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Memorandum

Attention	Joshua Jodoin
CC	Helen Ambrose
From	Shaun Coburn, EIT
Subject	Cascadia Expansion Project Phase 4 - Hydraulic Process and Alteration Report
Date	23 October 2020
Page	Page 1 of 8 (plus appendices)
Document Ref:	104703-01-MEM-001

1 Introduction

As part of the Vancouver Fraser Port Authority (Port Authority) Burrard Inlet Road and Rail Improvement Project, Canadian Pacific Railway Company (CP) is undertaking planning activities for Phase 4 of the Viterra Cascadia Terminal Capacity Expansion Project (Project), which is situated within the Second Narrows Traffic Control Zone (TCZ-2).The proposed track expansion involves widening the existing CP rail embankment and placing clean, engineered, fill material (riprap) extending into Burrard Inlet. The purpose of widening the embankment is to increase the number of rail tracks at the siding to improve capacity.

As part of the Project-related planning activities and the Project Environmental Review Application to Port Authority, there is a requirement to investigate the impacts of the proposed placement of material in Burrard Inlet on local, tidally induced hydraulics. Placing material within the channel reduces its cross-sectional area and can increase flow velocity, which could lead to erosion. Conversely, widening a channel can reduce flow velocity, which could lead to sediment deposition in the channel. This memorandum provides a review and summary of the available information and assessment of the local hydraulics to support the application submission.

2 Site Information

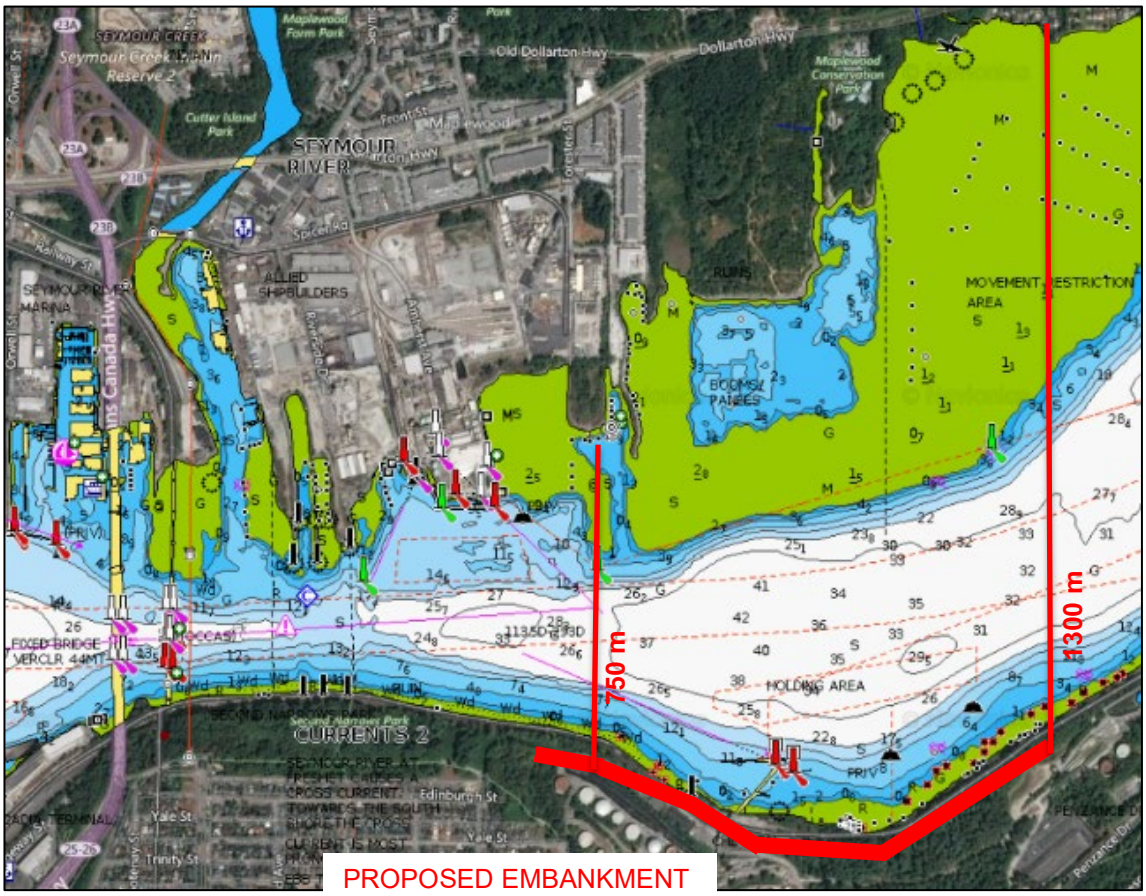
The tidal range at the Second Narrows Bridge is approximately 5.0 metres (m) with a mean water level at approximately +3.1 m above Chart Datum (CD). The tides are summarized in **Table 1** based on the values presented in Canadian Tide and Current Tables for the primary port of Vancouver.

Table 1 Tidal Information

Description	Height above (m CD)	Height above (m Geodetic Datum [GD])
Higher high water large tide (HHWLT)	+5.0	+1.9
Higher high water mean tide (HHWMT)	+4.5	+1.4
Mean water level (MWL)	+3.1	+0.0
Lower low water mean tide (LLWMT)	+1.2	-1.9
Lower low water large tide (LLWLT)	+0.1	-3.0

Source: Canadian Tide and Current Tables 2020

Based on publicly available data, the depth of Burrard Inlet adjacent to the proposed embankment is up to 43 m deep at lower low water large tide (LLWLT), and the inlet ranges between approximately 750 m and 1,300 m in width, as shown in **Figure 1**. Of note is the large intertidal area (shown in green) that will be dry at LLWLT, but submerged at higher high water large tide (HHWLT), which means the cross-sectional area of Burrard Inlet will differ quite significantly between low and high tides.



Source: Source: Navionics.com

Figure 1 Hydrographic chart showing Burrard Inlet east of the Second Narrows Bridge

3 Method

To investigate the impact of widening the existing embankment on the hydrodynamics through Burrard Inlet, consideration is given to the following equation to determine open channel flow:

$$Q = \bar{V}A$$

In this equation, Q = flow rate (cubic metres per second [m^3/s]), $\overline{V}$ = average velocity (metres per second [m/s]) through the channel cross-section, and A = cross-sectional area (square metres [m^2]).

For this assessment, it is assumed the flow rate (Q) through the channel is unchanged by the widening of the embankment as the hydraulic head upstream and downstream of the affected section is driven by the tides. Flows in all areas of interest for this study are expected to be subcritical for all stages of the tide.

4 Hydraulic Assessment

4.1 Existing Channel

The section of the channel with the smallest cross-sectional area will have the highest velocity, which is the key parameter when considering the susceptibility of the channel to erosion and geomorphological changes. Spot levels and distances have been obtained from Navionics.com for the three alignments shown in **Figure 2**. The three alignments were selected as being representative of the channel width at the locations shown. All alignments are perpendicular to the direction of flow through Burrard Inlet.

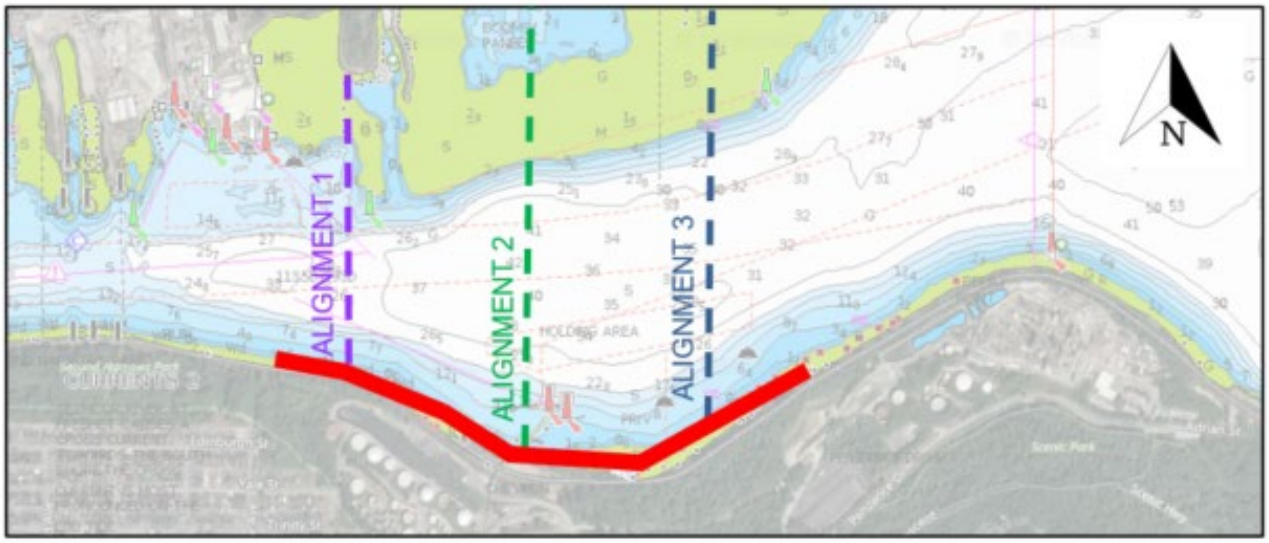


Figure 2 Alignments selected to assess impacts on the hydraulics of the channel

The channel cross-sections and key tide levels are shown in **Figure 3** with the origin being the top of bank along the south side of Burrard Inlet. Levels are shown relative to CD, which is 3.1 m below geodetic datum (**Table 1**).

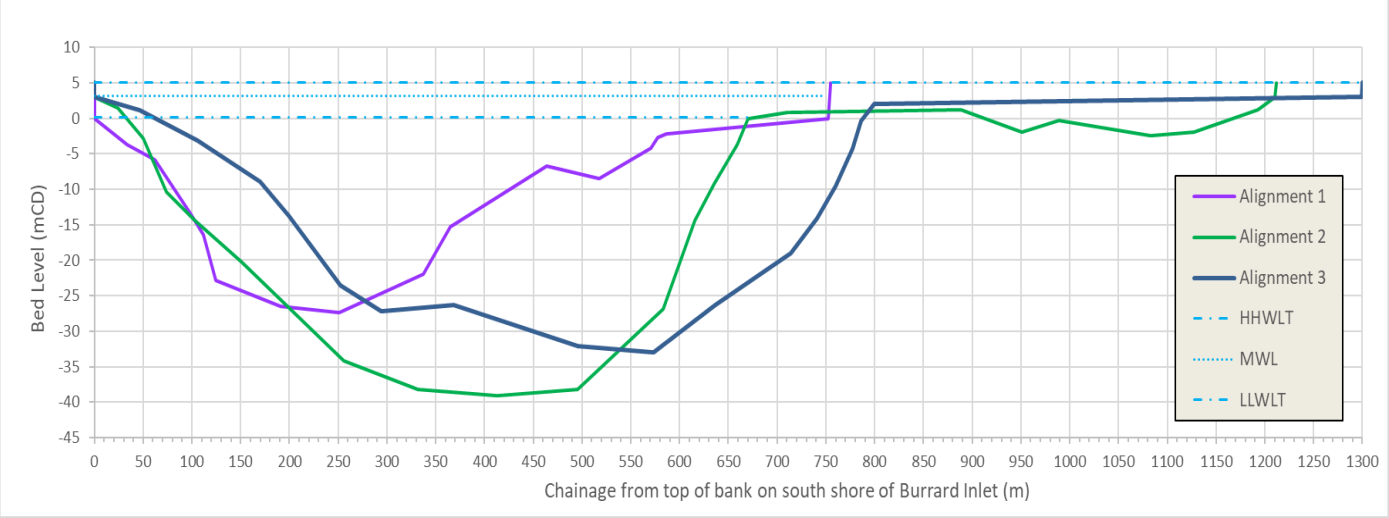


Figure 3 Typical channel cross-section at Alignments 1-3

The calculated flow areas at LLWLT, mean water level (MWL) and HHWLT for both alignments of the existing channel are summarized in **Table 2**.

Table 2 Cross-sectional Areas of Existing Channel for Alignments 1 to 3

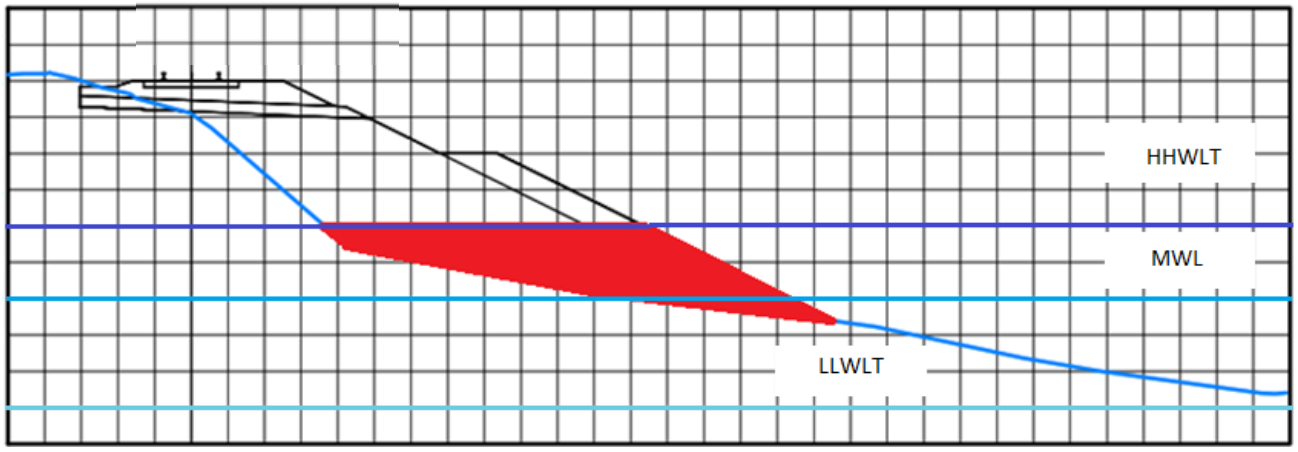
Reference Alignment	Cross-sectional Area of Flow at LLWLT	Cross-sectional Area of Flow at MWL	Cross-sectional Area of Flow at HHWLT
Alignment 1	6,950 m^2	8,950 m^2	10,060 m^2
Alignment 2	17,540 m^2	20,860 m^2	23,240 m^2
Alignment 3	15,505 m^2	17,985 m^2	20,500 m^2

As shown in **Table 2**, Alignment 1 has the smallest flow area of the three sections at all tide levels. Alignment 2 and Alignment 3 are located upstream of the first alignments, where the channel has a significantly larger cross-sectional area, as well as the broad intertidal areas, which also increase the cross-sectional area at higher tide levels.

4.2 Proposed Embankment Fill

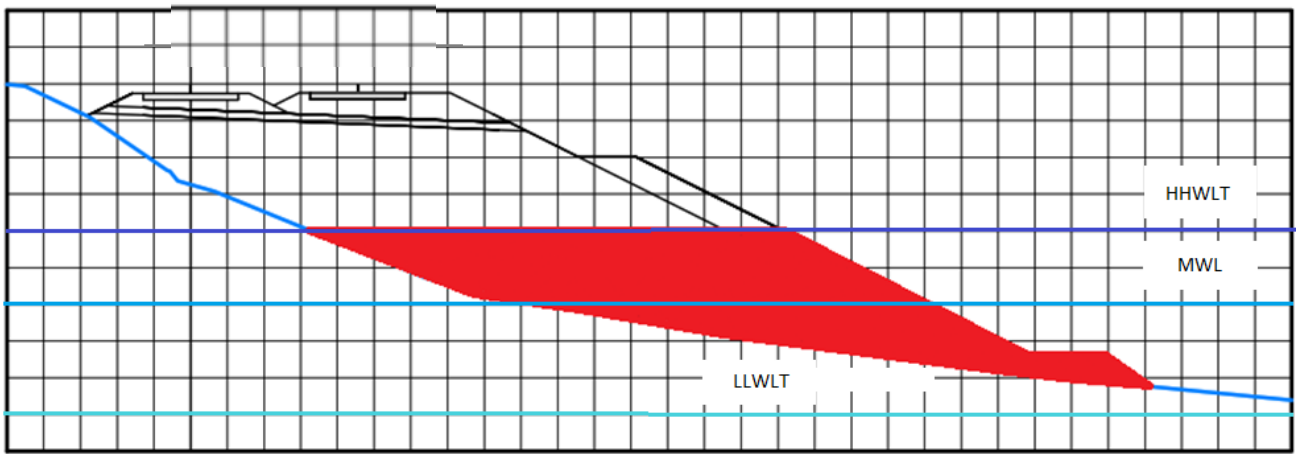
Embankment fill sections provided on Hatch drawings 362379-RW-100-S0-300 to 362379-RW-100-S0-309 (see **Appendix 1**) indicate that the existing channel bed will not be excavated as all new embankment material will be placed on top of the existing substrate. Some sections of track between Chainage 10+375 and Chainage 10+800 require excavation at the top of the embankment, which is well above the high water line and will therefore not affect the flow regardless of tide. Upon review, it is noted that the works in the vicinity of Alignment 2 will not require any infill to Burrard Inlet; therefore, only Alignments 1 and 3 are used in the analysis.

Placement of the embankment fill above the existing channel bed will reduce the flow area accordingly, up to a maximum reduction at the highest water level. Alignment 1 is located at Chainage 11+050, Alignment 2 at Chainage 10+600, and Alignment 3 at Chainage 10+200, as per Hatch drawing 362379-RW-100-S0-100 (see **Appendix 1**). At HHWLT (+1.9 m geodetic datum [GD]) it is estimated that the reduction in cross-sectional area will be approximately **16.8 m²** at Alignment 1 and **43.1 m²** at Alignment 3. These areas are indicated in red in **Figure** 4 and **Figure** 5.



Source: Hatch Drawing 362379-RW-100-S0-305 Ch 11+050

Figure 4 Alignment 1 proposed embankment cross-section, elevations in metres relative to GD



Source: Hatch Drawing 362379-RW-100-S0-301 Ch 10+200

Figure 5 Alignment 3 proposed embankment cross-section, elevations in metres relative to GD

4.3 Flow Area Reduction and Effect on Average Velocity

The expected maximum cross-sectional area of the proposed embankment is calculated to be **43.1 m^2** at Alignment 3. The predicted effect of Project construction on local channel hydraulics is summarized as follows:

- At HHWLT along Alignment 1 where the channel is at its most narrow, the percentage reduction in cross-sectional area is 0.17%.
- At HHWLT along Alignment 3 where the channel is nearly twice as large as Alignment 1 and the area of embankment is also more than double, the percentage reduction in cross-sectional area is 0.21%.

The average velocity of the flow is inversely proportional to the cross-sectional area for the same flow rate, so the average velocity increases as the cross-sectional area decreases. The maximum relative increase in average velocity through the channel is therefore estimated to be 0.21%.

The flow disturbance caused by the proposed embankment would be stronger in the immediate vicinity of the embankment and would be reduced toward the channel centre and north bank. The change in current velocity at distances greater than 3 times the embankment width, or approximately 60 m from the embankment toe, is expected to be negligible. Local bed scour around the embankment toe will likely be mitigated by design; however, based on local knowledge, it is expected that non-erodible rock substrate may continue along the shoreline into the proposed embankment area.

5 Discussion

Consideration has been given to three channel cross-sections to determine a realistic yet conservative estimate of the potential impacts on hydraulics within Burrard Inlet due to construction of the proposed widened embankment near the Viterra Cascadia Terminal. The average velocity of the hydraulic flow through the channel section at the embankment for flood or ebb tides could increase by up to 0.21% during HHWLT and less than 0.1% at MWL. Much of the works will occur above the MWL and would therefore result in negligible reductions in channel area. Further, the flow disturbance is expected to be primarily confined to the areas adjacent to the embankment, which is expected to be designed to resist scour and sized accordingly to prevent movement as a result of the riprap interaction with the flow.

A 0.21% change is expected in average velocity of the tidal flow in the channel adjacent to the proposed embankment for a relatively small duration in the tidal cycle, which is not expected to result in a measurable impact on the overall morphology of Burrard Inlet. Furthermore, the channel flow velocity will revert to existing velocities both upstream and downstream of the Project area.

Based on the assessment, at water levels of MWL and lower (i.e., approximately 50% of the time) there will be a negligible change in the channel hydraulics due to the construction of the proposed embankment. At water levels above MWL the percentage increase in average velocity through the section of interest is expected to vary gradually, increasing from zero at low water (LLWLT) to a maximum of approximately 0.21% at HHWLT. As noted, the increased velocity will be localized near the embankment; therefore, the average velocity change within the central area of the channel will be negligible. The effect on flow hydraulics, if any, within TCZ-2 is therefore expected to be unnoticeable for navigational purposes.

6 References

1. Fisheries and Oceans Canada, 2020. Canadian Tide and Current Tables. Available at http://www.charts.gc.ca/publications/tables-eng.html.
2. Port of Vancouver, 2018. Port Information Guide Port of Vancouver. Available at https://www.portvancouver.com/wp-content/uploads/2015/03/Port-of-Vancouver-Port-Information-Guide.pdf.

Appendix 1 – Reference Drawings

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LOCATION PLAN

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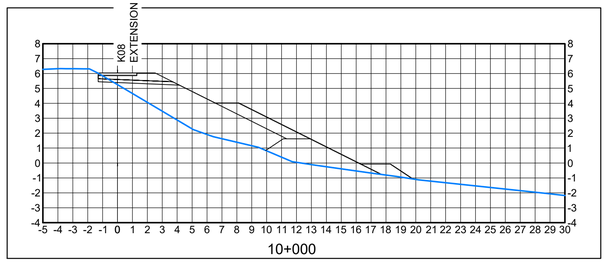

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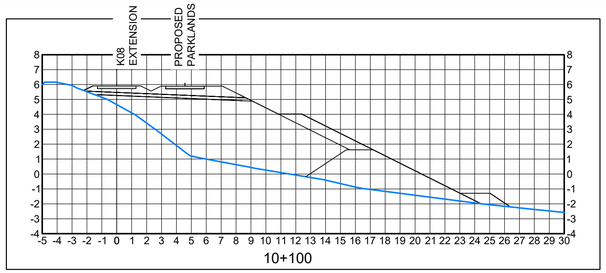

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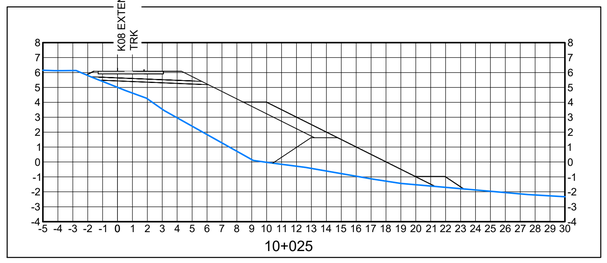

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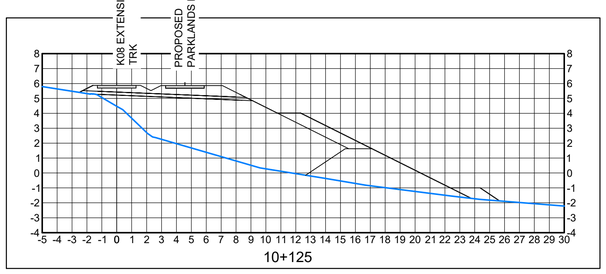

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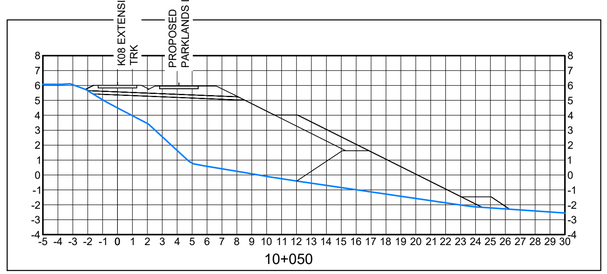

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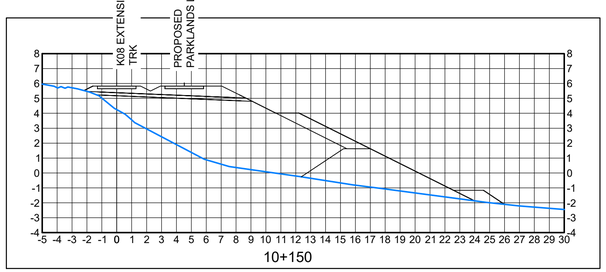

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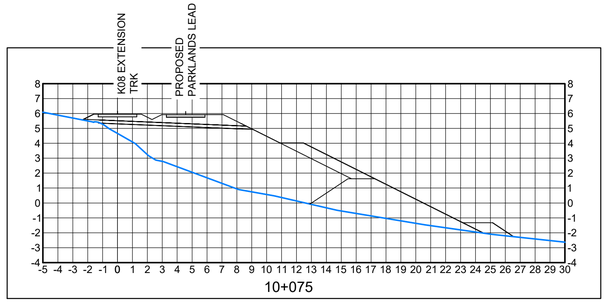

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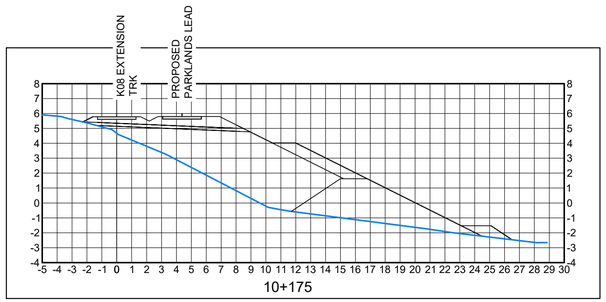

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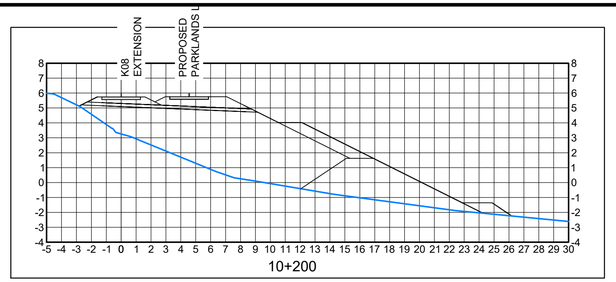

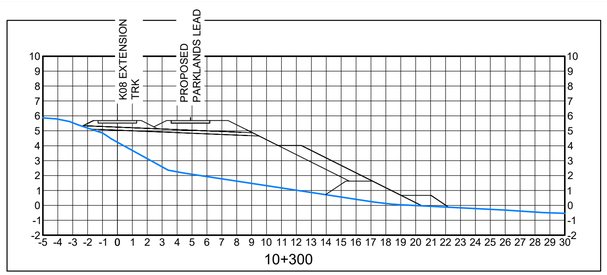

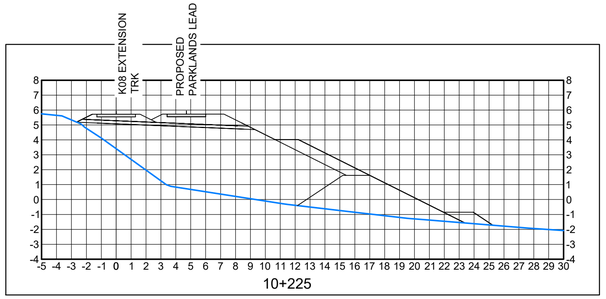

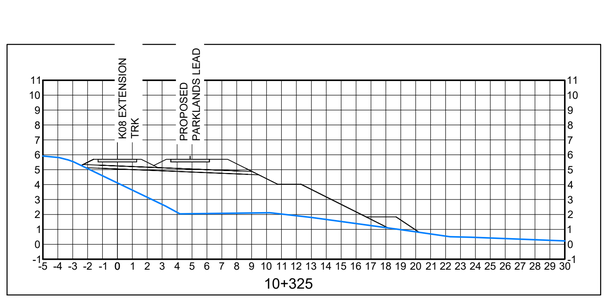

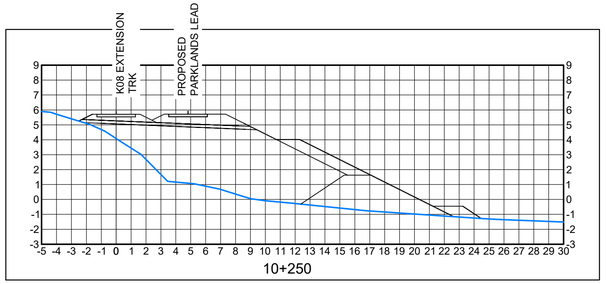

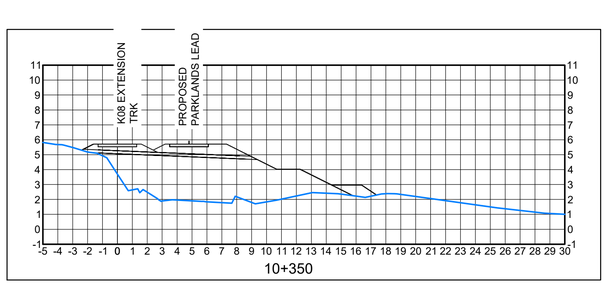

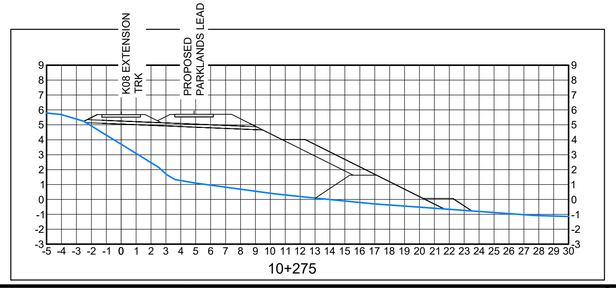

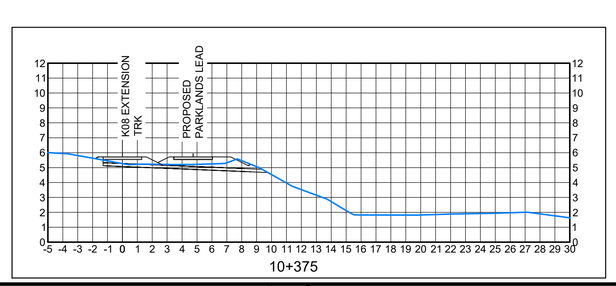

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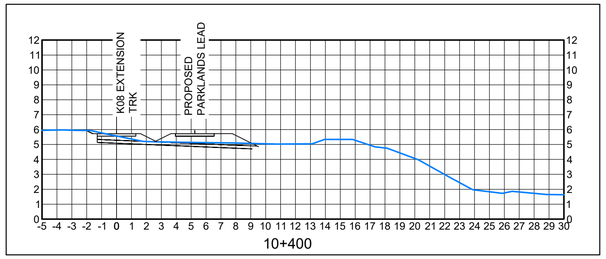

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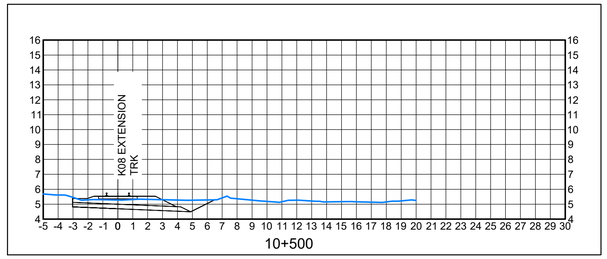

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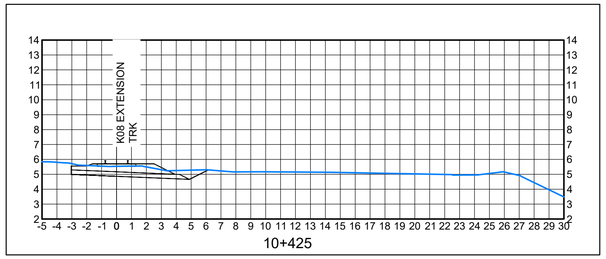

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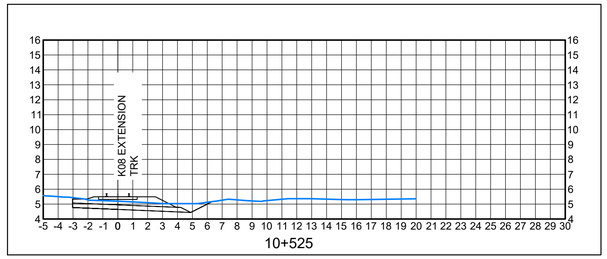

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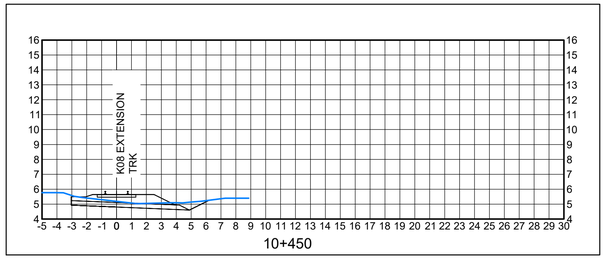

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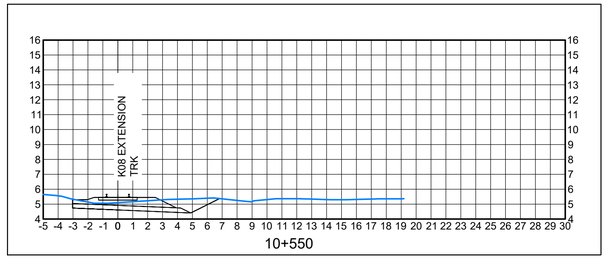

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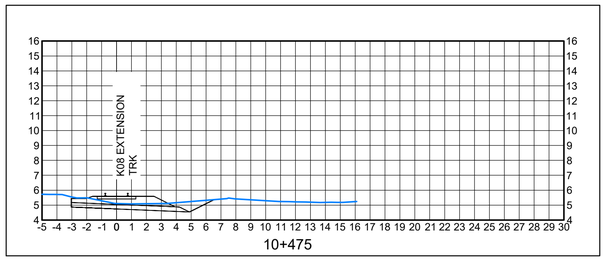

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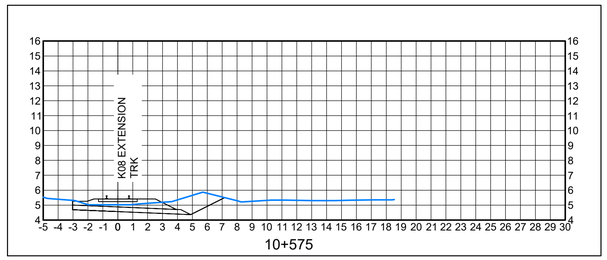

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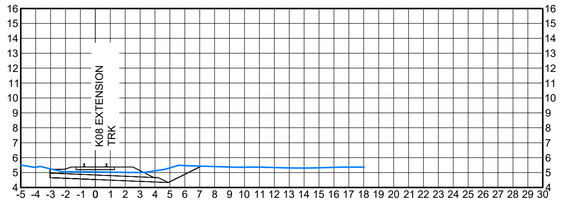

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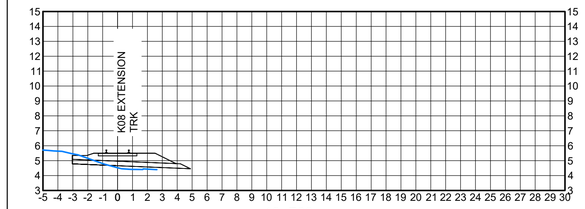

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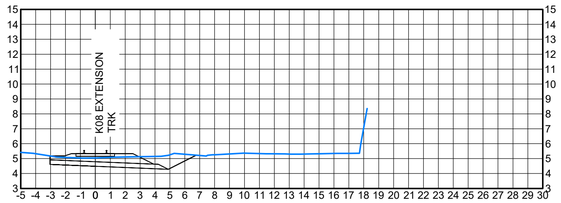

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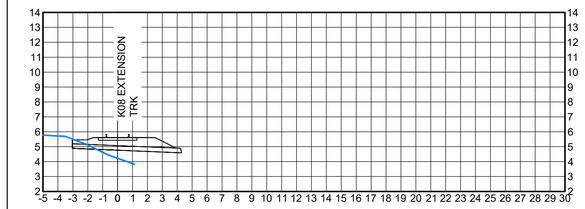

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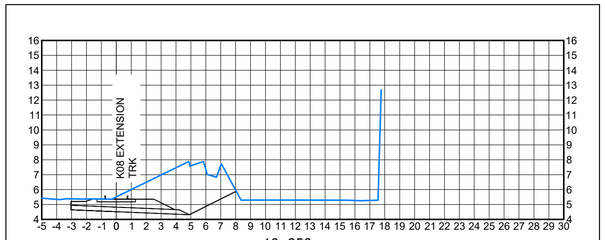

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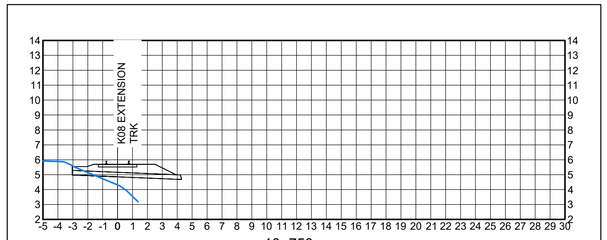

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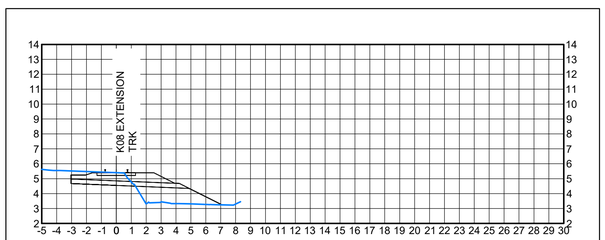

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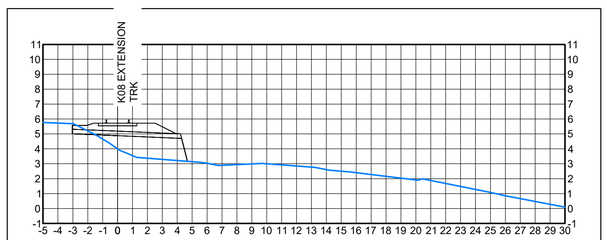

10+775

DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: 20-07-20
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: 20-07-20	J.L. DATE: 20-07-20
HATCH PROJECT No:	DWG SCALE(FULL SIZE):
362379	1:2000

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.
A	20-08-14	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

ENGINEERING PROJECTS - WEST

VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
OPTION 1 SECTIONS

DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-303	Rev. B

Sep 01 , 2020 , 1:23pm Login name: MAM872934
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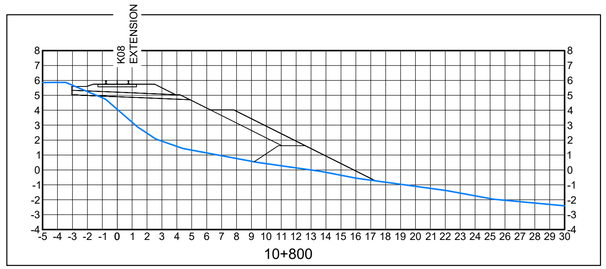
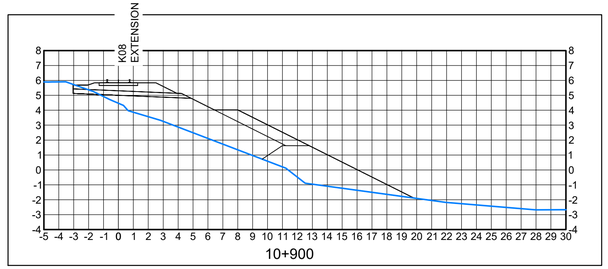
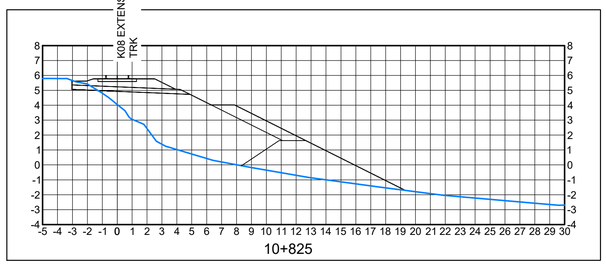
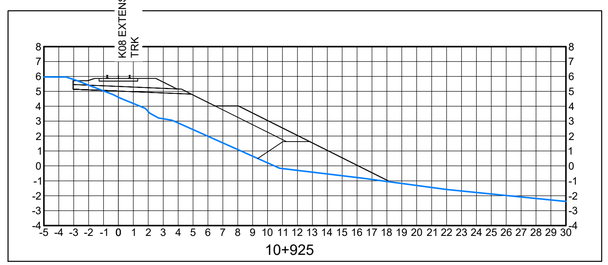
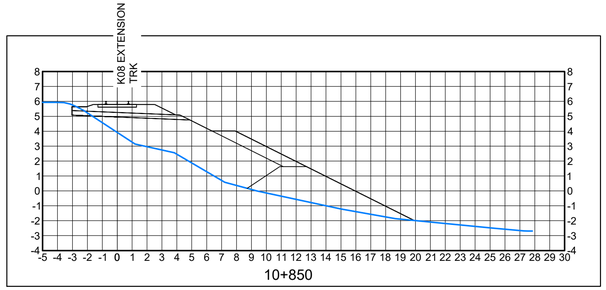
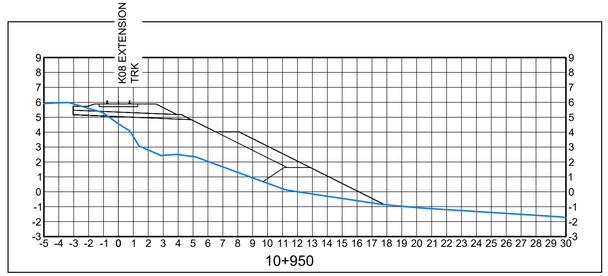


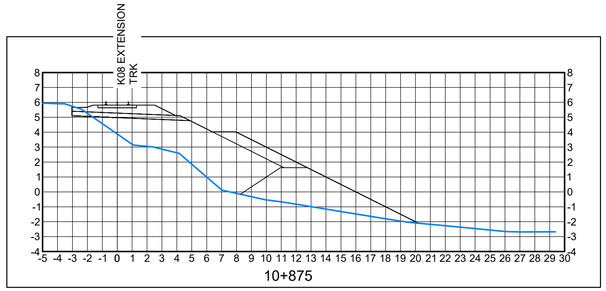


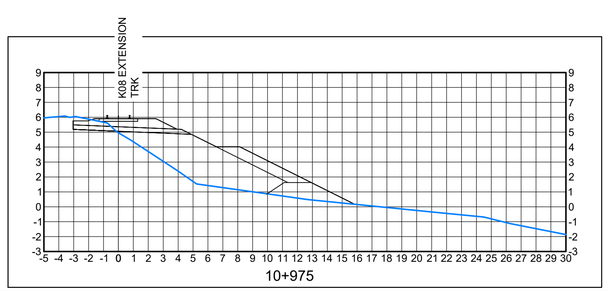












DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY: T.I. DATE: 20-07-20	DRAWN BY: T.I. DATE: 20-07-20
CHECKED BY: J.C. DATE: 20-07-20	PROJECT MANAGER: J.L. DATE: 20-07-20
HATCH PROJECT No: 362379	DWG SCALE(FULL SIZE): 1:2000

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.
A	20-08-14	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

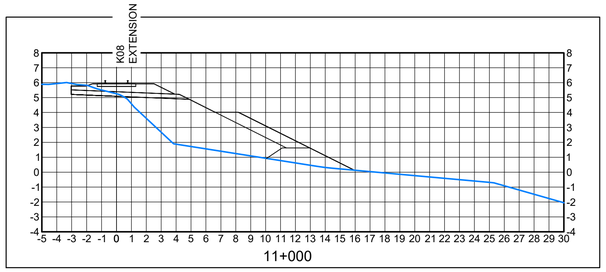
ENGINEERING PROJECTS - WEST

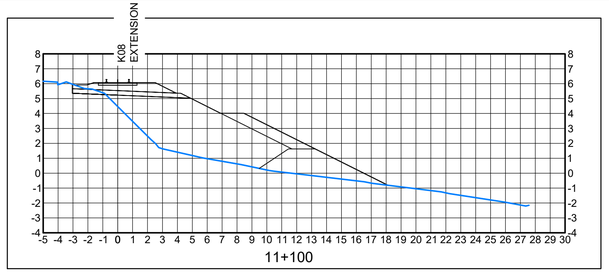
VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

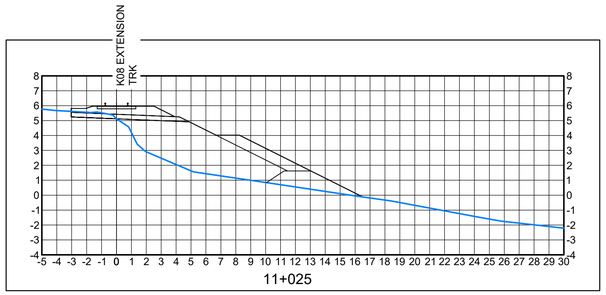
CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
OPTION 1 SECTIONS

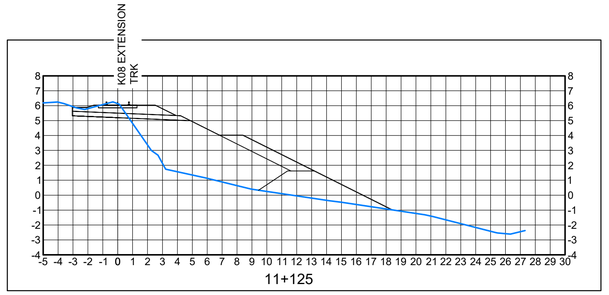
DWG. BY: CHK BY:	OFFICE FILE:
MANAGER - DESIGN:	SCALE:
	DATE:
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST	PLAN No. 362379-RW-100-S0-304 Rev. B

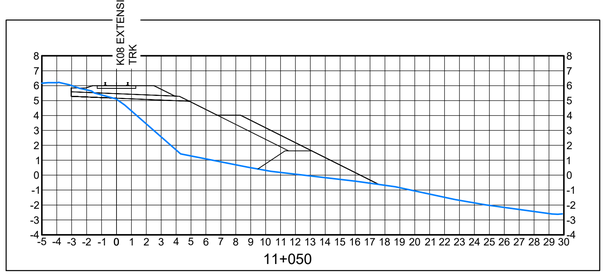
Sep 01 , 2020 , 1:23pm Login name: MAM872934
Drawing Name: C:\pwworking\hl\mam872934\d0693839\Sections for Golder.dwg

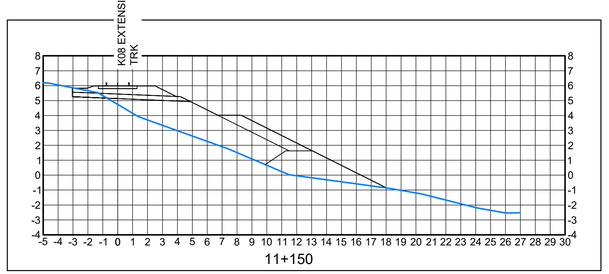


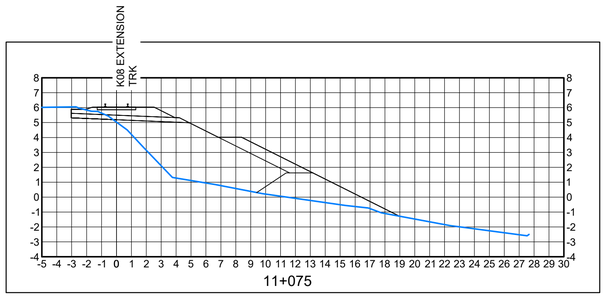


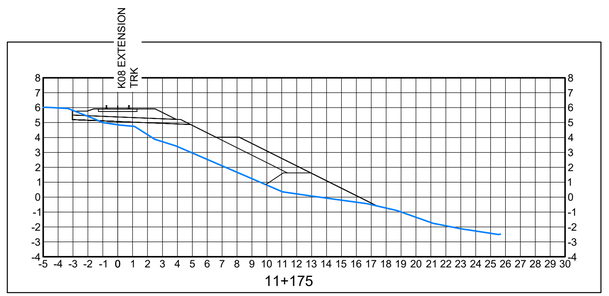












DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: **20-07-20**
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: **20-07-20**	J.L. DATE: **20-07-20**
HATCH PROJECT No: **362379**	DWG SCALE(FULL SIZE): **1:2000**

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.
A	20-08-14	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

ENGINEERING PROJECTS - WEST

VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
OPTION 1 SECTIONS

DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR, PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-305	Rev. B

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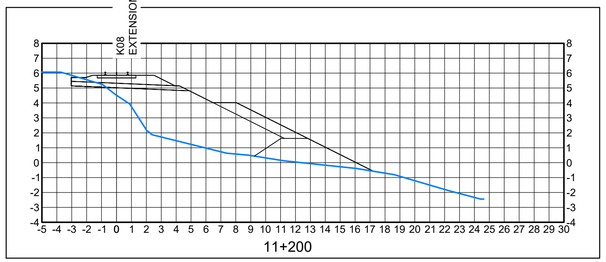

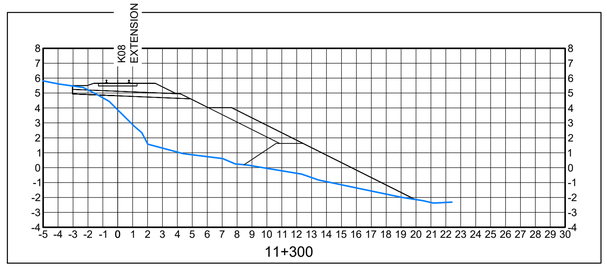

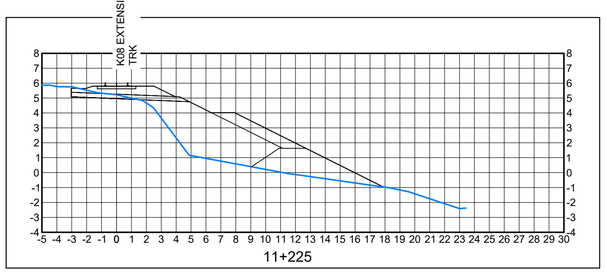

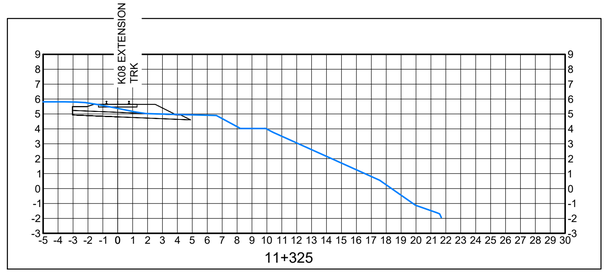

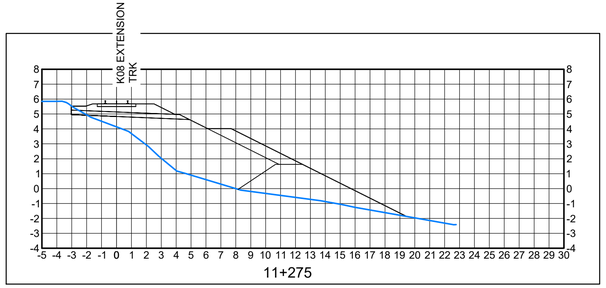

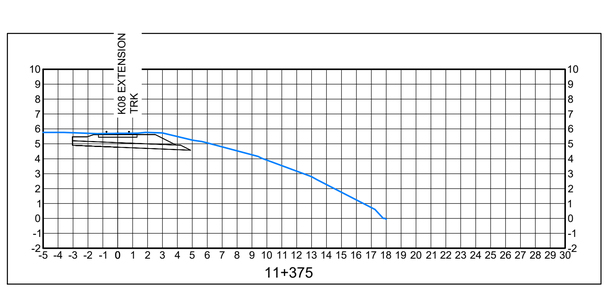

DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: 20-07-20
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: 20-07-20	J.L. DATE: 20-07-20
HATCH PROJECT No: 362379	DWG SCALE(FULL SIZE): 1:2000

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.
A	20-08-14	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

ENGINEERING PROJECTS - WEST

VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
OPTION 1 SECTIONS

DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-306	Rev. B

Sep. 01 , 2020 , 1:24pm Login name: IMAM872934
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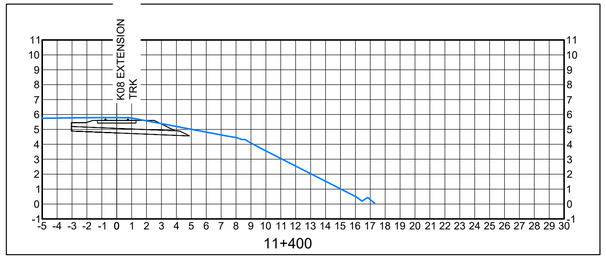

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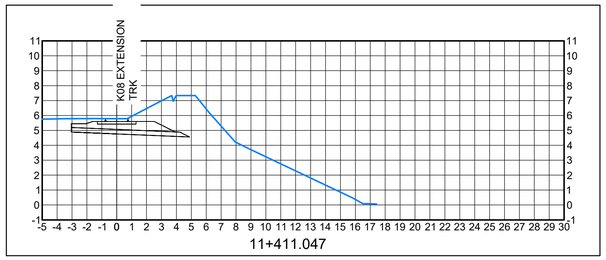

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DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: 20-07-20
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: 20-07-20	J.L. DATE: 20-07-20
HATCH PROJECT No: 362379	DWG SCALE(FULL SIZE): 1:2000

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.
A	20-08-14	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

ENGINEERING PROJECTS - WEST

VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

CASCADIA EAST EXTENSION - PHASE 4 PROPOSED SIDING EXTENSION OPTION 1 SECTIONS

DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-307	Rev. B

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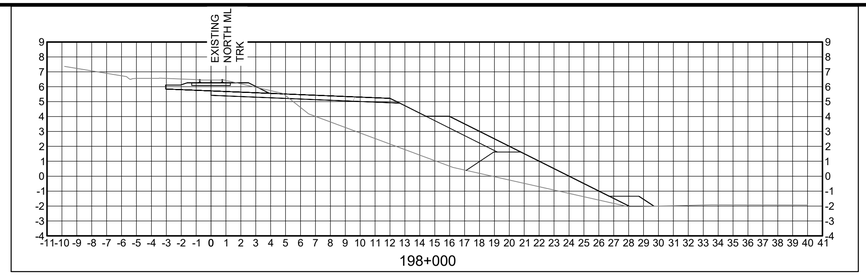
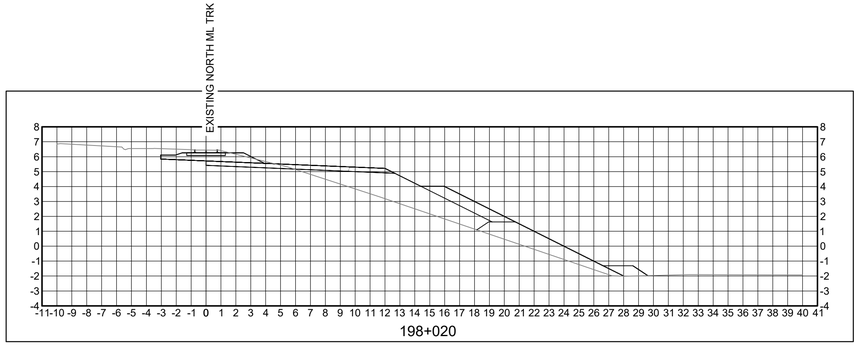
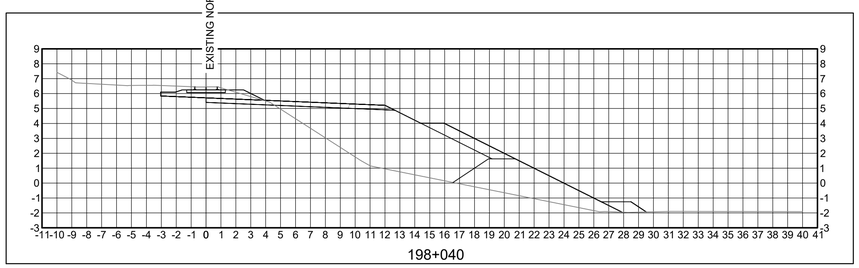
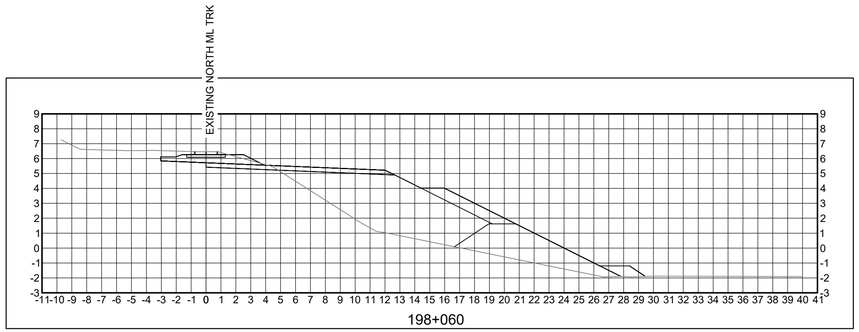








DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: 20-07-20
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: 20-07-20	J.L. DATE: 20-07-20
HATCH PROJECT No:	DWG SCALE(FULL SIZE):
362379	1:2000

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - ADDITIONAL SURVEY RECEIVED	T.I.
A	20-08-25	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

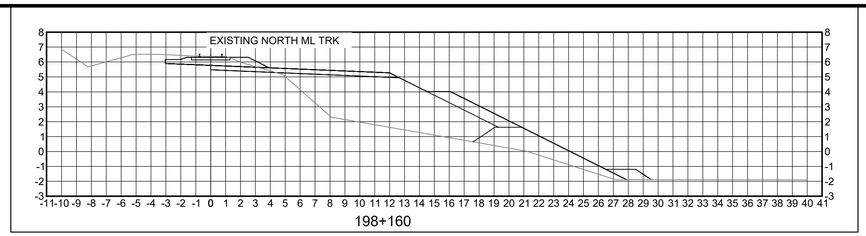
ENGINEERING PROJECTS - WEST

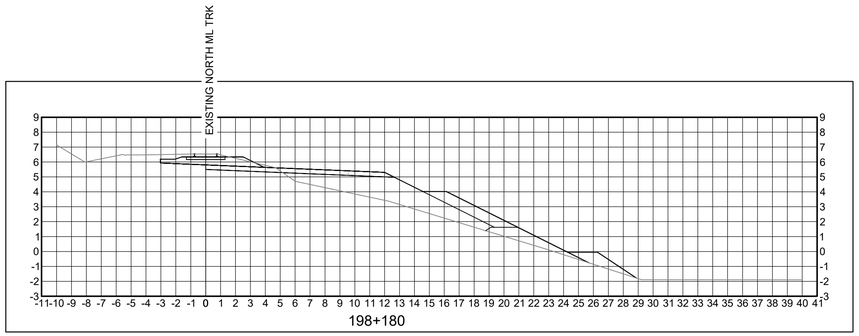
VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

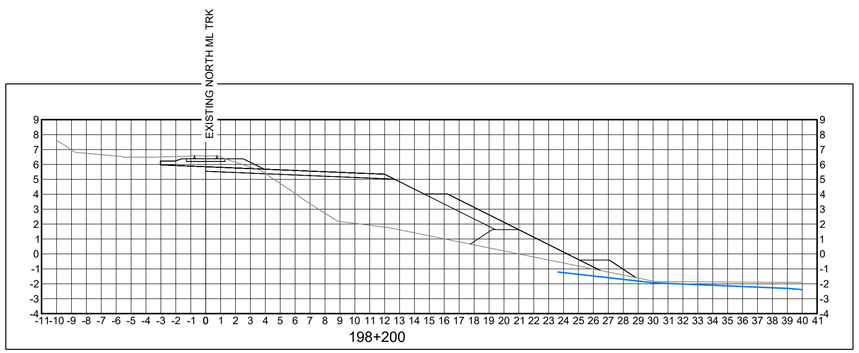
CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
#20 CROSSOVER PADS SECTIONS

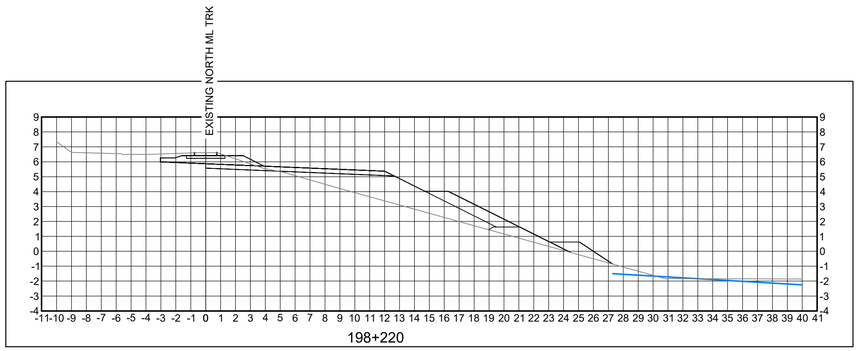
DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-308	Rev. B

Sep 01 , 2020 , 1:24pm Login name: MAM879234
Drawing Name: C:\pwworking\rh\mam879234\d0693839\Sections for Golder.dwg









DRAFT
DATE:

HATCH

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED

DESIGNED BY:	DRAWN BY:
T.I. DATE: 20-07-20	T.I. DATE: **20-07-20**
CHECKED BY:	PROJECT MANAGER:
J.C. DATE: **20-07-20**	J.L. DATE: **20-07-20**
HATCH PROJECT No: **362379**	DWG SCALE(FULL SIZE): **1:2000**

PROFESSIONAL SEALS

No.	DATE	REVISION	BY
B	20-09-01	ISSUED FOR INFORMATION ONLY - ADDITIONAL SURVEY RECEIVED	T.I.
A	20-08-25	ISSUED FOR INFORMATION ONLY - DRAFT	T.I.

CP

ENGINEERING PROJECTS - WEST

VANCOUVER DIVISION MILE 122.93 TO 124.16 CASCADE SUBDIVISION

CASCADIA EAST EXTENSION - PHASE 4
PROPOSED SIDING EXTENSION
#20 CROSSOVER PADS SECTIONS

DWG. BY:	CHK BY:	OFFICE FILE:	
		SCALE:	
MANAGER - DESIGN:		DATE:	
M.FAVREAU DIR. PROJECTS & PUBLIC WORKS - WEST		PLAN No. 362379-RW-100-S0-309	Rev. B

Sep 01 , 2020 , 1:24pm Login name: IMAM872934
Drawing Name: C:\pwworking\hi\imam872934\d0693839\Sections for Golder.dwg