



**Geotechnical Slope Stability Design Report of Porteau Cove Proposed
Campground- Lower Bench, Sea to Sky Highway, BC**

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Table of Contents

1. Scope of Work	3
2. Project Description and Site Conditions	3
3. Subsurface Soils and Groundwater Conditions	4
4. General Discussion	5
5. Slope Stability Analysis and Construction Geotechnical Recommendations	5
5.1. General Overview and References	5
5.2. Soil Strength Properties, Methodology and Analyses Results	6
5.3. Slope Stabilization Recommendations	7
6. Closure	9
Appendix “A”: The Reference Documents	10
Appendix “B”: Slope Stability Analyses Results	30
Appendix “C”: Drawings	35

1. Scope of Work

Lions Gate Excavation are considering constructing a campground at the location of existing Porteau Cove Quarry, between Sea-to-Sky Highway and Canadian Pacific (CP) Railways, in the area of Porteau Cove Marine Park, BC. RMTEC Engineers (RMTEC) was retained by Lions Gate Excavation to offer geotechnical engineering services for the purpose of performing the stability study of the lower bench of the proposed campground.

This report is prepared based on the available reference documents and initial investigations that had been conducted and reported by others. RMTEC did not conduct its own investigations on the Geotechnical parameters of the existing slopes and proceeded with the slope stability analysis using these available documents and investigations results and findings.

The reference documents which have been used for this report are as follows. All these documents are also presented in Appendix A. RMTEC has reviewed the following documents for the preparation of this slope stability analyses report:

Reference Documents:

- 1) Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC, issued by Frontera Geotechnical, #1364, dated October 19, 2022.
- 2) Aerial Survey Drawings, Issued by Spitfire Drone Survey, PLAN SHOWING ORTHOPHOTO AND CONTOURS FROM DRONE LIDAR, Project Code: SAAXXX, Drawing#: S22055-001, Sheet 1 of 1 Rev: A, Dated. September 6, 2022.
- 3) Proposed Site Plan, Porteau Cove Campground, Plan and Sections issued by Murdoch Company, Project No. 20.03, Drawings #L-1.0, L 1.1, Issued for Review, Dated March 14, 2022

This slope stability report provides a summary of the existing site conditions based on our field reconnaissance and according to the information provided to RMTEC. RMTEC Engineering has also reviewed the geology of the area to assist in our slope stability analyses.

2. Project Description and Site Conditions

“The site is located on a former quarry located on a west facing slope overlooking the Howe Sound. The site is bounded to the east by Highway 99 and to the west by a CN rail corridor and associated lines. The lot occupies approximately 7.3 ha and is approximately 700 m long by 160 m wide in the middle and tapering at the ends. The site slopes down from an elevation of approximately 50 m geodetic adjacent to the highway to approximately 7 m adjacent to the rail line. We understand that the former quarry was mined to an approximate elevation of between 0 and 1 m GD.

The constructed lower fill bench is approximately 40 - 60 m wide by 200 m long, at an elevation of 15 m GD. The western edge of the lower fill bench forms the crest of a slope approximately 8 m high at an angle of 35 degrees to horizontal. The slope overlooks an access road and the CN rail corridor. The slope is

armored with angular riprap estimated to be around 1 m thick on average and sourced locally from the southern end of the site” [Reference documents #1, 2.0 Site Description, Appendix A]

At the time of preparing this report, the lower platform portion on site was noted to be constructed to an approximate elevation of 15 m.a.s.l., sloping down towards the property line on the west side of the site, where CP railway tracks are located at an approximate elevation of 6 to 7 m.a.s.l. Our field observations and the review of the topographic data, provided to RMTEC, indicate that the existing slope grade is approximately 35° (on average) and the face of the slope is currently protected using a layer of riprap by an approximate thickness of about 1 m. The toe of this 8 to 9 m high slope is currently noted to have a setback of about 7 to 9 m with respect to the west property line. [Reference Document#2 and #3, Appendix A],

The total site area is approximately 70,000 to 75,000 m², though the focus of this report is on the slope stability and campground development over the lower platform area at an approximate elevation of 15 m.a.s.l. towards the west property line. This platform is approximately 200 m long in the N-S direction and between 30 to 60 m wide in the E-W direction. The site is bounded by Sea-to-Sky Highway to the east, CP Railways to the west, and adjacent vacant lots, covered in trees and vegetation to the north and south.

Based on the information provided to RMTEC, the soils at the lower platform area between the elevations of +6 to +15 m.a.s.l. are composed of deposited fill materials (mainly sand and gravel). Further details about the subsurface conditions and soil stratigraphy on site are presented in the following section.

3. Subsurface Soils and Groundwater Conditions

The subsurface materials at the lower platform area are anticipated to be composed a relatively thick layer of sand and gravel fill between the elevations of 6 to 15 m.a.s.l. Based on the review of the geotechnical test hole logs, provided to RMTEC [Reference Document#1, Appendix A], the fill is understood to be composed of silty sand and gravel with trace cobbles, dry to moist, grey and brown in color, compact to dense. The DCPT data obtained from the geotechnical investigation [Reference Document#1, Appendix A], on top of the lower platform on site, are indicative that the sand and gravel fill is expected to be compact to dense (occasionally very dense). It is also inferred from the DCPT data that thin layers of silt to silty sand should be expected to be interbedded within the sand and gravel fill.

The available test hole logs and the review of the site geology indicate that the fill materials on site are underlain by native sand and gravel. The native sand and gravel layer is noted to be dense and it is expected to contain traces of cobbles. Based on the review of the local surficial geology, this stratum is expected to extend down to below sea level.

Given the relative proximity of the site to the Ocean (Howe Sound) we expect that the groundwater level on site should be affected by the level of water in Howe Sound. Therefore, the groundwater level should be approximately 4 to 5 m below the toe of the existing slope (below the CP railway tracks).

4. General Discussion

As mentioned in the previous sections, the focus of this study is on the stability of the new (proposed) configuration of the lower platform as a part of the proposed campground construction at the subject property, located on the east side of CP Railways and west side of Sea-to-Sky Highway, in Porteau Cove Quarry, British Columbia. The subsurface soil stratigraphy and soil strength properties in our geotechnical assessment and slope stability analyses were based on the test hole logs, provided to us for the existing fill materials and the underlying sand. The specifications of the new fill materials, including sand and gravel and the new riprap, are based on our recommendations for the type and compaction quality of the new fills. These recommendations are as follows:

- 1) The new sand and gravel fill should contain less than 5% fines (less than 5% silt/clay soils that are finer than 75 microns in size)
- 2) The sand and gravel fill should be compacted to 95% of the maximum dry density obtained from modified proctor (ASTM D 1557).
- 3) The riprap for armoring the face of the slopes should be composed of 300 mm fractured rock. The bottom portion of the riprap should be composed of 500 to 1,000 mm large boulder.

Based on the above, RMTEC has completed a series of slope stability analyses to assess the existing slope conditions and the proposed slope stability based on the information provided. The stability assessment was completed in accordance with the standard provincial guidelines for slope stability analyses. The assumptions considered in the slope stability model, and the methodology of the slope stability analyses along with discussing the analyses results and geotechnical recommendations are presented in the following section.

Considering the sub-surface condition on site, with respect to the proposed improvement, RMTEC Engineering, is of the opinion that the proposed improvements are Geotechnically acceptable, and the site is Geotechnical safe for the intended use provided that our recommendations outlined in this document are satisfied during the construction.

5. Slope Stability Analysis and Construction Geotechnical Recommendations

5.1. General Overview and References

RMTEC has reviewed the slope stability of the existing slope in accordance with the standard provincial guidelines, including the “Guidelines for Landslide Assessments in British Columbia” (published by EGBC in March 2023). In addition to this, we have assessed the slope stability for the existing and the proposed campground site (lower platform) based on the slope stability criteria, set by the other nearest municipality in the area, the District of North Vancouver, (DNV) which outlines similar factors of safety for the slope stability, as follows:

- 1) A minimum factor of safety (FOS) of 1.5 for static conditions
- 2) A minimum factor of safety (FOS) of 1.0 for Pseudo-static conditions, representing the peak ground acceleration (PGA) that corresponds to an earthquake event, with a return period of 2,475 years in the site area.

The stability of the slope was assessed for the existing (pre-construction) conditions and for post-construction conditions. The results of the analyses were carried out for Section A-A, are presented o the Appendix B.

5.2. Soil Strength Properties, Methodology and Analyses Results

The slope stability analyses were completed using a finite element computer program (Slope/W by GeoStudio 2021). The limit equilibrium approach is applied in this program to calculate the factor of safety of the slopes against failure. The assumed soil strength parameters in the slope stability analyses are based on our understanding about the subsurface soil conditions which are summarized in Table 1. The soil strength properties of the existing fill, existing riprap and the existing native sand and gravel, were estimated based on the geotechnical investigation results and the test hole logs and DCPT profiles obtained for the existing soils on site. The new material, placed in front and on top of the existing slope would be considered as controlled material in terms of the soil particle size distribution and compaction. RMTEC requires reviewing the particle size charts, proctor data and field density testing data of the new fill materials to ensure that the design intent has been well-communicated with the construction team.

These materials are also shown on the attached drawings and also on the attached graphical presentation of the slope stability analyses results.

Table 1: Material properties considered in the slope stability analyses [Reference Document#1, Appendix A,

Soil Zone	Soil Material	Effective Friction Angle (Static and Seismic)	Effective Cohesion (Static and Seismic)	Unit Weight
1	Native, Dense Sand and Gravel	37°	0	19 KN/m ³
2	Existing Fill Material, Compact to Dense Sand and Gravel, Interbedded with silt	34°	0	18 KN/m ³
3	Existing Rip Rap, boulders, and large cobbles	45°	0	22 KN/m ³
4	New Fill Materials based on RMTEC recommendations	40°	0	20 KN/m ³
5	New Rip Rap materials on RMTEC recommendations	45°	0	22 KN/m ³

As stated, the factor of safety for the static conditions should be equal or higher than 1.5 to satisfy the referenced slope stability guidelines. As shown on the attached graphical slope stability analyses results, the FOS for both static and seismic (pseud-static) conditions for the existing slope geometry and material would not be met.

In order to satisfy the stability criteria, RMTEC recommended to place a toe-berm in front of the existing slope for further stabilization and to achieve the FOS criteria. The geometry of the toe-berm and the recommended material for the construction of the toe-berm are presented on the attached drawings. As shown on the attached drawings, RMTEC recommends using specific materials with specific geometry, including riprap and well-compacted sand and gravel) on top of the existing slope to ensure that the slope stability criteria for the lower platform of the proposed campground at an elevation of +15 m.a.s.l. are satisfied.

The results of the slope stability analyses for the static conditions (after the placement of the toe-berm) show that the FOS exceeds the minimum requirement of 1.5 and therefore, the static stability criterion would be satisfied. As shown on the attached results, the minimum FOS of 1.8 was achieved for this slope. In these analyses a uniform stress of 10 kPa was assumed on top of the slope (at the elevation of +15 m.a.s.l.) to represent the surcharge as a result of vehicles and trailers parked in the camping area. Although the factor of safety for the seismic (pseudo-static) analysis was improved upon adding the toe-berm to the existing slope, the minimum FOS of 1.0 for full PGA in accordance to NBCC 2020 (the latest National Building Code of Canada) was not achieved. However, in accordance to the EGBC guidelines, published in March 2023, the selection of peak ground acceleration (PGA) as the ground acceleration for the seismic analyses is generally considered to be a very conservative approach. This guideline has recently adopted a new method to calculate the displacement of the slopes that would not meet the FOS criteria of 1.0 for the conservative acceleration value that is equal to the PGA at the site and for the design earthquake event (with the return period of 2,475 years). This method, which is based on the coupled non-linear deformation analyses, was completed by Bray et. al and by Bray and Macedo, was recommended by EGBC guidelines and was used by RMTEC to calculate the anticipated maximum slope displacement at the design earthquake event. In this method, the yield acceleration of the slope (the acceleration that results in an FOS of 1.0 for the slope configuration and material properties) should be applied. Our stability analyses showed that the yield acceleration k_y for this slope (with the stabilizing toe-berm) would be 0.28g, where g is the acceleration of gravity on earth. Other conditions of using this method such as the acceptable range of T_s (fundamental period of the slope before any degradation) and the acceptable range of k_y were checked and they were all satisfied for this site and the subject slope. Based on the above, the estimated slope displacement for the design seismic event is limited 4.5 cm which is smaller than 15 cm and would be considered geotechnically acceptable by the referenced EGBC guidelines. Therefore, the proposed toe-berm, as shown on the attached drawings would satisfy the static and pseudo-static slope stability criteria. The results of the static and pseudo-static stability analyses for the proposed campground slope (lower platform) are graphically illustrated in the appendices of this report.

5.3. Slope Stabilization Recommendations

In the previous sections, a summary of the conditions of the existing slope for the new campground at Porteau Cove Quarry was presented. It was also shown that the stability of the lower platform at this proposed campground can be achieved by satisfying the criteria of the standard provincial and relevant municipal guidelines for slope stability. It is very important that the recommendations provided in this report are considered in the construction of the toe-berm and the proposed slope stabilization. These recommendations are listed below:

- The material properties and compaction of the new toe-berm should be reviewed and approved by RMTEC Engineering prior to importing to the site and during the compaction on site.

- The subgrade soils within the footprint of the new toe-berm should be reviewed and approved by RMTEC Engineering prior to the placement of the new toe-berm.
- No irrigation or discharged water should be allowed on top of the slope.
- It is recommended that a minimum setback of 2.0 m for any surcharge stress should be considered with respect to the backside of the riprap at the crest of the slope.
- The final slope geometry should follow the drawings presented in Appendix C of this report. RMTEC must check the final slopes to confirm that the slope angles are completed in accordance with the design.

RMTEC requires reviewing all of these conditions and to receive a confirmation that all of these geotechnical recommendations were considered in the overall construction work.

As required for “Letters of Assurance”, RMTEC will carry out sufficient field reviews during construction to ensure that the geotechnical design recommendations contained within this report have been adequately communicated to the design and construction team.

Further to completion of all the proposed improvements indicated, discussed and explained in this report, the lower bench of the Porteau Cove Camp ground will satisfy all the required factor of safety and the design criteria's and will be safe to be used for construction of the proposed as the Camp Ground.

6. Closure

This design report has been prepared for the use of our client and their construction team for the above-described temporary excavation at the above referenced property. Any other use of this report or the attached design is prohibited. The report has been prepared based on our knowledge regarding the subsurface soils and groundwater on site, provided to RMTEC. The construction of the additional bench must be reviewed and inspected and tested by RMTEC during the construction.

- Geotechnical Assessment Report (confirming the site is “safe for intended use”). Note that the geotechnical site plans submitted to date are not sufficient.

We trust our comments satisfy your demand at this stage. Should you have any questions about this letter, please call me on 778-898-5232 or email me on mzargari@rmtec.ca.

Mehdi Yousef Nasiri, MSc., EIT.



Cell: 1-778-898-5232
Email: mzargari@rmtec.ca
Website: www.rmtec.ca
Address: #204, 930 Harbourside Dr.
North Vancouver V7P 3S7

Mehrdad Zargari, MSc., P.Eng.



Cell: 1-778-898-5232
Email: mzargari@rmtec.ca
Website: www.rmtec.ca
Address: #204, 930 Harbourside Dr.
North Vancouver V7P 3S7



April 17, 2023

Permit to Practice EGBC: 1003530

Appendix “A”: The Reference Documents

Murrin Construction Ltd.
PO Box 91908
West Vancouver, BC V7V 4S4

October 19, 2022

File: 1364

Attention: Joe McInnis

**RE: Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench)
Porteau Cove Quarry, Highway 99, BC**

1.0 INTRODUCTION

Frontera Geotechnical Inc. (Frontera) was engaged by Murrin Construction Ltd. (Murrin) to provide geotechnical recommendations pertaining to the construction of a new campground located at Porteau Cove Quarry, BC.

Based on provided drawings the campground includes paved drive isles, RV sites, accessible and walk-in tent sites as well as yurt/tent sites, electrical, water and wastewater utilities and multiple washroom facilities all terraced on the west facing slope. Quarrying operations have been completed, and backfilling started in the summer of 2021. Frontera was not requested to review the placement of this initial lift of backfill, which is estimated to be in the order of 12 - 15 metres thick. It should be noted that the fill was placed at a steeper slope angle than was recommended in our preliminary backfill recommendations report dated April 1, 2020.

At the time of our review a proposed final grading plan for the site was not available. The site currently consists of a lower bench, filled to approximately 15 m GD elevation. The western edge of the lower bench consists of a relatively steep slope armoured with riprap overlooking an access road which runs alongside the CN ROW and rail line. We understand that the current elevation of the lower bench and associated armoured slope is at the proposed final grade. We understand that the lower bench is to be approximately 30 m wide and that further benches constructed with MSE retaining walls are proposed above. This report is focused on the lower bench slope, which was completed in the summer of 2022.

This report provides a summary of geotechnical investigations completed at the site, a geotechnical stability assessment of the lower bench, and provides geotechnical recommendations for the project and specific recommendations pertaining to stabilisation of the slope. General geotechnical recommendations for the project, including foundations, utilities and pavements etc. will be included in the Phase 2 report, once final grading plans and layout can be provided.

This report has been prepared exclusively for our client, for their use and the use of others on their design team, however, it remains the property of Frontera Geotechnical Inc.

2.0 SITE DESCRIPTION

The site is located on a former quarry located on a west facing slope overlooking the Howe Sound. The site is bounded to the east by Highway 99 and to the west by a CN rail corridor and associated lines. The lot occupies approximately 7.3 ha and is approximately 700 m long by 160 m wide in the middle and tapering at the ends. The site slopes down from an elevation of approximately 50 m geodetic adjacent to



the highway to approximately 7 m adjacent to the rail line. We understand that the former quarry was mined to an approximate elevation of between 0 and 1 m GD.

The constructed lower fill bench is approximately 40 - 60 m wide by 200 m long, at an elevation of 15 m GD. The western edge of the lower fill bench forms the crest of a slope approximately 8 m high at an angle of 35 degrees to horizontal. The slope overlooks an access road and the CN rail corridor. The slope is armoured with angular riprap estimated to be around 1 m thick on average and sourced locally from the southern end of the site.

3.0 SITE INVESTIGATIONS

Frontera completed a drill investigation on August 10, 2022. The investigation consisted of four solid stem auger holes on the lower bench drilled to a maximum depth of 14 m. The drill holes were supplemented with dynamic cone penetration test (DCPT) soundings. The primary purpose of the investigation was to assess the depth and quality of fill that had been placed on the site in the summer of 2021 without engineering review. Borehole locations are provided on the attached site investigation plan and borehole logs are included in Appendix A.

In March 2020, Frontera (then SFA Geotechnical Inc.) completed four test pits in the quarry face to support a stability assessment of the quarry face at that time.

4.0 SUBSURFACE CONDITIONS

4.1 Soil Conditions

The depth of fill on the lower bench at the time of the investigation was observed to range from 9 to greater than 15 m.

The fill was observed to be variable, consisting predominantly of sand with some silt, gravel and cobbles. Trace amounts of wood waste and organics were observed within isolated lenses of the fill. Based on DCPT soundings, the fill was inferred to generally be compact to dense, with isolated layers of loose material.

Native soils below the fill are expected to consist of dense sands and gravels in the vicinity of the lower bench.

4.2 Groundwater Conditions

Groundwater was not encountered in any of the test holes, and not expected in the relatively free-draining native deposits. The groundwater level is expected to be below the toe of the lower bench slope and be tidally influenced.

5.0 STABILITY ANALYSES

5.1 Introduction

To evaluate the stability of the slope, two-dimensional limit equilibrium analyses were undertaken using the software Slope/W. The stability of the fill slope is expressed using a factor of safety (FOS), which represents the ratio of resisting forces to driving forces acting on a specific critical failure surface.

One geotechnical cross section was selected for the most critical geometry for stability of the proposed slope. Analyses were completed for both static and seismic conditions. Cross sections were developed



based upon available survey data, observations from the site investigation, and geological interpretation. Two scenarios were analysed:

- Existing slope
- Existing Slope with a 4 m wide rockfill berm added at the toe

5.2 Seismic Considerations

Two analyses were completed considering seismic hazards corresponding to events with return periods of 475 and 2,475 years. Seismic analyses were undertaken using the pseudo-static approach, where seismic load is modelled by application of a horizontal acceleration equal to the peak ground acceleration (PGA). Probabilistic design earthquake parameters were provided by Natural Resources Canada assuming a firm ground site and are summarised in Table 1.

Table 1: Design Earthquake Hazards (NRC 2015)

Parameter	Moderate Design Earthquake	Major Design Earthquake
Return period (years)	475	2,475
Moment magnitude (M_w)	7.0	7.0
Firm ground PGA (g)	0.15	0.31
Firm ground peak ground velocity (PGV) (m/s)	0.21	0.46

Where the factor of safety is less than one in the seismic analyses, slope deformation was estimated using the approach developed by Bray et. al. (2007)¹. This empirical method estimates the horizontal seismic coefficient that corresponds to a slope displacement of 15 cm for the design earthquake and is based upon spectral acceleration and an assumed period of 0.5s. The seismic coefficient is then applied as a horizontal ground acceleration in the pseudo-static stability analysis; a FOS greater than 1 indicates that seismic displacements are likely to be less than 15 cm.

The subsurface soils are not expected to be prone to liquefaction or other forms of ground softening in consideration of the probabilistic seismic hazard.

5.3 Stability Criteria

The Squamish Lillooet Regional District does not stipulate risk tolerance criterion for slope instability for new campgrounds or residential developments. We have adopted the FOS-based criteria developed by the District of North Vancouver (2009), for new developments which specifies:

- FOS-based criteria:
 - Minimum static FOS of 1.5
 - For a major earthquake (2,475-year return period), minimum pseudo-static FOS of 1.0, or calculated slope displacements to be less than or equal to 15 cm

¹ Bray, JD and Travarasrou, T [2007]. Simplified procedure for estimating earthquake-induced deviatoric slope displacements. Journal of Geotechnical and Environmental Engineering, ASCE, Vol. 153, No.4. pp 381-392.



The risks associated with slopes meeting the above criteria are considered broadly acceptable. This criterion is consistent with the Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC (APEGBC 2010).

5.4 Material Parameters

Material parameters were selected for the various soil units based upon review of our site investigation data, empirical correlations to in-situ strengths tests and local experience.

Table 2: Stability Model Parameters

Unit	Material Model	γ (kN/m ³)	ϕ' (°)	c' (kPa)
Fill	Mohr – Coulomb	19	38	0
Riprap	Mohr – Coulomb	19	45	0
Native Sands and Gravels	Mohr – Coulomb	19	40	2

5.5 Results

Stability analysis results are presented in Table 3.

Table 3: Stability Analysis Results

Model Description	Factor of Safety			
	Static	Seismic (1:475 year)	Seismic (1:2,475 year)	Seismic k_{15} (1:2,475 year)
Existing Slope	1.3	1.0	0.7	1.0
Existing Slope with 4 m rockfill berm added at toe	1.5	1.2	0.9	1.2

The results show that the lower bench slope currently does not meet generally accepted risk tolerance standards for stability under static conditions, however it is expected to meet the seismic design criteria with slope deformations expected to be around 15 cm in a major earthquake.

Several remedial options were considered to increase the static stability of the slope. Our analysis indicates that placing additional material at the toe of the slope, in the form of a 4 m high toe-buttress, would likely be the most efficient way to increase slope stability and meet the recommended criteria.

6.0 DISCUSSION

The lower bench slope in its existing configuration does not meet current best practice guidelines for stability. This is largely due to the over-steepened slope angle and the mixed, variable nature of the bulk fill that has been placed. Based on our analysis, we recommend the addition of a buttress at the toe of the slope to increase the static stability of the lower bench slope to meet the recommended criteria outlined in Section 5.3.

We understand that quarried blast rock is currently available on the site and consider this to be a suitable material for use in the construction of the toe-buttress.



Alternatively, the buttress may be constructed using select bulk fill, regularly spaced horizontal geogrid reinforcement faced with blast rock (i.e., a reinforced soil slope). Detailed recommendations are provided in Section 7.1.2. It is anticipated that remedial works for the lower bench slope would be completed during the 2023 summer earthworks season.

Surface water has the potential to cause erosion damage and critically impact the overall stability of the lower bench slope. Adequate drainage and surface water management should be provided to divert surface water away from the slope before the 2022 – 2023 winter season. Detailed recommendation pertaining to surface water management are provided in Section 7.2 below and should be implemented prior to the 2022 – 2023 winter season.

7.0 RECOMMENDATIONS

7.1 Toe Buttress

7.1.1 Rockfill (Option 1)

The toe buttress shall be constructed within the existing access track to a minimum height of 4 m (measured vertically) from the toe of the current lower bench slope. The face batter of the toe berm shall be 2H:1V. There shall be a horizontal bench at least 2 m wide on the top of the placed rockfill.

The underside of the placed rockfill shall be a minimum of 500 mm below final grade, or the adjacent rail line elevation, whichever is lower. All loose soil, organics, construction waste, debris and other deleterious materials should be stripped from the rockfill area to expose a subgrade of dense sands and gravels prior to rockfill placement. Rockfill should be placed on flat benches in lifts not exceeding 1.2 m.

Our design parameters assume that the rockfill comprises 450 mm minus, clean, angular, granitic blast rock. The rockfill should have a minimum D_{50} of 100 mm. Rockfill should be placed from the base of the slope towards the crest with good interlock and consistent thickness. Frontera should review the rock prior to construction to approve suitability. Alternative rockfill gradations may be accepted and should be provided to Frontera for review prior to delivery to site.

Frontera can provide a rockfill toe-buttress design drawing upon request.

7.1.2 Reinforced Soil Slope (Option 2)

Select granular fill, placed with continuous horizontal geogrid reinforcement at regular intervals is a feasible alternative for constructing the toe buttress. The reinforced soil slope would need to have a minimum height of 4 m (measured vertically) from the toe of the current lower bench slope and have a minimum 2 m wide horizontal bench at the top. The outer face of the reinforced soil slope should be battered at 2H:1V and be faced with a single layer of blast rock, like the existing lower bench slope.

For the purposes of feasibility and costing, it should be assumed that 100% coverage of geogrid reinforcement will be required within the reinforced fill at 600 mm vertical spacing. The base of the reinforced fill should be constructed at least 500 mm below final grade, or the adjacent rail line elevation, whichever is lower.

Tensar UX1500 geogrid reinforcement is recommended along with approved 'select' granular fills that contain fines contents less than 8% and are free from any deleterious or unsuitable materials. The fill should be compacted to achieve a Maximum Dry Density of 98% Modified (ASTM D1557) at within 2% of optimum moisture content. Fills that do not fall within the material specification should not be used.



Frontera can provide a detailed design of the reinforced soil slope upon request.

7.2 Surface Water Management (Temporary)

Surface water management will have a large impact on maintaining a suitable level of stability over the 2022 – 2023 winter months and before the recommended remedial works or permanent surface water control measures can be implemented.

The surface of the lower bench should be graded such that all surface water is diverted away from the crest of the main slope using swales and ditches to a main collection drain at the east side of the lower bench. The main collection drain shall connect to the existing temporary soakage pit located at the northern end of the site. All soil surfaces shall be sealed using a drum roller once grades have been established to prevent any surface ponding and reduce infiltration. We recommend a minimum of 2% fall is established in all temporary swales and ditches at the site.

Appropriate sediment control measures shall be installed to control the potential migration of sediment and reduce the flow velocity of water in drains such as regular check dams, silt fencing and straw wattles. Any sediment dams should be regularly inspected over the winter months and cleaned out as needed to prevent the uncontrolled discharge of surface water.

We recommend that the lower bench slope is inspected monthly during the 2022-2023 winter, or during / following major storm events. Additional erosion and sediment control measures, such as placement of erosion control blanket or rockfill, or addition of surface drainage may be required to ensure the stability of the lower bench is not compromised.

Frontera can prepare a temporary sediment control and erosion plan upon request and can provide site review services during the winter months.

7.3 Master Plan Considerations

As final grading and layout plans are developed, we recommend that designers consider a minimum 5 m setback from the top of the lower bench slope for any building foundations, tent pads or RV parking areas.

Provided the 30 m setback to the second bench is maintained, we do not anticipate that future construction above the lower bench will impact the lower bench stability.

We understand that MSE walls of up to 5 m in height are proposed above the current lower bench and that construction is likely to be completed in the summer of 2023. In accordance with SLRD bylaws, proposed retaining walls that exceed 1.2 m in height will be required to be engineered.

We understand that the preferred MSE wall is rock-stack, utilizing locally available facing rock. For the purposes of developing a final grading plan and preliminary design / costing, we recommend that retaining walls have a face batter no steeper than 1H:4V and that the length of geogrid reinforcement is $1.2 \times H$, where H is the height of the wall.

Frontera can prepare detailed retaining wall drawings once a final grading plan is confirmed.

7.4 Additional Work

The following additional geotechnical items are recommended to be considered for the project moving forward:

- 1) Detailed design of the preferred remedial works for the lower bench slope;
- 2) Preparation of a Temporary Sediment Control and Erosion Plan & Site Review;



- 3) Detailed design of MSE retaining walls & global stability check on up-slope developments; and,
- 4) Ongoing fill placement review during Summer 2023 earthworks season.

8.0 CLOSURE

We are pleased to assist you with this project, and we trust this information is helpful and sufficient for your purposes at this time. Please do not hesitate to call the undersigned if you require clarification or additional details.

Yours truly,

Frontera Geotechnical Inc.

Reviewed by:

Ralph Burden, PhD, EIT
Geotechnical Engineer

Daniel Sims, B.E.(Hons), P.Eng.
Geotechnical Engineer

DRAFT



FRONTERA
GEOTECHNICAL

FRONTERA GEOTECHNICAL INC
1 - 38920 Queens Way
SQUAMISH, BC, V8B 0C3
604 898 1093

PROJECT TITLE:
Proposed Campground - Porteau Cove Quarry

TITLE:
Site Investigation Plan

DRAWING NO:		JOB NO:
1364-1		1364
SCALE:	DRAWN:	CHECKED:
1:500	RB	DS
PROJECTION:	DATE:	
EPSG:32610	22/10/18	

REV	DESCRIPTION:	DATE:
AMENDMENTS:		



DRAFT

APPENDIX A

BOREHOLE LOGS

Test Hole Log: TH22-01

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
0		Ground Surface				
1		FILL Sand with some coarse gravel. Dry. Brown. Dense.	45, 60, 60, 41, 21, 30			
2		FILL Variable layers of sand and silty sand with trace coarse gravel and trace organics. Moist. Grey. Compact.	13, 13, 16, 12, 14, 10, 8			
3		FILL Sand with trace silt and trace organics, variable. Dry - moist. Brown. Loose - compact	16, 16, 21, 50			
4		FILL Sandy silt with trace gravel. Moist. Grey. Stiff.	12, 20, 34, 55			
5		FILL Sand with trace gravel. Dry-moist. Brown. Compact - Dense.	19, 27, 25, 20, 20, 30			
6		FILL Sand with some silt and trace coarse gravel. Moist. Brown. Compact - dense	21, 14, 12, 11			
7		SAND Coarse sand with some coarse gravel and trace rounded cobbles. Dry. Compact - Dense				
8						
9						
10						

Date of Drilling: 08/10/2022

Rig Type: Solid Stem Auger

Logged By: RB

Datum:

Page: 1 of 2

Test Hole Log: TH22-01**Project No.:** 1364**Project:** Proposed Campground**Client:** Joe McInnis**Location:** Porteau Cove Quarry#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
11		End of Borehole	14			10.5 m - DCPT refusal.
12						
13						
14						
15						
16						
17						
18						
19						
20						

Date of Drilling: 08/10/2022**Rig Type:** Solid Stem Auger**Logged By:** RB**Datum:****Page:** 2 of 2

Test Hole Log: TH22-02

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
0		Ground Surface				
0		FILL Sand with some cobbles. Dry. Brown. Dense.	9			1.5 m Drill out for DCPT
1			27			
2			43			
3			16			
3		FILL Silty sand with trace cobbles. Moist. Grey. Loose - Dense.	16			
4			10			
4			6			
4			7			
5			55			
5			45			
5			14			
6			60			
6			45			
6		FILL Silty and with trace cobbles. Variable. Moist. Grey / Brown. Loose - Dense	6			
7			45			
7			50			
8			60			
8		FILL Sand with trace silt and trace cobbles. Compact - Dense	21			
9			32			
9			60			
9			55			
9		FILL Silty sand with trace cobbles. Moist. Grey. Compact - Dense	45			
10			20			
10			30			
10			55			

Date of Drilling: 08/10/2022

Rig Type: Solid Stem Auger

Logged By: RB

Datum:

Page: 1 of 2

Test Hole Log: TH22-02

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
11		FILL Sand with trace cobbles, organics and silt. Moist. Brown. Compact - Dense	15			
12		FILL Silty sand with trace cobbles. Moist. Brown. Compact.	20			
13		End of Borehole	20			
14			18			
15			21			
16			20			
17			28			
18			18			
19			40			
20			19			

Date of Drilling: 08/10/2022

Rig Type: Solid Stem Auger

Logged By: RB

Datum:

Page: 2 of 2

Test Hole Log: TH22-03

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
0		Ground Surface				
1		FILL Sand with trace silt and gravel, variable. Dry - moist. Grey / brown. Loose - Compact	2 1 3 7 4			
2			38 59 38 31			
3		FILL Sand with trace silt and gravel, variable. Dry - moist. Grey / brown. Loose - Compact.	47 49 60			
4			30 11 7 6			
5		FILL Sand with trace silt and gravel, variable. Dry - moist. Grey / brown. Loose - Compact	14 21 13 10 9 5 6 4			
6			8 17 13 8 8 8			
7			10 8			
8						
9		FILL Coarse sand with cobbles and trace silt and wood waste. Compact.				
10						

Date of Drilling: 08/10/2022

Rig Type: Solid Stem Auger

Logged By: RB

Datum:

Page: 1 of 2

Test Hole Log: TH22-03

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
11			12			
			14			
			15			
			33			
12			14			
			12			
			14			
13		SAND Coarse sand with some gravel. Moist - wet.	13			
			31			
			35			
14		End of Borehole				40.9m - DCPT refusal.
15						
16						
17						
18						
19						
20						

Date of Drilling: 08/10/2022

Rig Type: Solid Stem Auger

Logged By: RB

Datum:

Page: 2 of 2

Test Hole Log: TH22-04

Project No.: 1364

Project: Proposed Campground

Client: Joe McInnis

Location: Porteau Cove Quarry



#1 - 38920 Queens Way
Squamish, BC V8B 0K8
604-898-1093
www.fronterageo.ca

Depth (m)	Soil Profile		Dynamic Cone Penetration Resistance (blows/0.3m)	Water Content (%)	Groundwater/Well	Remarks
	Strata	Description				
0		Ground Surface				
1		FILL Sand with trace cobbles. Dry. Compact.	17 23 15 10 9			
2		FILL Sand with trace cobbles and silt. Moist - wet. Compact to Dense.	6 22 26 42 28			
3			31 27			
4			20 50			
5			60 60 55			
6		FILL Sand with some cobbles. Dry to moist.	48 60 57 60 60			
7						6.3 m - DCPT refusal.
8		End of Borehole				7.2 m - Auger refusal.
9						
10						

Date of Drilling: 08/10/2022

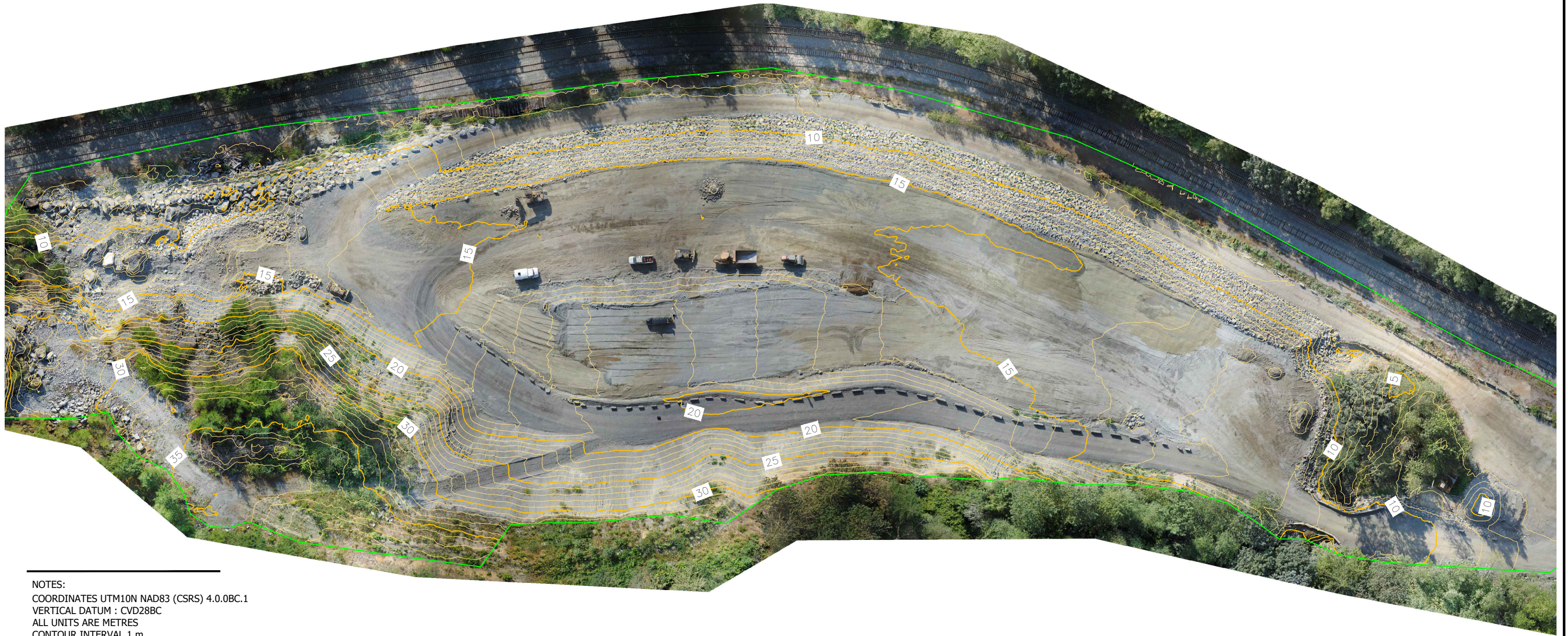
Rig Type: Solid Stem Auger

Logged By: RB

Datum:

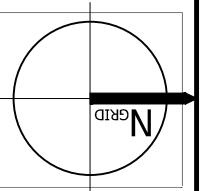
Page: 1 of 1

PATH: W:\Operations\Current Projects\S22055 - Porteau Cove\2.5D\Files\2.CAD\Porteau Cove Drawing.dwg



NOTES:
COORDINATES UTM10N NAD83 (CSRS) 4.0.0BC.1
VERTICAL DATUM : CVD28BC
ALL UNITS ARE METRES
CONTOUR INTERVAL 1 m
FLIGHT DATE 31ST AUGUST 2022

SCALE (ANSI SIZE B): 1:1000
0 15 30 METRES



PRODUCED BY:



Spitfire Drone Survey
378 Esplanade E
North Vancouver, BC
V7L A4 Canada
Office: 604.674.6900
Fax: 604.904.2434
info@spitfiredronesurvey.com
www.spitfiredronesurvey.com

CLIENT:

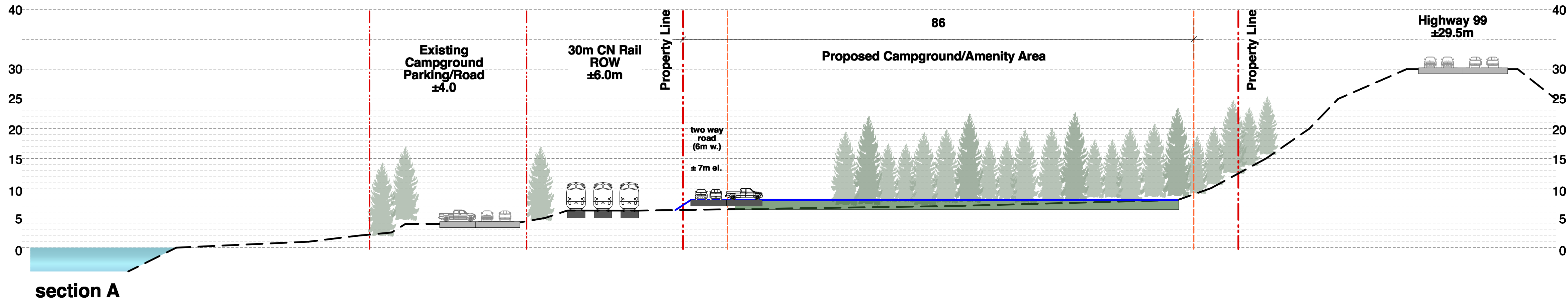
JOE MCINNIS

TITLE:
**PLAN SHOWING ORTHOPHOTO AND CONTOURS
FROM DRONE LIDAR**

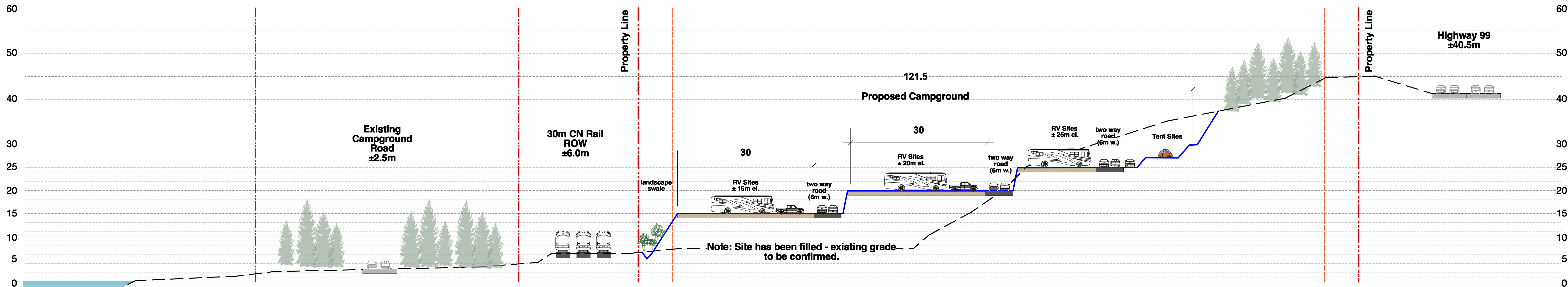
PROJECT:
PORTEAU COVE FILL SITE

A	2022-09-05	ISSUED FOR REVIEW	GR	SB	RB
REV.	YYYY-MM-DD	DESCRIPTION	SURVEYED	PREPARED	REVIEWED

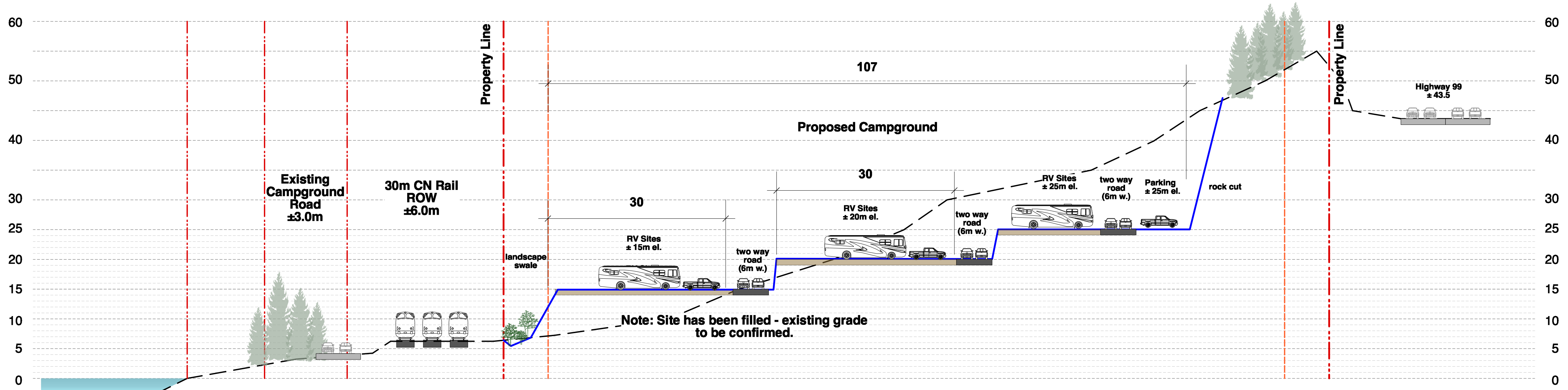
PROJECT CODE: SAAXXX DRAWING#: S22055-001 SHEET 1 OF 1 REV: A



section A



section B



section C

MURDOCH COMPANY

Architecture + Planning Ltd.
#1000 West 13th Street
P.O. Box 1394
Whistler, B.C. V0N 1B0
Ph: 905-6992
email: murdoch@telus.net

Scale:

Drawn By:

AS SHOWN

BM/JL

Project No:

20.03

Sheet No:

20.03

L-1.1

SITE SECTIONS

Sheet Title:

SITE SECTIONS

Project

PORTEAU COVE CAMPGROUND
PORTEAU COVE, BC

Date:

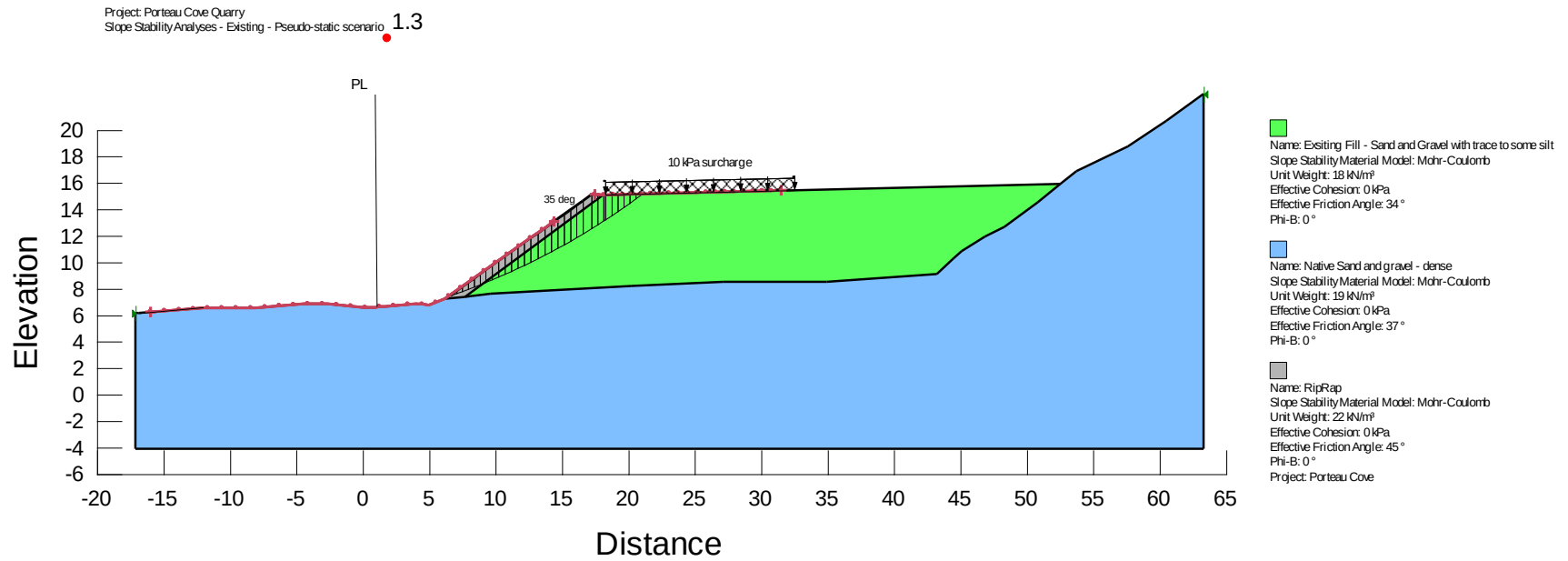
Issued For:

22/03/14

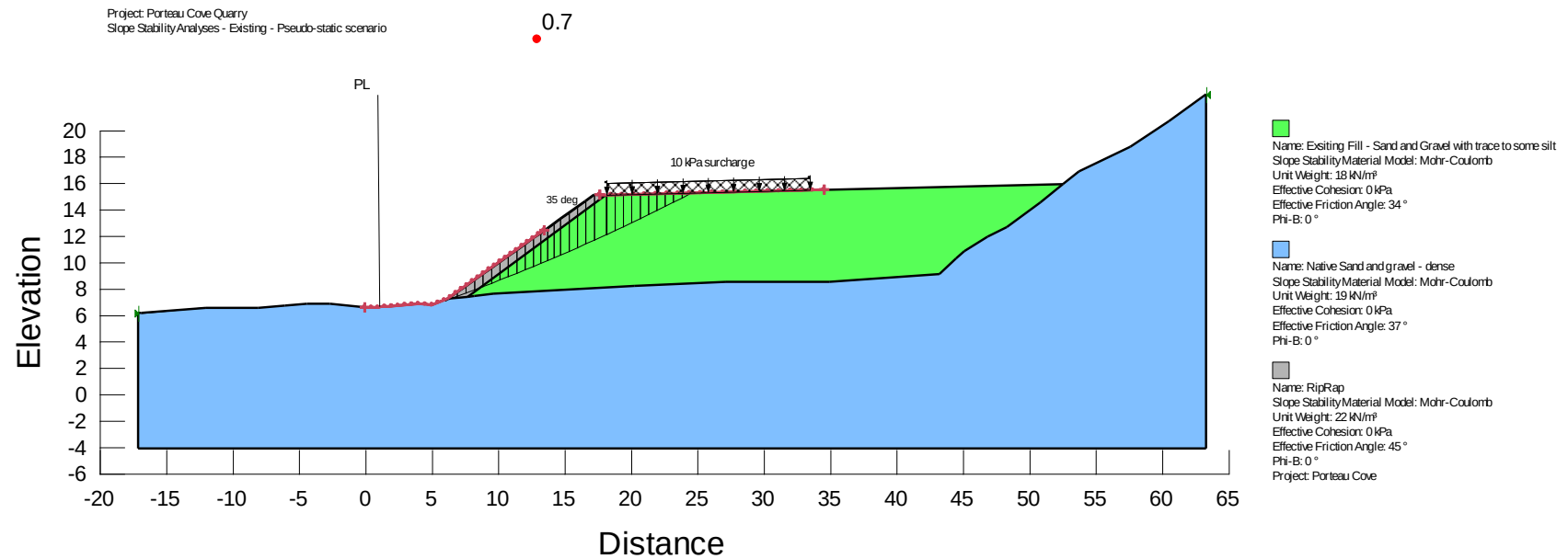
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Appendix “B”: Slope Stability Analyses Results

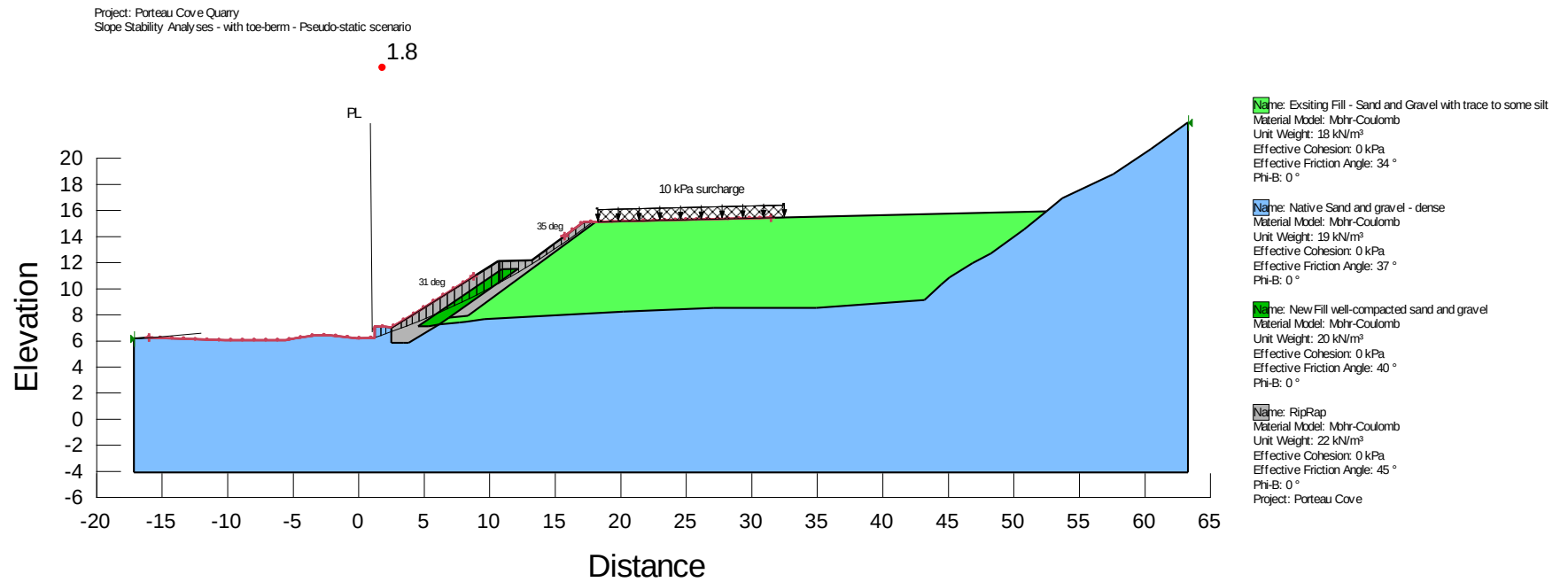
Existing configuration (static)



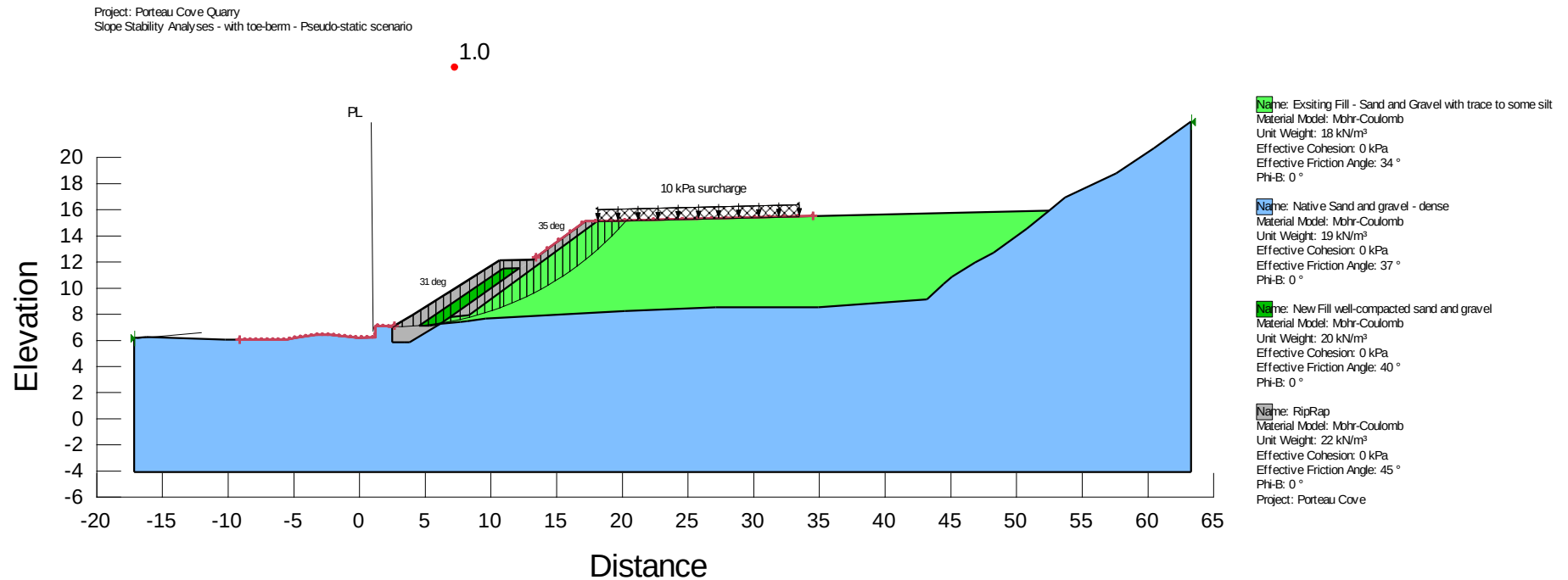
Existing configuration (pseudo-static) – PGA = 0.4g



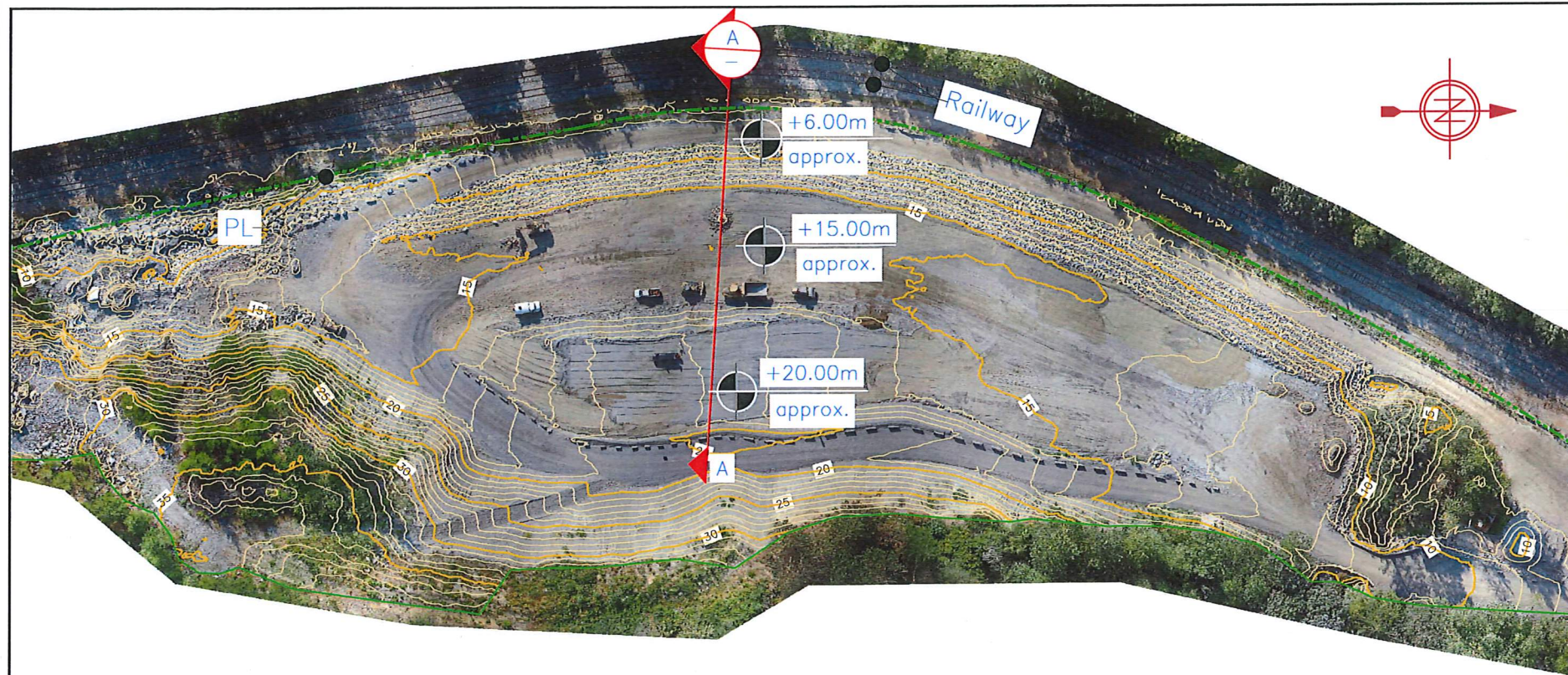
New configuration with stabilizing toe-berm (static)



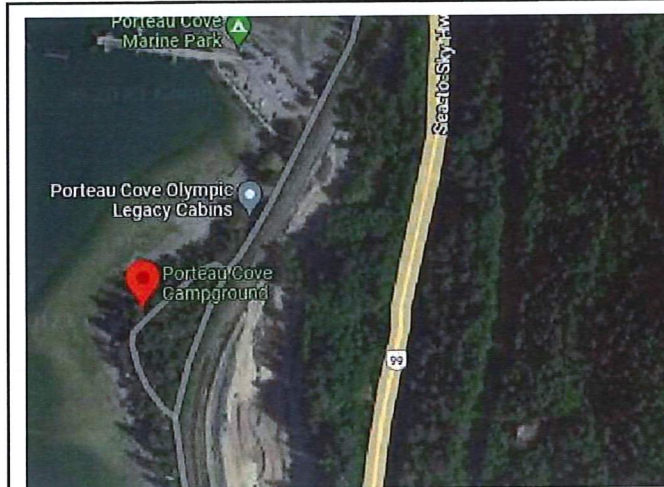
New configuration with stabilizing toe-berm (pseudo-static) - yield analyses with $k_y = 0.28g$



Appendix “C”: Drawings

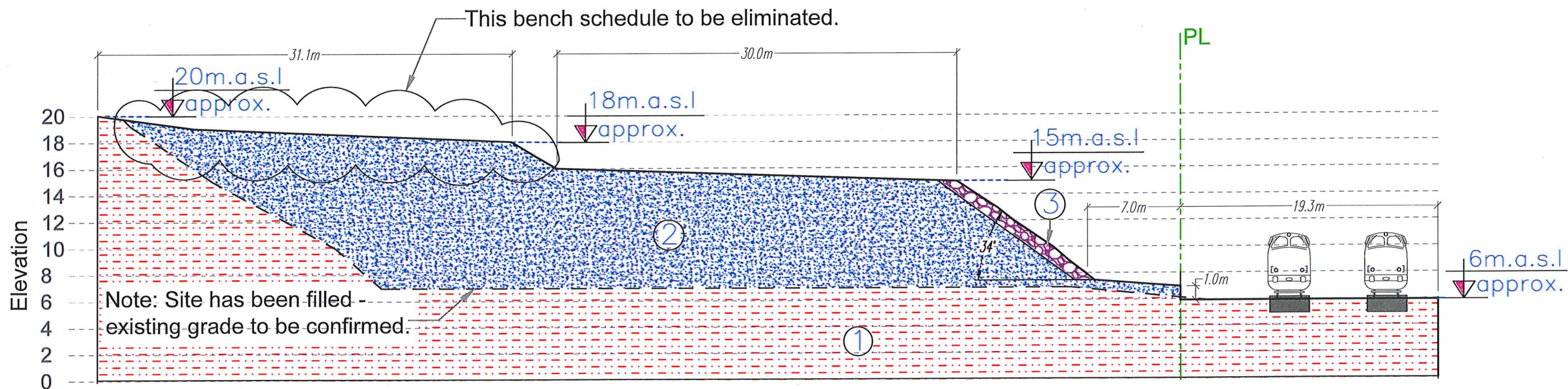


SITE PLAN
PORTEAU COVE PROPOSED CAMPGROUND N.T.S



KEY PLAN
N.T.S

Notes:
- All dimensions are in meter unless otherwise noted



EXISTING CONDITION OF THE PORTEAU COVE CAMPGROUND BENCHES
SECTION A-A (N.T.S)

Reference:
- Slope Stability Analysis Report - Proposed Campground - Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC, Issued by Frontera Geotechnical, #1364, dated October 19, 2022.
- Aerial Survey Drawings, Issued by Spitfire Drone Survey, PLAN SHOWING ORTHOPHOTO AND CONTOURS FROM DRONE LIDAR, Project Code: SAAXXX, Drawing#: S22055-001, Sheet 1 of 1 Rev: A, Dated: September 6, 2022
- Proposed Site Plan, Porteau Cove Campground, Plan and Sections issued by Mordoch Company, Project No. 20.03, Drawings #L-1.0, L 1.1, Issued for Review, Dated March 14, 2022

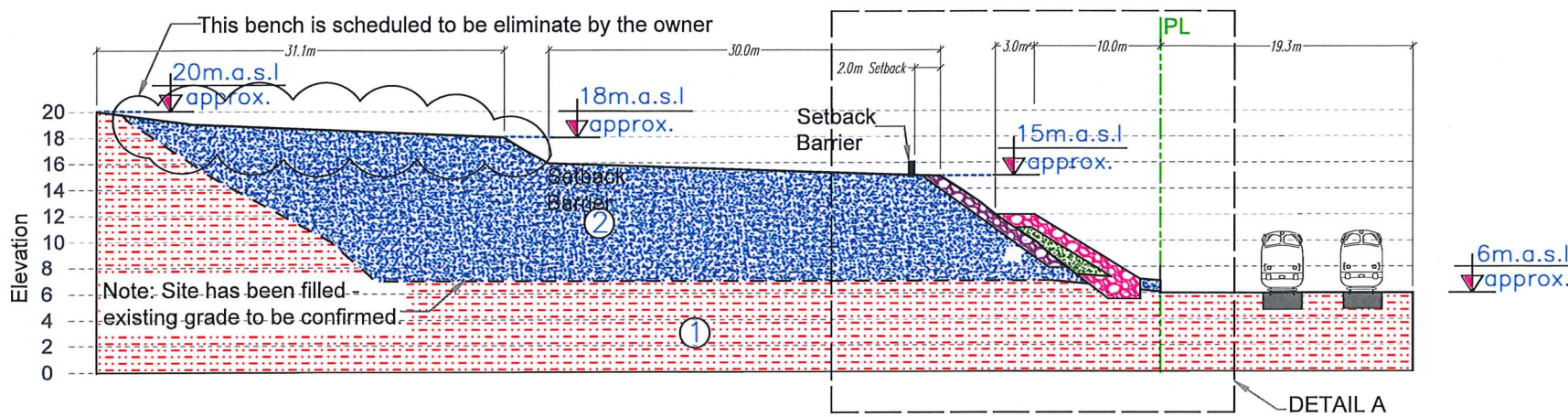
Permit Stamp



REVISIONS		
No.	Date	Description

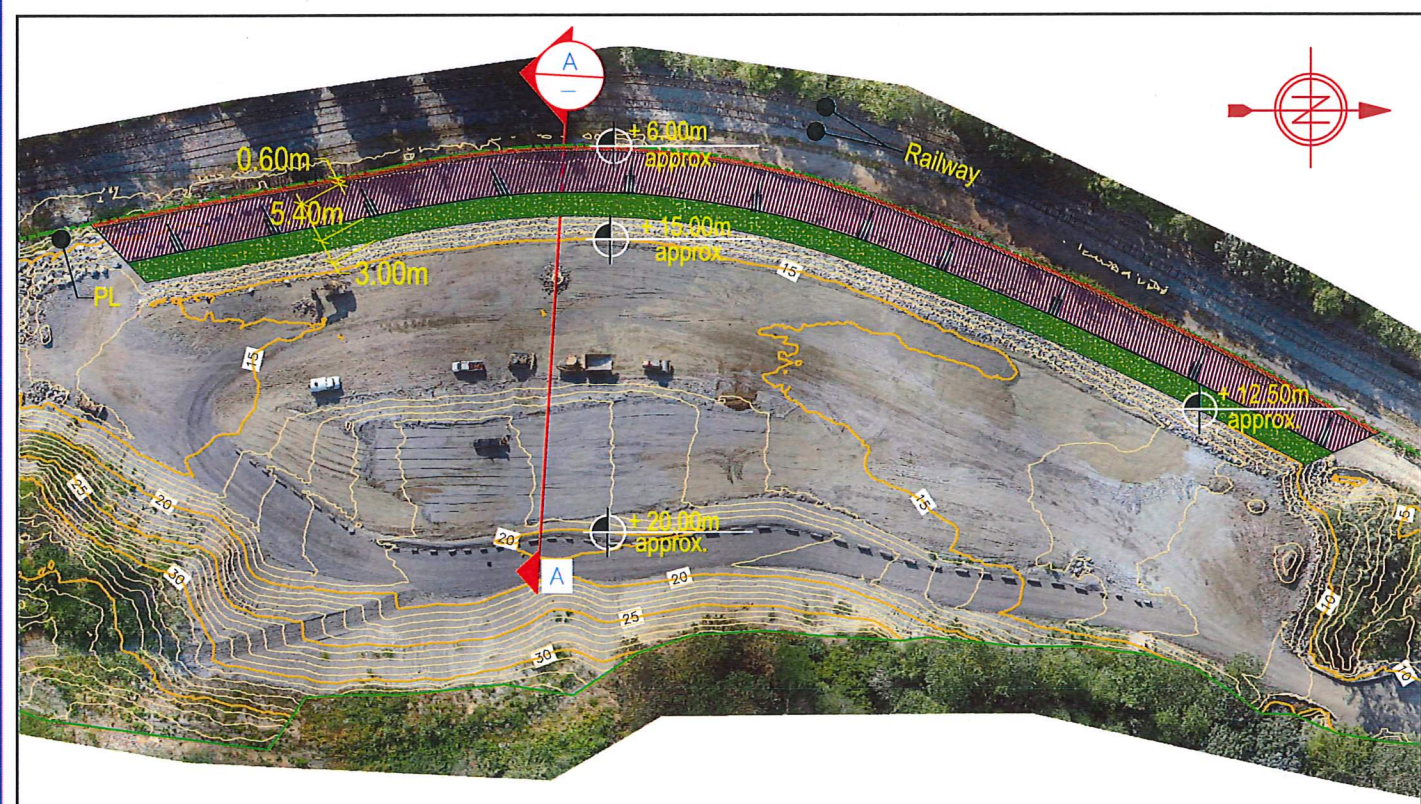
Client	LIONS GATE EXCAVATION LTD
Title	SLOPE STABILITY OF THE LOWER BENCH OF THE PROPOSED CAMPGROUND
Description	PLAN AND SECTIONS
Address	PORTEAU COVE QUARRY, HIGHWAY 99, BC

Job No.	230001	Date	12-June-23
Drawn By	F.P.	Approved By	M.Z.
Drawing Number	RM-23001-DG-001-00	Scale	AS SHOWN

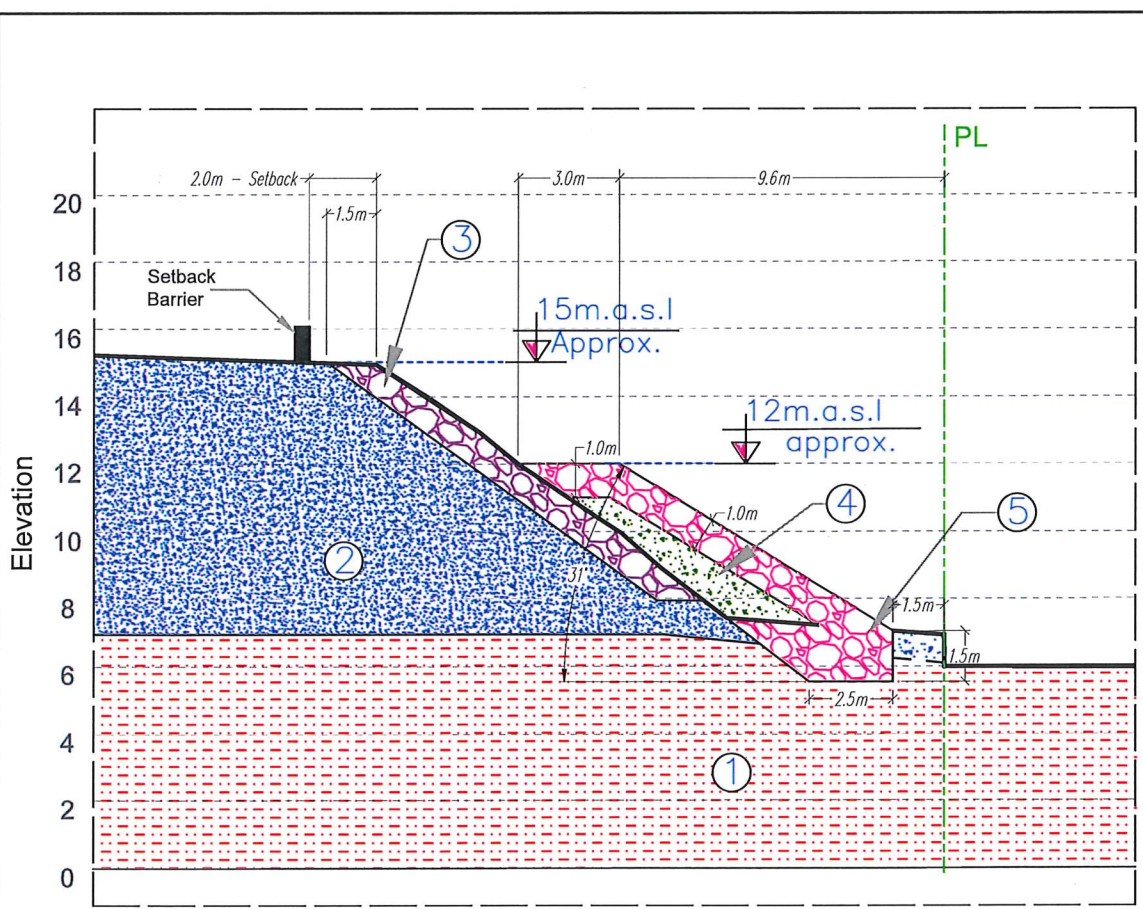


PROPOSED ADDITIONAL FILLED SLOPE
STABILITY OF LOWER BENCH -
PORTEAU COVE CAMPGROUND (N.T.S)

Material Type	Material Detail Description	Comments
1	Native material contains dense Sand and Gravel and Bed Rock.	As per the Referenced Geotechnical Report " Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC", Issued by Frontera Geotechnical,#1364, dated October 19, 2022. Soil strength properties were selected based on DCPT provided in the test hole login this report
2	Filled materials with Sand and Gravel, Compacted to Dense with intermeddled of thin silt layers,	As per the Referenced Geotechnical Report " Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC", Issued by Frontera Geotechnical,#1364, dated October 19, 2022. Soil strength properties were selected based on DCPT provided in the test hole login this report
3	Existing Rip Rap, Boulders and Large Cobbles with the thickness of almost 1.0m	As per the Referenced Geotechnical Report " Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC", Issued by Frontera Geotechnical,#1364, dated October 19, 2022. Soil strength properties were selected based on DCPT provided in the test hole login this report
4	New Fill Materials	Sand and Gravel, well-compacted to 95% standard proctor, RMTEC to review the compaction data. soil gradation chart should be reviewed prior to importing the soils to the site.
5	Rip Rap ; Boulders and Large Cobbles	Boulders and Large Cobbles, Rip Rap sizes to be confirmed by RMTEC Engineers before placing on the slope.



SITE PLAN
PORTEAU COVE PROPOSED CAMPGROUND
ELIMINATE BY THE OWNER N.T.S



DETAIL A
N.T.S



Reference:

- Slope Stability Analysis Report – Proposed Campground – Phase 1 (lower bench), Porteau Cove Quarry, Highway 99, BC, Issued by Frontera Geotechnical,#1364, dated October 19, 2022.
- Aerial Survey Drawings, Issued by Spitfire Drone Survey, PLAN SHOWING ORTHOPHOTO AND CONTOURS FROM DRONE LIDAR, Project Code: SAAXXX, Drawing#: S22055-001, Sheet 1 of 1 Rev: A, Dated. September 6, 2022
- Proposed Site Plan, Porteau Cove Campground, Plan and Sections issued by Mordoch Company, Project No. 20.03, Drawings #L-1.0, L 1.1, Issued for Review, Dated March 14, 2022

Permit Stamp



REVISIONS	
No.	Description

Client
LIONS GATE EXCAVATION LTD

Title
SLOPE STABILITY OF THE LOWER BENCH OF THE PROPOSED CAMPGROUND

Description
PLAN AND SECTIONS

Address
PORTEAU COVE QUARRY, HIGHWAY 99, BC

Project No. 230001	Date 12-June-23
Drawn By F.P	Approved By M.Z
Drawing Number RM-23001-DG-001-00	Scale AS SHOWN