2005)
- Following work conducted with the affected regulators, assessors, and community members the formation and submission of an assessment application to the Whitehorse Designated Office is recommended.

[1] The regulatory circumstance, defined under YESAA, where a territorial agency is the proponent and an authorization or grant of an interest in land would be required for the activity to be undertaken by a private individual.

- Upon determination of adequacy and commencement of the Evaluation, it is suggested that all regulatory application be submitted in order to commence the regulatory process. This step should create timeline efficiencies for the overall process.
- Continued updates should be provided to the community throughout the process.

8.1.4 Erosion Protection at Swan Haven

As identified in the "Flood Mitigation Options" section of this report the Swan Haven area consists of steep cliffs which are being undercut causing erosion of the shoreline. Section 7.0 further outlines the use of fill to flatten the upper portion of the slope and an outer face of riprap to provide a buffer and further protection.

The protection measure outlined will be require further detail to better understand the potential permit requirements, however it is believed that assessment may be required under Part 9, Item (8) or (9). Based on the information provided for the proposed option the following steps are suggested for approaching the assessment and regulatory process.

- An overview of the work intended to be undertaken should be presented at a community information session in advance of the permitting and assessment process.
- Early contact should be undertaken to describe the proposed project to an assessor at the Whitehorse Designated Office, a local DFO representative, YG Water Resources and a representative from YG Department of Energy, Mines and Resources. This meeting should be used to provide an overview of the project and present the assessors and regulators with an opportunity to outline information that would be required for the project. The inclusion of a YG Environment representative should also be considered given the potential impacts to the Swan Haven viewing area as well as the area designation as key waterfowl habitat. (YG, 2008)
- After information has been presented and received from the various parties, preparation and submission of the application for assessment is recommended. Further regulatory application should be submitted upon a determination of adequacy and evaluation commenced. Within all applications, and project planning, careful consideration should be given to the timing of construction in order to minimize impacts to the environment and social concern for the project.

8.2 UPPER LIARD

As identified in Section 7 of the report Upper Liard can be divided into two separate areas the Right Flood Bank and the Left Flood Bank. For both an option has been presented with the acknowledgement that the area lacks baseline data which would be needed to design the potential flood mitigations.

8.2.1 Right Bank Flood Mitigation

The option presented for flood control on the right bank of the Liard River was the upgrading of the riverfront road. The increase in elevation of the road is proposed to act as a dyke providing flood protect to the area. The alteration or relocation of a single residence located between the road and the Liard River has also been identified.

Given the proposed option for road development EBA recommends that Yukon Government utilize the same regulatory strategy presented for the Marsh Lake Area. In summary:

- Detail development plans and activities required to undertake the project.
- Review of the Assessable Activities, Exceptions and Executive Committee Project Requirements to determine if the upgrade would trigger an assessment or the need for regulatory approval. As described earlier in this section, a determination of whether an assessment will be required is dependent on an understanding of the project design details. For instance whether the road upgrades will increase the width or length of the road or whether work will occur within 30 m of a water body.
- Conduct a community meeting to inform local residents of the project and expected activities and scheduling.
- Engage assessors and potential regulators (i.e. Watson Lake Designated Office, YG Water Resources, YG Land Branch; DFO).
- Submit an application for assessment (Watson Lake Designated Office) and upon evaluation commencing submit all other regulatory applications.
- Provide regular update to the community.

With respect to the possible alteration or relocation of a residence, this section would need further detail prior to the development of a regulatory strategy.

8.2.2 Left Bank Flood Mitigation

Through the assessment conducted EBA determined that the left bank of the Liard River would require the upgrading of an existing dyke through an increase in height as an extension in length. This flood mitigation would require a similar regulatory and assessment approach as that of a dyke being constructed in the South McClintock area as such please refer to the steps outlined in the "Flood and Erosion Control Measures at the Army Beach and the South McClintock Areas".

In summary the following approach is recommended for the left bank flood mitigation:

- Development of community information package and conduct of community meetings as well as meeting with the affected First Nation should be undertaken. It should be noted that the dyke does not appear to be located on private property and is an existing structure; therefore, permission would not appear to be a requirement.

- Yukon Government should arrange to meet and discuss the project with representatives of the Watson Lake Designated Office, YG Department of Energy, Mines and Resources – Lands Branch, YG Water Resources, and DFO. This meeting should be used to present the project conceptually and request the identification of any potential issues or concerns as well as any information which will be required by the differing agencies.
- Formation and submission of an assessment application to the Watson Lake Designated Office, after communication with community members and government representatives, is recommended.
- Upon determination of adequacy and commencement of the evaluation, all regulatory application should be submitted in order to commence the regulatory process.
- Continued updates should be provided to the community throughout the process.

8.3 REGULATORY STRATEGY CONCLUSION

The information presented represents an overview of a potential strategy for each option associated with the Marsh Lake and Upper Liard areas. A refined strategy can be prepared upon a decision for which flood mitigation options would be pursued and subsequently the creation of a detailed plan for development.

9.0 PUBLIC MEETING

A public meeting was held at on April 22, 2008 at the Marsh Lake Community Centre. Approximately 80 residents attended the meeting together with EBA and government representatives. Information from the preliminary draft report was presented for discussion.

10.0 DISCUSSION AND RECOMMENDATIONS

This study has investigated the flood threats to the communities of Marsh Lake and Upper Liard. Flood damage estimates and flood and erosion mitigation measures have been developed for both communities as discussed below.

10.1 MARSH LAKE

In the Marsh Lake area, the flood threat is from sustained high lake levels during the annual summer freshet. These flood levels can persist for many weeks and sometimes for months. The flood of record occurred in 2007 and inundated many homes and yards near South McClintock Point and the southern half of Army Beach Drive. This flood has a return period of approximately 80 years and resulted in water levels estimated to be within 0.20 m of the 200-year flood level. The 200-year flood would reach the main floor elevation of about 10 homes including three at South McClintock. Erosion of the lakeshore is the dominant issue along the north half of Army Beach Drive.

Recommendations for Marsh Lake include:

1. It is recommended that the 200-year flood be adopted as the design standard for the Marsh Lake area since this represents only a marginal increase of 0.20 m from the recent 2007 flood level.
2. Upgrade the roads and driveways to maintain dry access to properties during floods. Assuming a freeboard allowance of 0.30 m for roads and 0.10 m for driveways, the cost of this work is estimated at $182,600 based on $20/m^3 for gravel.
3. A dyke system can be built to tie into the raised roads at the south end of Army Beach Drive and at South McClintock Point; however, the construction of the dyke could result in significant negative impacts to low lying properties in terms of infill to yards and lost views. A dyke or bank protection is the only way to mitigate the erosion issue so it is recommended but might have to be implemented in stages according to available funds. The total cost of the dyke works at Army Beach Drive and South McClintock is about $1,710,000 which increases to about $1,893,000 when the road and driveway upgrades are included. These costs are comparable to the corresponding 200-year potential flood damage estimate of $1,966,000 at Marsh Lake while the 50-year damage estimate is $1,560,000. The KGS Group suggest the works should not exceed about $1,600,000 to maintain a benefit/cost ratio of 1.0. The flood works therefore appear to be marginally more costly than the estimated benefits; however the difference is not large and does not account for the damages associated with long-term erosion of the shoreline at the north half of Army Beach Drive. If these erosion costs were included, it is likely that the overall project would have a benefit to cost ratio of approximately 1.0.
4. The bank protection to the shoreline at Swan Haven is estimated to cost $411,000. There is no flood damage information associated with this site as the issue is only erosion. Nevertheless, this area should be protected otherwise it will eventually undermine some residences and infrastructure.

10.2 UPPER LIARD

The flood threat to Upper Liard is short term during the annual freshet. The available information at Upper Liard is not sufficient to support a reliable benefit cost analysis. Nevertheless, some preliminary findings are presented below.

The 200-year potential flood damages are estimated at $1,281,000 while the corresponding 50-year damage estimate is $987,000. The preliminary mitigation works at Upper Liard are estimated to cost approximately $930,000 and since this estimate may be high, the mitigation works likely have a benefit to cost ratio greater than one.

Additional surveys and hydraulic studies are required at Upper Liard to better define the flood profile and flood impacts.

Prepared by:
EBA Engineering Consultants Ltd.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
R. J. WALLWORK

R.J. Wallwork

PROFESSIONAL ENGINEER
YUKON TERRITORY
J. RICHARD TRIMBLE

J Richard Trimble Aug 27/08

Robert J. Wallwork, M.Eng., P.Eng.
Senior Water Resources Engineer

Richard Trimble, M.Sc., P.Eng., ECF
Project Manager

PERMIT TO PRACTICE
EBA ENGINEERING CONSULTANTS LTD.
SIGNATURE J Richard Trimble
Date Aug 27/08
PERMIT NUMBER PP003
Association of Professional
Engineers of Yukon

REFERENCES

ftp://ftp.geomaticsyukon.ca/Environment/pdf-maps/WildlifeKeyArea/.

Government of Canada. 2005. Assessable Activities, Exceptions and Executive Committee Project Regulation. Her Majesty the Queen Right of Canada. November 28, 2005.

Government of Canada. 2005. Highlights Carcross/Tagish First Nation Final Agreement and Self Government Agreements. Indian and Northern Affairs Canada.

Government of Yukon. 2007. Key Wildlife Areas Mapping.

http://www.ainc-inac.gc.ca/nr/prs/s-d2005/02718bbk_e.html.

FIGURES

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 1.1-1.2_R0.dwg [FIGURE 1.1] August 22, 2008 - 3:04:52 pm (BY: JON BOKIC)

SCALE 1:250,000

2 0 2 6 10km

CLIENT

Yukon Government

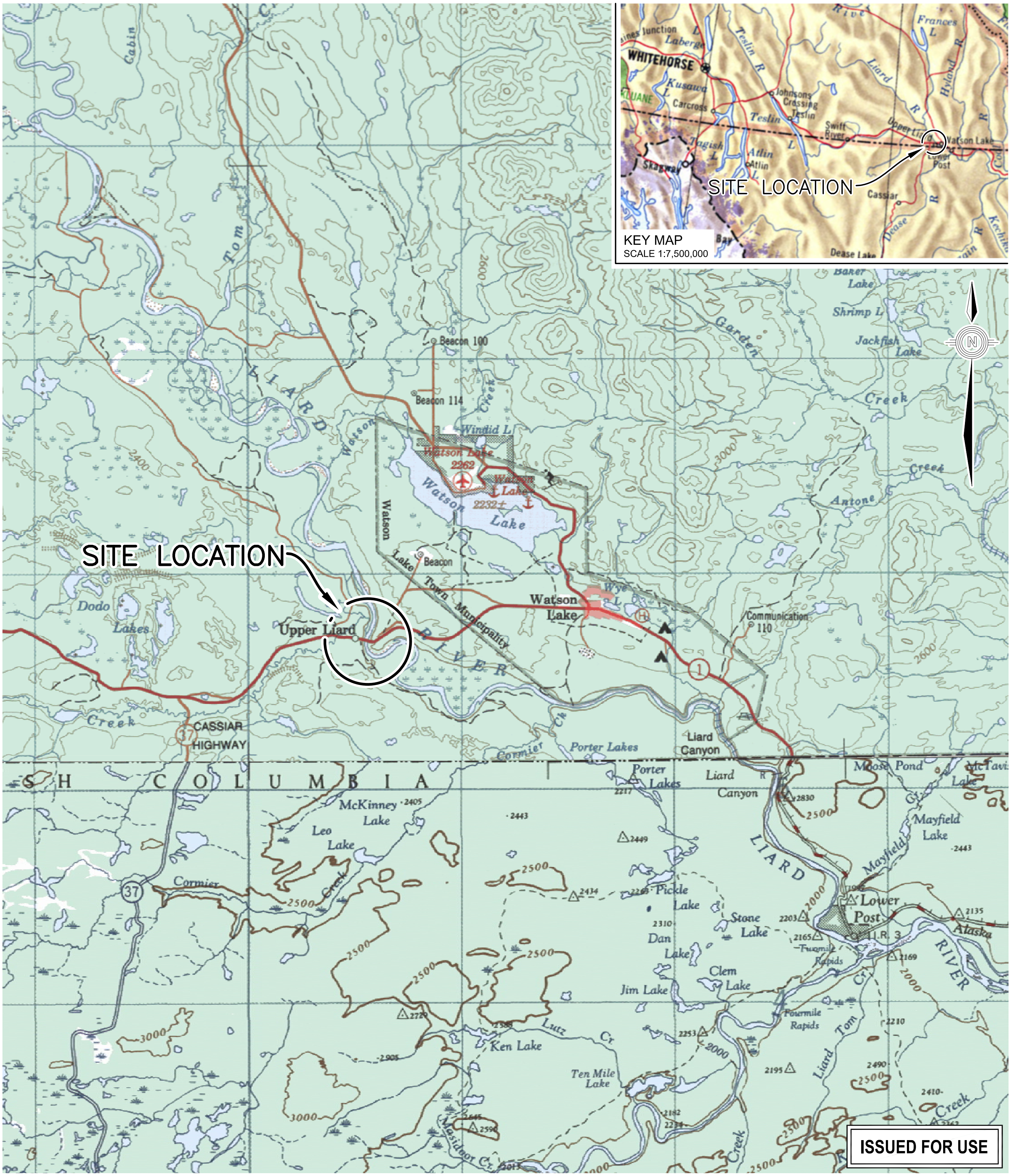
EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

LOCATION PLAN FOR MARSH LAKE SITE

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	0
OFFICE	DATE		
VANC	April 15, 2008		

Figure 1.1



SCALE 1:250,000

2 0 2 6 10km

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

LOCATION PLAN FOR UPPER LIARD SITE

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	0
OFFICE	DATE		
VANC	April 14, 2008		

Figure 1.2

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 1.1-1.2_R0.dwg [FIGURE 1.2] August 22, 2008 - 3:05:32 pm (BY: JON BOKIC)

NOTES

All dimensions are in metres unless noted otherwise

LEGEND

SA3 Soil Sample 3

SCALE 1:15,000

100 0 100 300 600m

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE SITE PLAN
SHOWING SOIL SAMPLE LOCATIONS AND
PROPOSED BORROW AND RIPRAP SOURCES

PROJECT NO.	DWN	CKD	REV
V13201069	JSB	JRT	1
OFFICE	DATE		
WHSE	June 11, 2008		

Figure 2.1

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 2.1_R1.dwg [FIGURE 2.1] August 22, 2008 - 3:10:42 pm (BY: JON BOKIC)

LEGEND

NOTES

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

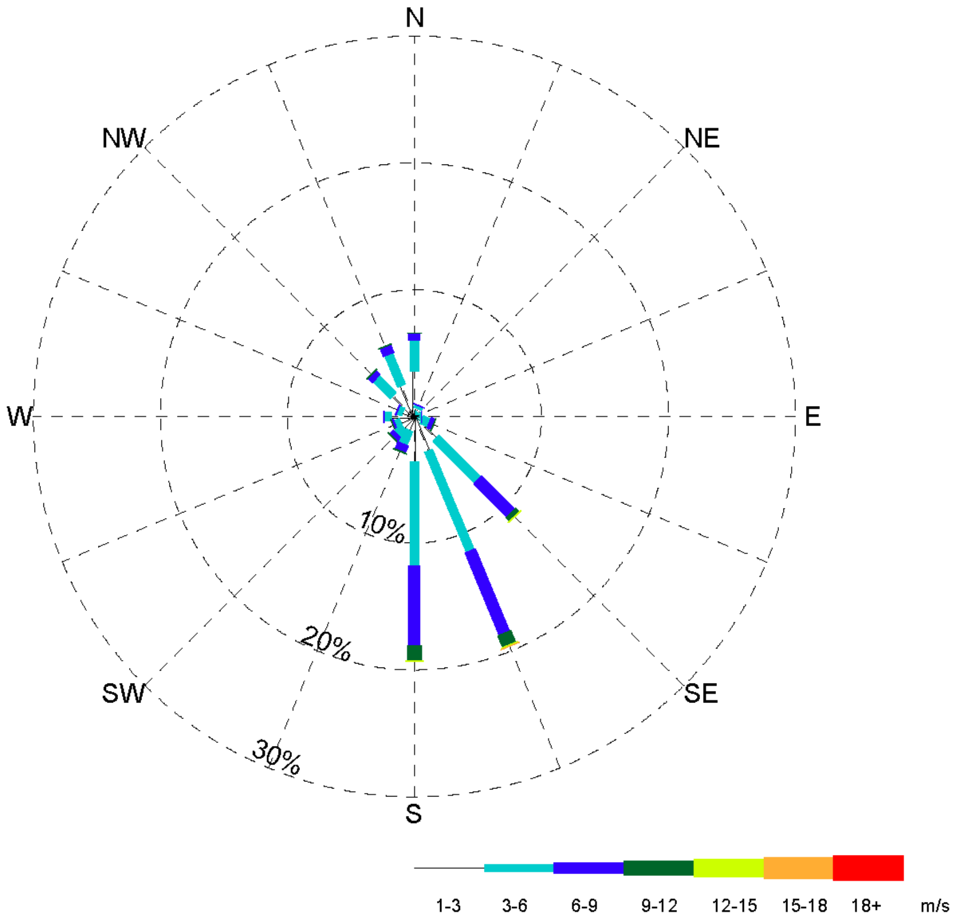
Whitehorse Airport
Canadian Atmosphere and Environment Service Climate Station

PROJECT NO.	DWN	CKD	REV
V13201069	EW	RJW	1

OFFICE	DATE
EBA-VANC	April 2008

Figure 5.1

\\van-eb-file001\Vancouver\Engineering\V132\Projects\V13201069 Marsh Lake Upper Liard\Working\EW\figures\Fig5.1-eba.doc



Whitehorse Airport
NAD 83 location
N60° 43' 0.0" W135° 4' 0.0"
Elevation
Sea level
Length of Record
Start Date
End Date
Comment:

Wind Speed & Direction Frequency Distribution Table

	Percent Occurrence (%)								
Direction	**0-1 m/s**	**1-3 m/s**	**3-6 m/s**	**6-9 m/s**	**9-12 m/s**	**12-15 m/s**	**15-18 m/s**	**18+ m/s**	**Total (%)**
ENE	-	0.17	0.04	-	-	-	-	-	0.22
NE	-	0.31	0.07	-	-	-	-	-	0.39
NNE	-	0.67	0.24	0.03	-	-	-	-	0.95
N	-	3.55	2.44	0.57	0.05	-	-	-	6.62
NNW	-	2.65	2.66	0.68	0.04	-	-	-	6.02
NW	-	2.37	1.88	0.47	0.04	-	-	-	4.77
WNW	-	0.96	0.42	0.07	-	-	-	-	1.46
W	-	1.82	0.53	0.07	-	-	-	-	2.42
WSW	-	1.14	0.48	0.18	0.02	-	-	-	1.82
SW	-	1.20	0.73	0.41	0.04	-	-	-	2.38
SSW	-	1.14	1.17	0.60	0.06	-	-	-	2.98
S	-	3.54	8.25	6.27	1.19	0.11	-	-	19.36
SSE	-	2.91	8.57	7.02	1.00	0.10	0.01	-	19.62
SE	-	2.38	4.68	3.67	0.39	0.05	-	-	11.17
ESE	-	0.62	0.64	0.35	0.03	-	-	-	1.64
E	-	0.44	0.14	0.02	-	-	-	-	0.60
Calm	17.59	-	-	-	-	-	-	-	17.59
Total (%)	17.59	25.86	32.94	20.42	2.87	0.29	0.04	-	100.00

LEGEND

NOTES

CLIENT

Yukon Government

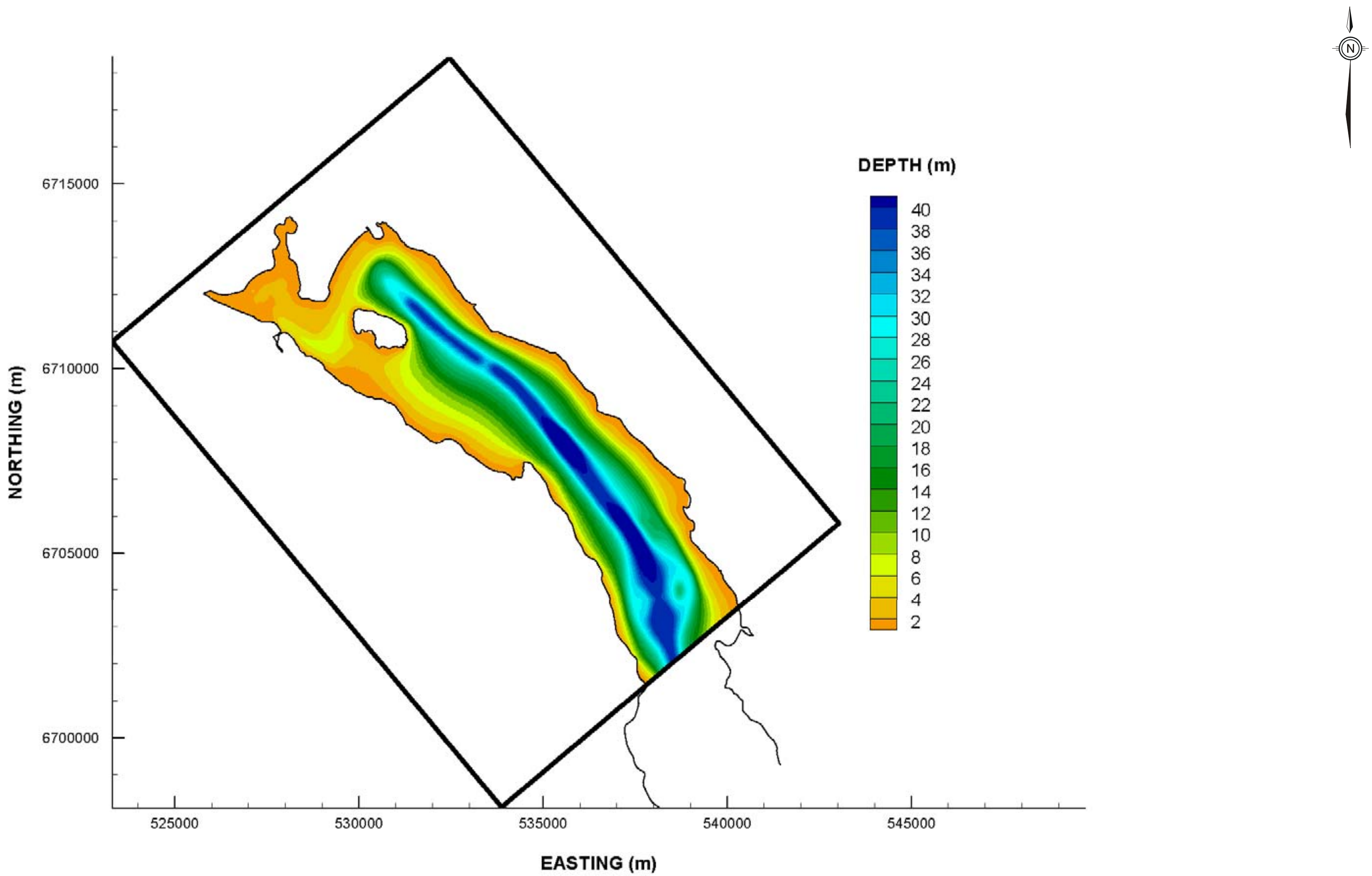
EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

Whitehorse Airport Station
Wind Rose
1953 - 2007

PROJECT NO.	DWN	CKD	REV
V13201069	EW	RJW	1
OFFICE	DATE		
EBA-VANC	April 2008		

Figure 5.2



LEGEND

NOTES

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

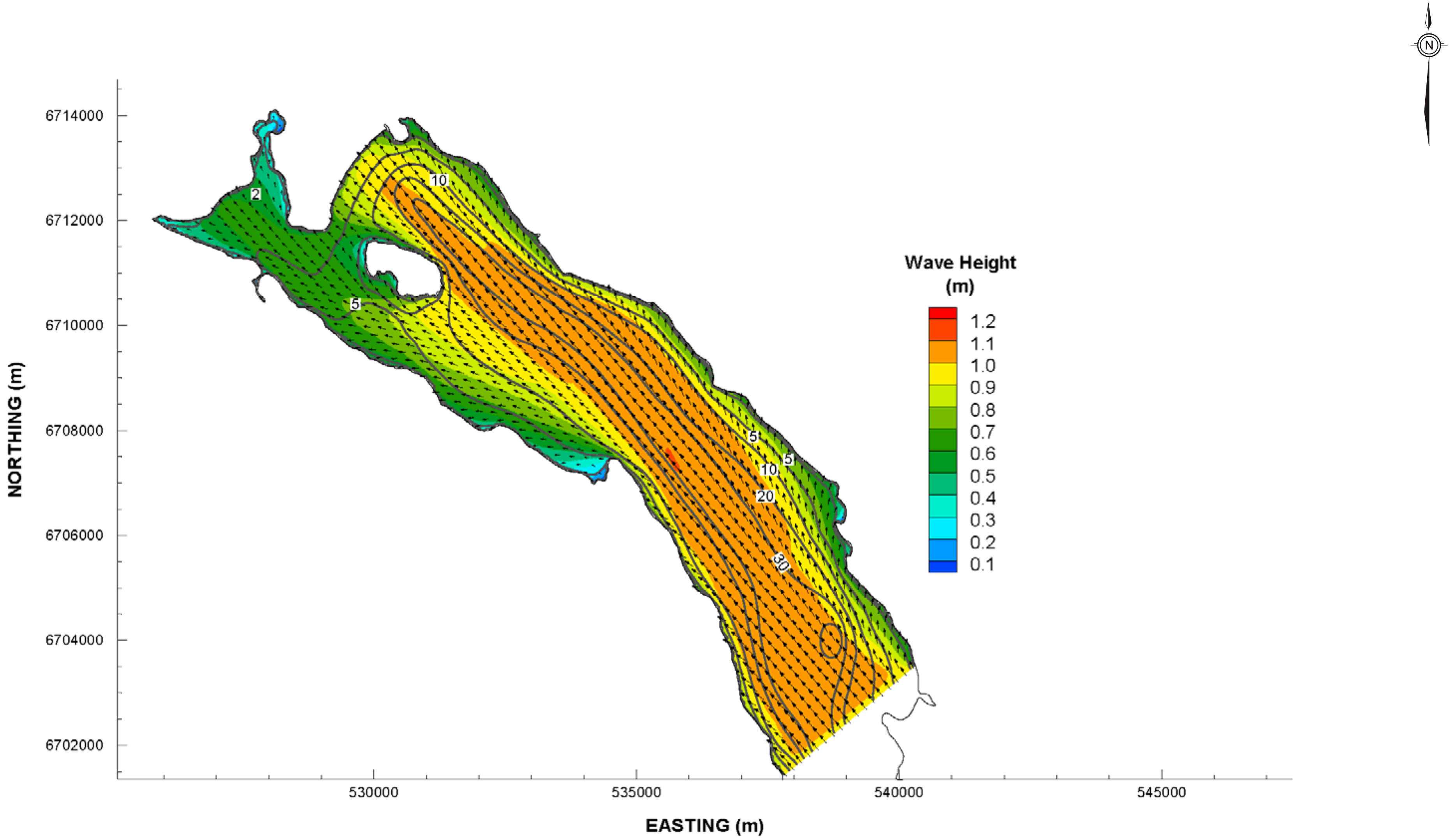
MARSH LAKE AND UPPER LIARD FLOOD STUDY

Bathymetry Grid
SWAN Model

PROJECT NO.	DWN	CKD	REV
V13201069	EW	RJW	1

OFFICE	DATE
EBA-VANC	April 2008

Figure 5.3



LEGEND

NOTES

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

SWAN Model Result
10 Year Storm Event + 200 year Flood Level

PROJECT NO.	DWN	CKD	REV
V13201069	EW	RJW	1

OFFICE	DATE
EBA-VANC	April 2008

Figure 5.4

\\van-eb-file001\Vancouver\Engineering\V132\Projects\V13201069 Marsh Lake Upper Liard\Working\EW\figures\Fig5.4-eba.doc

NOTES

All dimensions are in metres unless noted otherwise

SCALE 1:15,000

100 0 100 300 600m

LEGEND

Section Location

12 / 7 — Section Identifier — Sheet Number

CLIENT

Yukon Government

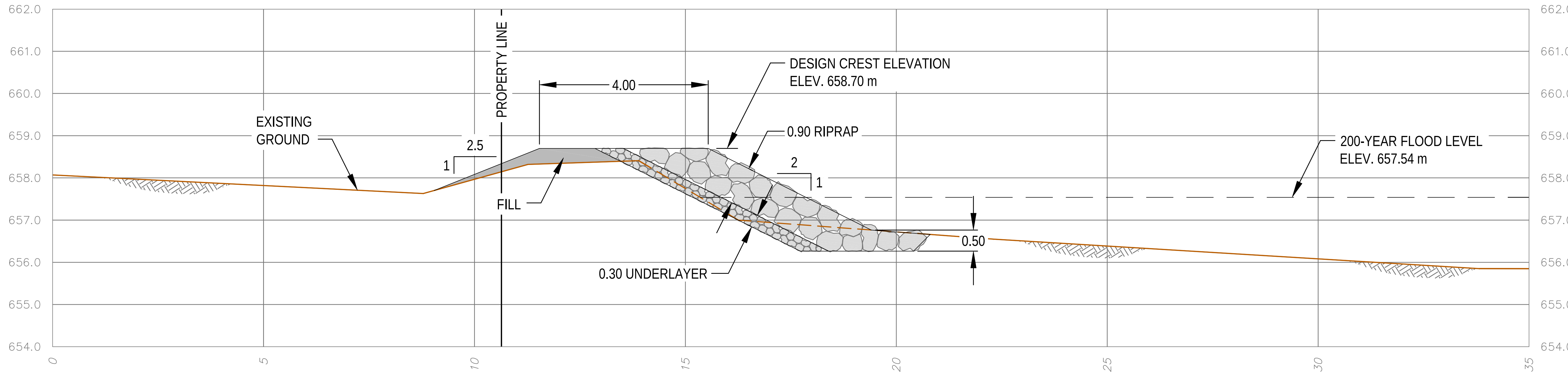
EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

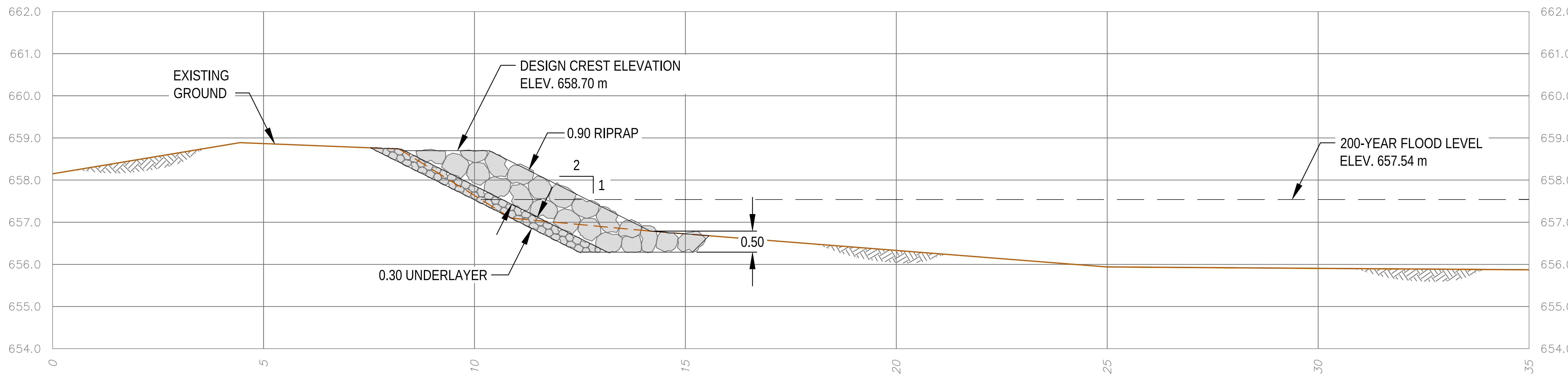
MARSH LAKE SITE PLAN

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	1
OFFICE	DATE		
VANC	June 18, 2008		

Figure 7.1



SECTION 2/1
SITE 1



SECTION 1/1
SITE 1

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100
1 0 1 2 4m

CLIENT
Yukon Government

EBA Engineering Consultants Ltd.

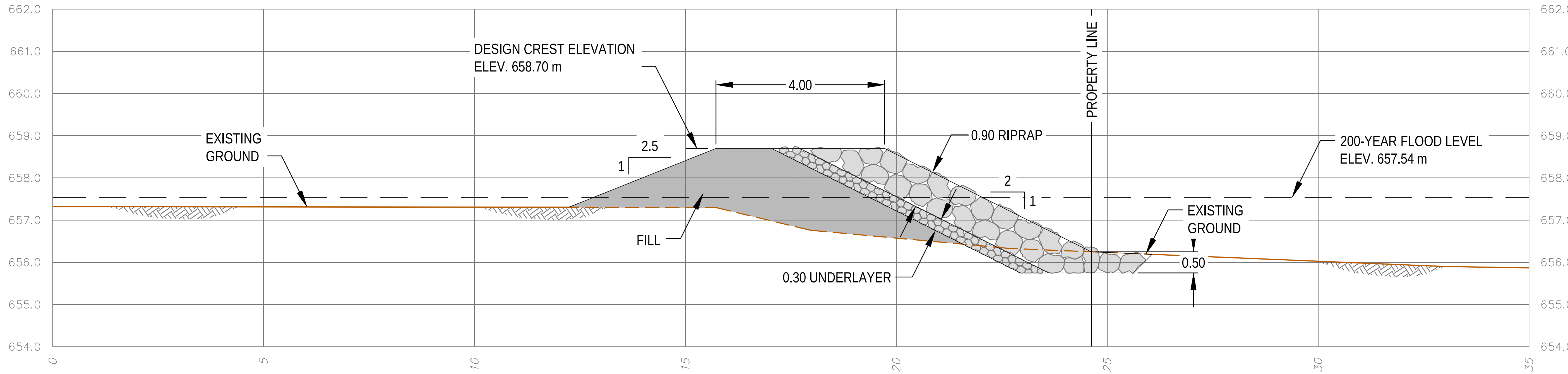
MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE SECTIONS 1 AND 2

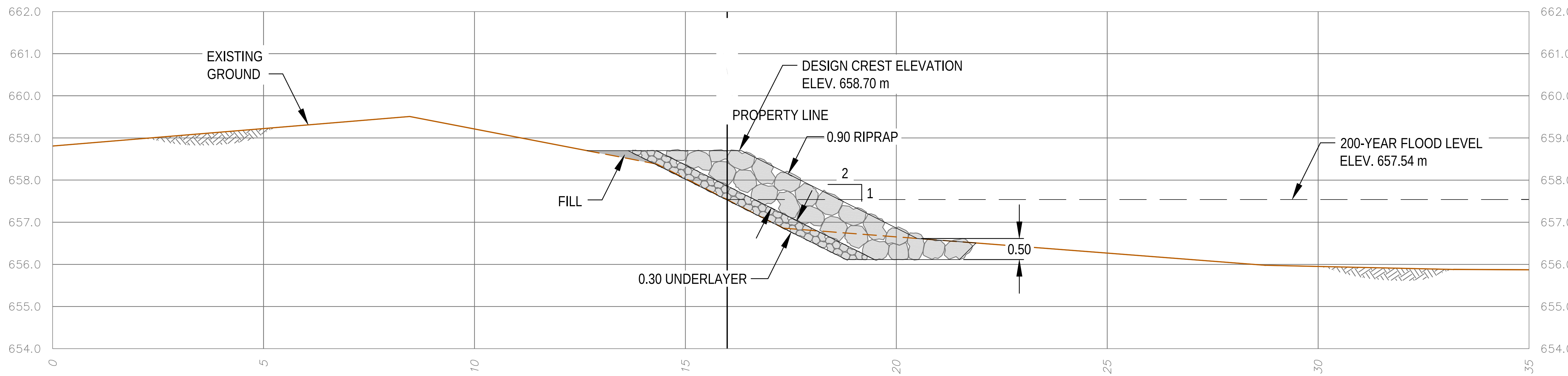
PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	1
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.2

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.1-7.7_R2.dwg [FIGURE 7.2] August 22, 2008 - 3:30:04 pm (BY: JON BOKIC)



SECTION 4 / 1
SITE 1



SECTION 3 / 1
SITE 1

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100
1 0 1 2 4m

CLIENT
Yukon Government

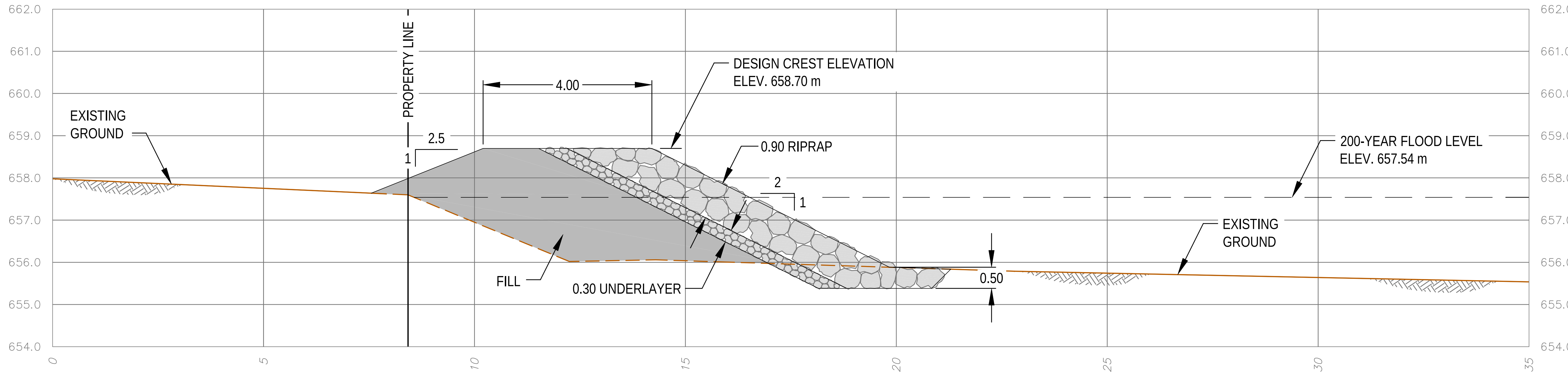
EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

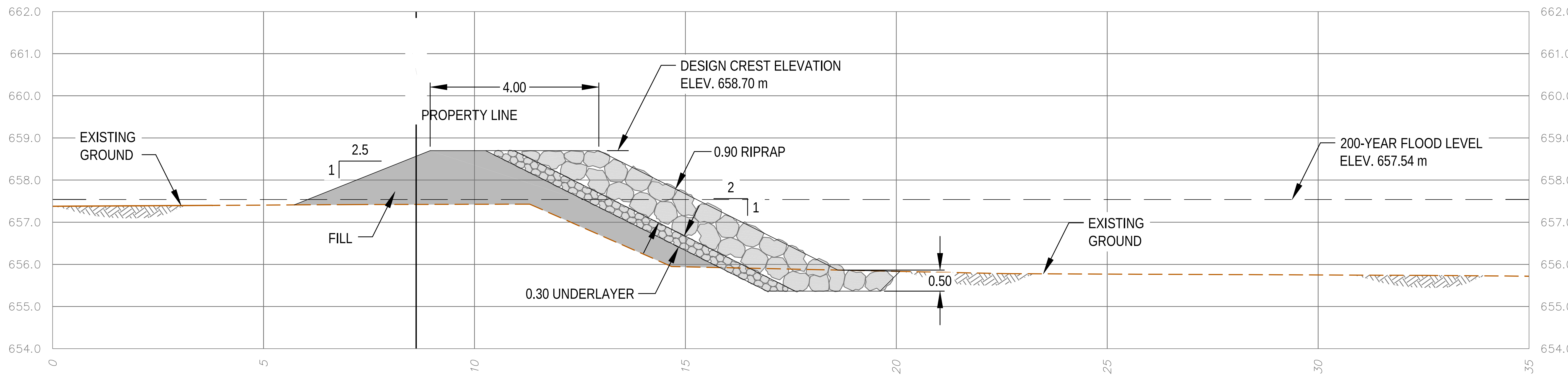
MARSH LAKE SECTIONS 3 AND 4

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	2
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.3



SECTION 6
SITE 1 1



SECTION 5
SITE 1 1

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100
1 0 1 2 4m

CLIENT
Yukon Government

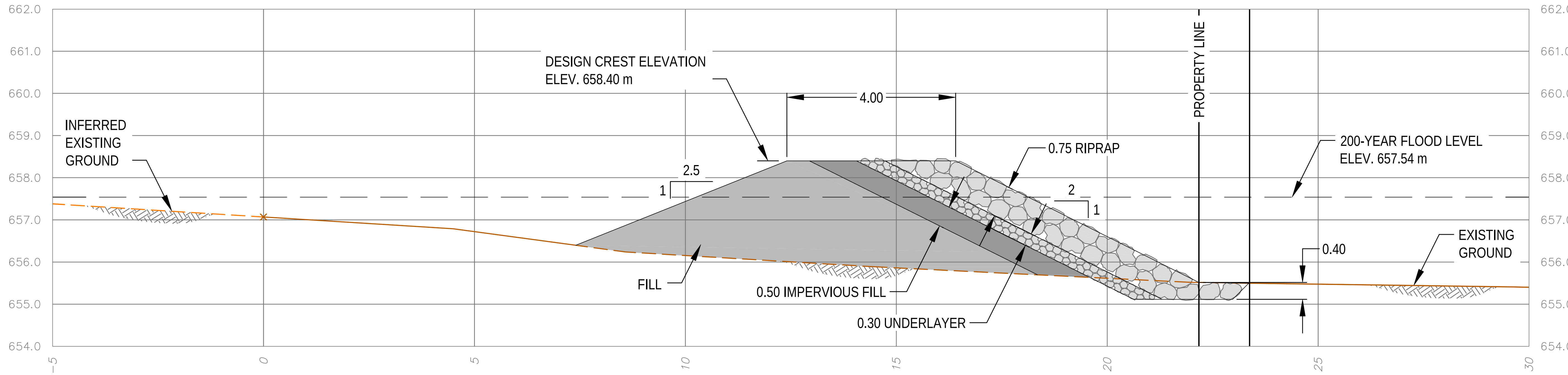
EBA Engineering Consultants Ltd.
eba

MARSH LAKE AND UPPER LIARD FLOOD STUDY

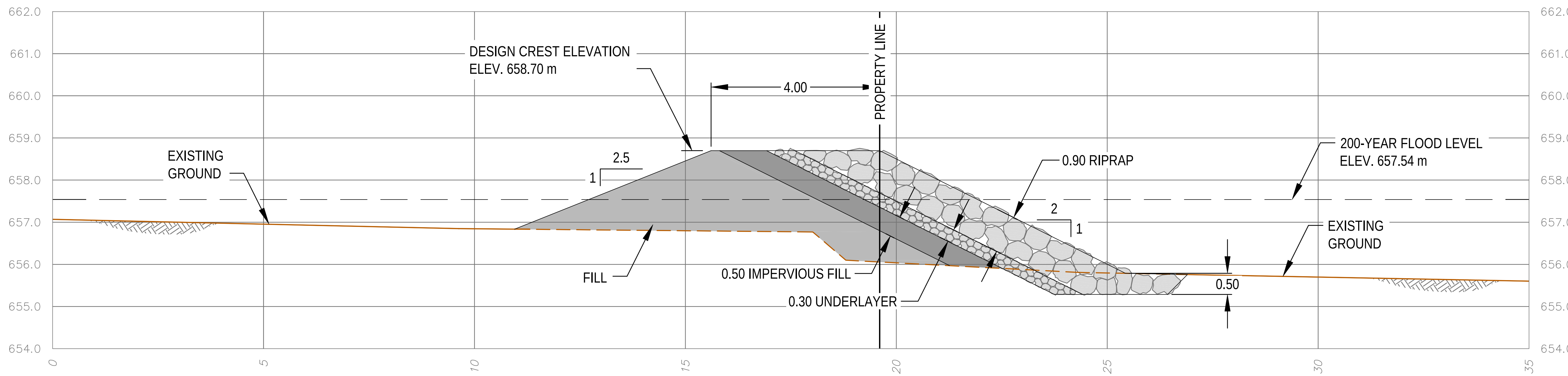
MARSH LAKE SECTIONS 5 AND 6

PROJECT NO.	DWN	CKD	REV	
V13201069	JAB	RJW	2	Figure 7.4
OFFICE	DATE			
VANC	August 20, 2008			

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.1-7.7_R2.dwg [FIGURE 7.4] August 22, 2008 - 3:30:07 pm (BY: JON BOKIC)



SECTION 8/1
SITE 2



SECTION 7/1
SITE 1

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100

1 0 1 2 4m

CLIENT

Yukon Government

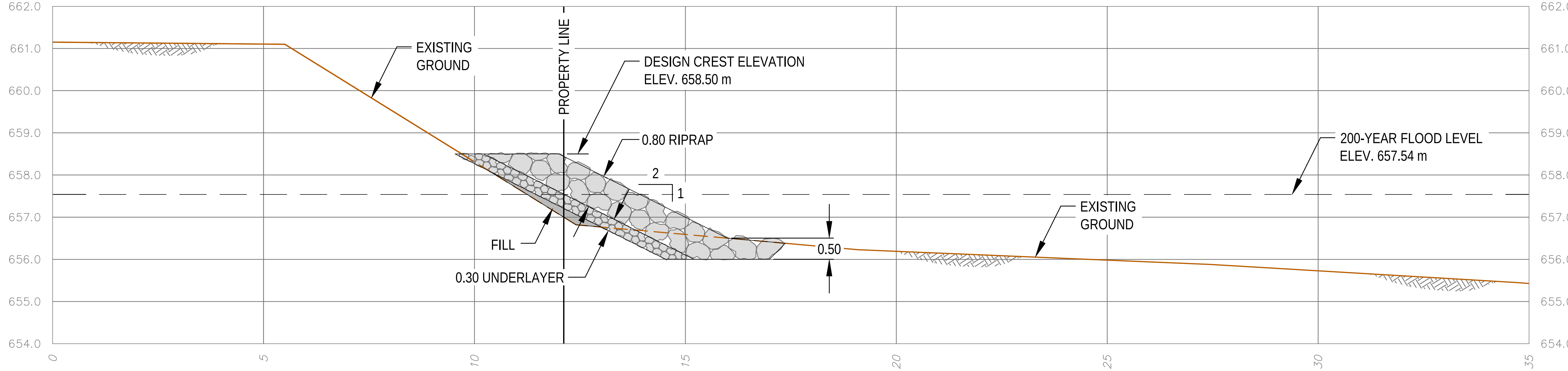
MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE SECTIONS 7 AND 8

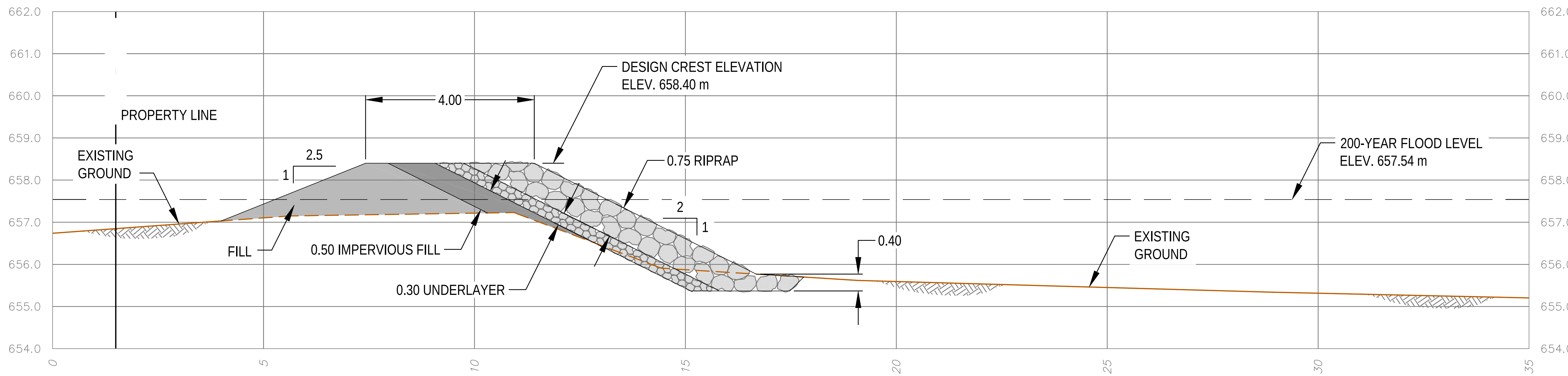
EBA Engineering Consultants Ltd.

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	2
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.5



SECTION 10/1
SITE 3



SECTION 9/1
SITE 2

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100

1 0 1 2 4m

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

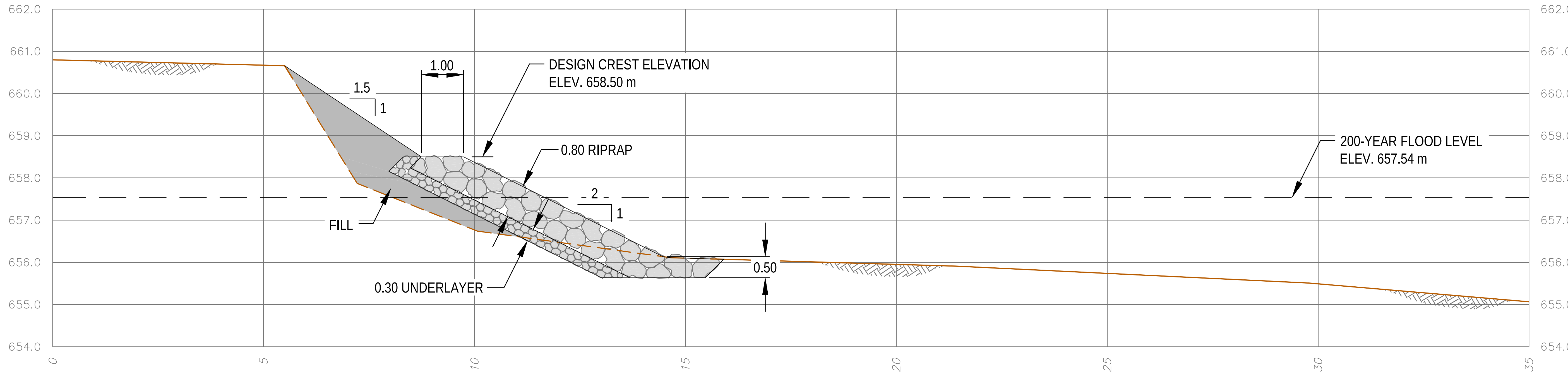
MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE SECTIONS 9 AND 10

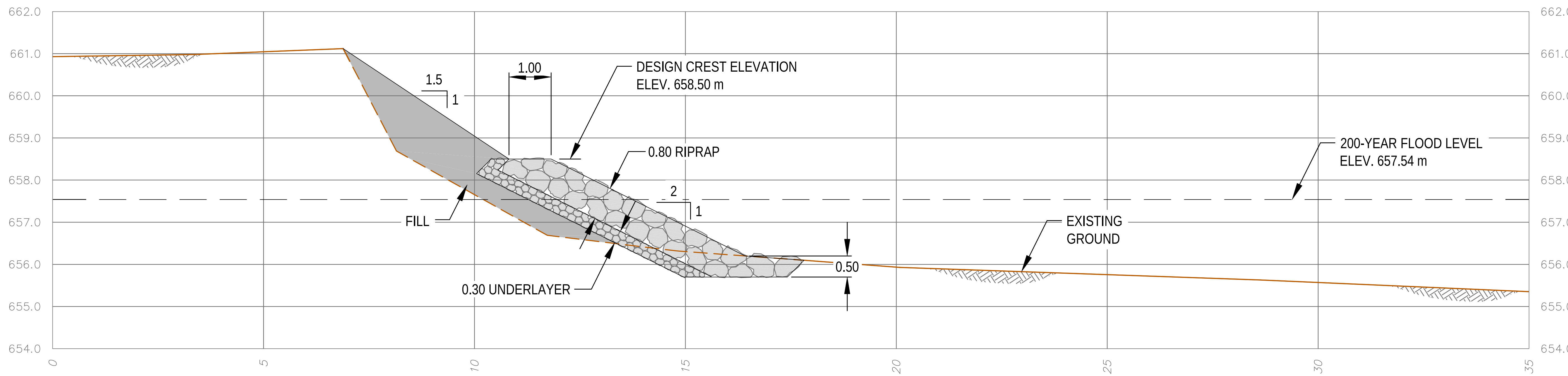
PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	1
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.6

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.1-7.7_R2.dwg [FIGURE 7.6] August 22, 2008 - 3:30:10 pm (BY: JON BOKIC)



SECTION 12 / 1
SITE 3



SECTION 11 / 1
SITE 3

ISSUED FOR USE

NOTES

- All dimensions are in metres unless noted otherwise
- The designs shown are based on limited information. Detailed design would take into account the surveyed locations of the houses and dyke designs would be reviewed and revised accordingly.

SCALE 1:100

1 0 1 2 4m

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

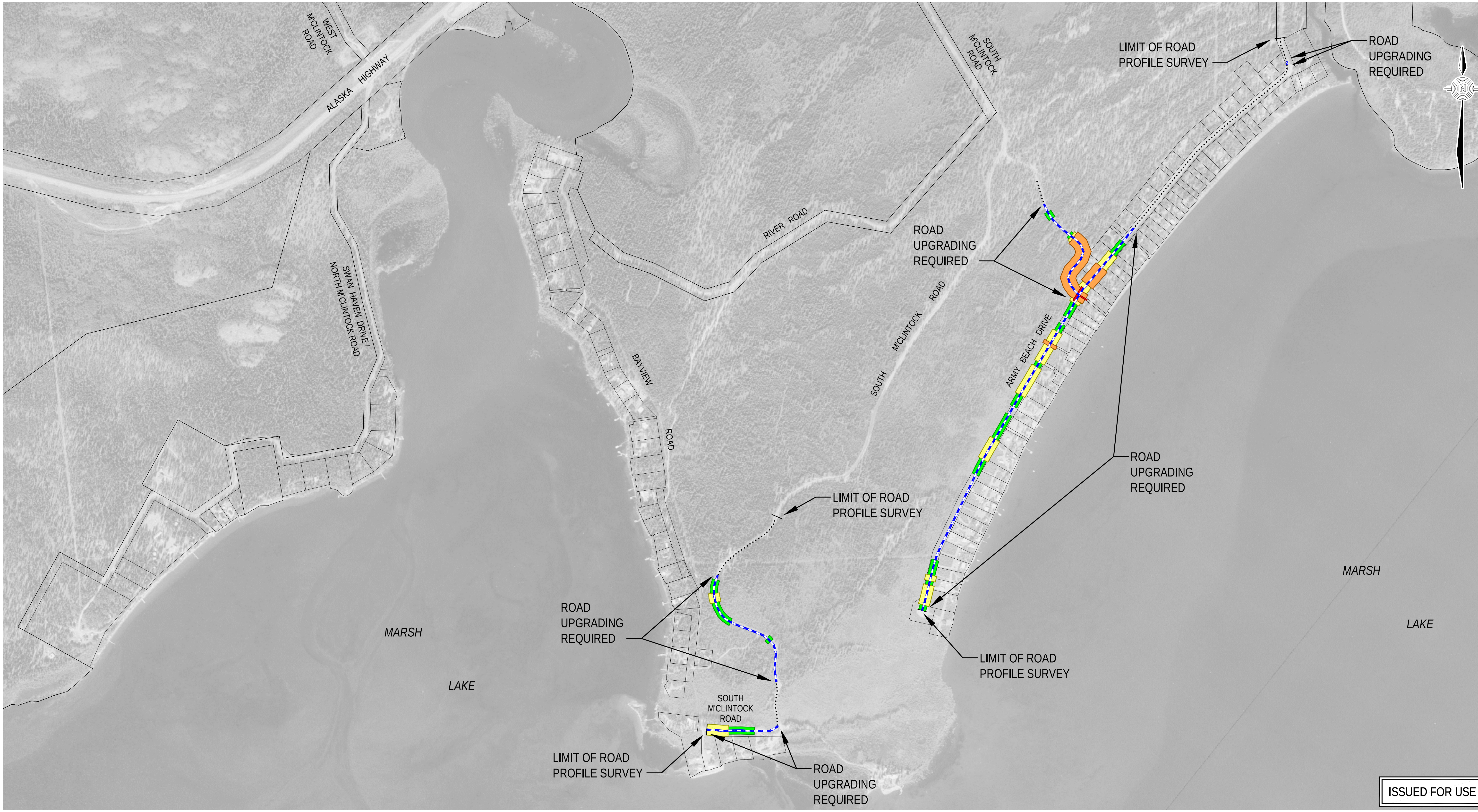
MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE SECTIONS 11 AND 12

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	1
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.7

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.1-7.7_R2.dwg [FIGURE 7.7] August 22, 2008 - 3:30:11 pm (BY: JON BOKIC)



Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.8_R2.dwg [FIGURE 7.8] August 22, 2008 - 3:32:12 pm (BY: JON BOKIC)

NOTES

All dimensions are in metres unless noted otherwise

SCALE 1:10,000

100 0 100 200 400m

LEGEND

- ℄ of Existing Road
- Road Upgrade Needed (657.84m Elev.)
- 200-year Flood Limit (657.54m Elev.)
- 100-year Flood Limit (657.39m Elev.)
- 50-year Flood Limit (657.24m Elev.)
- 20-year Flood Limit (657.03m Elev.)

CLIENT

Yukon Government

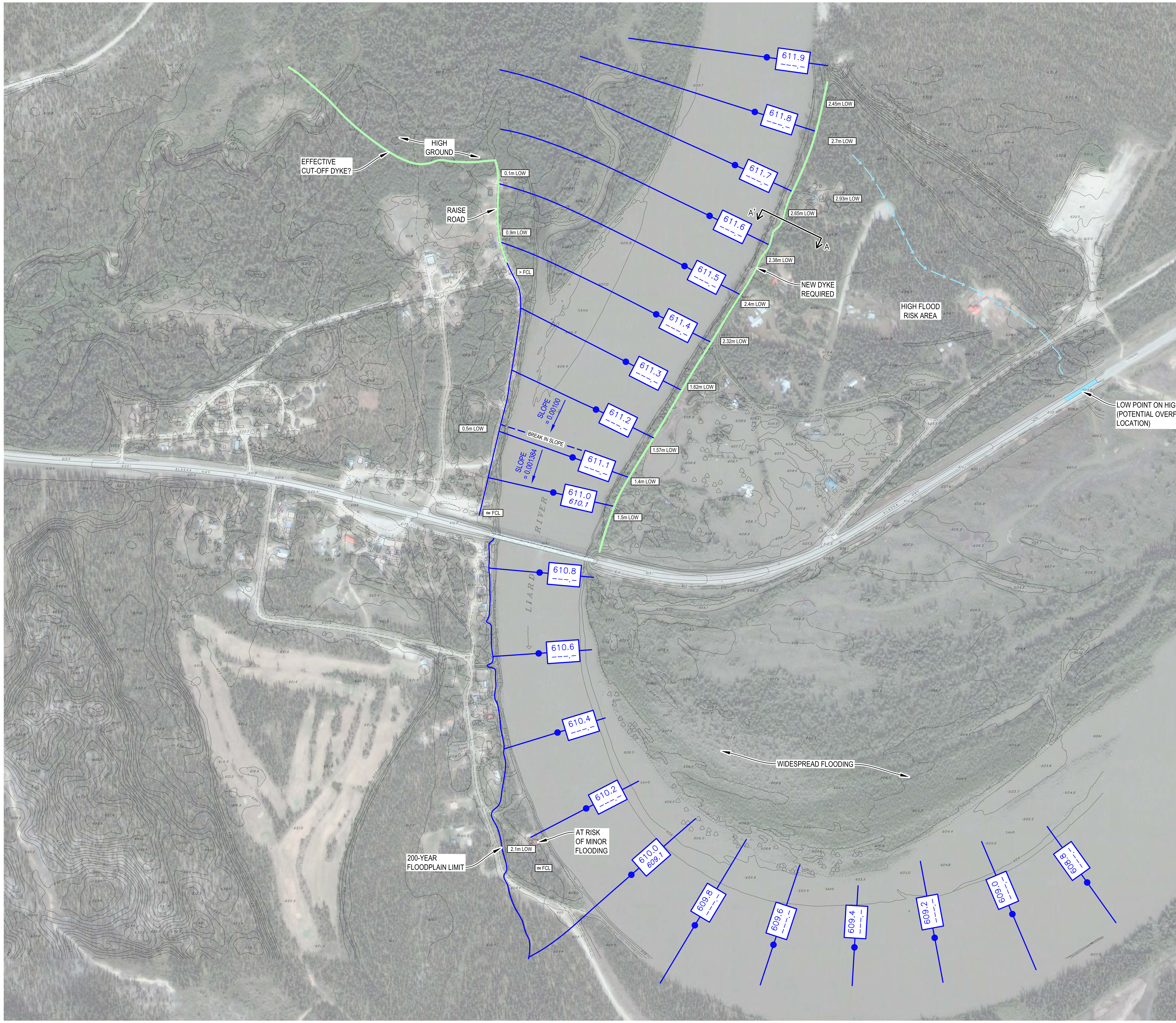
EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

MARSH LAKE FLOOD IMPACTS TO ROADS AND PROPOSED ROAD UPGRADES

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	2
OFFICE	DATE		
VANC	August 20, 2008		

Figure 7.8



FLOOD LEVELS AT BRIDGE

RETURN PERIOD (years)	FLOOD LEVEL (m)	FREEBOARD ALLOWANCE (m)	DYKE LEVEL (m)
20	609.36	0.60	609.96
50	609.75	0.60	610.35
100	610.01	0.60	610.61
200	610.26	0.60	610.86

ISSUED FOR USE

NOTES

All dimensions are in metres unless noted otherwise

SCALE 1:4000

LEGEND

Proposed Dyke Location
Potential Flooding Route to Alaska Highway
200-Year Floodplain Limit - includes freeboard

Flood Levels (includes freeboard allowance)

21.00 — 200-Year Frequency
20.53 — 20-Year Frequency

REVISIONS

NUM	DATE	DWN	CKD	APR	DESCRIPTION

DRAWING STATUS

NUM	DATE	APR	DESCRIPTION
B	2008/08/22	RJW	ISSUED FOR USE
A	2008/04/21	RJW	ISSUED FOR REVIEW

PROFESSIONAL SEAL

CLIENT

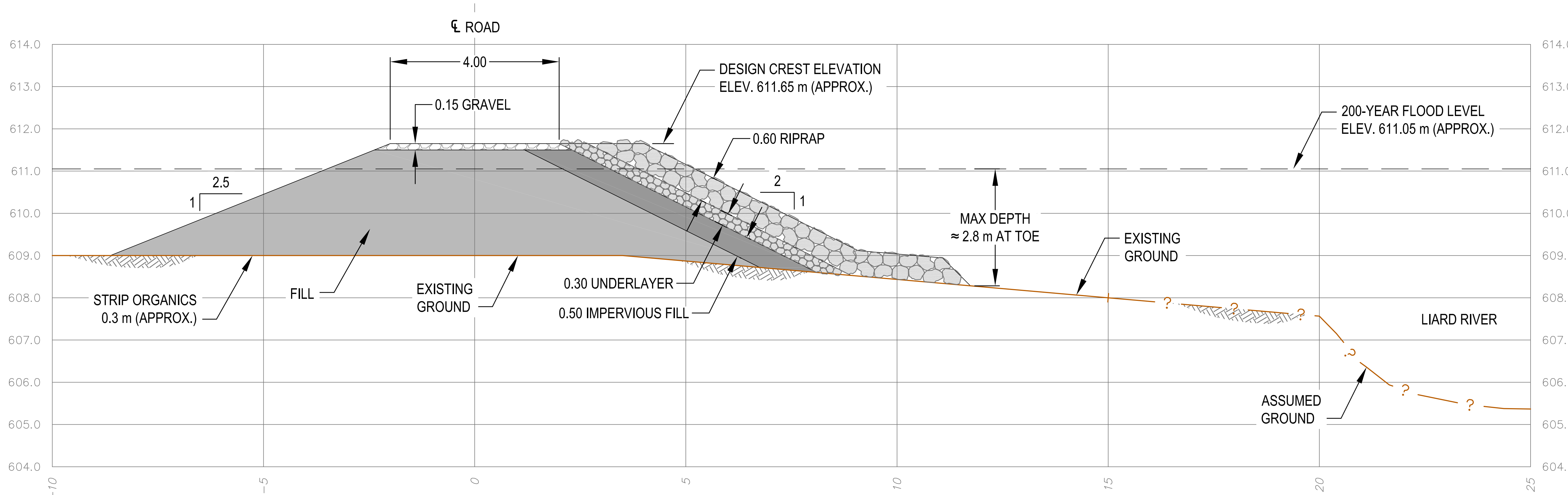
Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

UPPER LIARD SITE PLAN

PROJECT No.	OFFICE	DES	CKD	REV	DRAWING
V13201069	VANC	RJW	RJW	0	Figure 7.9
DATE:	SHEET No.	DWN	APP	STATUS	
April 21, 2008	1 of 1	JAB	RJW	B	



SECTION A 7.9
LOOKING DOWNSTREEAM

TYPICAL SETBACK DYKE SECTION (200-YEAR DESIGN STANDARD)

Q:\Vancouver\Drafting\Engineering\V132\V13201069\V13201069_FIG 7.10_R0.dwg [FIGURE 7.10] August 22, 2008 - 3:38:20 pm (BY: JON BOKIC)

ISSUED FOR USE

NOTES

All dimensions are in metres unless noted otherwise

SCALE 1:100

1 0 1 2 4m

CLIENT

Yukon Government

EBA Engineering Consultants Ltd.

MARSH LAKE AND UPPER LIARD FLOOD STUDY

UPPER LIARD
TYPICAL FLOOD MITIGATION MEASURES

PROJECT NO.	DWN	CKD	REV
V13201069	JAB	RJW	0
OFFICE	DATE		
VANC	April 21, 2008		

Figure 7.10

APPENDIX

APPENDIX A MARSH LAKE-ANALYSIS OF ROAD/DRIVEWAY ELEVATIONS AND REQUIRED ADJUSTMENTS

APPENDIX A
Marsh Lake-Analysis of Road/Driveway Elevations and Required Adjustments

MARSH LAKE AND UPPER LIARD FLOOD STUDY:					**Marsh Lake - Analysis of Road/Driveway Elevations and Required Adjustments**									
Marsh Lake 200-year Flood Level =			**657.54**	m	Sections of roads and driveways to be upgraded are highlighted.									
Freeboard Allowance for Roads =			0.30	m	Freeboard Allowance for Driveways =				0.10	m				
Design Road Grade =			**657.84**	**m**	**Design Driveway Grade =**				**657.64**	**m**				

South McClintock Road:

* Driveway elevation points 2 and 3 from Lot 1048 A are common to 1048 B and have been omitted.

Drawing Sheet No.	Driveway at: Building Lot No.	Approx. Road Sta.	Road C/L Elevation m	Road 1	> House or Lake 2	3	4	5	6	Average Driveway Elevation (points 2-6) m	Driveway Design Grade Minus Average Driveway Elev. m	Driveway Length m	Driveway Upgrade Required Yes/No	Driveway Upgrade Volume W = 4.5 m m3
				Driveway Elevations Starting at Road Shoulder m										
11		4+248.5	658.20											
11		4+226.5	657.97											
11		4+205.3	658.10											
11		4+161.7	658.05											
11		4+118.7	658.83											
11		4+076	658.94											
11		4+054.3	658.40											
11		4+032.7	657.61											
11		4+011	657.39											
1	36A	0+000/4+000	657.42	*657.54*	657.71	657.92	657.74			657.79	-0.15	42	No	
1	Road	0+072	657.50	*657.57*	657.49	657.37	657.41	657.48		657.44	0.20	53	Yes	48.30
1	Road	0+188	657.67	*657.56*	657.48	657.49	657.44			657.47	0.17	35	Yes	26.77
2	1048 A	0+467	657.83	*657.88*	657.83	657.83	658.21	658.18		658.01	-0.37	20	No	
2 & 3	1048 B*	0+467	657.83	*657.88*	657.83	657.70	657.26	657.28	657.09	657.43	0.21	75	Yes	70.20
3	1046-1047	0+592	657.44	*657.37*	656.87	656.77	657.07	656.89	656.91	656.90	0.74	76	Yes	252.40
3	1044-1045	0+675	656.98	*656.98*	656.93	656.91	656.94	657.22	657.31	657.06	0.58	95	Yes	247.09
3	1012A	0+665	657.37	*657.36*	657.29	656.99	656.91			657.06	0.58	48	Yes	124.56
Average Road C/L Elev. =			**657.50**	**m**		**Average Driveway Elev. =**				**657.23**	**m**			
Average Road Grade Adj. =			**0.336**	**m**		**Average Driveway Adj. with FB =**				**0.412**	**m**			
Road Length Requiring Upgrade =			584	m from plans		Driveway Length Requiring Upgrade =						382	m	
Total Volume Road Upgrade =			**1766**	**m3**		**Total Volume (m3) for Driveway Upgrade =**								**769.32**

Army Beach Drive:

Drawing Sheet No.	Driveway at: Building Lot No.	Approx. Road Sta.	Road C/L Elevation m	Road 1	> House or Lake 2	3	4	5	6	Average Driveway Elevation (points 2-6) m	Driveway Design Grade Minus Average Driveway Elev. m	Driveway Length m	Driveway Upgrade Required Yes/No	Driveway Upgrade Volume W = 4.5 m m3
				Driveway Elevations Starting at Road Shoulder										
10	1 Block H	2+879	657.90	*658.02*	657.67	657.55	657.51			657.58	0.06	42	Yes	11.97
10	Road	2+865	658.09	*658.26*	658.20	658.43	658.43			658.35	-0.71	33	No	
10	2 Block J	2+815	659.22	*659.34*	659.28	658.98				659.13	-1.49	15	No	
9	4	2+556	658.80	*658.74*	658.70	658.85				658.78	-1.14	9	No	
9	2 Block K	2+552	658.74	*658.66*	658.45					658.45	-0.81	9	No	
9	49	2+520	658.68	*658.50*	659.29	659.28				659.29	-1.64	9	No	
9	3 Block K	2+499	658.79	*658.74*	658.57					658.57	-0.93	8	No	
9	7	2+460	658.92	*658.77*	658.84	658.88				658.86	-1.22	5	No	
9	1A Block L	2+440	658.82	*658.73*	658.86	658.45				658.66	-1.01	16	No	
9	9	2+407	658.83	*658.68*	658.72	659.74	659.73	659.52		659.43	-1.79	21	No	
9	10	2+373	658.78		658.86	659.05	659.40			659.10	-1.46	32	No	
9	2 Block L	2+341	658.61	*658.44*	658.68	658.41	658.12			658.40	-0.76	20	No	
8	12	2+320	658.33	*658.27*	658.56	659.42	659.42			659.13	-1.49	20	No	
8	3 Block L	2+319	658.32	*658.22*	658.47	658.43	657.92			658.27	-0.63	19	No	
8	70	2+268	657.85	*657.80*	658.70	658.99				658.85	-1.21	19	No	
8	4 Block L	2+267	657.84	*657.74*	657.76	657.52				657.64	0.00	14	No	
8	1 Block M	2+222	657.55	*657.48*	657.85	657.58				657.72	-0.08	18	No	
8	15A	2+192	657.48	*657.36*	657.65	658.71	658.63			658.33	-0.69	31	No	
8	16A	2+173	657.36	*657.30*	657.44	658.33	658.72			658.16	-0.52	24	No	
8	17A	2+152	657.21	*657.86*	658.43	658.84				658.64	-1.00	26	No	
8	18A	2+127	657.24	*657.18*	656.96					656.96	0.68	9	Yes	27.54
8	19-1A	2+078	657.19	*657.04*	657.26					657.26	0.38	10	Yes	17.10
4 / 8	Access	-0+33 / 2+035	657.37	*657.21*	657.29	*657.40*				657.35	0.29	16	Yes	21.24
4	21	0+006	657.45	*657.37*	656.96	656.99				656.98	0.66	12	Yes	35.91
4	22-1	0+035	657.53	*657.41*	657.50					657.50	0.14	9	Yes	5.67
4	22-2	0+055	657.58	*657.40*	657.05	657.06				657.06	0.59	14	Yes	36.86
4	23	0+083	657.41	*657.25*	657.10	657.42				657.26	0.38	12	Yes	20.52
4	24	0+119	657.25	*657.11*	657.00	657.04				657.02	0.62	13	Yes	36.27
4	26A	0+179	657.37	*657.17*	656.74	656.68				656.71	0.93	14	Yes	58.59
4	28	0+245	657.34	*657.19*	656.94	656.95				656.95	0.69	14	Yes	43.78
5	28	0+277	657.35	*657.17*	656.84	656.97				656.91	0.74	13	Yes	43.00
5	29	0+319	657.53	*657.35*	656.96	656.91				656.94	0.71	12	Yes	38.07
5	64	0+330	657.55	*657.46*	656.95	656.90				656.93	0.72	14	Yes	45.05
5	Access	0+382	657.46	*657.30*	656.84	656.75				656.80	0.84	16	Yes	60.84
5	67	0+414	657.42	*657.35*	657.37	657.31				657.34	0.30	13	Yes	17.55
5	68	0+421	657.40	*657.33*	657.06	657.07				657.07	0.57	16	Yes	41.40
5	35	0+518	657.47	*657.30*	657.03	656.99				657.01	0.63	13	Yes	36.85
6	53	0+577	657.63	*657.46*	657.09	657.02				657.06	0.58	13	Yes	34.22
6	54	0+598	657.64	*657.45*	657.31	657.32				657.32	0.32	12	Yes	17.55
6	55	0+629	657.70	*657.52*	657.05	656.95				657.00	0.64	12	Yes	34.56
6	56	0+660	657.68	*657.47*	657.09	656.94				657.02	0.62	15	Yes	42.19
6	57	0+679	657.65	*657.42*	657.03	656.90				656.97	0.68	11	Yes	33.41
6	58	0+728	657.56	*657.41*	657.07	657.02				657.05	0.59	15	Yes	40.16
6	59	0+766	657.63	*657.54*	657.16	656.92				657.04	0.60	13	Yes	35.10
6	60	0+805	657.47	*657.33*	657.15	657.13				657.14	0.50	10	Yes	22.50
6	61	0+825	657.40	*657.24*	657.07	657.16				657.12	0.52	15	Yes	35.44
6	62	0+867	657.37	*657.28*	657.14	657.01				657.08	0.56	13	Yes	33.05
7	63	0+878	657.31	*657.19*	656.85	656.82				656.84	0.80	14	Yes	50.71
7	66	0+934	657.48	*657.15*	656.98	657.04				657.01	0.63	16	Yes	45.36
Average Road C/L Elev. =			**657.47**	**m**		**Average Driveway Elev. =**				**657.20**	**m**			
Average Road Grade Adj. =			**0.373**	**m**		**Average Driveway Adj. with FB =**				**0.444**	**m**			
Road Length Requiring Upgrade =			1200	m from plans		Driveway Length Requiring Upgrade =						421	m	
Total Volume Road Upgrade =			**4031**	**m3**		**Total Volume (m3) for Driveway Upgrade =**								**1022.47**

APPENDIX A
Marsh Lake - Analysis of Road/Driveway Elevations and Required Adjustments

MARSH LAKE AND UPPER LIARD FLOOD STUDY:

Marsh Lake - Analysis of Taylor Road Elevations and Required Adjustments

Marsh Lake 200-year Flood Level =	**657.54**	m
Freeboard Allowance for Roads =	0.30	m
Design Road Grade =	**657.84**	**m**

Taylor Road: north of intersection with Army Beach Drive

Drawing Sheet No.	Road Location Building Lot No.	Road Location Approx. Road Sta.	Road C/L Elevation m
14	4 Block M	5+017.13	657.07
14	4 Block M	5+039.14	657.06
14	4 Block M	5+057.00	656.97
14	4 Block M	5+077.43	656.96
14	3 Block M	5+101.23	657.14
14	3 Block M	5+120.52	657.20
14	3 Block M	5+141.24	657.19
14		5+163.36	656.90
14		5+181.18	657.06
14		5+204.86	657.57
14		5+224.19	657.79
14		5+245.49	657.75
14		5+263.21	657.55
14		5+284.08	657.50
14		5+301.91	657.64
14		5+328.00	658.10
14		5+354.79	658.66
14		5+377.08	658.95

Average Road C/L Elev. =	**657.29**	**m**
Average Road Grade Adj. =	**0.550**	**m**
Road Length Requiring Upgrade =	308.8	m from plans
Total Volume Road Upgrade =	**1528**	**m3**

Section of road to be upgraded is highlighted.

APPENDIX A
Marsh Lake-Analysis of Road/Driveway Elevations and Required Adjustments

Marsh Lake Flood Control: Analysis of Building Elevations and Flood Risk

Marsh Lake 200-year Flood Level = 657.54 m

Bold = At risk relative to 200-year flood level

South McClintock Road:

Drawing		Bldg. 1	Bldg. 2	Bldg. 3	Bldg. 1	Bldg. 2	Bldg. 3	**Average**
Sheet	**Building**	**Buildings: Main Floor Elevations m**			**Floor Elevations wrt 200-yr Flood Level m**			**Difference**
No.	**Lot No.**	House	Garage/Other	Other	House	Garage/Other	Other	**m**
3	1044	657.71	**657.21**	**657.05**	0.17	**-0.33**	**-0.49**	-0.22
3	1045	658.47	**657.09**		0.93	**-0.45**		0.24
3	1046	657.63			0.09			0.09
3	1047	**656.80**			**-0.74**			-0.74
3	1048	**657.14**	**657.38**		**-0.40**	**-0.16**		-0.28
	1012A		658.3			0.76		0.76
	1011	**657.4**			**-0.14**			-0.14
	20		657.6	657.6		0.06	0.06	0.06
	797	657.8	**657.2**		0.26	**-0.34**		-0.04
	21	657.8			0.26			0.26
	36A	657.8	657.8	658.7	0.26	0.26	1.16	0.56
	24		659.8			2.26		2.26
	37	660.2			2.66			2.66
	26	658.6	**657.5**		1.06	**-0.04**		0.51
	27	657.8	**657.5**		0.26	**-0.04**		0.11
	38	658.3			0.76			0.76
	39	658.6			1.06			1.06
	30	658.6			1.06			1.06
	40A	658.4	657.7		0.86	0.16		0.51
	41A	658.2			0.66			0.66
	33A	658.5	658.4		0.96	0.86		0.91
	34A	658.9			1.36			1.36
At risk:		**3 houses**	**6 garages etc.**	**1 other bldgs.**				
Avg. floor el.: m		657.11	657.31	657.05				
Avg. flood depth: m		0.43	0.23	0.49	**-0.43**	**-0.23**	**-0.49**	

Army Beach Drive:

Drawing		Bldg. 1	Bldg. 2	Bldg. 3	Bldg. 1	Bldg. 2	Bldg. 3	**Average**
Sheet	**Building**	**Buildings: Main Floor Elevations m**			**Floor Elevations wrt 200-yr Flood Level m**			**Difference**
No.	**Lot No.**	House	Garage/Other	Other	House	Garage/Other	Other	**m**
8	19-2A	658.5		**657.1**	0.96		**-0.44**	0.26
4	Access							
4	20	658.6		657.7	1.06		0.16	0.61
4	21	657.7	**656.8**	**657.1**	0.16	**-0.74**	**-0.44**	-0.34
4	22-1	657.6	**657.2**	657.4	0.06	**-0.34**	**-0.14**	-0.14
4	22-2	658.0			0.46			0.46
4	23	657.8			0.26			0.26
4	24							
4	25	658.1			0.56			0.56
4	26A	658.2			0.66			0.66
4	27A	**657.3**	**656.6**		**-0.24**	**-0.94**		-0.59
4	28	658.2			0.66			0.66
5	29	**657.4**	**655.1**		**-0.14**	**-2.44**		-1.29
5	64	657.9			0.36			0.36
5	65	658.0			0.46			0.46
5	Access							
5	67	**657.2**	**657.2**		**-0.34**	**-0.34**		-0.34
5	68	**656.7**			**-0.84**			-0.84
5	35	658.4			0.86			0.86
5	52	658.2			0.66			0.66
6	53	658.2	**656.6**		0.66	**-0.94**		-0.14
6	54	657.8	**656.5**		0.26	**-1.04**		-0.39
6	55		**656.9**	**657.3**		**-0.64**	**-0.24**	-0.44
6	56	658.5	**657.0**	**656.9**	0.96	**-0.54**	**-0.64**	-0.07
6	57	658.1	**656.8**		0.56	**-0.74**		-0.09
6	58	**656.6**	**656.9**		**-0.94**	**-0.64**		-0.79
6	59	657.6			0.06			0.06
6	60	657.6			0.06			0.06
6	61	**657.5**			**-0.04**			-0.04
6	62	658.1	**656.8**		0.56	**-0.74**		-0.09
7	63	**657.1**			**-0.44**			-0.44
7	66	657.9			0.36			0.36
At risk:		**7 houses**	**12 garages etc.**	**4 other bldgs.**				
Avg. floor el.: m		657.1	656.70	657.10				
Avg. flood depth: m		0.43	0.84	0.44	**-0.43**	**-0.84**	**-0.38**	

APPENDIX

APPENDIX B COST ESTIMATE FOR FLOOD MITIGATION WORK - MARSH LAKE

APPENDIX B
Cost Estimate for Flood Mitigation Work-Marsh Lake

MARSH LAKE AND UPPER LIARD FLOOD STUDY: **Cost Estimate for Flood Mitigation Work - Marsh Lake**
See Figures 7.1 to 7.7 for plan and cross section layout

ARMY BEACH
Note: Distance from Section 1 to 7 is 1707 m

Quantities:

Cross Section No.	Effective Length m	Excavation Area m2	Excavation Vol. m3	Fill Area m2	Fill Vol. m3	Riprap Area m2	Riprap Vol. m3	Underlayer Area m2	Underlayer Vol. m3	Impervious Area m2	Impervious Vol. m3
1	303.40	2.051	622.27	0.000	0.00	5.143	1560.39	2.575	781.26	0.000	0.00
2	297.50	2.272	675.92	0.947	281.73	5.196	1545.81	1.633	485.82	0.000	0.00
3	275.50	1.997	550.17	0.150	41.33	5.496	1514.15	1.734	477.72	0.000	0.00
4	303.00	1.862	564.19	8.644	2619.13	6.268	1899.20	1.979	599.64	0.000	0.00
5	296.00	1.773	524.81	7.270	2151.92	7.061	2090.06	2.237	662.15	0.000	0.00
6	253.00	1.804	456.41	11.959	3025.63	7.014	1774.54	2.224	562.67	0.000	0.00
7	195.70	1.818	355.78	9.952	1947.61	7.219	1412.76	2.289	447.96	3.088	604.32
Totals	**1924.10**		**3749.56**		**10067.34**		**11796.90**		**4017.21**		**604.32**

Costs: Bank protection/dyke construction

Item	Quantity	Unit	Unit Rate	Cost
Excavation	3749.56	m3	10.00	$37,496
Imported fill	6317.79	m3	15.00	$94,767
Riprap	11796.90	m3	100.00	$1,179,690
Underlayer	4017.21	m3	40.00	$160,688
Impervious	604.32	m3	20.00	$12,086
Geotextile	13390.69	m2	5.00	$66,953
Using underlayer		**Sub-total =**		**$1,484,728**
Using geotextile		**Sub-total =**		**$1,390,993**

Costs: Road and Driveway Upgrades

Item	Quantity	Unit	Unit Rate	Cost
Army Beach Drive:				
Driveway gravel	1030	m3	20.00	$20,600
Road gravel	4030	m3	20.00	$80,600
Taylor Rd gravel	1530	m3	20.00	$30,600
				$131,800

Total Cost (dyke plus road/driveway upgrades) = $1,616,528
Total Cost (dyke plus road/driveway upgrades) = $1,522,793

SOUTH McCLINTOCK
Note: Distance from Section 8 to 9 is 171 m

Quantities:

Cross Section No.	Effective Length m	Excavation Area m2	Excavation Vol. m3	Fill Area m2	Fill Vol. m3	Riprap Area m2	Riprap Vol. m3	Underlayer Area m2	Underlayer Vol. m3	Impervious Area m2	Impervious Vol. m3
8	145.50	1.300	189.15	14.000	2037.00	5.736	834.59	2.202	320.39	3.056	444.65
9	130.50	1.441	188.05	4.092	534.01	5.279	688.91	2.033	265.31	1.484	193.66
Totals	**276.00**		**377.20**		**2571.01**		**1523.50**		**585.70**		**638.31**

Costs: Bank protection/dyke construction

Item	Quantity	Unit	Unit Rate	Cost
Excavation	377.20	m3	10.00	$3,772
Imported fill	2193.81	m3	15.00	$32,907
Riprap	1523.50	m3	100.00	$152,350
Underlayer	585.70	m3	40.00	$23,428
Impervious	638.31	m3	20.00	$12,766
Geotextile	1952.33	m2	5.00	$9,762
Using underlayer		**Sub-total =**		**$225,223**
Using geotextile		**Sub-total =**		**$211,557**

Costs: Road and Driveway Upgrades

Item	Quantity	Unit	Unit Rate	Cost
Driveway gravel	770	m3	20.00	$15,400
Road gravel	1770	m3	20.00	$35,400
				$50,800

Total Cost (dyke plus road/driveway upgrades) = $276,023
Total Cost (dyke plus road/driveway upgrades) = $262,357

SWAN HAVEN
Note: Distance from Section 10 to 12 is 220 m

Quantities:

Cross Section No.	Effective Length m	Excavation Area m2	Excavation Vol. m3	Fill Area m2	Fill Vol. m3	Riprap Area m2	Riprap Vol. m3	Underlayer Area m2	Underlayer Vol. m3	Impervious Area m2	Impervious Vol. m3
10	197.00	1.870	368.39	0.325	64.03	4.749	935.55	1.674	329.78	0.000	0.00
11	110.00	1.832	201.52	5.562	611.82	5.202	572.22	1.803	198.33	0.000	0.00
12	353.00	2.119	748.01	4.010	1415.53	5.337	1883.96	1.847	651.99	0.000	0.00
Totals	**660.00**		**1317.92**		**2091.38**		**3391.73**		**1180.10**		**0.00**

Costs: Bank protection/dyke construction

Item	Quantity	Unit	Unit Rate	Cost
Excavation	1317.92	m3	10.00	$13,179
Imported fill	773.46	m3	15.00	$11,602
Riprap	3391.73	m3	100.00	$339,173
Underlayer	1180.10	m3	40.00	$47,204
Impervious	0.00	m3	20.00	$0
Geotextile	3933.66	m2	5.00	$19,668
Using underlayer		**Sub-total =**		**$411,158**
Using geotextile		**Sub-total =**		**$383,623**

Notes:
Geotextile is optional as a replacement to the underlayer.
Assume geotextile area = underlayer vol./0.3.
The geotextile option ignores changes to the excavation volume.

Cost Summary Using Underlayer:

Total Bank Protection/Dyke Construction Cost =	$2,121,109
Road and Driveway Upgrades	$182,600
Grand Total Using Underlayer =	**$2,303,709**

Cost Summary Using Geotextile:

Total Bank Protection/Dyke Construction Cost =	$1,986,172
Road and Driveway Upgrades	$182,600
Grand Total Using Geotextile =	**$2,168,772**

APPENDIX

APPENDIX C COST ESTIMATE FOR FLOOD MITIGATION WORK - UPPER LIARD

APPENDIX C
Cost Estimate for Flood Mitigation Work-Upper Liard

MARSH LAKE AND UPPER LIARD FLOOD STUDY: **Cost Estimate for Flood Mitigation Work - Upper Liard**
See Figures 7.9 and 7.10 for plan and cross section layout

LEFT BANK SETBACK DYKE Note: Distance from Section 1 to 5 is 969 m

Quantities:

Cross Section No.	Effective Length m	Excavation Area m2	Excavation Vol. m3	Fill Area m2	Fill Vol. m3	Riprap Area m2	Riprap Vol. m3	Underlayer Area m2	Underlayer Vol. m3	Impervious Area m2	Impervious Vol. m3
1	179.50	0.000	0.00	25.724	4617.46	5.790	1039.31	2.343	420.57	3.635	652.48
2	169.50	0.000	0.00	23.333	3954.94	5.246	889.20	2.070	350.87	3.177	538.50
3	174.50	0.000	0.00	21.822	3807.94	5.803	1012.62	2.330	406.59	3.565	622.09
4	231.50	0.000	0.00	11.760	2722.44	5.017	1161.44	1.908	441.70	2.787	645.19
5	214.00	0.000	0.00	11.031	2360.63	4.297	919.56	1.583	338.76	2.333	499.26
Totals	**969.00**		**0.00**		**17463.41**		**5022.12**		**1958.48**		**2957.53**

Costs:

Item	Volume	Unit	Unit Rate	Cost
Excavation	0.00	m3	10.00	$0
Imported fill	17463.41	m3	15.00	$261,951
Riprap	5022.12	m3	100.00	$502,212
Underlayer	1958.48	m3	40.00	$78,339
Impervious	2957.53	m3	20.00	$59,151
Gravel	630.82	m3	20.00	$12,616
		Sub-total =		**$914,269**

Note: the above estimates were based on five cross sections developed from the McElhanney topography (Upper Liard - 2 m contour interval, date unknown). This mapping does not represent the left bank dike correctly as it is much higher toward the north end than the typical ground elevations shown on the McElhanney plan. Current topographic mapping is required in order to develop better estimates, however, the above estimates are likely substantially high.

RIGHT BANK ROAD DYKE

Assume the road is raised as a dyke for a distance of 190 m at a road width of 9 m.
Maximum upgrade required is 0.9 m tapering to zero at either end.

Upgrade Volume = 0.5x0.9x9x190 = 769.5 m3

Item	Volume	Unit	Unit Rate	Cost
Gravel	769.50	m3	20.00	$15,390
		Sub-total =		**$15,390**

Grand Total = $929,659

APPENDIX

APPENDIX D MARSH LAKE WIND DATA MEMO

TO: Bob Wallwork

DATE: June 9th, 2008

C:

MEMO NO:

FROM: Edwin Wang

FILE:

SUBJECT: **Marsh Lake Wind Data**

The Polarcom report stated that "the correlation between the Phillips monitoring site data and the Whitehorse Airport wind data was too weak to project a long term average wind speed for the Phillips site". No further data comparison between the two stations was discussed in the report. The purpose of this review is to evaluate the relationship between the Phillips wind monitoring site wind data and the Whitehorse Airport wind data, which was used to determine the design wave conditions for the Marsh Lake Upper Liard study.

A wind frequency distribution was determined from the Whitehorse Airport station data over the same sampling period (August 2000 – July 2001) as the Phillips monitoring station. Comparisons in terms of average wind speed and frequency of occurrence for each direction are presented in the table and figures below.

	AVERAGE WIND SPEED (M/S)		FREQUENCY OF OCCURRENCE (%)	
	Phillips Monitoring Site	Whitehorse Airport	Phillips Monitoring Site	Whitehorse Airport
N	1.08	3.24	3.82	8.11
NNE	1.34	2.51	4.00	1.44
NE	1.40	2.59	6.03	0.41
ENE	1.38	2.53	4.60	0.37
E	1.86	2.34	6.15	0.59
ESE	**2.79**	**3.58**	**9.62**	**1.27**
SE	**3.69**	**4.57**	**18.29**	**4.68**
SSE	**3.76**	**5.72**	**8.62**	**21.97**
S	3.45	5.92	5.43	27.50
SSW	2.30	4.09	3.21	3.32
SW	1.73	3.98	3.11	.09
WSW	1.23	2.98	2.50	2.16
W	1.35	0.34	2.70	19.21
WNW	2.35	2.48	6.37	0.96
NW	2.03	2.92	11.88	1.62
NNW	1.09	3.36	3.66	4.30

HAY & COMPANY CONSULTANTS – A Division of EBA Engineering Consultants Ltd.

p. 604.875.6391 • f. 604.875.8363

#900 - 1066 West Hastings Street • Vancouver, British Columbia V6E 3X2 • CANADA

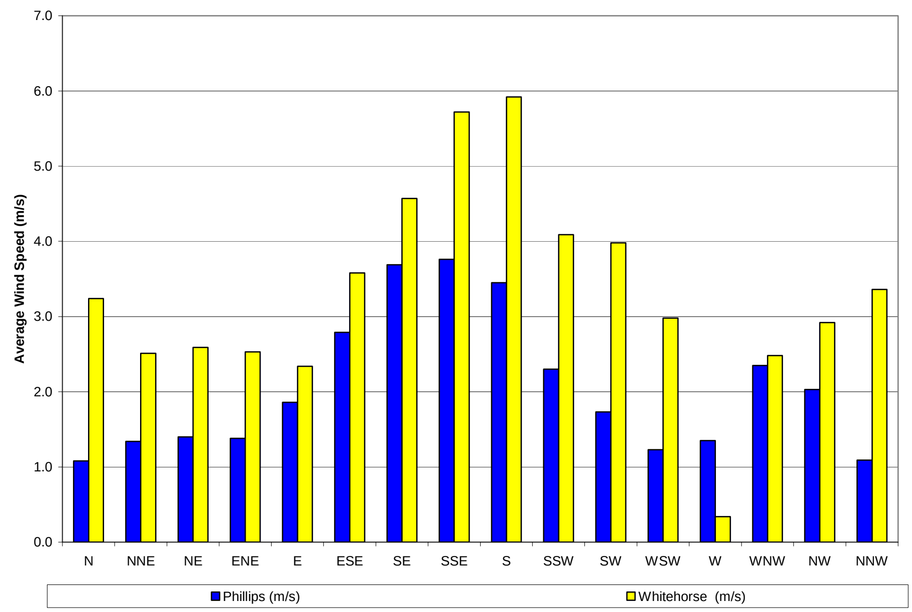


Figure 1. Average Wind Speed Per Direction

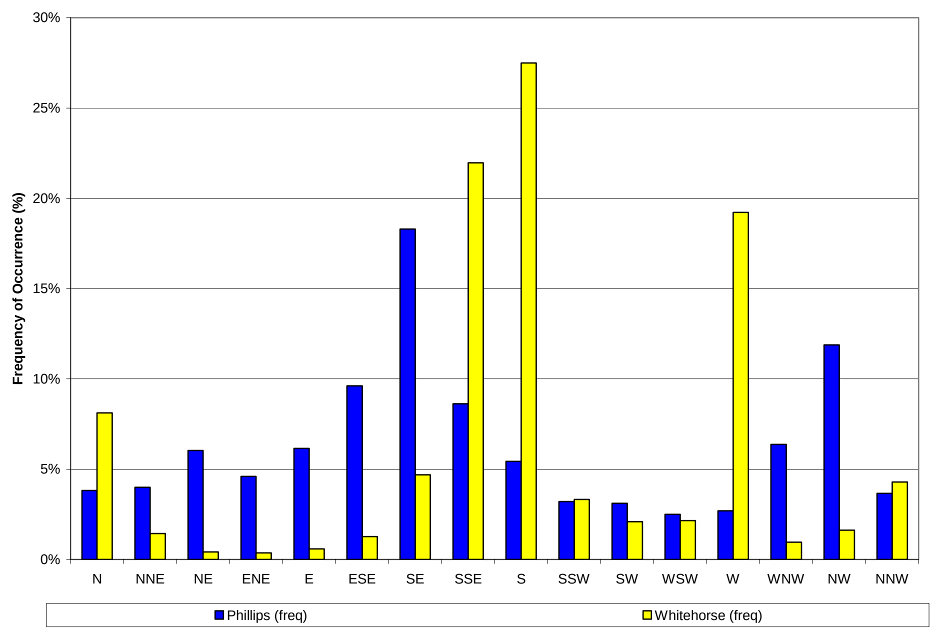


Figure 2. Frequency of Occurrence Per Direction

Winds at the Phillips monitoring sites were mainly from the SE and NW and winds at the Whitehorse Airport were predominately from the S and W. With the exception of winds from the west, the average wind speeds recorded at the Whitehorse Airport were stronger than the one recorded at the Phillips monitoring station. Note that there appears to be a problem with the Westerly winds at Whitehorse Airport as the average wind speed from the West is only 0.34 m/s, which is much smaller than the values from the other directions.

For the Marsh Lake Upper Liard study, the design waves were determined based on the southeasterly storm events recorded at the Whitehorse Airport. The southeasterly storms included storms generated by winds from the ESE, SE and SSE. From the table above, one notes that the average wind speeds at the Whitehorse Airport from these three directions are 1.24 to 1.52 times greater than the ones collected at the Phillips monitoring site. This suggests that the design wave values derived for the Marsh Lake Upper Laird study by using the Whitehorse Airport data were not underestimated.

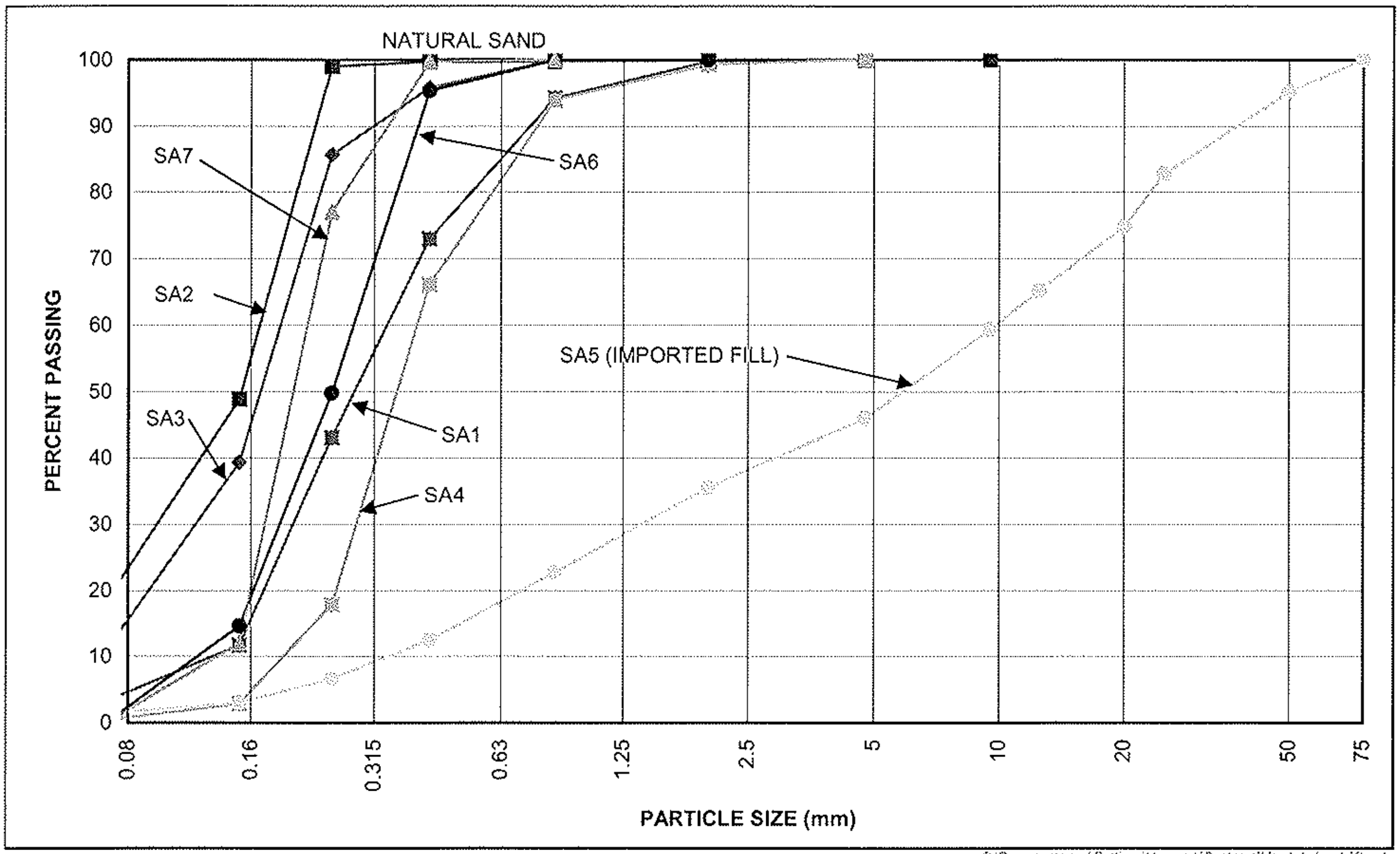
APPENDIX

APPENDIX E LAYFIELD NONWOVEN SPECS AND AGGREGATE ANALYSIS REPORT

EBA Engineering Consultants Ltd.

AGGREGATE ANALYSIS REPORT

PROJECT:	Marsh Lake Flood Study	SAMPLE NO:	SA1 - SA7
ADDRESS:	Marsh Lake, YT	SAMPLE DESCRIPTION:	
PROJECT NO:	V13201069	SAND	
DATE PRODUCED:	Mar 26/08 By: EBA		
DATE TESTED:	Mar 31/08 By: KJT	NAT. MOISTURE CONT.:	n/a
CLIENT:	YTG	COLOUR PLATE #:	n/a
		BULK REL DENSITY:	n/a
		BULK REL. DENSITY (SSD):	n/a
ATTENTION:	Jeff Boehmer	APPARENT REL. DENSITY:	n/a
		ABSORPTION:	n/a



Remarks: ____________________

Reviewed by: [signature], P.Eng.

Data presented hereon is for the sole use of the stipulated client. EBA is not responsible, nor can be held liable, for use made of this report by any other party, with or without the knowledge of EBA.

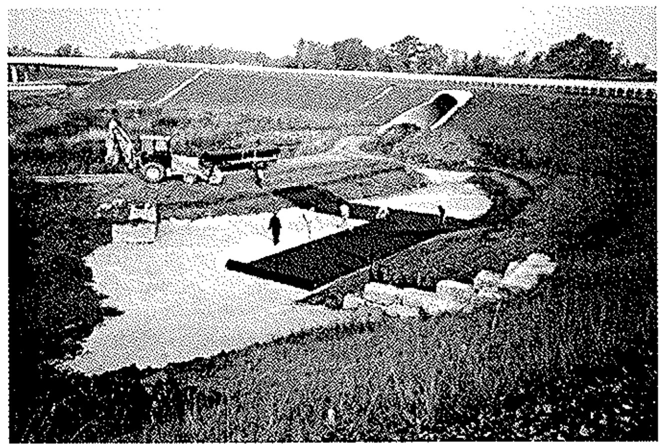
The testing services reported herein have been performed by an EBA technician to recognized industry standards, unless otherwise noted. No other warranty is made. These data do not include or represent any interpretation or opinion of specification compliance or material suitability. Should engineering interpretation be required, EBA will provide it upon written request.

eba

Geotextiles - Nonwoven

Non-woven needle-punched geotextiles offer excellent water flow properties for drainage and other applications.

Needle-punched non-woven geotextiles are made from polypropylene fibres that are tangled together in a needle-punching process. The fibres may be made in continuous or short lengths and achieve their strength by interlocking. Needle-punched non-woven geotextiles have excellent water flow rates and are used for filtration of soil fines. Needle-punched non-woven geotextiles have been used in drainage applications including trench drains, as a wrapping for perforated pipe, for erosion protection, and combined with three-dimensional structures to create prefabricated drains. They are also commonly used with geomembranes to provide a protective cushion. Needle-punched non-woven primary functions: filtration; separation; protection; drainage. Secondary functions: reinforcement.



19 Nov 2007	Non-Woven Needle-Punched Geotextiles - US Values								
	ASTM	**LP3.5**	**LP4**	**LP4.5**	**LP6**	**LP7**	**LP8**	**LP10**	**LP12**	**LP16**
Grab Tensile (lbs)	D4632	90	100	120	160	180	205	250	300	380
Elongation (%)	D4632	50	50	50	50	50	50	50	50	50
Tear (lbs)	D4533	40	50	50	65	75	85	100	115	145
Puncture (lbs)	D4833	60	65	70	90	105	130	160	180	240
AOS (sieve)	D4751	50	70	70	70	70	80	100	100	100
Permittivity (sec-1)	D4491	2.2	2.0	1.8	1.6	1.5	1.4	1.2	1.0	0.7
Water Flow (gpm/ft²)	D4491	150	140	120	110	100	90	80	75	50
Weight[1] (oz/yd²) Nominal	D5261	3.5	4.0	4.5	6.0	7.0	8.0	10.0	12.0	16.0
Thickness[1] (mil) Nominal	D5199	40	45	50	70	85	85	100	110	165
UV (500 hrs)	D4355	70%	70%	70%	70%	70%	70%	70%	70%	70%
Roll Size (ft)		15 x 360	15 x 360	15 x 360	15 x 300[2]	15 x 300[2]	15 x 300[2]	15 x 300	15 x 300	15 x 150
Roll Weight[1] (lbs)		160	172	190	202	220	250	308	400	250

Note[1]: Typical values. All other values are minimum average roll values (MARV).
Note[2]: LP6, LP7, and LP8 may be 15 x 360 ft depending on inventory

minimum

Layfield Geosynthetics and Industrial Fabrics Ltd.
www.geomembranes.com
service@geomembranes.com

Geosynthetics, North America
Toll Free: 800-840-2884
Tel: 780-453-6731
Fax: 780-455-5218

Geosynthetics, US West Coast
Toll Free: 800-796-6868
Tel: 425-254-1075
Fax: 425-254-1575

19 Nov 2007	Non-Woven Needle-Punched Geotextiles - Metric Values									
	ASTM	**LP3.5**	**LP4**	**LP4.5**	**LP6**	**LP7**	**LP8**	**LP10**	**LP12**	**LP16**
Grab Tensile (N)	D4632	401	445	533	711	800	911	1,110	1,330	1,690
Elongation (%)	D4632	50	50	50	50	50	50	50	50	50
Tear (N)	D4533	178	222	222	289	333	378	444	511	644
Puncture (N)	D4833	267	289	311	400	467	578	711	800	1,070
AOS (microns)	D4751	300	212	212	212	212	180	150	150	150
Permittivity (sec-1)	D4491	2.2	2.0	1.8	1.6	1.5	1.4	1.2	1.0	0.7
Water Flow (l/min/m^2)	D4491	6,095	5,689	4,885	4,480	4,074	3,657	3,251	3,055	2,035
Weight[1] (g/m^2) Typical	D5261	119	136	153	203	237	271	339	407	542
Thickness[1] (mm) Nominal	D5199	1.2	1.5	1.3	1.7	2.1	2.1	2.9	3.0	4.1
UV (500 hrs)	D4355	70%	70%	70%	70%	70%	70%	70%	70%	70%
Roll Size (m)		4.57 x 110	4.57 x 110	4.57 x 110	4.57 x 91.4[2]	4.57 x 91.4[2]	4.57 x 91.4[2]	4.57 x 91.4	4.57 x 91.4	4.57 x 45.7
Roll Weight[1] (kg)		73	78	86	92	99	113	140	181	112

minimum

APPENDIX

APPENDIX F ESTIMATION OF POTENTIAL FLOOD DAMAGES (KGS GROUP, FINAL REPORT AUGUST 2008)

EBA Engineering Consultants Ltd.

MARSH LAKE / UPPER LIARD FLOOD STUDY
ESTIMATION OF POTENTIAL FLOOD DAMAGES

FINAL REPORT
AUGUST 2008

KGS Group Project: 07-1455-03

KGS GROUP

KONTZAMANIS ▪ GRAUMANN ▪ SMITH ▪ MACMILLAN INC.
CONSULTING ENGINEERS & PROJECT MANAGERS

EXECUTIVE SUMMARY

KGS Group has completed a study of potential flood damages at residences at Marsh Lake and at Upper Liard. For both sites, a range of flood peaks was analyzed, associated with flood frequencies of 1 in 20 years to 1 in 200 years. The financial value of potential flood damages were based on typical extents of damages that have been incurred elsewhere in North America and documented by authoritative sources. They include:

- direct costs for repair of physical damages to residences, supplementary buildings, and their contents, and to public and private infrastructure.

- indirect costs: relocation costs during the flood event, the cost of temporary protective measures, and for security, pre-emptive protection and rescue purposes (e.g., fire and police protection).

The losses do not include reduction in business revenues or intangible losses such as the effects of stress and anxiety on the affected residents.

The estimated damages range from $1,354,000 to $1,966,000 for Marsh Lake and $644,000 to $1,281,000 for Upper Liard.

TABLE OF CONTENTS

PAGE

1.0 INTRODUCTION

This section outlines the approaches and assumptions that were used in this study to estimate the potential flood damages at Marsh Lake and at the community of Upper Liard, Yukon, for a range of flood magnitudes. Since there was no definitive financial information available on the actual damages that were incurred in the flood of 2007, estimations were made using information on flood damages from other jurisdictions in Canada and the United States.

The flood levels used in this study for the purpose of flood damage calculations are shown in Table 1.

TABLE 1: PEAK FLOOD LEVELS – MARSH LAKE / UPPER LIARD

Flood Event	Annual Probability of Being Exceeded (%)	Water Level – Marsh Lake (m)	Water Level – Upper Liard* (m)
1 in 20 year	5	657.03	609.87
1 in 50 year	2	657.24	610.27
1 in 200 year	0.5	657.54	610.78

*At the downstream end of the east bank dyke

The derivation of these elevations is described in Section 4.0.

At Upper Liard, a dyke on the left bank extents from a location about 850 m upstream of the Alaska Highway bridge to a location about 350 m upstream of the bridge and prevent flooding from the high water levels. However, the floodwaters can enter the left bank area around the downstream end of the dyke. The water levels at that location were derived from the river slope described in Section 4.0.

1.1 DAMAGES CAUSED BY FLOODING

Floods produce a variety of both direct and indirect damages. Typical direct costs resulting from flooding include repair of physical damages to residences, supplementary buildings, and their contents, as well as damage to vehicles and to public and private infrastructure. Typical indirect costs due to flooding include: relocation costs during the flood event, loss of business due to interruption of operations and transportation; reduced income caused by evacuation and reoccupation of premises; increased cost of transportation due to detours; and the cost of temporary protective measures, and for security, pre-emptive protection and rescue purposes (e.g., fire and police protection).

Details of the computation of these potential damages are described in the following paragraphs. The estimations have been made with existing information provided by local authorities, and with methods and limitations that are generally in line with Canadian guidelines[1]. Guidelines[2,3,4,5,6,7] used by the U.S Army Corps of Engineers have also been considered.

Residential Building Damage

Damages to residential buildings comprise the dominant component of potential damages, and were computed using a "depth-damage curve". This relationship is a fundamental tool that is used in estimating flood damages, and relates estimated flood damages to a particular water level measured relative to the first floor elevation of the structure. The potential damages are normally provided as a percentage of the replacement value of the building. The depth-damage relationships that were applied for Marsh Lake and Upper Liard were based on the following precedents that were considered:

- Depth-damage curves based on existing recent information such as documented damages[2] incurred in Grand Forks in 1997.

- The curve adopted by the Royal Commission[8] in 1957 for a comprehensive study of potential flood damages in Winnipeg, Manitoba. In recent years, it has been referred to as the "Templeton Curve". It relates flooded depth to damage to structure and contents as a percentage of the replacement value of the structure. It has been criticized for predicting low estimated damages for basement flooding, based on the premise that basement utilization as living space was less prevalent in the late 1950's than it is today.

- Information generated by surveys of residential damage[9] in Fort McMurray, Alberta, and has been adjusted to represent the Yukon conditions after the 1979 flood in the Athabasca River, by ECOS Engineering Ltd.

- Curves prepared by the U.S. Federal Insurance Administration (USFIA) using thousands of reported flood damages in various areas of the U.S.[10].

- Curves[11] prepared by the U.S. Army Corps of Engineers (USACE) from survey data of actual damage from a sample of 400 residences, 80 commercial establishments, and 20 public structures and their contents in Grand Forks, North Dakota after the 1997 flood that inundated about 90% of that community of 60,000 people.

- Standard USACE depth – damage curves[12] based on statistical assessment of various flood events in the U.S.

- Damage claims from rural residences in Manitoba south of Winnipeg as a result of the devastating and well documented 1997 flood in the Red River. This data originated from the records of the Emergency Measures Organization of Manitoba, and was analyzed in a separate study[13] by KGS Group for the International Joint Commission.

The information upon which the depth damage relationships are based include a wide variety of potential damages, including:

- Structural damage
- Interior finishes
- Building contents, including heating and water systems
- Landscaping and yard works
- Septic facilities

The curve that was selected and applied to represent Marsh Lake and the Upper Liard area is a blended curve that was based on, or influenced by, the data described above. It is shown in Figure 1. Given the uncertainties in estimations of this type, it was considered that a broad range should be identified to bracket the possible upper and lower limits. The lower limit was defined by the lowest relationship of the data available and represents the curve typically applied by the USACE.

The best estimate is based on the actual depth-damage curve used to compute potential flood damages in Winnipeg for the economic justification of recent major upgrades to the flood protection system for that city. An adjustment was applied below the first floor to reflect the fact that most residences in the Yukon have crawl spaces under the first floor, and do not have basements of the type usually constructed in Winnipeg.

The upper limit was based on actual data from Emergency Measures Organization in Manitoba for damages incurred to residences in southern Manitoba in the devastating flood of 1997. It is the highest curve of all the data available, and was considered to be an indicator of the highest conceivable losses.

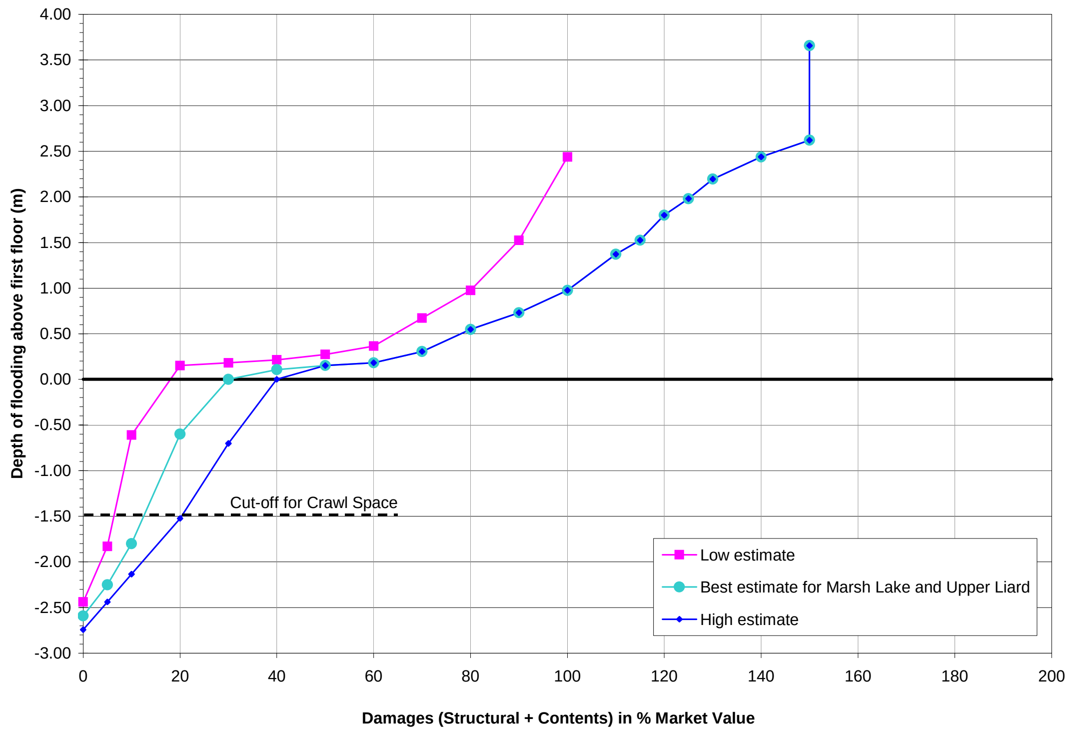


FIGURE 1: LOW, BEST AND UPPER LIMITS OF THE DEPTH-DAMAGE CURVE

The damages to each property were computed by:

- Estimating the depth of floodwaters relative to the first floor level that was surveyed by Challenger Geomatics staff for every residence that could potentially be flooded for the range of flood events considered.

- Looking up from Figure 1 the damage as a percentage of replacement value of the building, for the lower, best estimate or upper limit cases

- Multiplying the percentage by the replacement value of the building to derive the value of the flood damages in dollars

It should be noted that it is common practice in flood control economics that the depreciated replacement value of buildings be used in the estimation of damages. The depreciated replacement value was estimated for the Marsh Lake/Upper Liard areas using the assessed value of the residences that were supplied to KGS Group by the Yukon Community Services in Whitehorse. These assessed values were prorated upwards based on local input that indicated that the replacement values were considerably more than the assessed values. One house, for example, that was being sold by the owner was priced such that the building was estimated to be about 41% greater than the assessed value. This ratio was applied to all the assessed values to obtain the replacement value. The average replacement value of all the houses for both areas was computed to be $87,250 per residence. This was deemed to be a reasonable indicator for the area at risk.

Vehicle Damages

Damages to vehicles can occur in areas where floodwaters rise swiftly and vehicles cannot be moved before being engulfed. In both the Marsh Lake and Upper Liard areas, however, the rise in water level is typically relatively gradual, and losses due to inundation of vehicles has not been considered to be a significant factor. As a result, no additional allowance for this was made.

Relocation Costs

These costs would be incurred by evacuees from the flood, and include:

- Travel and lodging
- Food
- Cleanup costs
- Moving/storage costs

- Vandalism
- Medical
- Miscellaneous expenses

They reflect the incremental costs of households that are evacuated, above what would be paid out to meet normal living costs if the flood had not occurred. A value of $13,000 per flooded residence was adopted, based on the actual USACE data for similar households that were flooded in 1997 in Grand Forks, North Dakota, and with allowances applied for inflation since 1997 (30%) and for an additional allowance for costs of subsistence in the north (30%).

Roads

In some other flood-vulnerable centers, there have been major public facilities that could be damaged and special estimates have been required. For Marsh Lake and the Upper Liard areas, the only infrastructure that could potentially be damaged is the transportation system, including public and private roads/driveways. For estimation of potential damages to this system, an average damage of $25,000 per kilometer has been adopted. This was based on actual data for damages incurred in southern Manitoba in the 1997 flood where hundreds of kilometers of roadways were inundated. The typical pattern of damage was due to the erosive action of flowing water over the road surface and shoulders when it was initially overtopped. The estimate for Marsh/Upper Liard was increased for inflation since 1997 and for higher costs of construction in the north.

Flood Fighting and Emergency Response Costs

Flood fighting and emergency response costs in Grand Forks, North Dakota[14], in 1997 were $83,000,000 for a population of 60,000. This is approximately $2,200 per person, or a total of approximately $130,000 for the Marsh Lake area and $40,000 for the Upper Liard area. These values have been adopted for each flood event.

Business Income Loss

Business income loss is often a significant component of real damages that are incurred during devastating floods that cause the stoppage of economic activities. However, current policies[1,3] restrict this category to only include effects of a loss in national economic development to the extent that the loss cannot be made up by postponement of an activity or by transferring the activity to some other establishment. The losses need to be viewed from the national perspective, and may be compensated after the flood, or during the flood elsewhere in the national economy. Both Canadian and American guidelines for economic analyses of flood protection direct that they not be included. Consequently, business losses have been excluded from the summation of damages, as they were excluded in the economic studies of flood protection in Winnipeg.

Disruption to Transportation

In some flood-vulnerable centers, a significant cost can be incurred because of disruption of transportation and the need for detours around affected areas. In the case of Marsh Lake, however, this was not considered a factor, and no special allowance was included for it.

For Upper Liard, there could be an impact on the Alaska Highway for floods exceeding a magnitude of the 1 in 20 year event. Flooding on the highway would cause a potentially major short-term impact on the flow of goods and services. Quantification of this potential impact would be difficult and has been deemed to be beyond the scope of the current study.

1.2 FLOOD DAMAGES – RESULTS OF COMPUTATIONS

For all of the calculations undertaken in this study and reported herein, it is assumed that in the proximity of the affected buildings, all facilities below the water level would be flooded. There is no consideration given to temporary protection works, such as sandbags. The results of the analyses are reported separately for Marsh Lake and Upper Liard in the sections below.

Detailed results are shown in the tables included in Appendix A.

Marsh Lake

At Marsh Lake, the first floor elevations were surveyed for 46 properties, which correspond to the residences potentially flooded for the 200-year water level.

Almost all of the houses are built with a crawl space. However, at residences where a developed basement was confirmed to exist by a site visit, the upper limit depth-damage curve was applied to represent the potential for more damage below the first floor.

The “best estimates” of the computed damages are summarized in Table 3.

TABLE 3: BEST ESTIMATES OF POTENTIAL FLOOD DAMAGES FOR MARSH LAKE AREA ($2008)

Type of Damage	1:20 Year	1:50 Year	1:200 Year
Residential (Structures / Contents)	665,000	838,000	1,173,000
Roads	0	7,000	65,000
Relocation costs	559,000	585,000	598,000
Flood Fighting / Emergency Response	130,000	130,000	130,000
TOTALS	**1,354,000**	**1,560,000**	**1,966,000**

The lower limit of the calculations for Marsh Lake, using the lower depth damage curve shown in Figure 1 resulted in damages of approximately 23.4% less than the best estimate. Conversely, the upper limit showed damages of about 18.5% greater than the best estimate.

Upper Liard

The Upper Liard studied area is limited to the 11 properties located on the east side of the Liard River.

As there was no recent survey of the ground or the first floor elevations in Upper Liard, the ground level at the residences is estimated from Figure 7.9. The first floor elevation is considered to be one metre above the ground elevation. The depths of flooding were then calculated for the June, 2007 flood and compared with the highwater marks observed during the site inspection[15] on June 19, 2007. When required, some adjustments in the estimated first floor elevations were made to match the observed water depths.

The "best estimates" of the computed damages are summarized in Table 4.

TABLE 4: BEST ESTIMATES OF POTENTIAL FLOOD DAMAGES FOR UPPER LIARD ($2008)

Type of Damage	1:20 Year	1:50 Year	1:200 Year
Residential (Structures/ Contents)	437,000	771,000	1,060,000
Roads	37,000	46,000	51,000
Relocation costs	130,000	130,000	130,000
Flood Fighting / Emergency Response	40,000	40,000	40,000
TOTALS	**644,000**	**987,000**	**1,281,000**

The calculations for the Upper Liard area using the lower depth damage curve shown in Figure 1 resulted in damages of approximately 21% less than the best estimates. Conversely, the upper limit showed damages of about 4% greater than the best estimates.

1.3 DISCUSSION

The potential flood damages that have been estimated are based on what would be expected from experience in other locations in Canada for similar depths of flooding. These figures could be adjusted to be more reflective of the direct experience in 2007 at Marsh Lake/Upper Liard, if such information becomes available.

On a per-residence basis, the potential flood damages could be substantial. However, because the floods are relatively infrequent, and the number of residences that are affected is relatively small, the strict economic justification for large expenditures on flood protection measures is limited. For example, the damages estimated for the Marsh Lake area range from $1.4 million to $2.0 million per event for flood frequencies from once in 20 years to once in 200 years. Assuming that the threshold flood above which flood damages could begin to be incurred is once in 8 years, it can be shown with standard methods of estimating average annual averted damages, that the benefits of a protection scheme would be approximately $1,600,000 million for Marsh Lake. This would be the maximum benefit assuming a present value factor of 10 applied to the estimated average annual damages. In order for the cost of the flood protection scheme not to exceed the direct benefits that would be achieved, the cost of the protection must not exceed approximately $1,600,000. This is the point at which the ratio of Benefits to Costs is equal to 1.0.

On the other hand, it must also be recognized that there are intangible benefits that cannot be quantified in such an economic evaluation, and would contribute towards a decision to implement a flood protection scheme.

1.4 REFERENCES

1. Federal Guidelines for the National Flood Damage Reduction Program", Environment Canada, 1985.

2. General Reevaluation Report for Flood Control Red River, Red Lake River, East Grand Forks, Minnesota, Grand Forks, North Dakota; McLean, VA, November, 1997.

3. US Army Corps of Engineers, personal communication

4. US Army Corps of Engineers, "Guidelines for Risk and Uncertainty Analysis in Water Resources Planning", Volume II, Fort Belvoir, VA, March, 1992.

5. National Economic Development Procedures Manual – Urban Flood Damage; Fort Belvoir, VA, March, 1988.

6. US Army Corps of Engineers, "Catalog of Residential Depth-Damage Functions", Fort Belvoir, VA, May, 1992.

7. Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies; Carbondale, IL, May, 1996.

8. Royal Commission on Flood Cost Benefit; Winnipeg, Manitoba, December, 1958

9. ECOS Engineering Services Ltd., "Development of Depth-Damage Curves for Residential and Farm Structures in Southern Manitoba", report to Environment Canada, Inland Waters Directorate, Regina, Saskatchewan, July 1983.

10. FEMA documents – excerpts provided by USACE

11. Grand Forks Data – copies of internal files from USACE

12. US Army Corps of Engineers, "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies", Carbondale, IL, May, 1996.

13. Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps, Draft Report, KGS Group, September, 1999.

14. The Red River Flood of 1997, An Assessment of Damage and Long Term Economic Recovery, Newport Beach, CA, January, 1999.

15. Flood report for Upper Liard, June 19, 2007 inspection, Mike Kroeker, 2007

APPENDICES

APPENDIX A

FLOOD DAMAGES SUMMARY TABLES

Marsh lake - Flood damages summary table

20-YEAR FLOOD	Legal Description	Structure Type	Basement Type	Floor Elevation (m)	Water Depth (m) 20-year flood	Damages % of Replacement cost Low Estimate	Best Estimate	High Estimate	Replacement cost 2008 $	Damages in $ Low Estimate	Best Estimate	High Estimate
Army Beach	Lot 192A	House, main floor	Developed	658.5	-1.47	6.5	20.7	20.7	$153,464	$9,931	$31,700	$31,700
	Lot 20	House		658.6	-1.57	0.0	0.0	0.0	$71,261	$0	$0	$0
	Lot 21	House		657.7	-0.67	9.8	19.4	30.4	$81,907	$7,988	$15,904	$24,935
	Lot 22-1	House		657.6	-0.57	10.5	20.5	31.9	$212,515	$22,356	$43,566	$67,727
	Lot 22-2	House		658.0	-0.97	8.5	16.9	26.7	$68,413	$5,830	$11,573	$18,288
	Lot 23	House (on skids)		657.8	-0.77	9.3	18.6	29.2	$23,011	$2,150	$4,276	$6,711
	Lot 25	House		658.1	-1.07	8.1	16.1	25.5	$9,236	$749	$1,485	$2,357
	Lot 26A	House	Developed	658.2	-1.17	7.7	24.3	24.3	$6,162	$475	$1,497	$1,497
	Lot 27A	House		657.3	-0.27	14.5	25.5	36.1	$133,710	$19,330	$34,096	$48,334
	Lot 28	House		658.2	-1.17	7.7	15.2	24.3	$11,774	$907	$1,795	$2,861
	Lot 29	House		657.4	-0.37	13.1	23.8	34.7	$154,987	$20,372	$36,939	$53,815
	Lot 64	House		657.9	-0.87	8.9	17.8	27.9	$66,030	$5,898	$11,720	$18,453
	Lot 65	House		658.0	-0.97	8.5	16.9	26.7	$71,896	$6,127	$12,162	$19,219
	Lot 67	House		657.2	-0.17	15.8	27.2	37.6	$274,978	$43,361	$74,702	$103,323
	Lot 68	Garage		656.7	0.33	56.1	71.0	71.0	$121,838	$68,338	$86,546	$86,546
	Lot 35	House		658.4	-1.37	6.9	13.6	21.9	$12,493	$860	$1,697	$2,732
	Lot 52	House		658.2	-1.17	7.7	15.2	24.3	$15,172	$1,168	$2,314	$3,687
	Lot 53	House		658.2	-1.17	7.7	15.2	24.3	$74,124	$5,709	$11,304	$18,013
	Lot 54	House		657.8	-0.77	9.3	18.6	29.2	$127,253	$11,888	$23,648	$37,109
	Lot 55	Cabin		657.3	-0.27	14.5	25.5	36.1	$32,726	$4,731	$8,345	$11,830
	Lot 56	House		658.5	-1.47	6.5	12.7	20.7	$117,256	$7,588	$14,950	$24,221
	Lot 57	House		658.1	-1.07	8.1	16.1	25.5	$49,674	$4,030	$7,989	$12,675
	Lot 58	House	Developed	656.6	-1.57	6.1	19.2	19.2	$117,862	$7,144	$22,683	$22,683
	Lot 59	House		657.6	-0.57	10.5	20.5	31.9	$20,121	$2,117	$4,125	$6,412
	Lot 60	House		657.6	-0.57	10.5	20.5	31.9	$76,211	$8,017	$15,623	$24,288
	Lot 61	House		657.5	-0.47	11.8	22.2	33.3	$14,650	$1,733	$3,247	$4,878
	Lot 62	House		658.1	-1.07	8.1	16.1	25.5	$371,013	$30,096	$59,671	$94,670
	Lot 63	House		657.1	-0.07	17.1	28.8	39.0	$16,229	$2,772	$4,679	$6,330
	Lot 66	House		657.9	-0.87	8.9	17.8	27.9	$57,133	$5,103	$10,141	$15,967
South McClintock	Lot 1012A	Cabin		658.3	-1.27	7.3	14.4	23.1	$59,262	$4,321	$8,544	$13,682
	Lot 1011	House		657.4	-0.37	13.1	23.8	34.7	$20,910	$2,749	$4,984	$7,261
	Lot 20	Cabin		657.6	-0.57	10.5	20.5	31.9	$89,563	$9,422	$18,360	$28,543
	Lot 797	House		657.8	-0.77	9.3	18.6	29.2	$66,383	$6,202	$12,336	$19,359
	Lot 21	Blue House		657.8	-0.77	9.3	18.6	29.2	$14,551	$1,359	$2,704	$4,243
	Lot 36A	House		657.8	-0.77	9.3	18.6	29.2	$141,705	$13,238	$26,334	$41,324
	Lot 24	Cabin		659.8	-2.77	0.0	0.0	0.0	$11,167	$0	$0	$0
	Lot 37	House		660.2	-3.17	0.0	0.0	0.0	$18,866	$0	$0	$0
	Lot 26	House		658.6	-1.57	0.0	0.0	0.0	$51,141	$0	$0	$0
	Lot 27	House		657.8	-0.77	9.3	18.6	29.2	$56,879	$5,314	$10,570	$16,587
	Lot 38	House		658.3	-1.27	7.3	14.4	23.1	$14,608	$1,065	$2,106	$3,372
	Lot 39	House		658.6	-1.57	0.0	0.0	0.0	$95,344	$0	$0	$0
	Lot 30	House		658.6	-1.57	0.0	0.0	0.0	$340,839	$0	$0	$0
	Lot 40A	House		658.4	-1.37	6.9	13.6	21.9	$42,258	$2,908	$5,740	$9,242
	Lot 41A	House		658.2	-1.17	7.7	15.2	24.3	$12,253	$944	$1,869	$2,978
	Lot 33A	House		658.5	-1.47	6.5	12.7	20.7	$101,830	$6,590	$12,983	$21,034
	Lot 34A	House		658.9	-1.87	0.0	0.0	0.0	$62,618	$0	$0	$0
								TOTAL	$3,763,276	**$360,880**	**$664,909**	**$938,886**

Marsh lake - Flood damages summary table

50-YEAR FLOOD	Legal Description	Structure Type	Basement Type	Floor Elevation	Water Depth (m)	Damages % of Replacement cost			Replacement cost	Damages in $		
				(m)	50-year flood	Low Estimate	Best Estimate	High Estimate	2008 $	Low Estimate	Best Estimate	High Estimate
Army Beach	Lot 192A	House, main floor	Developed	658.5	-1.26	7.3	23.2	23.2	$153,464	$11,253	$35,616	$35,616
	Lot 20	House		658.6	-1.36	6.9	13.7	22.0	$71,261	$4,933	$9,739	$15,672
	Lot 21	House		657.7	-0.46	12.0	22.3	33.4	$81,907	$9,799	$18,293	$27,388
	Lot 22-1	House		657.6	-0.36	13.3	24.0	34.9	$212,515	$28,213	$51,004	$74,093
	Lot 22-2	House		658.0	-0.76	9.4	18.7	29.3	$68,413	$6,419	$12,770	$20,034
	Lot 23	House (on skids)		657.8	-0.56	10.7	20.7	32.0	$23,011	$2,451	$4,756	$7,366
	Lot 25	House		658.1	-0.86	9.0	17.8	28.1	$9,236	$829	$1,647	$2,592
	Lot 26A	House	Developed	658.2	-0.96	8.6	26.9	26.9	$6,162	$528	$1,655	$1,655
	Lot 27A	House		657.3	-0.06	17.2	29.0	39.1	$133,710	$23,015	$38,776	$52,340
	Lot 28	House		658.2	-0.96	8.6	17.0	26.9	$11,774	$1,008	$2,001	$3,162
	Lot 29	House		657.4	-0.16	15.9	27.3	37.7	$154,987	$24,643	$42,363	$58,458
	Lot 64	House		657.9	-0.66	9.8	19.5	30.6	$66,030	$6,467	$12,876	$20,196
	Lot 65	House		658.0	-0.76	9.4	18.7	29.3	$71,896	$6,746	$13,421	$21,054
	Lot 67	House		657.2	0.04	18.5	33.7	42.6	$274,978	$50,940	$92,804	$117,209
	Lot 68	Garage		656.7	0.54	65.7	79.6	79.6	$121,838	$80,068	$97,039	$97,039
	Lot 35	House		658.4	-1.16	7.7	15.3	24.4	$12,493	$967	$1,916	$3,051
	Lot 52	House		658.2	-0.96	8.6	17.0	26.9	$15,172	$1,299	$2,579	$4,074
	Lot 53	House		658.2	-0.96	8.6	17.0	26.9	$74,124	$6,347	$12,601	$19,905
	Lot 54	House		657.8	-0.56	10.7	20.7	32.0	$127,253	$13,554	$26,299	$40,736
	Lot 55	Cabin		657.3	-0.06	17.2	29.0	39.1	$32,726	$5,633	$9,491	$12,810
	Lot 56	House		658.5	-1.26	7.3	14.5	23.2	$117,256	$8,598	$17,002	$27,213
	Lot 57	House		658.1	-0.86	9.0	17.8	28.1	$49,674	$4,457	$8,859	$13,943
	Lot 58	House	Developed	656.6	-1.36	6.9	22.0	22.0	$117,862	$8,159	$25,921	$25,921
	Lot 59	House		657.6	-0.36	13.3	24.0	34.9	$20,121	$2,671	$4,829	$7,015
	Lot 60	House		657.6	-0.36	13.3	24.0	34.9	$76,211	$10,117	$18,291	$26,571
	Lot 61	House		657.5	-0.26	14.6	25.7	36.3	$14,650	$2,137	$3,760	$5,317
	Lot 62	House		658.1	-0.86	9.0	17.8	28.1	$371,013	$33,291	$66,164	$104,138
	Lot 63	House		657.1	0.14	19.8	47.3	49.2	$16,229	$3,219	$7,674	$7,983
	Lot 66	House		657.9	-0.66	9.8	19.5	30.6	$57,133	$5,595	$11,141	$17,474
South McClintock	Lot 1012A	Cabin		658.3	-1.06	8.2	16.2	25.6	$59,262	$4,832	$9,581	$15,194
	Lot 1011	House		657.4	-0.16	15.9	27.3	37.7	$20,910	$3,325	$5,715	$7,887
	Lot 20	Cabin		657.6	-0.36	13.3	24.0	34.9	$89,563	$11,890	$21,495	$31,226
	Lot 797	House		657.8	-0.56	10.7	20.7	32.0	$66,383	$7,070	$13,719	$21,250
	Lot 21	Blue House		657.8	-0.56	10.7	20.7	32.0	$14,551	$1,550	$3,007	$4,658
	Lot 36A	House		657.8	-0.56	10.7	20.7	32.0	$141,705	$15,093	$29,286	$45,362
	Lot 24	Cabin		659.8	-2.56	0.0	0.0	0.0	$11,167	$0	$0	$0
	Lot 37	House		660.2	-2.96	0.0	0.0	0.0	$18,866	$0	$0	$0
	Lot 26	House		658.6	-1.36	6.9	13.7	22.0	$51,141	$3,540	$6,989	$11,247
	Lot 27	House		657.8	-0.56	10.7	20.7	32.0	$56,879	$6,058	$11,755	$18,208
	Lot 38	House		658.3	-1.06	8.2	16.2	25.6	$14,608	$1,191	$2,362	$3,745
	Lot 39	House		658.6	-1.36	6.9	13.7	22.0	$95,344	$6,600	$13,030	$20,969
	Lot 30	House		658.6	-1.36	6.9	13.7	22.0	$340,839	$23,595	$46,581	$74,960
	Lot 40A	House		658.4	-1.16	7.7	15.3	24.4	$42,258	$3,272	$6,480	$10,321
	Lot 41A	House		658.2	-0.96	8.6	17.0	26.9	$12,253	$1,049	$2,083	$3,290
	Lot 33A	House		658.5	-1.26	7.3	14.5	23.2	$101,830	$7,467	$14,765	$23,633
	Lot 34A	House		658.9	-1.66	0.0	0.0	0.0	$62,618	$0	$0	$0
								TOTAL	$3,763,276	**$459,889**	**$838,134**	**$1,161,972**

KGS GROUP

Marsh lake - Flood damages summary table

200-YEAR FLOOD	Legal Description	Structure Type	Basement Type	Floor Elevation (m)	Water Depth (m) 200-year flood	Damages % of Replacement cost: Low Estimate	Best Estimate	High Estimate	Replacement cost 2008 $	Damages in $: Low Estimate	Best Estimate	High Estimate
Army Beach	Lot 192A	House, main floor	Developed	658.5	-0.96	8.6	26.9	26.9	$153,464	$13,141	$41,210	$41,210
	Lot 20	House		658.6	-1.06	8.2	16.2	25.6	$71,261	$5,810	$11,521	$18,270
	Lot 21	House		657.7	-0.16	15.9	27.3	37.7	$81,907	$13,023	$22,388	$30,893
	Lot 22-1	House		657.6	-0.06	17.2	29.0	39.1	$212,515	$36,579	$61,629	$83,187
	Lot 22-2	House		658.0	-0.46	12.0	22.3	33.4	$68,413	$8,184	$15,279	$22,876
	Lot 23	House (on skids)		657.8	-0.26	14.6	25.7	36.3	$23,011	$3,357	$5,906	$8,351
	Lot 25	House		658.1	-0.56	10.7	20.7	32.0	$9,236	$984	$1,909	$2,956
	Lot 26A	House	Developed	658.2	-0.66	9.8	30.6	30.6	$6,162	$603	$1,885	$1,885
	Lot 27A	House		657.3	0.24	44.4	64.7	64.7	$133,710	$59,327	$86,491	$86,491
	Lot 28	House		658.2	-0.66	9.8	19.5	30.6	$11,774	$1,153	$2,296	$3,601
	Lot 29	House		657.4	0.14	19.8	47.3	49.2	$154,987	$30,745	$73,290	$76,233
	Lot 64	House		657.9	-0.36	13.3	24.0	34.9	$66,030	$8,766	$15,847	$23,021
	Lot 65	House		658.0	-0.46	12.0	22.3	33.4	$71,896	$8,601	$16,057	$24,041
	Lot 67	House		657.2	0.34	57.2	71.4	71.4	$274,978	$157,240	$196,454	$196,454
	Lot 68	Garage		656.7	0.84	75.6	94.4	94.4	$121,838	$92,060	$115,075	$115,075
	Lot 35	House		658.4	-0.86	9.0	17.8	28.1	$12,493	$1,121	$2,228	$3,506
	Lot 52	House		658.2	-0.66	9.8	19.5	30.6	$15,172	$1,486	$2,958	$4,640
	Lot 53	House		658.2	-0.66	9.8	19.5	30.6	$74,124	$7,259	$14,454	$22,671
	Lot 54	House		657.8	-0.26	14.6	25.7	36.3	$127,253	$18,564	$32,661	$46,181
	Lot 55	Cabin		657.3	0.24	44.4	64.7	64.7	$32,726	$14,521	$21,169	$21,169
	Lot 56	House		658.5	-0.96	8.6	17.0	26.9	$117,256	$10,041	$19,933	$31,487
	Lot 57	House		658.1	-0.56	10.7	20.7	32.0	$49,674	$5,291	$10,266	$15,902
	Lot 58	House	Developed	656.6	-1.06	8.2	25.6	25.6	$117,862	$9,609	$30,218	$30,218
	Lot 59	House		657.6	-0.06	17.2	29.0	39.1	$20,121	$3,463	$5,835	$7,876
	Lot 60	House		657.6	-0.06	17.2	29.0	39.1	$76,211	$13,118	$22,101	$29,832
	Lot 61	House		657.5	0.04	18.5	33.7	42.6	$14,650	$2,714	$4,944	$6,244
	Lot 62	House		658.1	-0.56	10.7	20.7	32.0	$371,013	$39,516	$76,676	$118,768
	Lot 63	House		657.1	0.44	62.4	75.5	75.5	$16,229	$10,133	$12,260	$12,260
	Lot 66	House		657.9	-0.36	13.3	24.0	34.9	$57,133	$7,585	$13,712	$19,919
South McClintock	Lot 1012A	Cabin		658.3	-0.76	9.4	18.7	29.3	$59,262	$5,561	$11,062	$17,354
	Lot 1011	House		657.4	0.14	19.8	47.3	49.2	$20,910	$4,148	$9,888	$10,285
	Lot 20	Cabin		657.6	-0.06	17.2	29.0	39.1	$89,563	$15,416	$25,973	$35,059
	Lot 797	House		657.8	-0.26	14.6	25.7	36.3	$66,383	$9,684	$17,038	$24,091
	Lot 21	Blue House		657.8	-0.26	14.6	25.7	36.3	$14,551	$2,123	$3,735	$5,281
	Lot 36A	House		657.8	-0.26	14.6	25.7	36.3	$141,705	$20,672	$36,371	$51,426
	Lot 24	Cabin		659.8	-2.26	0.0	0.0	0.0	$11,167	$0	$0	$0
	Lot 37	House		660.2	-2.66	0.0	0.0	0.0	$18,866	$0	$0	$0
	Lot 26	House		658.6	-1.06	8.2	16.2	25.6	$51,141	$4,169	$8,268	$13,112
	Lot 27	House		657.8	-0.26	14.6	25.7	36.3	$56,879	$8,298	$14,599	$20,642
	Lot 38	House		658.3	-0.76	9.4	18.7	29.3	$14,608	$1,371	$2,727	$4,278
	Lot 39	House		658.6	-1.06	8.2	16.2	25.6	$95,344	$7,773	$15,414	$24,445
	Lot 30	House		658.6	-1.06	8.2	16.2	25.6	$340,839	$27,788	$55,102	$87,385
	Lot 40A	House		658.4	-0.86	9.0	17.8	28.1	$42,258	$3,792	$7,536	$11,861
	Lot 41A	House		658.2	-0.66	9.8	19.5	30.6	$12,253	$1,200	$2,389	$3,748
	Lot 33A	House		658.5	-0.96	8.6	17.0	26.9	$101,830	$8,720	$17,311	$27,345
	Lot 34A	House		658.9	-1.36	6.9	13.7	22.0	$62,618	$4,335	$8,558	$13,771
								TOTAL	$3,763,276	**$709,043**	**$1,172,624**	**$1,455,301**

Upper Liard - Flood damages summary table

20-YEAR FLOOD	Legal Description	Basement Type	Floor Elevation	Water Depth (m)	Damages % of Replacement value			Replacement Value	Damages in $		
			(m)	20-year flood	Low Estimate	Best Estimate	High Estimate	2008 $	Low Estimate	Best Estimate	High Estimate
Upper Liard	B&C Block 1		610.0	-0.13	16.3	27.9	38.2	$83,641	$13,666	$23,328	$31,946
	Lot 1043		610.2	-0.28	14.4	25.4	36.1	$105,101	$15,104	$26,686	$37,894
	Lot 1025		610.1	-0.18	15.7	27.1	37.5	$252,446	$39,591	$68,305	$94,621
	Lot 1024		609.7	0.17	26.9	56.9	56.9	$45,007	$12,108	$25,610	$25,610
	Lot 1-78		609.6	0.27	49.9	67.4	67.4	$237,162	$118,239	$159,913	$159,913
	Lot 1-2 & 1021		609.8	0.07	19.0	36.9	44.8	$151,434	$28,718	$55,855	$67,871
	Lot 1044		609.9	-0.03	17.7	29.6	39.6	$23,618	$4,169	$6,981	$9,358
	Lot 1045		610.5	-0.63	9.9	19.8	31.1	$27,100	$2,691	$5,360	$8,418
	Lot 1046							$0	$0	$0	$0
	Lot 1048		610.0	-0.13	16.3	27.9	38.2	$98,207	$16,046	$27,390	$37,510
	Lot 1047	Developed	610.0	-0.13	16.3	38.2	38.2	$98,658	$16,120	$37,682	$37,682
							TOTAL	$1,122,374	$266,451	$437,111	$510,823

50-YEAR FLOOD	Legal Description	Basement Type	Floor Elevation	Water Depth (m)	Damages % of Replacement value			Replacement Value	Damages in $		
			(m)	50-year flood	Low Estimate	Best Estimate	High Estimate	2008 $	Low Estimate	Best Estimate	High Estimate
Upper Liard	B&C Block 1		610.0	0.27	48.5	66.8	66.8	$83,641	$40,602	$55,849	$55,849
	Lot 1043		610.2	0.12	19.5	41.9	47.6	$105,101	$20,510	$44,054	$50,002
	Lot 1025		610.1	0.22	40.3	62.7	62.7	$252,446	$101,840	$158,210	$158,210
	Lot 1024		609.7	0.57	66.6	80.9	80.9	$45,007	$29,953	$36,419	$36,419
	Lot 1-78		609.6	0.67	69.8	86.4	86.4	$237,162	$165,615	$204,876	$204,876
	Lot 1-2 & 1021		609.8	0.47	63.3	76.6	76.6	$151,434	$95,813	$115,980	$115,980
	Lot 1044		609.9	0.37	60.0	72.5	72.5	$23,618	$14,162	$17,120	$17,120
	Lot 1045		610.5	-0.23	14.9	26.1	36.7	$27,100	$4,044	$7,071	$9,933
	Lot 1046							$0	$0	$0	$0
	Lot 1048		610.0	0.27	48.5	66.8	66.8	$98,207	$47,673	$65,574	$65,574
	Lot 1047	Developed	610.0	0.27	48.5	66.8	66.8	$98,658	$47,892	$65,875	$65,875
							TOTAL	$1,122,374	$568,104	$771,028	$779,838

200-YEAR FLOOD	Legal Description	Basement Type	Floor Elevation	Water Depth (m)	Damages % of Replacement value			Replacement Value	Damages in $		
			(m)	200-year flood	Low Estimate	Best Estimate	High Estimate	2008 $	Low Estimate	Best Estimate	High Estimate
Upper Liard	B&C Block 1		610.0	0.78	73.4	91.8	91.8	$83,641	$61,427	$76,784	$76,784
	Lot 1043		610.2	0.63	68.5	84.2	84.2	$105,101	$72,015	$88,495	$88,495
	Lot 1025		610.1	0.73	71.8	89.7	89.7	$252,446	$181,258	$226,362	$226,362
	Lot 1024		609.7	1.08	81.8	102.5	102.5	$45,007	$36,827	$46,144	$46,144
	Lot 1-78		609.6	1.18	83.6	105.0	105.0	$237,162	$198,379	$249,137	$249,137
	Lot 1-2 & 1021		609.8	0.98	80.0	100.0	100.0	$151,434	$121,149	$151,437	$151,437
	Lot 1044		609.9	0.88	76.7	95.9	95.9	$23,618	$18,120	$22,650	$22,650
	Lot 1045		610.5	0.28	50.1	67.6	67.6	$27,100	$13,583	$18,318	$18,318
	Lot 1046							$0	$0	$0	$0
	Lot 1048		610.0	0.78	73.4	91.8	91.8	$98,207	$72,124	$90,155	$90,155
	Lot 1047	Developed	610.0	0.78	73.4	91.8	91.8	$98,658	$72,455	$90,569	$90,569
							TOTAL	$1,122,374	$847,337	$1,060,050	$1,060,050

APPENDIX

APPENDIX G TERMS AND CONDITIONS

ENVIRONMENTAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of EBA's investigation. The client, and any other parties using this report with the express written consent of the client and EBA, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and EBA, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

The client acknowledges that EBA is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of this report, EBA may have relied on information provided by persons other than the client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of EBA providing the services requested, the client agrees that EBA's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

1. With respect to any claims brought against EBA by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to EBA under this Agreement, whether the action is based on breach of contract or tort;
2. With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless EBA from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by EBA, whether the claim be brought against EBA for breach of contract or tort.

4.0 JOB SITE SAFETY

EBA is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of EBA personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with EBA with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for EBA to properly provide the service, EBA is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform EBA of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of EBA may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect EBA employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay EBA for any expenses incurred as a result of such discoveries and to compensate EBA through payment of additional fees and expenses for time spent by EBA to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

10.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.