Stantec

Memo

To:	John Steil	From:	Michael Yuan Karen Hartel
	Vancouver, BC		Burnaby, BC
File:	1161107845	Date:	January 25, 2019

Reference: Geotechnical Considerations - Descanso Bay
Gabriola Island Ferry Terminal

OVERVIEW

BC Ferries (BCF) is in the process of producing a Terminal Development Plan (TDP) for the Gabriola Island Terminal. The TDP will develop a concept level plan for the upgrades to the terminal which are anticipated to include the construction and a new berth as well as improvements to parking, queuing lanes, and traffic flows. Passenger amenities such as a waiting room with washroom facilities are also included in the TDP. This plan will provide the framework for BCF to implement the upgrade strategies over the next 25 years.

The implementation of the TDP will require rezoning and updates to the Gabriola Island Official Community Plan (OCP). Stantec has been retained by BCF to aide with this process.

The conceptual layout of the proposed terminal upgrade includes expansion of the traffic queuing area, requiring placement of fill within Descanso Bay. This memorandum summarizes geotechnical considerations related to the shoreline expansion.

EXISTING CONDITIONS AND PROPOSED SHORELINE EXPANSION

As shown on Figure 1, the existing queuing lane is located at the crest of the embankment that forms the southern shoreline of the Descanso Bay inlet. Based on the McElhanney Consulting Services “Topographic Survey of Gabriola Terminal” Plan dated 22 December 2017, existing grade at the asphalt queuing lane ranges from approximately El. 9 m (Chart Datum) at the intersection of North and Easthom Roads to El. 6 m adjacent to the loading ramp. The existing riprap embankment slopes towards the inlet from the north edge of the queuing lane at an approximate 2 horizontal to 1 vertical (2H:1V) grade. As indicated on the McElhanney survey, the toe of the existing embankment fill is approximately 14 m from the edge of asphalt at the crest of the slope. Based on the Terra Remote Sensing, Inc. Plan titled “Gabriola Hydrographic Survey Contoured Bathymetry” dated 26 April 2018, existing grade along the toe of the embankment ranges from approximately El. 1.5 m at the east end of the queuing lane to El. 0.5 m at the west end.

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Figure 1 Existing Conditions

BC Ferries proposed terminal development conceptual layout (dated 18 May 2018), shown in plan on Figure 2 below, necessitates placement of fill within the inlet to accommodate the three proposed queuing lanes along the north side of the terminal.

Two following concepts have been considered by BC Ferries for the revised shoreline condition:

Option A – Concrete block gravity wall with riprap toe berm

Based on the BC Ferries Conceptual Layout plan dated 18 May 2018, Option A included a vertical concrete block wall constructed to just above the design road grade retaining the required fill behind the wall, with the base of wall supported by a leveling pad. The conceptual section also included a riprap toe berm along the seaward face of the wall.

Option B – Riprap revetment slope (similar to the existing condition)

Option B includes construction of a riprap revetment slope extending from the edge of the design roadway down to the mudline. The riprap revetment includes a shear key extending below the mudline at the toe of the revetment.

BCF's preferred option is the concrete block gravity wall (Option A). The approximate location of the wall in plan relative to the existing riprap revetment is indicated on Figure 2.

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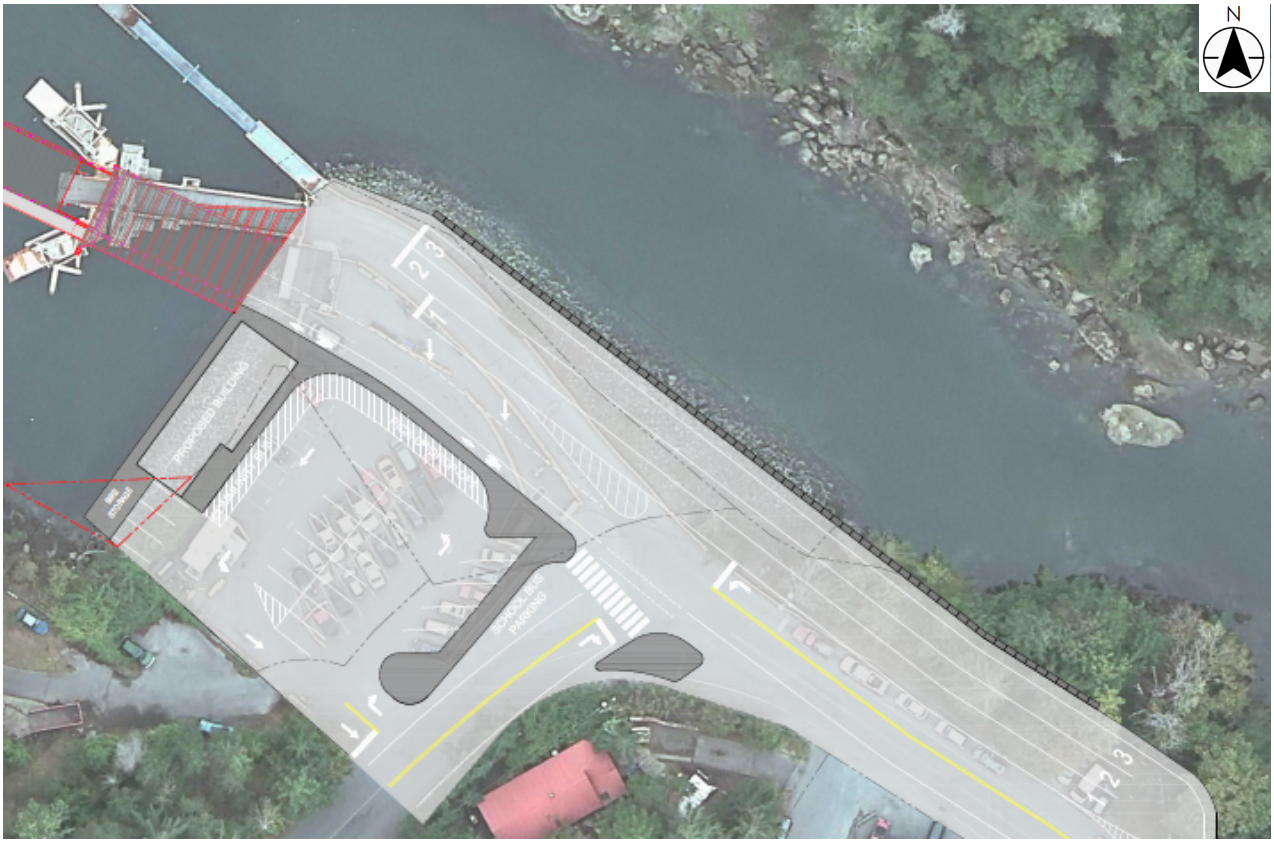

Figure 2 BC Ferries Conceptual Layout

AVAILABLE SUBSURFACE DATA AND ANTICIPATED SUBSURFACE CONDITIONS

SURFICIAL GEOLOGY

Based on the surficial geology map of Nanaimo (Map 27-1963 by Halstead, E. C., 1961), the Gabriola Island Terminal is situated within the surficial geology unit described as exposed bedrock or varied stony, loamy and clayey marine veneer commonly less than 1.5 m thick overlying bedrock.

AVAILABLE SUBSURFACE DATA

A geotechnical assessment report titled “Geotechnical Assessment – Foreshore Erosion Protection, BC Ferry Terminal, Gabriola Island, BC” dated 25 July 2007, prepared by Levelton Engineering Solutions (Levelton) was provided to Stantec. Based on our review of this report, Levelton conducted a site reconnaissance and hand probing program at the site on 15 June 2007, with an additional hand probing program completed on 28 June 2007 at low tide. The purpose of the probes was to provide an indication of subsurface conditions (depth of sediment and depth/elevation of bedrock or firm material) along the toe of the existing revetment. Each of the hand probes was generally advanced to the length of the probe rod (length of the rod depended on the

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number of rods available at the time of the probing program), or effective refusal within very dense soils or inferred bedrock. Bedrock was inferred when a "ringing" was encountered at the effective refusal depth.

In general, surficial deposits penetrable by hand probe were encountered ranging from 2.6 m to 6.8 m thick, with the exception of one location where the hand probe extended beyond 8.5 m depth (i.e., available length of rod at the time) near the northern corner of the embankment. Very little resistance was experienced probing into the surficial deposits until the depth of effective refusal. Based on probing as well as the presence of sand soils near the toe of the existing embankment, subsurface conditions seaward of the existing embankment toe are inferred to consist of loose sand overlying bedrock.

Exposed bedrock comprised of sandstone was observed along the existing embankment near the start of the queuing lanes to the northeast.

ANTICIPATED SUBSURFACE CONDITIONS

Based on the data obtained from Levelton's hand probing programs, we anticipated that, at the location of the proposed shoreline expansion, the riprap of the existing embankment overlies relatively loose sand deposits up to approximately 7 m in thickness which are underlain by sandstone bedrock.

Based on the BC Ferries Conceptual Layout plan dated 18 May 2018, the mean sea level (MSL) is at El. 2.99 m with the highest high water level (HHWL) and the lowest low water level (LLWL) at El. 5.09 m and El. -0.12 m, respectively.

PRELIMINARY EVALUATION OF SHORELINE EXPANSION ALTERNATIVES

The expansion of the uplands area to accommodate additional designated queuing lanes necessitates fill placement above the existing shoreline embankment slope and within the Descanso Bay inlet beyond the existing embankment toe. Consequently, an expansion of the existing waterlot in this area is proposed as part of the terminal upgrade. Stantec has performed a concept-level geotechnical evaluation of the options for shoreline expansion in order to provide a preliminary assessment of the required limits of fill within the waterlot associated with each option.

The geotechnical evaluation is based on assumed subsurface conditions as described previously; no subsurface investigation has been completed for this assessment. A single representative design section was selected based on the bathymetric and topographic survey provided. The design section includes the following:

- Plan location of seaward face of wall and crest of proposed embankment based on BCF "Approximate Retaining Wall Location" shown on the Conceptual Plan dated 18 May 2018
- Finished grade at adjacent queuing lane El. 8 m
- Adjacent existing mudline El. 1 m
- Uniform traffic surcharge loading of 4.8 kPa within the queuing lanes (applied 1 m behind the seaward face of wall/crest of slope)
- Seismic loads have not been considered in the preliminary analyses

Details of the evaluations and resulting shoreline fill and structure geometries are presented below. A typical cross section for each of the two conceptual design options is presented in Figure A2 in the attachment.

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Option A – Concrete block gravity wall with riprap toe berm

A conceptual section of this option was included on the BC Ferries Conceptual Layout plan dated 18 May 2018. The section included a vertical concrete block wall retaining the required fill, with the base of wall supported by a leveling pad at approximate El. 1.5 m, and top of wall at approximate El. 8.3 m. The conceptual section also included a riprap toe berm along the seaward face of the wall, with an approximate 1 m wide crest at the top of the berm at El. 4.5 m, base of berm at El. 1.5 m, and berm slope of 2H:1V. Based on the inferred bedrock elevation indicated in the Levelton report of approximately El. -2 m, and the likely condition of loose material overlying bedrock, in our preliminary analyses, we considered a wall with a base at El. 0 m. In addition, a 2° batter was included for the face of the wall for additional stability and resistance against overturning forces.

Stantec conducted a preliminary analysis to assess wall stability with respect to overturning, sliding, and bearing capacity. The analysis was based on the conceptual section and geometry indicated above, utilizing assumed engineering parameters for the native sand, fill, and riprap materials based on professional judgement. Results of the analyses indicated that overturning failure was the governing failure mode, and the width of the concrete block wall would need to be increased to 3 m at the bottom of the wall, stepping back incrementally to 0.75 m at the top of the wall, to achieve a satisfactory Factor of Safety (FoS) of 1.5 under the static loading condition.

Anticipated toe of fill (associated with the riprap stability berm) is presented in plan relative to the proposed waterlot expansion on Figure. A1, attached. The resulting wall geometry is shown in section on Figure A2, attached.

Option B – Riprap revetment slope

This option includes construction of a riprap armoured fill slope extending from the edge of the design roadway at approximately El. 8 m down to the mudline at approximately El. 1 m, at a revetment slope of 2H:1V. The approximate 3 m thick riprap revetment profile includes a shear key embedded approximately 1 m below mudline at the toe of the revetment for additional resistance to slope failure within the underlying loose sand. Engineered fill would be required for the general shoreline extension after removal of the existing riprap at the current revetment slope.

Stantec conducted a preliminary assessment of slope stability of the proposed revetment slope under static loading condition. Results of the analyses indicated that the slope configuration described above would achieve a satisfactory FoS of 1.5 under the static loading condition provided that the riprap section includes a minimum 1 m deep shear key. It should be noted that dimensions of the shear key and base elevation of the riprap are sensitive to the assumptions relative to characteristics of the foundation soils and depth to firm material or bedrock. These dimensions may require modification as additional subsurface data is collected and design advances.

Anticipated toe of riprap associated with the revetment slope is presented in plan relative to the proposed waterlot expansion on Figure A1, attached; the revetment geometry is shown in section on Figure A2, attached.

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CONCLUSIONS

Based on the results of our preliminary analyses, both Option A and Option B conceptual designs achieve satisfactory stability in the static loading condition. The preliminary analyses are based on assumed subsurface conditions and associated engineering parameters; these analyses are considered appropriate to establish approximate limits of fill relative to the proposed waterlot. Additional exploration and analyses will be required for detailed design. In addition, the preliminary analyses do not consider seismic loading. Depending on seismic performance criteria, wall and/or revetment geometry and anticipated toe of fill relative to waterlot would need to be reassessed.

The top of the stability berm of Option A extends seawards at a 2H:1V side slope from roughly mid-height of the retaining wall, and therefore, would encroach less into the waterlot as compared to Option B, where the top of the revetment slope extends at a 2H:1V side slope from the design road grade. Option A is therefore preferred from the standpoint of minimizing the footprint of fill within the Descanso Bay inlet.

Both options will require excavation below existing mudline, and below mean tide. Depending on the final design elevation of the base of the wall and levelling pad (Option A), and riprap shear key (Option B), excavation below lower low water may also be required. Dewatering will likely be required for construction of the leveling pad and wall, depending on final base elevation. For both options, a filter layer will be required beneath the riprap to prevent loss of the finer-grained native sand or granular fill material adjacent and below the riprap. It would be preferable to place the filter fabric (or filter material) in the dry, and again depending on final base elevations of the shear key or leveling pad, dewatering may be required. Placement of the riprap for the shear key could be accomplished without the need for dewatering once the filter layer is in place.

The site conditions present constructability challenges for both options and will affect overall cost. Although the riprap revetment slope represents a larger footprint of fill within the inlet, there may be construction and cost advantages associated with Option B, particularly if the need for dewatering could be avoided.

We trust that this information is sufficient for your requirements at the present time. Should you have any questions or require any additional information, please do not hesitate to contact the undersigned.

Regards,

Stantec Consulting Ltd.

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Geotechnical Engineer

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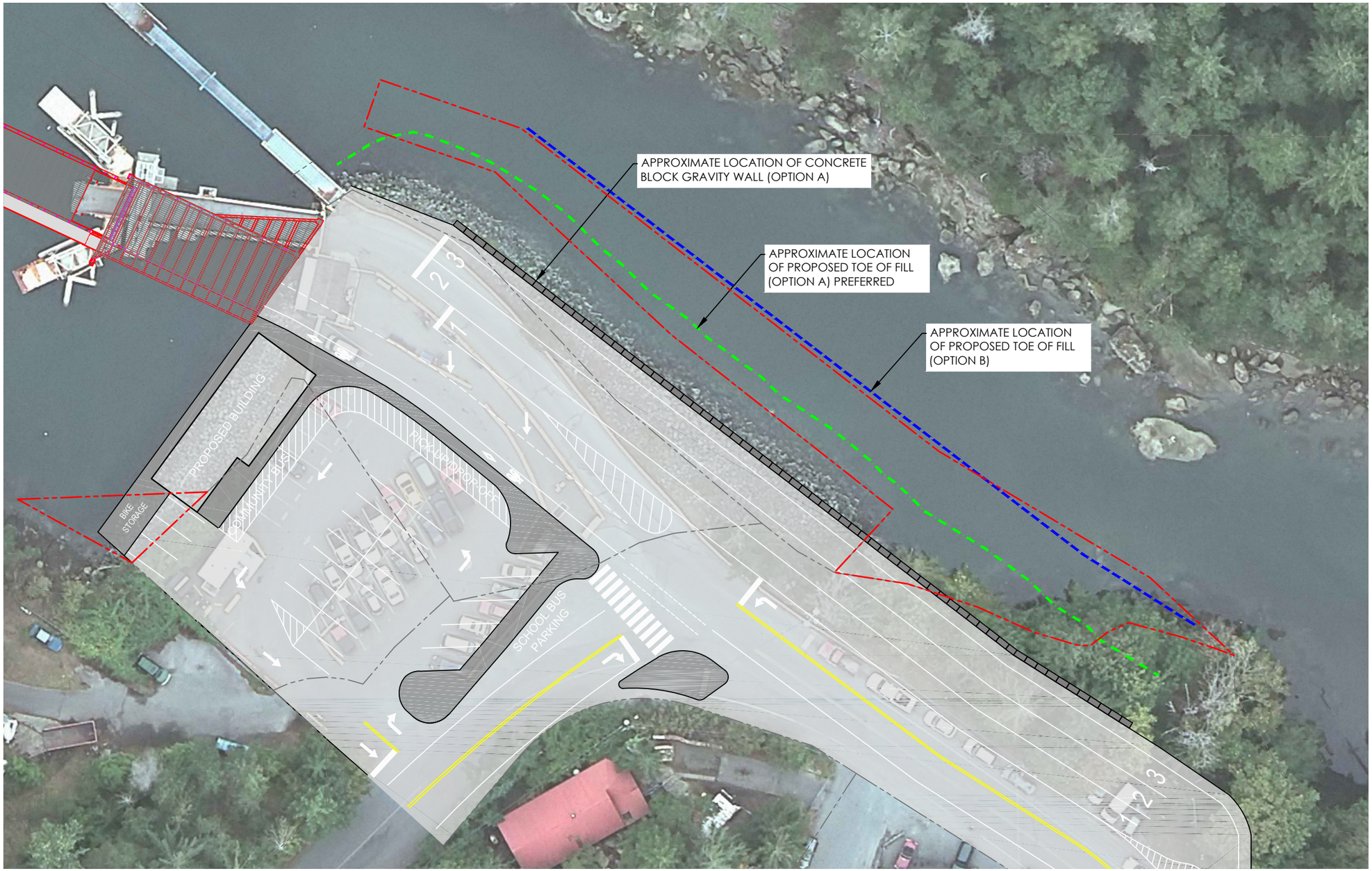
Attachment: Figure A1 – Site Plan Showing Proposed Slope Options
Figure A2 – Schematic Conceptual Sections – Options A & B



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ORIGINAL SHEET - ANSI B

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2019/01/15 4:14 PM By: Huynh, Gordon

Sources

Project Information

Project No.:	1161107845
Scale:	1:500
Date:	2019-JAN-15
Drawn by:	G. HUYNH
Checked by:	M. YUAN

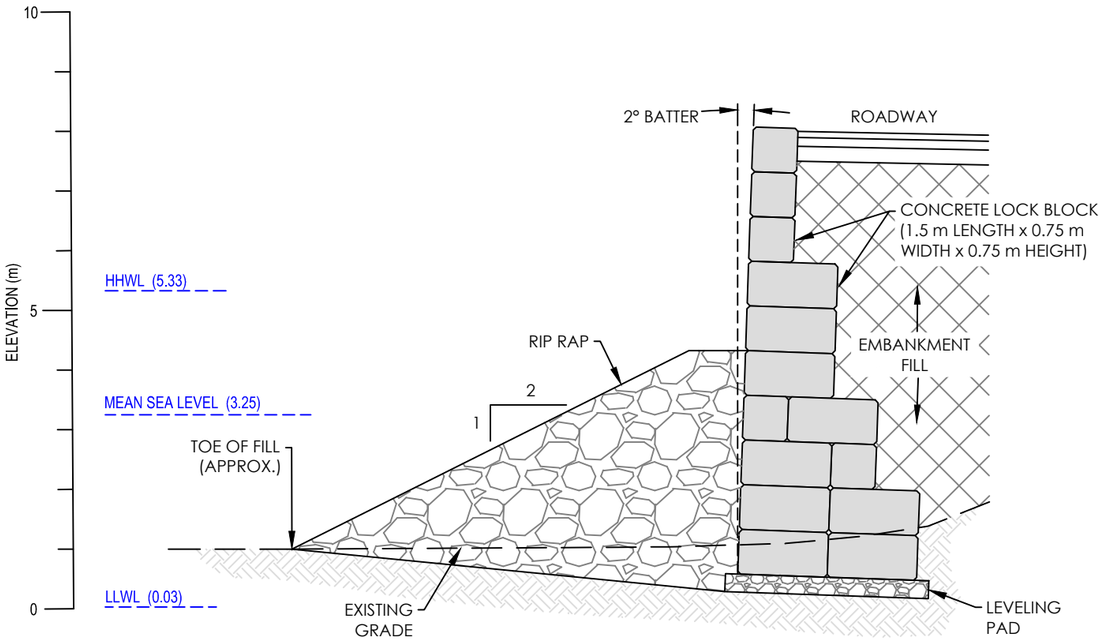
Project Location
GABRIOLA ISLAND, BC

Client/Project
BC FERRIES

GABRIOLA ISLAND PROPOSED WATER LOT EXPANSION

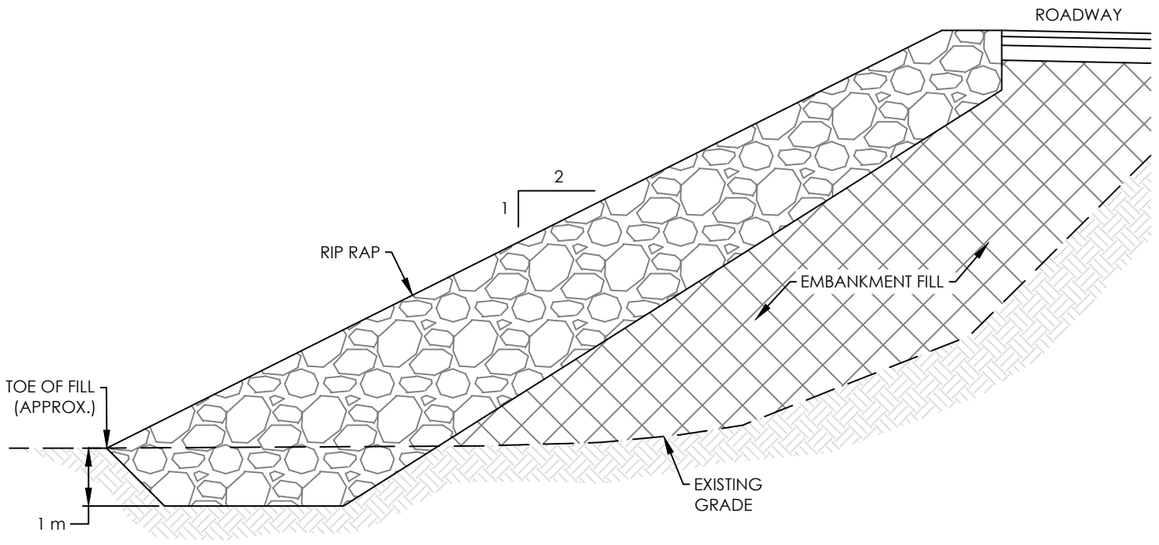
TITLE
SITE PLAN SHOWING PROPOSED SLOPE OPTIONS

Figure No.
A1



OPTION A - CONCRETE BLOCK GRAVITY WALL (PREFERRED)

SCALE: 1:100



OPTION B - RIP RAP REVETMENT

SCALE: 1:100

NOTE:
ELEVATIONS TO BE DETERMINED IN DETAILED DESIGN.

SCALE IN METRES

0 1 2 3 4 5

1:100

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ORIGINAL SHEET - ANSI B

Sources

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Project No.:	1161107845
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Drawn by:	G. HUYNH
Checked by:	M. YUAN

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GABRIOLA ISLAND, BC

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GABRIOLA ISLAND PROPOSED WATER LOT EXPANSION

TITLE

SCHEMATIC CONCEPTUAL SECTIONS - OPTIONS A & B

Figure No.

A2