GEOTECHNICAL ASSESSMENT REPORT

Proposed Mixed Use Development
1047 Richmond Road
Ottawa, Ontario

December 5, 2024

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APPENDICES

1 INTRODUCTION

Terrapex Environmental Ltd. (Terrapex) was retained by Fengate Development Holdings LP to prepare a geotechnical assessment for the proposed residential development at the property located at 1047 Richmond Road, Ottawa, Ontario (hereafter referred to as the “Site”). Authorization to proceed with this study was given by Mr. Lee Marlowe of Fengate Development Holdings LP.

The Site is located at 1047 Richmond Road in Ottawa, Ontario. The site is approximately 2.5 acres. The site is currently vacant.

The site is bordered to the east by a residential tower, to the south by Richmond Road, to the west by New Orchard Avenue and the north by a low-rise residential building. For this report, Richmond Road is considered to be oriented in an east-west direction.

Based on communications with the Client, we understand that Fengate was originally planning to develop the Site with three residential towers with 36 to 40-storeys (called Towers A, B and C) and three six-storey podiums. The proposed development also included a park, a drop-off area, an outdoor amenity and access roadways. The development included three levels of underground parking extending under the entire development site excluding the future park.

According to the latest development plan (rla Architecture, Nov 6, 2024) provided by the Client, Terrapex understands that the proposed development scheme has changed, and Fengate is contemplating to develop the Site in two phases, where the Phase 1, will include a thirty-six (36) storey mixed use building (Tower A) and a three-storey podium structure within the western portion of the site. The proposed Phase 1 development also includes a 1,000 m^2 of parkland dedication, a drop-off area, an outdoor amenity, soft landscaping features and access roadways. The Phase 1 development includes two levels of underground parking which will encompass the entire development area, excluding the parkland dedication.

Golder Associates conducted a geotechnical and hydrogeological investigation at the subject site in support of the initial development plan in 2021. Their investigation included drilling of ten boreholes advanced 7.6 m to 15.5 m below the existing ground surface (mbgs). A copy of the above report was provided to Terrapex. Terrapex referred to Golder’s borehole data and laboratory test results to prepare the current geotechnical assessment report, in support of the latest development plan.

The borehole location plan, overlaid on the latest development plan, is presented in Appendix B.

The purpose of this investigation was to characterize the underlying soil, bedrock and groundwater conditions, to determine the relevant geotechnical properties of encountered ground condition and to provide geotechnical engineering recommendations for the proposed development.

This report presents the results of the investigation performed in accordance with the general terms of reference outlined above and is intended for the guidance of the owner and the design architects or engineers only. It is assumed that the design will be in accordance with the applicable building codes and standards.

2 PAST FIELD WORK

The fieldwork for this investigation was carried out by Golder during the period between September 21 and 30, 2021 in conjunction with the fieldwork of the Phase II Environmental Site Assessment. It consisted of ten (10) boreholes (BH21-01 to BH21-10) advanced by drilling contractor CCC Geotechnical and Environmental Drilling of Ottawa. The locations of the boreholes are shown in **Appendix B**.

The boreholes designated as BH21-01 through BH21-10 were advanced to depths ranging from 7.6 m to 15.5 m below ground surface (mbgs).

Standard penetration tests were carried out in the course of advancing the boreholes through the overburden to take representative soil samples and to measure penetration index values (N-values) to characterize the condition of the various soil materials. The number of blows of the striking hammer required to drive the split spoon sampler to 300 mm depth was recorded and these are presented on the logs as penetration index values. Results of SPT are shown on the borehole log sheets in **Appendix C** of this report.

The boreholes were sampled with split spoon sampler to approximate depths ranging from 1.6 to 4.8 mbg in auger refusal. Boreholes BH21-01 to BH21-05 were subsequently advanced to a depth of approximately 7.6 m into the bedrock using a pneumatic hammer rock drilling (air hammered). No rock cores were recovered from these boreholes. The remaining boreholes designated as BH21-06 to BH21-10 were cored using an HQ-size coring bit to approximate depths ranging from 7.5 to 15.5 m.

Monitoring wells were advanced in all Boreholes except for BH21-08 to allow for groundwater measurement and to perform in-situ hydraulic conductivity testing. Groundwater measurements were made in the monitoring wells on October 05, 2021. The results of the groundwater measurements are discussed in Section 4.6 of this report.

At borehole BH21-08, a 63.5 mm inside diameter rigid PVC casing was grouted over the full depth of the borehole to allow for Vertical Seismic Profile (VSP) testing to determine the shear wave velocity profile of the soil and rock.

The borehole locations were marked in the field and surveyed by Golder. The positions and ground surface elevations at the borehole locations were determined using a Trimble R8 GPS survey unit. The Geodetic reference system used for the survey is the North American Datum of

1983 (NAD83). The borehole coordinates are based on the Universal Transverse Mercator (UTM Zone 09) coordinate system. The elevations are referenced to Geodetic datum (CGVD28).

3 PAST LABORATORY TESTS

The soil samples and bedrock cores retained from the boreholes were visually classified by Golder and natural water content and grain size distribution were conducted on selected soil samples, and Uniaxial Compressive Strength (UCS) tests were carried out on selected bedrock samples. The results of these tests and Standard Penetration Tests are presented on the borehole log sheets attached in **Appendix C** of this report.

In addition, two samples of soil from boreholes BH21-06 and BH21-10 were submitted to Eurofins Environment Testing by Golder for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of these tests are enclosed in **Appendix H**; discussed in Section 5.11 of this report.

4 SITE AND SUBSURFACE CONDITONS

Full details of the subsurface soil, and groundwater conditions at the site are given on the Borehole Log Sheets attached in **Appendix C** of this report. Images of the bedrock core runs are presented in Appendix E of this report.

The following paragraphs present a description of the site and a commentary on the engineering properties of the various soil materials contacted in the boreholes.

It should be noted that the boundaries of the soil types indicated on the borehole logs are inferred from non-continuous soil sampling and observations made during drilling. These boundaries are intended to reflect transition zones for the purpose of geotechnical design, and therefore, should not be construed as exact planes of geological change.

4.1. SITE DESCRIPTION

The Site is located at 1047 Richmond Road in Ottawa, Ontario. The site is approximately 2.5 acres and is currently occupied by a single-story car dealership located in the middle of the site, surrounded by asphalt-paved parking and driveways. Land uses surrounding the Site are commercial and residential.

The site is generally flat. The ground surface elevations established at the borehole locations range from 64.64 m to 66.07 m.

4.2. ASPHALTIC CONCRETE AND GRANULAR MATERIAL

Asphaltic concrete pavement is present at all borehole locations. The thickness of the asphaltic concrete ranges from approximately 50 to 100 mm. The granular material supporting the asphaltic concrete ranges from 110 to 540 mm in thickness.

4.3. FILL MATERIAL

Fill material is present below the granular base course in all the boreholes. The fill material generally consists of sand, silty sand to gravelly silty sand. The fill materials extend to approximate depths ranging from 0.9 and 2.4 mbgs.

The fill materials are mostly brown to dark-brown, grey-brown in color and moist in appearance. The water content of two samples of fill were about 10% by weight.

Standard penetration resistance testing (SPT) carried out in the cohesionless sand, silty sand to gravelly silty sand soils provided N-values ranging from 1 to 35, indicating a very loose to dense (typically compact) state of packing. It should be noted that the higher N-values at surface could be due to encountering gravel pieces.

Grain size analysis was carried out on two samples of the fill materials. The test results enclosed in Appendix D as Figure B-1 and Figure B-2.

4.4. NATIVE SOIL (GLACIAL TILL)

Native soil deposits were encountered in boreholes BH21-04 to BH21-05 and BH21-08 and BH21-10.

4.4.1 SILTY SAND

A deposit of silty sand in a heterogeneous mixture of gravel, cobbles, and boulders is present below the pavement structure and fill material in boreholes BH21-04 to BH21-05 and BH21-08 and BH21-10, extending to approximately depths ranging from 3.1 and 4.8 mbgs on weathered bedrock.

The silty sand is grey to grey-brown in color. The water content of the silty sand samples ranges from 7 to 14% by weight, generally being moist to very moist in appearance.

Standard penetration resistance testing (SPT) carried out in the silty sand soils provided N-values ranging from 46 to 50, indicating a dense to very dense compactness.

Grain size analysis was carried out on selected samples of the native soils. The test results are enclosed in **Figure B-3**, **Appendix D**.

4.5. BEDROCK CONDITIONS

Bedrock was encountered at depths of 0.9 mbg to 3.7 mbg at all boreholes, corresponding to geodetic elevations varying from 61.4 m to 65.2 m. At the location of Boreholes BH21-06 through BH21-10, bedrock was proven by rock coring to depths varying from 9.4 to 15.5 mbg.

A zone of highly weathered bedrock was encountered in boreholes BH21-02, BH21-03, BH21-06 and BH21-09 by augering and SPT sampling to depths varying from 0.9 to 3.1 m. The thickness of the weathered zone ranged approximately from 0.5 to 1.7 m at these borehole locations.

The approximate depth, core length and geodetic elevation of the ground surface and bedrock surface, where auger refusal was encountered at each borehole location, is provided in the Table below. The highly weathered portion of the bedrock is ignored in the Table.

Table Summary of Bedrock Information

Borehole No.	Elevation of Ground Surface (m)	Depth of Bedrock (m)	Core Length (m)	Elevation of Bedrock Surface (m)
21-01	65.7	1.8	N/A[1]	63.9
21-02	65.5	3.1	N/A[1]	62.4
21-03	65.2	3.1	N/A[1]	62.2
21-04	65.1	3.7	N/A[1]	61.4
21-05	65.5	3.7	N/A[1]	61.8
21-06	65.0	1.9	7.5	63.1
21-07	66.1	1.6	8.1	64.4
21-08	64.6	3.2	12.3	61.4
21-09	65.9	1.7	13.8	64.2
21-10	65.9	4.8	10.7	61.1

Note: [1] No bedrock core recovery due to pneumatic hammer rock drilling

The bedrock surface should not be considered accurate to better that +/- 0.5 m and some variations in the bedrock surface elevation across the site should be expected.

According to the available borehole log records, the bedrock encountered is described as medium grey dolostone with shale, limestone and sandstone interbeds to depths ranging from 9.1 to 13.2 m below ground surface. A light grey sandstone was encountered with thin partings of shale below the dolostone layer in boreholes BH21-08 to BH21-10 at depths ranging from 9.1 to 13.2 below ground surface, extending to termination depth of the boreholes at 15.4 to 15.5 m.

Rock Quality Designation (RQD) values of the bedrock are shown on the record of drillhole logs. The RQD values of the recovered cores range from about 0 to 100% but more typically in the range of 75 to 100% below ground level.

Based on Table 3.10 of the Canadian Foundation Engineering manual (CFEM) 4th Edition, the bedrock is classified as “very poor to excellent” for RQD ranging from 0 to 100% and “good to excellent quality” for RQD ranging from 75 to 100% at depth below ground surface. Photographs of the recovered bedrock core are presented in **Appendix E.**

Unconfined Compressive Strength (UCS) test determinations were completed on nine (9) core specimens of the bedrock. The results of the unconfined compression test carried out on the core specimens indicate rock strengths ranging from 86 to 144 MPa.

Based on the UCS test results, the bedrock is classified as “strong” and its hardness grade is R4 according to Table 3.5 of the CFEM (4th Edition).

The UCS test results and values are also presented **in Figures B-4 and B-5 in Appendix D.**

4.6. GROUNDWATER CONDITIONS

The groundwater levels were measured in the boreholes during their advancement and subsequently in the monitoring wells on October 5, 2021. The groundwater table measured in the monitoring wells was at depths of 2.7 m to 9.3 m, corresponding to geodetic elevations of 56.7 m to 62.4 m. The recorded water levels reflect the groundwater conditions on the dates they were measured and are provided below.

Summary of Groundwater Level Measurement Results

Borehole No.	Geologic Unit of Screed Interval	Depth of Screened Interval (m)	Ground Surface Elevation (m)	Groundwater Level		Date of Measurement
				Depth below ground surface* (m)	Elevation (m)	
21-01	Dolostone	4.57 – 7.62	65.73	7.60	58.13	Oct. 5, 2021
21-02	Dolostone	3.96 – 7.01	65.46	3.32	62.14	Oct. 5, 2021
21-03	Dolostone	4.57 – 7.62	65.24	3.22	62.02	Oct. 5, 2021
21-04	Dolostone	4.57 – 7.62	65.09	2.70	62.39	Oct. 5, 2021
21-05	Dolostone	4.57 – 7.62	65.47	3.94	61.53	Oct. 5, 2021
21-06	Dolostone	6.33 – 9.38	65.00	6.84	58.16	Oct. 5, 2021
21-07	Dolostone	6.68 – 9.73	66.07	9.34	56.73	Oct. 5, 2021
21-09	Dolostone	6.63 – 9.68	65.90	Dry	Dry	Oct. 5, 2021
21-10	Sandstone	12.40 – 15.45	65.89	8.85	57.04	Oct. 5, 2021

It should be noted that groundwater levels are subject to seasonal fluctuations. A higher groundwater level condition may likely develop in the spring and following significant rainfall events.

5 DISCUSSION AND RECOMMENDATIONS

The following discussions and recommendations are based on the factual data obtained from the boreholes advanced at the site and are intended for use by the client and their design architects and engineers only.

It is understood that the existing building at the Site was recently demolished. As part of the Phase 1 development, it is proposed to redevelop the Site with a thirty-six (36) storey mixed use building and a three-storey podium, including two levels of underground parking which will encompass the entire development site excluding the parkland dedication; with the remainder of the Site being developed with a 1,000 m^2 of parkland dedication, a drop-off area, an outdoor amenity, soft landscaping features and access roadways. The proposed development plan is shown in **Appendix B.**

The construction methods described in this report are not specifications or recommendations to the contractors or as the only suitable methods. The collected data and the interpretation presented in this report may not be sufficient to assess all the factors that may influence the construction. Contractors bidding on this project or conducting work associated with this project should make their own interpretation of the factual data and/or carry out their own investigations as they might deem necessary. The contractor should also select the method of construction, equipment and sequence based on their previous experience on similar projects.

5.1. EXCAVATION

Based on the borehole findings, excavations for foundations, basements, sewer trenches and utilities will be carried out through fill, native soil (glacial till), weathered bedrock and sound bedrock.

Excavation of the soil strata is not expected to pose any difficulty and can be carried out with heavy hydraulic excavators.

Excavations for the foundations should be carried out so as to minimize the disturbance of bedrock at the design founding elevations. In this regard, it may be necessary to use a hydraulic hammer for foundation excavations.

Bedrock excavation is anticipated across the site. According to the rock core data from current and previous investigations, the bedrock generally consists of good to strong dolostone with interbedded shale, limestone and sandstone of variable bed thicknesses and depths across the site. Bedrock excavation is expected to be carried out using line drilling and blasting, hoe ramming or both. Provision should be made in the excavation contract to include the use of these techniques for excavation in bedrock. Any blasting should be carried out in accordance with City of Ottawa Special Provision S.P. No: F-1201 and under the supervision of a blasting specialist engineer. Vibration monitoring of the blasting operation should be carried out to ensure that the blasting always meets the limiting vibration criteria.

The contractor should submit a complete and detailed blasting design and monitoring proposal prepared by a blasting/vibrations specialist prior to commencing blasting. This would have to be reviewed and accepted in relation to the requirements of the blasting specifications. Vibration monitoring of the blasting should be carried out to ensure that the blasting meets the limiting vibration criteria at all times. A pre-blast condition survey should be carried out of surrounding structures and utilities located within 75 m of the excavation site.

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). With respect to the OHSA, the near surface fill materials and the underlying native soils above the groundwater table are expected to conform to Type 3 soils. Soils situated below the water table are considered Type 4 soils. The bedrock is classified as type 1 soil.

Temporary excavations for slopes in Type 3 soils should not exceed 1.0 horizontal to 1.0 vertical. Excavations in Type 2 soil may be cut with vertical side-walls within the lower 1.2 m height of excavation and 1.0 horizontal to 1.0 vertical above this height. Locally, where loose or soft soil is encountered at shallow depths or within zones of persistent seepage, it may be necessary to flatten the side slopes as necessary to achieve stable conditions.

For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation. Excavation side-slopes should not be unduly left exposed to inclement weather. Excavation slopes consisting of sandy soils will be prone to gullying in periods of wet weather, unless the slopes are properly sheeted with tarpaulins.

Where workers must enter excavations extending deeper than 1.2 m below grade, the excavation sidewalls must be suitably sloped and/or braced in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects.

Where the basement walls of the proposed development will extend to the property limits, sufficient space will not be available to slope the sidewalls of the basement excavation; as such it will be necessary to shore the basement excavation walls. Shoring recommendations are provided in Section 5.7.3 of this report.

Where space permits, temporary open cut may be used for basement excavations. The safe side slope angle for open excavations should conform to the Occupational Health and Safety Act requirements.

5.2. GROUNDWATER CONTROL

Based on observations made during drilling of the boreholes, and close examination of the soil samples extracted from the boreholes, groundwater seepage is expected to occur within excavation extended below an approximate depth of 2.7 mbg. In the event that excavations will extend below the groundwater table it will be necessary to lower the groundwater level a minimum of 1 m below the lowest excavation level in the overburden, and to the base of the excavation in bedrock. The dewatering system should be designed and installed by specialist contractor. The contractors should make their own assessments for temporary control of groundwater seepage into the excavation.

The hydrogeological study by Golder for this project should be referred to for recommendations for estimated dewatering volumes during the construction and during the service life of the building and requirements for the application for Permit to Take Water (PTTW), should this be deemed necessary.

5.3. SITE GRADING

Based on the Civil Drawings provided by the Client, only minor modifications to site grading will be required. The existing services will have to be decommissioned, and the excavations left behind will need to be engineered.

The site consists of fill which is underlain by a deposit of silty sand in a heterogeneous mixture of gravel, cobbles, and boulders, which are in turn underlain by bedrock. The existing soil condition is not susceptible to considerable long-term settlement. Given the above, any ground settlement as a result of the proposed grading will be negligible.

5.4. ENGINEERED FILL

The following recommendations regarding construction of engineered fill should be adhered to during the construction stage:

- All surface vegetation, organic materials, loose or soft fill soils, and softened and/or disturbed soils must be removed, and the exposed subgrade soils proof-rolled under the supervision of the Geotechnical Engineer prior to placement of new fill.
- If the fill will be used to support structures, the existing fill must be removed in its entirety prior to placement of new fill.
- Soils used as engineered fill should be free of organics and/or other unsuitable material. The engineered fill must be placed in lifts not exceeding 200 mm in thickness and compacted to at least 98% Standard Proctor maximum Dry Density (SPMDD).
- Engineered fill operations should be monitored and compaction tests should be performed on a full-time basis by a qualified engineering technician supervised by the project engineer.
- The boundaries of the engineered fill must be clearly and accurately laid out in the field by qualified surveyors prior to the commencement of engineered fill construction. The top of the engineered fill should extend a minimum of 2.5 m beyond the envelope of the proposed structures. Where the depth of engineered fill exceeds 1.5 m, this horizontal distance of

2.5 m beyond the perimeter of the structure should be increased by at least 1 m for each 1.5 m depth of fill.

- The engineered fill operation should take place in favorable climatic conditions. If the work is carried out in months where freezing temperatures may occur, all frost affected material must be removed prior to the placement of frost-free fill.
- If unusual soil conditions become apparent during construction, due to subsurface groundwater influences, our office should be contacted in order to assess the conditions and recommend appropriate remedial measures.

5.5. REUSE OF ON-SITE EXCAVATED SOIL

On-site excavated inorganic soils, and soils free of construction debris and other deleterious materials are considered suitable for reuse as backfill provided their water content is within 2% of their optimum water contents (OWC) as determined by Standard Proctor test, and the materials are effectively compacted with a heavy sheepsfoot compactor.

While the quality of the on-site soils is considered unsuitable for backfilling. Measured water content within the fill and native soils (glacial till) within the presumed excavation depth generally range from approximately 10 to 14%. The native soils are moist to very moist and are unsuitable for use as engineered fill.

5.6. SERVICE TRENCHES

Civil and Grading plans were not available at the time of preparation of this report. Services can be supported on undisturbed native deposits or on bedrock. The type of bedding depends mainly on the strength of the subgrade immediately below the invert levels.

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Normal Class ‘B’ bedding is recommended for underground utilities. Granular ‘A’ or 19 mm crusher-run limestone can be used as bedding material; all granular materials should meet OPS 1010 specifications. The bedding material should be compacted to a minimum of 95% SPMD. Bedding details should follow the applicable governing design detail (i.e. City of Ottawa, OPSD). Trenches dug for these purposes should not be unduly left exposed to inclement weather.

Pipe bedding and backfill for flexible pipes should be undertaken in accordance with OPSD 802.010. Pipe embedment and cover for rigid pipes should be undertaken in accordance with OPSD 802.030.

If unsuitable bedding conditions occur, careful preparation and strengthening of the trench bases prior to sewer installation will be required. The subgrade may be strengthened by placing a thick mat consisting of 50 mm crusher-run limestone. Field conditions will determine the depth of stone required. Geotextiles and/or geogrids may be helpful, and these options should be reviewed by Terrapex on a case-by-case basis.

Sand cover material should be placed as backfill to at least 300 mm above the top of pipes. Placement of additional granular material may be required for use of smaller compaction equipment for the first few lifts above the pipe to prevent damage to the pipe during the trench backfill compaction.

It is recommended that service trenches be backfilled with on-site excavated materials such that at least 95% of SPMDD is obtained in the lower zone of the trench and 98% of SPMDD for the upper 1000 mm.

Impermeable clay should be provided across the entire width of the service trenches. It is recommended that the seals be at least 1.0 m in length along the trench (in accordance with the city of Ottawa Standard S8). The seals should be constructed near the property line along all service installations.

In areas of narrow trenches or confined spaces such as around manholes, catch basins, etc., the use of aggregate fill such as Granular ‘B’ Type I (OPSS 1010) is required if there is to be postconstruction grade integrity.

5.7. FOUNDATION DESIGN

The proposed Tower A and the adjoining podium with two levels of underground parking can be supported with shallow footings on sound bedrock. According to the available architectural drawings the average mean grade is 65.4 masl. The finished floor elevation of the P2 underground parking level can be assumed at 6 to 7 mbgs.

Conventional strip and spread foundations placed on undisturbed sound bedrock at/below 58.0 masl may provide a bearing resistance of 5 MPa at ULS. Foundations designed for the above bearing pressure are expected to settle less than 25 mm total and 19 mm differential.

All footing subgrades must be evaluated by the Geotechnical Engineer prior to placing formwork and foundation concrete to ensure that the surface exposed at the excavation base is consistent with the design geotechnical bearing resistance. Any surficially weathered bedrock should be removed prior to pouring concrete.

Rainwater or groundwater seepage entering the foundation excavations must be pumped away (not allowed to pond). The foundation subgrade soils should be protected from freezing, inundation, and equipment traffic. If unstable subgrade conditions develop, Terrapex should be contacted to assess the conditions and make appropriate recommendations.

Frost protection may not be required for footings placed on sound bedrock.

5.8. CONCRETE SLAB-ON-GRADE

At the proposed depths of the lowest underground floor slabs, it is expected that the subgrade will consist of sound bedrock which is suitable for slab-on-grade construction.

Subgrade preparation should include the removal of any fractured or delaminated rock pieces. After removal of all unsuitable materials, the subgrade should be inspected and adjudged as satisfactory before preparing the granular base course. Any loose or unsuitable subgrade areas should be sub-excavated and replaced with suitable approved compacted backfill; placed in maximum lifts of 200 mm thickness and compacted to at least 98% of SPMDD.

It is recommended that a combined moisture barrier and a levelling course, having a minimum thickness of 200 mm and comprised of free draining material such as 19 mm clear stone (OPSS 1004) compacted by vibration to a dense state underlain by non-woven geotextile (filter fabric) separating the clear stone and the underlying sand.

Provided the subgrade, underfloor fill and granular base are prepared in accordance with the above recommendations, the recommended Modulus of Subgrade Reaction (Ks) for slab design will be 40,000 kPa/m.

Perimeter and subfloor drainage shall be installed in accordance with the specifications provided in Appendix H.

5.9. SHORING DESIGN

It is anticipated that the excavation for the underground parking structure for the Phase 1 development will extend close to the north, south and west property limits and as such it may not be possible to slope the banks of the excavation. In this regard it will be necessary to shore the excavation walls above the sound bedrock where the excavation is close to the property boundaries. The east boundary of the Phase 1 development may not require shoring.

Soldier pile and wood lagging system may be used as the shoring system.

Vertical cuts into the sound bedrock will be possible. However, remedial works such as steel mesh, shotcrete should be implemented to ensure that rock pieces do not fall down and endanger workers in the excavation.

Where space permits, temporary open cut may be used for basement excavations. The safe side slope angle for open excavations should conform to the Occupational Health and Safety Act requirements.

The design of temporary shoring for the support of the subsoils must account for the presence of structures and buried services on the adjacent properties, and the existing subsurface conditions at the site.

The lateral restraining force for the shoring system may be provided by employing either rakers or tieback anchors. The latter is favorable because they do not protrude into the excavations as is the case with rakers. The use of tieback anchors will depend on whether permission is obtained to extend the anchors to the required distance on to the neighboring properties.

The shoring design should be based on the procedure detailed in the latest edition of the Canadian Foundation Engineering Manual.

The active earth pressure coefficient: Ka to be used for the design of the shoring system, should be as follows:

> = 0.5 where adjacent building footings or buried services fall within an envelope formed by a 75° line drawn from the base of the excavation wall to the ground surface.
>
> = 0.4 where adjacent building footings or buried services fall within an envelope formed by a 60° line drawn from the base of the excavation wall to the ground surface.
>
> = 0.3 where adjacent building footings or buried services fall outside an envelope formed by a 45° line drawn from the base of the excavation wall to the ground surface.
>
> = 0.25 where adjacent building footings or buried services are outside an envelope formed by a 30° line drawn from the base of the excavation wall to the ground surface.

Anchors extended into the sound bedrock may be designed based on skin frictions of 700 kPa. These values depend on the anchor installation method and grouting procedures. Gravity poured concrete can result in low bond values, while pressure grouted anchors will give higher values and produce a more satisfactory anchor.

It will be necessary to perform load tests on the tiebacks to confirm the bond stresses assumed in the design of anchors.

Movement of the shoring system is inevitable. Vertical movements will result from the vertical loads on the soldier piles resulting from the inclined tiebacks and inward horizontal movement will result from the earth and water pressures. The magnitude of this movement can be controlled by sound construction practices. The lateral and vertical movement of the shoring system must be monitored especially at locations in which settlement sensitive structures are present, to ensure that movements are kept within acceptable range.

5.10. ROCK ANCHORS

Rock anchors may be used to provide resistance against overturning and uplift. Rock anchors may be designed based on skin friction of 700 kPa in sound bedrock. The value depends on the anchor installation method and grouting procedures. Gravity poured concrete can result in lower bond values, while pressure grouted anchors will give higher values and produce a more satisfactory anchor.

The effective unit weight of the bedrock could be considered as 26 kN/m^3 above the groundwater level and 16 kN/m^3 below the groundwater level.

The designer should also assess the potential failure within the rock mass due to anchor pull-out. Resistance to rock mass failure around the anchors is provided by: (i) effective weight of a conical rock mass around each anchor, with the apex of the cone at the tip of the anchor and an apex angle of 60^o, (ii) tensile strength of the rock mass.

Where the anchors are closely spaced in a row and the conical zones of influence coincide, the weight of the truncated trapezoidal rock mass around the row of anchors must be considered as the resistive force, instead of single cones around each anchor.

For inclined anchors, the weight of the rock mass should be projected along the axis of the anchor.

In preliminary design, the tensile strength of the rock mass may be neglected. Its contribution can be evaluated during the detailed design stage.

Pre-production and proof tests shall be conducted in accordance with the requirements of OPSS 942, under full-time supervision of the geotechnical engineer.

Provisions shall be made for protection of the rock anchors from corrosion.

5.11. LATERAL EARTH PRESSURE

Parameters used in the determination of earth pressure acting on temporary shoring walls are defined below.

Parameter	Definition	Units
Φ’	Angle of Internal Friction	degrees
γ	Bulk Density	kN/m^3
S_u	Undrained Shear Strength	kPa
K_a	active earth pressure coefficient (Rankine)	dimensionless
K_o	at-rest earth pressure coefficient (Rankine)	dimensionless
K_p	passive earth pressure coefficient (Rankine)	dimensionless
K_{ae}	active earth pressure coefficient (Mononobe-Okabe)	dimensionless
K_{pe}	passive earth pressure coefficient (Mononobe-Okabe)	dimensionless

5.11.1 Static Conditions

The appropriate un-factored values for use in the design of structures subject to unbalanced earth pressures at this site are tabulated as follows:

SOIL PARAMETER VALUES

Soil	Parameter				
	Φ'	γ	Ka	Kp	Ko
Fill	28°	20	0.36	2.77	0.53
Silty Sand (Glacial Till)	31°	21.5	0.32	3.12	0.48
Weathered Bedrock	35°	26	0.27	3.69	0.43
Sound Bedrock	45°	26	0.17	5.83	0.29

1. Passive and sliding resistance within the zone subject to frost action (i.e. within 1.8 m below finished grade) should be disregarded in the lateral resistance computations.

Subsurface walls subject to unbalanced earth pressures must be designed to resist a pressure that can be calculated based on the following formula:

$$\mathbf{P = K (\gamma h + q)}$$

where P = lateral pressure in kPa acting at a depth h (m) below ground surface
K = applicable lateral earth pressure coefficient
γ = bulk unit weight of backfill (kN/m^3)
h = height at any point along the interface (m)
q = the complete surcharge loading (kPa)

This equation assumes that free-draining backfill and positive drainage is provided to ensure that there is no hydrostatic pressure acting in conjunction with the earth pressure. The coefficient of earth pressure at rest (K_o) should be used in the calculation of the earth pressure on the basement walls.

Subsurface walls that are subject to unbalanced earth and hydrostatic pressures must be designed to resist a pressure that can be calculated based on the following formula:

$$\mathbf{P = K [\gamma (h - h_w) + \gamma' h_w + q] + \gamma_w h_w}$$

where P = lateral pressure in kPa acting at a depth h (m) below ground surface
K = applicable lateral earth pressure coefficient
H = height at any point along the interface (m)
h_w = depth below the groundwater level at point of interest (m)
γ = bulk unit weight of backfill (kN/m^3)

γ' = the submerged unit weight (kN/m^3) of exterior soil ($\gamma' = \gamma - \gamma_w$)
γ_w = unit weight of water, assume a value of 9.8 kN/m^3
q = the complete surcharge loading (kPa)

Resistance to sliding of earth retaining structures is developed by friction between the base of the footing and the soil. This friction (R) depends on the normal load on the soil contact (N) and the frictional resistance of the soil (tan Φ') expressed as: $R = N \tan \Phi'$. This is an ultimate resistance value and does not contain a factor of safety.

5.11.2 Dynamic Conditions

Below grade walls subjected to lateral seismic forces can be designed using the pseudo-static approach using the Mononobe-Okabe equations.

The total active thrust under seismic loading (P_{ae}) is recommended to be expressed as follows:

$$P_{ae} = ½ K_{ae}\gamma H^2 \times (1- k_v)$$

Where: H = Height of the wall, K_{ae} = horizontal component of active earth pressure coefficient including effects of earthquake loading,

k_v = Vertical component of the earthquake acceleration typically a range of 2/3 x k_h to 1/3 k_h is considered but a value closer to 2/3 x k_h is recommended

k_h = Horizontal component of the earthquake acceleration, typically Peak Ground Acceleration (PGA) or a factor thereof is used. The Site Class-adjusted PGA for the Site is 0.244 g at Site Class A, where g is the acceleration due to gravity.

For passive earthquake pressure (P_{pe}) the following equation can be used:

$$P_{pe} = ½ K_{pe}\gamma H^2 \times (1- k_v)$$

Where: K_{pe} = horizontal component of passive earth pressure coefficient including effects of earth-quake loading

The above equation includes both the active pressures under static (P_a) as well as the increased force due to seismic forces. The active force under static conditions is assumed to act at a point of (0.3 x H) above the base and the seismic force is assumed to act near (0.6 x H) above the base, where H is the height of the wall. Therefore, the point of application for P_{ae} may be calclated from the following:

$$h = [(0.33H \times P_a) + (0.6H \times P_e)]/ P_{ae}$$

The following soil parameters are presented to assist Designers in designing retaining walls for this Site under seismic conditions using the pseudo-static approach:

Table 7-3: Lateral Earth Pressure Soil Parameter Values – Dynamic Conditions

Soil	Parameter					
	Φ'	γ	K_{ae}	K_{pe}	K_{ae}	K_{pe}
			Non-yielding Wall		Yeilding Wall	
Fill	28°	20	0.55	2.32	0.44	2.56
Silty Sand (Glacial Till)	31°	21.5	0.5	2.66	0.40	2.90
Weathered Bedrock	35°	26	0.43	3.19	0.34	3.45
Sound Bedrock	45°	26	0.3	5.21	0.23	5.53

5.12. PAVEMENT DESIGN

5.12.1 On-Grade Construction

Based on the existing topography of the subject site and the data collected during the field investigation, it is anticipated that the sub-grade for the asphaltic concrete pavement will generally consist of fill material. Given the frost susceptibility and drainage characteristics of the subgrade soils, the following pavement structure design is recommended for the Site:

RECOMMENDED ASPHALTIC CONCRETE PAVEMENT STRUCTURE DESIGN
(MINIMUM COMPONENT THICKNESSES)

Pavement Layer	Compaction Requirements	Thickness and Material (Light Duty Pavement)	Thickness and Material (Heavy Duty Pavement)
Surface Course Asphaltic Concrete	97% Marshall Density	40 mm Hot-Laid HL3	50 mm Hot-Laid HL3
Binder Course Asphaltic Concrete	97% Marshall Density	50 mm Hot-Laid HL8	70 mm Hot-Laid HL8
Granular Base	100% SPMDD	150 mm compacted depth OPSS Granular A	150 mm compacted depth Granular A
Granular Sub-Base	100% SPMDD	300 mm compacted depth Granular B	450 mm compacted depth Granular B

* SPMDD - Standard Proctor maximum dry density (ASTM-D698)

Subgrade preparation should include the removal of weak and softened soils. After removal of all unsuitable materials, the subgrade should be proof rolled with heavy rubber-tired equipment and adjudged as satisfactory before preparing the granular base course. The proof-rolling operation should be witnessed by the Geotechnical Engineer. Any soft or unsuitable subgrade areas which deflect significantly should be sub-excavated and replaced with suitable engineered fill material compacted to at least 98% of SPMDD.

The granular pavement structure materials should be placed in lifts not exceeding 150 mm thick and be compacted to a minimum of 100% SPMDD. Asphaltic concrete materials should be rolled and compacted per OPSS 310. The granular and asphaltic concrete pavement materials and their placement should conform to OPSS 310, 501, 1010 and 1150, and the pertinent Municipality specifications. Further, it is recommended that the Municipality's specifications should be referred to for use of higher grades of asphalt cement for asphaltic concrete where applicable.

The long-term performance of the proposed pavement structure is highly dependent upon the subgrade support conditions. Stringent construction control procedures should be maintained to ensure that uniform subgrade moisture and density conditions are achieved. In addition, the need for adequate drainage cannot be over-emphasized. The finished pavement surface and underlying subgrade should be free of depressions and should be crowned and sloped to provide effective drainage. Surface water should not be allowed to pond adjacent to the outside edges of pavement areas. Sub-drains must be provided to facilitate effective and assured drainage of the pavement structures as required to intercept excess subsurface moisture and minimize subgrade softening. The invert of sub-drains should be maintained at least 0.3 m below subgrade level.

As part of the subgrade preparation, proposed pavement areas should be stripped of unsuitable earth fill and other obvious objectionable material. Fill required to raise the grades to design elevations should be free of organic material and at a water content which will permit compaction to the specified densities. Soft or spongy subgrade areas should be sub-excavated and properly replaced with suitable approved backfill compacted to 98% SPMDD. For fine-grained clay soils as encountered at the site, the degree of compaction specification alone cannot ensure distress free subgrade. Proof-rolling of the roadway subgrade must be carried out and witnessed by Terrapex personnel for final recommendations of sub-base thickness.

Additional comments on the construction of pavement areas are as follows:

- As part of the subgrade preparation, the proposed pavement areas should be stripped of vegetation, topsoil, unsuitable earth fill and other obvious objectionable material. The subgrade should be properly shaped and sloped as required, and then proof-rolled. Loose/soft or spongy subgrade areas should be sub-excavated and replaced with suitable approved material compacted to at least 98% of SPMDD.

- Where new fill is needed to increase the grade or replace disturbed portions of the subgrade, excavated inorganic soils or similar clean imported fill materials may be used, provided their moisture content is maintained within 2 % of the soil's optimum moisture content. All fill must be placed and compacted to not less than 98% of SPMDD.

- For fine-grained soils, as encountered at the site, the degree of compaction specification alone cannot ensure distress free subgrade. Proof-rolling must be carried out and witnessed by Terrapex personnel for final recommendations of sub-base thicknesses.

- In the event that pavement construction takes place in the spring thaw, the late fall, or following periods of significant rainfall, it should be anticipated that an increase in thickness of the granular sub-base layer will be required to compensate for reduced subgrade strength.

5.12.2 Above Parking Garage Roof

The pavement above the parking garage roof slab may be comprised of a minimum of 75 mm thick layer of granular ‘A’ topped with asphaltic concrete having a minimum thickness of 80 mm (40 mm HL8 and 40 mm HL3). The asphaltic concrete materials should be rolled and compacted in accordance with OPSS 310 requirements.

The critical section of pavement will be at the transition between the pavement on grade and the pavement above the garage roof slab. In order to alleviate the detrimental effects of dynamic loading / settlement / pavement depression in the backfill to the rigid garage roof structure, it is recommended that an approach type slab be constructed at the entrance/exit points, by extending the granular sub-base to greater depths along the exterior garage wall.

5.13. TREES

Given the sandy nature of the fill and native materials, the overburden soil is not susceptible to settlements induced by moisture suction by tree roots.

5.14. EARTHQUAKE DESIGN PARAMETERS

The Ontario Building Code (2012) stipulates the methodology for earthquake design analysis, as set out in Subsection 4.1.8.7. The determination of the type of analysis is predicated on the importance of the structure, the spectral response acceleration, and the site classification.

The parameters for determination of the Site Classification for Seismic Site Response are set out in Table 4.1.8.4.A of the Ontario Building Code (2012). The classification is based on the determination of the average shear wave velocity in the top 30 metres of the site stratigraphy, where shear wave velocity (vs) measurements have been taken.

Based on the geophysical data provided by Golder, the Vertical Seismic Profiling (VSP) test results indicated that the average shear wave velocity in the upper 30 from the bedrock surface (Vs30) was about 1,700 m/s. Provided that the foundations for the proposed building will be founded on bedrock, the site designation for seismic analysis is Class A. Test results of the VSP are presented in Appendix F.

The site specific 5% damped spectral acceleration coefficients, and the peak ground acceleration factors are provided in the 2012 Ontario Building Code - Supplementary Standard SB-1 (August 15, 2006), Table 1.2, location Ottawa, Ontario.

5.15. CHEMICAL CHARACTERIZATION OF SUBSURFACE SOIL

Two samples of soil from boreholes BH21-06 and BH21-10 were submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The Certificate of Analysis provided by the analytical chemical testing laboratory is contained in **Appendix G** of this report and summarized below:

Borehole Number	Sample Number	Depth Intervals (m)	Chlorides (%)	Sulphates (%)	pH	Resistivity (Ohm-cm)
21-06	2	1.5 – 1.9	0.007	<0.01	8.9	4,350
21-10	3	2.3 – 2.7	<0.002	0.01	8.4	6,670

The test results revealed that the pH index of the soil samples is 8.4 and 8.9, indicating a slight alkalinity.

The water-soluble sulphate content of the tested samples are <0.01% and 0.01%. The concentration of water-soluble sulphate content of the tested sample is below the CSA Standard of 0.1% water-soluble sulphate (Table 12 of CSA A23.1, Requirements for Concrete Subjected to Sulphate Attack). Special concrete mixes against sulphate attack are therefore not required for the sub-surface concrete of the proposed buildings.

6. LIMITATIONS OF REPORT

The Limitations of Report, as quoted in Appendix ‘A’, are an integral part of this report.

Yours respectfully,
Terrapex Environmental Ltd.

LICENSED PROFESSIONAL ENGINEER
Meysam Najari
M. NAJARI
100573726
Dec 5, 2024
PROVINCE OF ONTARIO

Yacouba Doro, P.Eng.
Senior Geotechnical Project Manager

Meysam Najari, Ph.D. P.Eng.
Vice President - Geotechnical Services

APPENDIX A

LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

This report has been completed in accordance with the terms of reference for this project as agreed upon by Fengate Development Holdings LP (the Client) and Terrapex Environmental Ltd. (Terrapex) and generally accepted engineering consulting practices in this area.

The conclusion and recommendations in this report are based on information determined at the inspection locations. Soil and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction which could not be detected or anticipated at the time of the soil investigation. If new or different information is identified, Terrapex should be requested to re-evaluate its conclusions and recommendations and amend the report as appropriate.

The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known to us, in our analysis certain assumptions had to be made as set out in this report. The actual conditions may, however, vary from those assumed, in which case changes and modifications may be required to our recommendations.

This report was prepared for the sole use of Fengate Development Holdings LP. Terrapex accepts no liability for claims arising from the use of this report, or from actions taken or decisions made as a result of this report, by parties other than Fengate Development Holdings LP. The material herein reflects Terrapex’s judgement in light of the information available to it at the time of preparation. We recommend, therefore, that we be retained during the final design stage to review the design drawings and to verify that they are consistent with our recommendations, or the assumptions made in our analysis. We also recommend that we be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the test holes. In cases where these recommendations are not followed, Terrapex’s responsibility is limited to accurately interpreting the conditions encountered at the test holes, only.

The comments given in this report on potential construction problems and possible methods are intended for the guidance of the design engineer, only. The number of inspection locations may not be sufficient to determine all the factors that may affect construction methods and costs. Contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work.

APPENDIX B

SITE LOCATION PLAN AND GENERAL SITE LAYOUT

LEGEND

🟥	SITE BOUNDARY
🟦	PHASE 1 DEVELOPMENT BOUNDARY
⌖	MONITORING WELL (BY Golder)

0 5 10 15 20
Metres

DATA SOURCE: CITY OF OTTAWA, PROPOSED SITE PLAN PROVIDED BY CLIENT.
MAP PROJECTION: NAD 1983 UTM ZONE 18N

CLIENT:
FENGATE

SITE LOCATION:
1047 RICHMOND ROAD
OTTAWA, ONTARIO

TERRAPEX

TITLE:
SITE PLAN

DRAWN BY:	PROJECT NO.:	CHECKED BY:
JS	CO972.00	YD
REVISION:	DATE:	FIGURE:
00	SEPTEMBER 2024	1

C:\Users\jserroul\OneDrive - Terrapex Environmental Ltd\PROJECTS\Ottawa\CO900\CO972.00 1047 Richmond Rd, Ottawa\MXD\GEOTECH\CO972.00 FIG 1 SITE PLAN.mxd

APPENDIX C

BOREHOLE LOG SHEETS

PROJECT: 21494078

RECORD OF BOREHOLE: 21-01

SHEET 1 OF 1

LOCATION: N 5026314.5 ;E 361326.2

BORING DATE: September 24, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m	HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	65.73						
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT	0.00						Flush Mount Casing
		FILL - (SW) gravelly SAND, angular; brown (PAVEMENT STRUCTURE); non-cohesive, moist	0.10	1	SS	19	ND	Metals	
1		FILL - (SM) gravelly SILTY SAND; grey to dark brown, trace sand (SP); non-coohesive, moist, compact to very loose	65.43 0.30	2	SS	4	ND		
				3	SS	2	ND	PHCs, VOCs	
2	Air Hammer H Bit	BEDROCK (Auger Refusal) (Air hammer from 1.83 m to 7.62 m)	63.90 1.83						Bentonite Seal
4									SIlica Sand
6									50 mm Diam. PVC #10 Slot Screen
		End of Borehole	58.11 7.62						∇

HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕: 100 200 300 400

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] □ ND = Not Detected: 100 200 300 400

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—O^W—⊣ Wl: 20 40 60 80

End of Borehole

Note(s):

1. Water level measured at a depth of 7.63 m (Elev. 58.13 m) on October 5, 2021

2. Borehole log not for geotechnical purposes.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-02

SHEET 1 OF 1

LOCATION: N 5026359.3 ;E 361297.8

BORING DATE: September 21, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected	ADDITIONAL LAB. TESTING
	GROUND SURFACE	65.46					
Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT	0.08					
	FILL - (SW) gravellyl SAND, angular; grey (PAVEMENT STRUCTURE); non-cohesive, moist	65.16 0.30	1	SS	22	ND	
	FILL - (SP) SAND, fine to medium, trace silt; brown; non-cohesive, moist, compact to dense	64.24 1.22	2	SS	31	ND	Metals
	FILL - (SM/GP) SILTY SAND and GRAVEL; dark brown, contains brick fragments and rootlets; non-cohesive, moist, compact	63.63 1.83	3	SS	10	ND	
	Highly weathered BEDROCK	62.41 3.05	4	SS	>84	ND	
			5	SS	>50	ND	PHCs, VOCs
Air Hammer H Bit	BEDROCK (Auger Refusal) (Air hammer from 3.05 M TO 7.62 M)	57.84 7.62					
	End of Borehole						

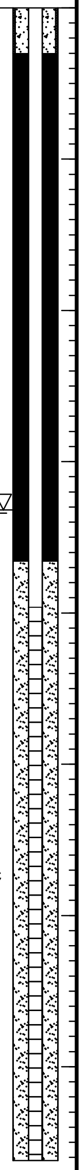
HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected: 100, 200, 300, 400

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] □ ND = Not Detected: 100, 200, 300, 400

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20, 40, 60, 80

PIEZOMETER OR STANDPIPE INSTALLATION



Flush Mount Casing

Bentonite Seal

SIlica Sand

50 mm Diam. PVC #10 Slot Screen

Note(s):

1. Water level measured at a depth of 3.32 m (Elev. 62.14 m) on October 5, 2021

2. Borehole log not for geotechnical purposes.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-03

SHEET 1 OF 1

LOCATION: N 5026355.1 ;E 361289.2

BORING DATE: September 21 & 22, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected (100, 200, 300, 400)

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] □ ND = Not Detected (100, 200, 300, 400)

HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3})

WATER CONTENT PERCENT Wp ⊢—O^W—⊣ Wl (20, 40, 60, 80)

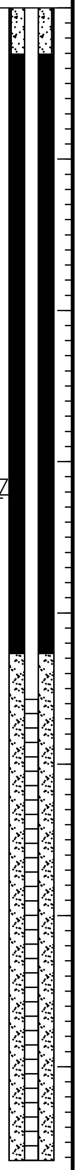
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	HEADSPACE	ADDITIONAL LAB. TESTING
		GROUND SURFACE	65.24					
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT						
		FILL - (SW) gravelly SAND, angular; grey (PAVEMENT STRUCTURE); non-cohesive, moist	0.08	1	SS	43	⊕□ ND	VOCs
		FILL - (SP) SAND, fine to medium, trace silt; brown; non-cohesive, moist, dense	64.63 0.61	2	SS	31	⊕□ ND	PHCs
1		FILL - (SM) SILTY SAND, some topsoil, trace gravel; dark brown, contains shale fragments; non-cohesive, moist, compact	64.02 1.22	3	SS	12	⊕□ ND	Metals
2		Highly weathered BEDROCK	63.41 1.83	4	SS	>94	⊕□ ND	
				5	SS	52/ 6"		
3	Air Hammer H Bit	BEDROCK (Auger Refusal) (Air hammer from 3.05 m to 7.62 m)	62.19 3.05					
7		End of Borehole	57.62 7.62					

Note(s):

1. Water level measured at a depth of 4.22 m (Elev. 62.02 m) on October 5, 2021

2. Borehole log not for geotechnical purposes.

PIEZOMETER OR STANDPIPE INSTALLATION



Flush Mount Casing

Bentonite Seal

SIlica Sand

50 mm Diam. PVC #10 Slot Screen

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-04

SHEET 1 OF 1

LOCATION: N 5026369.7 ;E 361313.7

BORING DATE: September 21, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

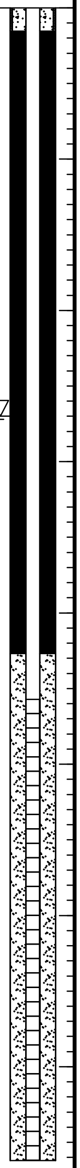
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	65.09						
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT							Flush Mount Casing
		FILL - (SM) SILTY SAND, trace gravel; brown to grey brown, contains wood fragments; non-cohesive, moist, loose to compact	0.05	1	SS	9	ND	VOCs	
1				2	SS	10	ND		
				3	SS	7	ND		
2				4	SS	14	ND		Bentonite Seal
		(SM) gravelly SILTY SAND; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, dense	62.65 2.44	5	SS	49	ND		▽
3				6	SS	55/4"	ND	PHCs	
4	Air Hammer H Bit	BEDROCK (Auger Refusal) (Air hammer from 3.66 m to 7.62 m)	61.43 3.66						SIlica Sand
6									50 mm Diam. PVC #10 Slot Screen
		End of Borehole	57.47 7.62						

HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕: 100 200 300 400

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] ☐ ND = Not Detected: 100 200 300 400

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT Wp ⊢—O^W—⊣ Wl: 20 40 60 80



Note(s):

1. Water level measured at a depth of 2.70 m (Elev. 62.39 m) on October 5, 2021

2. Borehole log not for geotechnical purposes.

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-05

SHEET 1 OF 1

LOCATION: N 5026358.2 ;E 361327.9

BORING DATE: September 22/24, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

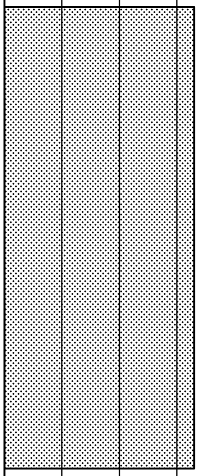
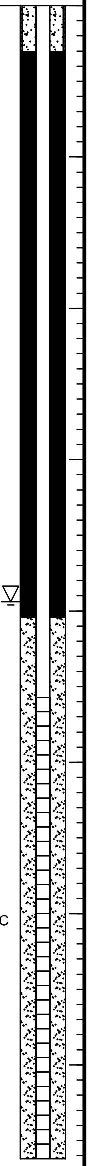
HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected 100 200 300 400

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] ☐ ND = Not Detected 100 200 300 400

HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	HEADSPACE	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	65.47						
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT							Flush Mount Casing
		FILL - (SP) SAND, fine to coarse, some gravel, trace silt; brown; non-cohesive, moist, compact	0.08	1	SS	15	⊕ ND		
1		FILL - (SM/GW) SILTY SAND and GRAVEL; dark brown, contains wood fragments; non-cohesive, moist, compact	64.86 0.61	2	SS	20	⊕ ND	PHCs, VOCs	
				3	SS	52/ 0"	⊕ ND	PHCs, VOCs	
2		Possible FILL - (SP) SILTY SAND, fine to coarse, trace silt, trace gravel; grey brown; non-cohesive, moist, compact to dense	64.02 1.45	4	SS	20	⊕ ND		Bentonite Seal
				5	SS	39	⊕ ND		
3		(SM) gravelly SILTY SAND, non-plastic fines; grey brown, contains cobbles (GLACIAL TILL); non-cohesive, moist, dense	62.73 2.74	6	SS	46	⊕ ND		
				7	SS	34/ 10"	⊕ ND		
4–7	Air Hammer H Bit	BEDROCK (Auger Refusal) (Air hammer from 3.65 m to 7.62 m)	61.82 3.65						∇ SIlica Sand 50 mm Diam. PVC #10 Slot Screen
8		End of Borehole	57.85 7.62						

Note(s):

1. Water level measured at a depth of 3.94 m (Elev 61.53 m) on October 5, 2021

2. Borehole log not for geotechnical purposes.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-06

SHEET 1 OF 2

LOCATION: N 5026317.1 ;E 361275.1

BORING DATE: September 30, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		65.00							
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT		0.05							Flush Mount Casing
		FILL - (SW) gravelly SAND, angular; grey (PAVEMENT STRUCTURE); non-cohesive, moist		0.20							
		FILL - (SP) SAND, fine to medium, trace silt; brown; non-cohesive, moist, loose									
1		FILL - (SM) gravelly SILTY SAND; grey brown, contains organic matter, possible cobbles; non-cohesive, moist, loose		64.09 0.91	1	SS	37				Bentonite Seal
		Highly weathered BEDROCK		63.63 1.37	2	SS	>76				
2		Borehole continued on RECORD OF DRILLHOLE 21-06		63.12 1.88							
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: RI

CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-06

SHEET 2 OF 2

LOCATION: N 5026317.1 ;E 361275.1

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 30, 2021

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

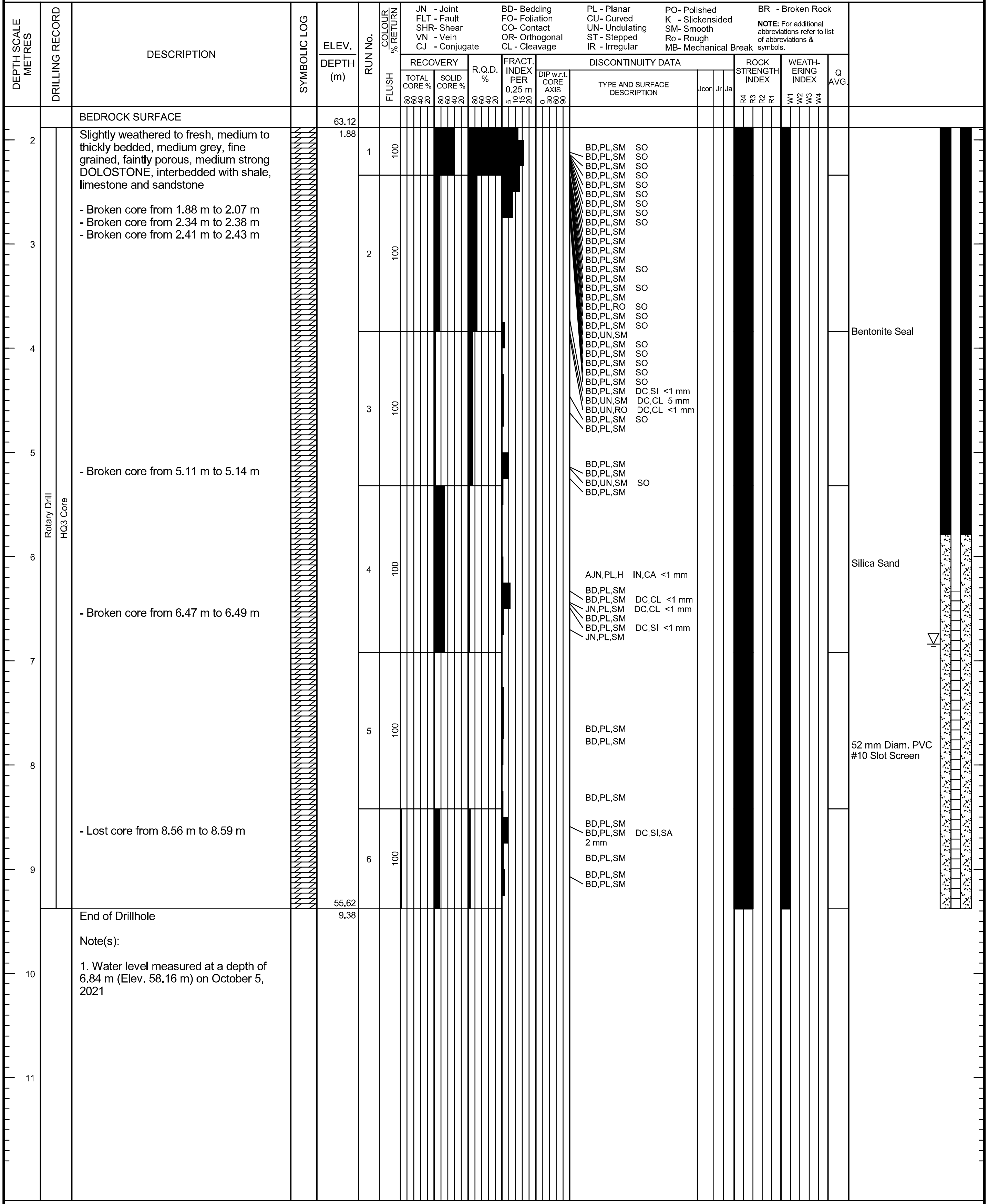
BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.



Description	Elev. / Depth (m)	Run No.	Flush % Return	Type and Surface Description	
BEDROCK SURFACE	63.12				
Slightly weathered to fresh, medium to thickly bedded, medium grey, fine grained, faintly porous, medium strong DOLOSTONE, interbedded with shale, limestone and sandstone - Broken core from 1.88 m to 2.07 m - Broken core from 2.34 m to 2.38 m - Broken core from 2.41 m to 2.43 m	1.88	1	100	BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO	
		2	100	BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM SO BD,PL,SM BD,PL,SM SO BD,PL,SM BD,PL,RO SO BD,PL,SM SO BD,PL,SM SO BD,UN,SM	Bentonite Seal
- Broken core from 5.11 m to 5.14 m		3	100	BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM SO BD,PL,SM DC,SI <1 mm BD,UN,SM DC,CL 5 mm BD,UN,RO DC,CL <1 mm BD,PL,SM SO BD,PL,SM BD,PL,SM BD,PL,SM BD,UN,SM SO BD,PL,SM	
- Broken core from 6.47 m to 6.49 m		4	100	AJN,PL,H IN,CA <1 mm BD,PL,SM BD,PL,SM DC,CL <1 mm JN,PL,SM DC,CL <1 mm BD,PL,SM BD,PL,SM DC,SI <1 mm JN,PL,SM	Silica Sand
		5	100	BD,PL,SM BD,PL,SM BD,PL,SM	52 mm Diam. PVC #10 Slot Screen
- Lost core from 8.56 m to 8.59 m	55.62 9.38	6	100	BD,PL,SM BD,PL,SM DC,SI,SA 2 mm BD,PL,SM BD,PL,SM BD,PL,SM	
End of Drillhole Note(s): 1. Water level measured at a depth of 6.84 m (Elev. 58.16 m) on October 5, 2021					

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-07

SHEET 1 OF 2

LOCATION: N 5026297.0 ;E 361328.4

BORING DATE: September 30, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	66.07					
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT	0.05					Flush Mount Casing
		FILL - (SW) gravelly SAND, angular; grey (PAVEMENT STRUCTURE); non-cohesive, moist	65.82 0.25					
		FILL - (SP) SAND, fine to medium, trace sand; brown; non-cohesive, moist	65.64 0.43					
		FILL - (SM) gravelly SILTY SAND; dark brown; non-cohesive, moist, loose	65.16 0.91					
1		Highly weathered BEDROCK		1	SS	92		Bentonite Seal
			64.45	2	SS	50/4"		
		Borehole continued on RECORD OF DRILLHOLE 21-07	1.62					
2								
3								
4								
5								
6								
7								
8								
9								
10								

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DEPTH SCALE

1 : 50

GOLDER

LOGGED: RI

CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-07

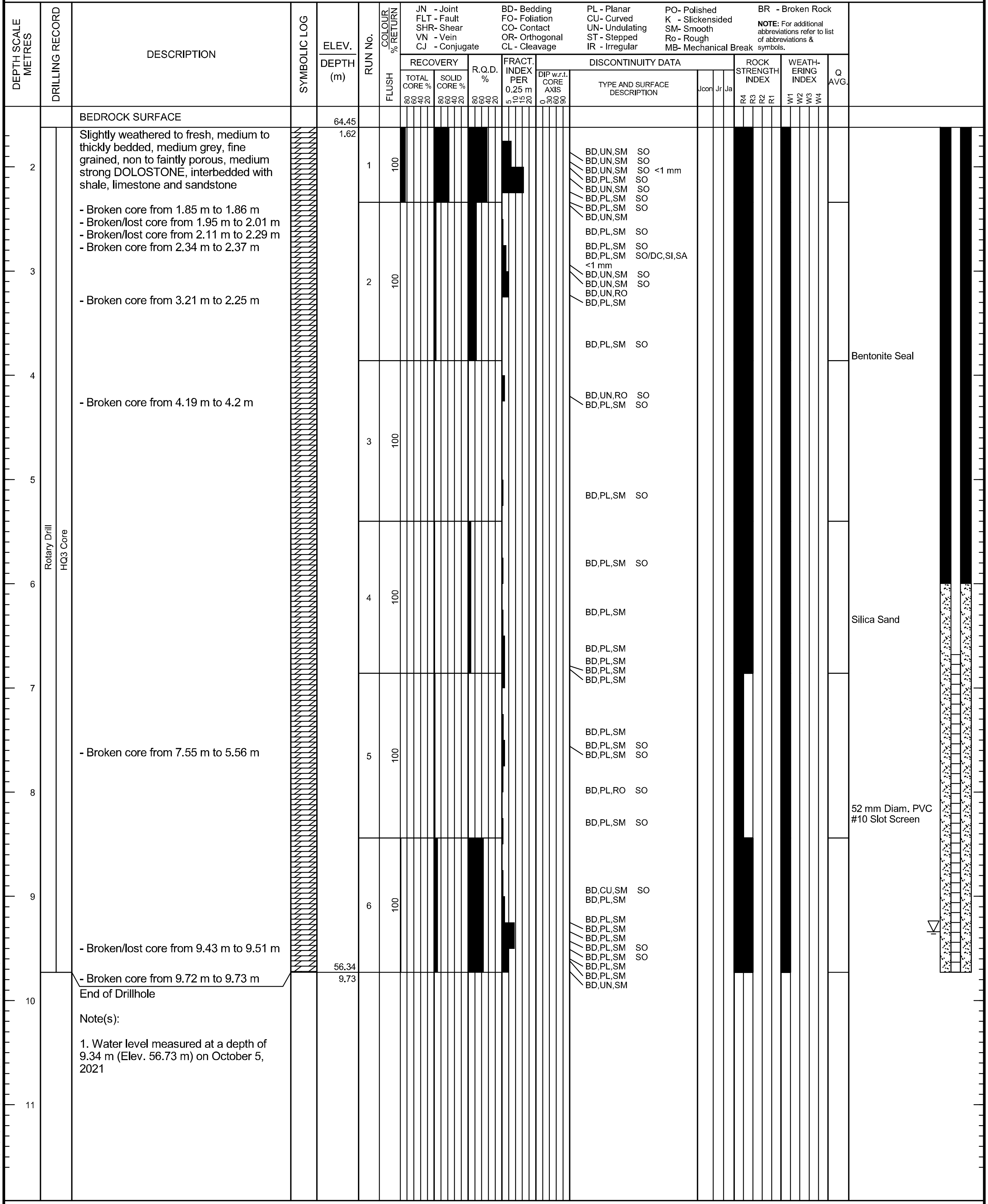
SHEET 2 OF 2

LOCATION: N 5026297.0 ;E 361328.4
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 30, 2021
DRILL RIG: CME 55
DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	



BEDROCK SURFACE — 64.45

1.62 — Slightly weathered to fresh, medium to thickly bedded, medium grey, fine grained, non to faintly porous, medium strong DOLOSTONE, interbedded with shale, limestone and sandstone

- Broken core from 1.85 m to 1.86 m
- Broken/lost core from 1.95 m to 2.01 m
- Broken/lost core from 2.11 m to 2.29 m
- Broken core from 2.34 m to 2.37 m
- Broken core from 3.21 m to 2.25 m
- Broken core from 4.19 m to 4.2 m
- Broken core from 7.55 m to 5.56 m
- Broken/lost core from 9.43 m to 9.51 m
- Broken core from 9.72 m to 9.73 m

56.34
9.73

End of Drillhole

Note(s):

1. Water level measured at a depth of 9.34 m (Elev. 56.73 m) on October 5, 2021

BD,UN,SM SO
BD,UN,SM SO
BD,UN,SM SO <1 mm
BD,PL,SM SO
BD,UN,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,UN,SM

BD,PL,SM SO

BD,PL,SM SO
BD,PL,SM SO/DC,SI,SA
<1 mm
BD,UN,SM SO
BD,UN,SM SO
BD,UN,RO
BD,PL,SM

BD,PL,SM SO

BD,UN,RO SO
BD,PL,SM SO

BD,PL,SM SO

BD,PL,SM SO

BD,PL,SM

BD,PL,SM
BD,PL,SM
BD,PL,SM
BD,PL,SM

BD,PL,SM
BD,PL,SM SO
BD,PL,SM SO

BD,PL,RO SO

BD,PL,SM SO

BD,CU,SM SO
BD,PL,SM

BD,PL,SM
BD,PL,SM
BD,PL,SM
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM
BD,PL,SM
BD,UN,SM

Bentonite Seal

Silica Sand

52 mm Diam. PVC #10 Slot Screen

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-08

SHEET 1 OF 3

LOCATION: N 5026385.1 ;E 361306.5

BORING DATE: September 28, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	64.64					
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT	0.05					
		FILL - (SW) gravelly SAND, angular; grey (PAVEMENT STRUCTURE); non-cohesive, moist	0.16					
		FILL - (SP) SAND, fine to medium, trace silt; brown; non-cohesive, moist	64.11 0.53					
1		FILL - (SM) gravelly SILTY SAND; dark brown, contains organic matter (rootlets); non-cohesive, moist, loose to compact		1	SS	6		
2		(SM) gravelly SILTY SAND; grey to grey brown, trace organic matter, weathered shale and thick laminations to thin beds of sand, fine to medium (GLACIAL TILL); non-cohesive, moist, compact to very dense	62.81 1.83	2	SS	23		
				3	SS	56		
3		Highly weathered BEDROCK	61.59 3.05	4	SS	50/ 6"		
		Borehole continued on RECORD OF DRILLHOLE 21-08	3.2					
4								
5								
6								
7								
8								
9								
10								

DEPTH SCALE

1 : 50

GOLDER

LOGGED: RI

CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-08

SHEET 2 OF 3

LOCATION: N 5026385.1 ;E 361306.5

INCLINATION: -90° AZIMUTH: ---

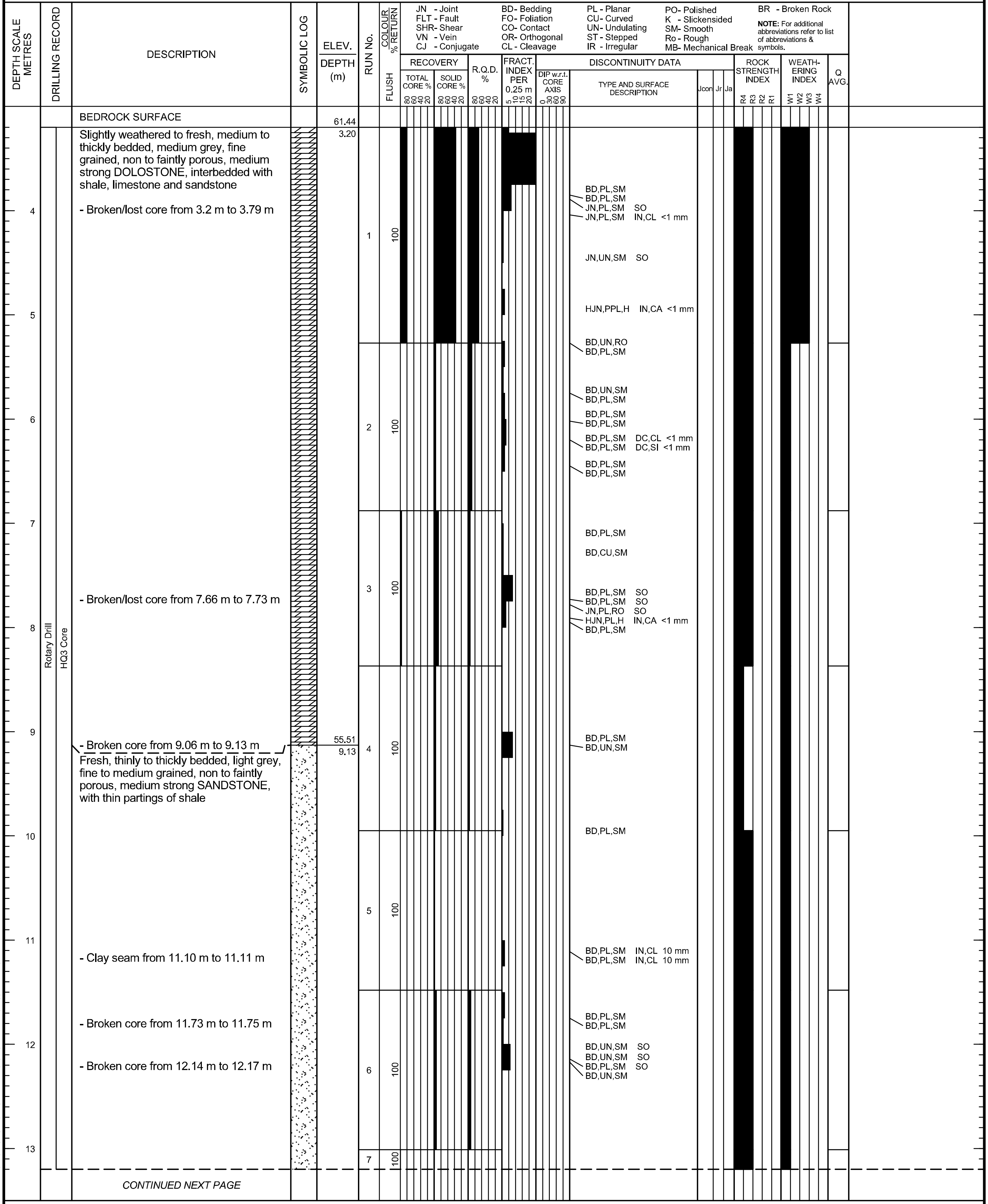
DRILLING DATE: September 28, 2021

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	



BEDROCK SURFACE — 61.44 / 3.20

Slightly weathered to fresh, medium to thickly bedded, medium grey, fine grained, non to faintly porous, medium strong DOLOSTONE, interbedded with shale, limestone and sandstone

- Broken/lost core from 3.2 m to 3.79 m

- Broken/lost core from 7.66 m to 7.73 m

- Broken core from 9.06 m to 9.13 m

55.51 / 9.13

Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE, with thin partings of shale

- Clay seam from 11.10 m to 11.11 m

- Broken core from 11.73 m to 11.75 m

- Broken core from 12.14 m to 12.17 m

Discontinuity data:

BD,PL,SM
BD,PL,SM
JN,PL,SM SO
JN,PL,SM IN,CL <1 mm

JN,UN,SM SO

HJN,PPL,H IN,CA <1 mm

BD,UN,RO
BD,PL,SM

BD,UN,SM
BD,PL,SM

BD,PL,SM
BD,PL,SM

BD,PL,SM DC,CL <1 mm
BD,PL,SM DC,SI <1 mm

BD,PL,SM
BD,PL,SM

BD,PL,SM

BD,CU,SM

BD,PL,SM SO
BD,PL,SM SO
JN,PL,RO SO
HJN,PL,H IN,CA <1 mm
BD,PL,SM

BD,PL,SM
BD,UN,SM

BD,PL,SM

BD,PL,SM IN,CL 10 mm
BD,PL,SM IN,CL 10 mm

BD,PL,SM
BD,PL,SM

BD,UN,SM SO
BD,UN,SM SO
BD,PL,SM SO
BD,UN,SM

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-08

SHEET 3 OF 3

LOCATION: N 5026385.1 ;E 361306.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 28, 2021

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25 m 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	ROCK STRENGTH INDEX R4 R3 R2 R1	WEATHERING INDEX W1 W2 W3 W4	Q AVG.
		--- CONTINUED FROM PREVIOUS PAGE ---																
14	Rotary Drill HQ3 Core	Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE, with thin partings of shale - Lost core from 13.59 m to 13.60 m			7	100						BD,PL,SM SO BD,UN,SM SO BD,UN,SM SO						
15				49.15	8	100						BD,UN,RO						
16 17 18 19 20 21 22 23		End of Drillhole		15.49														

DEPTH SCALE
1 : 50

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-09

SHEET 1 OF 3

LOCATION: N 5026279.3 ;E 361293.7

BORING DATE: September 29, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		65.90					
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALT		0.05					Flush Mount Casing
		FILL - (SW) gravelly SAND, angular; grey (PAVEMENT STRUCTURE)		65.65 0.25					
		FILL - (SP) SAND, fine to medium, trace to some silt; brown; non-cohesive, moist		65.34 0.56					
1		FILL - (SM/ML) gravelly SILTY SAND to sandy SILT; brown to dark brown, contains weathered shale and organic matter; non-cohesive, moist, loose			1	SS	5		Bentonite Seal
		Highly weathered BEDROCK		64.38 1.52	2	SS	50/ 5"		
		Borehole continued on RECORD OF DRILLHOLE 21-09		1.65					
2									
3									
4									
5									
6									
7									
8									
9									
10									

DEPTH SCALE

1 : 50

GOLDER

LOGGED: RI

CHECKED: AG

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PROJECT: 21494078

RECORD OF DRILLHOLE: 21-09

SHEET 2 OF 3

LOCATION: N 5026279.3 ;E 361293.7

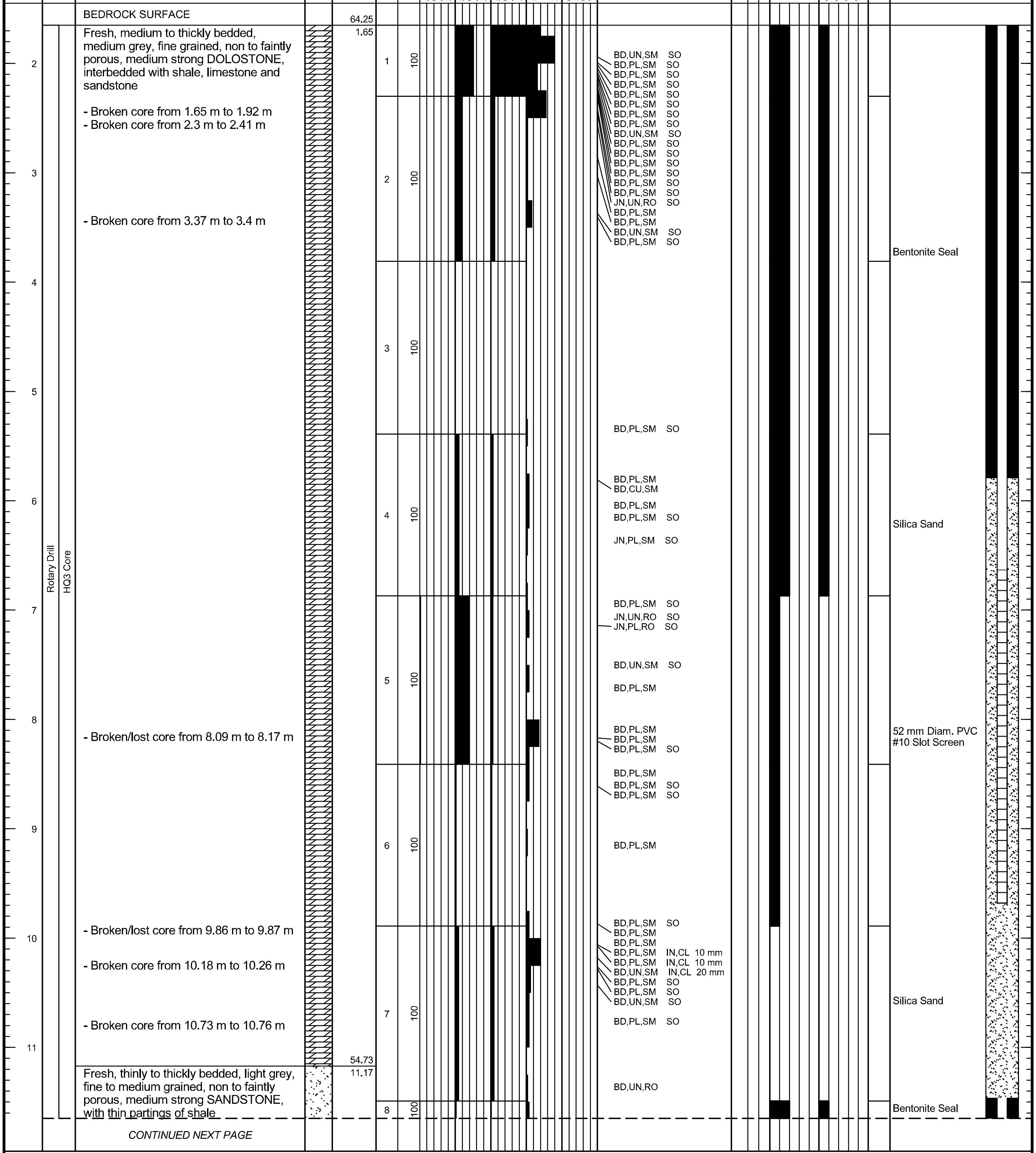
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 29, 2021
DRILL RIG: CME 55
DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Cleavage
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
Ro - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.



Depth (m)	Elev.	Description
	64.25	BEDROCK SURFACE
1.65		Fresh, medium to thickly bedded, medium grey, fine grained, non to faintly porous, medium strong DOLOSTONE, interbedded with shale, limestone and sandstone - Broken core from 1.65 m to 1.92 m - Broken core from 2.3 m to 2.41 m - Broken core from 3.37 m to 3.4 m - Broken/lost core from 8.09 m to 8.17 m - Broken/lost core from 9.86 m to 9.87 m - Broken core from 10.18 m to 10.26 m - Broken core from 10.73 m to 10.76 m
11.17	54.73	Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE, with thin partings of shale

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Discontinuity data:

BD,UN,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,UN,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM SO
JN,UN,RO SO
BD,PL,SM
BD,PL,SM
BD,UN,SM SO
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM
BD,CU,SM
BD,PL,SM
BD,PL,SM SO
JN,PL,SM SO
BD,PL,SM SO
JN,UN,RO SO
JN,PL,RO SO
BD,UN,SM SO
BD,PL,SM
BD,PL,SM
BD,PL,SM
BD,PL,SM SO
BD,PL,SM
BD,PL,SM SO
BD,PL,SM SO
BD,PL,SM
BD,PL,SM SO
BD,PL,SM
BD,PL,SM
BD,PL,SM IN,CL 10 mm
BD,PL,SM IN,CL 10 mm
BD,UN,SM IN,CL 20 mm
BD,PL,SM SO
BD,PL,SM SO
BD,UN,SM SO
BD,PL,SM SO
BD,UN,RO

Installation:

Bentonite Seal
Silica Sand
52 mm Diam. PVC #10 Slot Screen
Silica Sand
Bentonite Seal

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-09

SHEET 3 OF 3

LOCATION: N 5026279.3 ;E 361293.7

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 29, 2021
DRILL RIG: CME 55
DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	
		--- CONTINUED FROM PREVIOUS PAGE ---					
12–15.5	Rotary Drill HQ3 Core	Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE, with thin partings of shale - Broken core from 11.67 m to 11.68 m - Lost core from 12.42 m to 12.43 m - Broken core from 13.84 m to 13.85 m	50.40 15.50	8 9 10	100 100 100	BD,UN,SM BD,UN,SM BD,UN,RO BD,UN,SM BD,UN,SM BD,PL,SM SO	Bentonite Seal
		End of Drillhole Note(s): 1. Borehole was dry on October 5, 2021					

Column headings: RECOVERY (TOTAL CORE %, SOLID CORE %; 80 60 40 20) · R.Q.D. % (80 60 40 20) · FRACT. INDEX PER 0.25 m (5 10 15 20) · DIP w.r.t. CORE AXIS (0 30 60 90) · Jcon Jr Ja · ROCK STRENGTH INDEX (R4 R3 R2 R1) · WEATHERING INDEX (W1 W2 W3 W4) · Q AVG. · SYMBOLIC LOG

Depth scale: 12 13 14 15 16 17 18 19 20 21

MIS-RCK 004 21494078.GPJ GAL-MISS.GDT 12/16/21 ZS

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF BOREHOLE: 21-10

SHEET 1 OF 3

LOCATION: N 5026360.8 ;E 361363.7

BORING DATE: September 29, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢——O^W——⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	65.89
ASPHALT	0.05
FILL - (SM) gravelly SILTY SAND; brown; non-cohesive, moist	65.15 0.74
FILL - (SM) gravelly SILTY SAND; grey brown, trace organic matter; non-cohesive, moist, compact	64.37 1.52
(SM) gravelly SILTY SAND; grey brown, contains cobbles and boulders (GLACIAL TILL); non cohesive, moist, dense to very dense	61.09 4.8
Borehole continued on RECORD OF DRILLHOLE 21-10	

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	10
2	SS	46
3	SS	73
4	RC	DD
5	RC	DD
6	SS	>50

PIEZOMETER OR STANDPIPE INSTALLATION:

Flush Mount Casing

Bentonite Seal

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-10

SHEET 2 OF 3

LOCATION: N 5026360.8 ;E 361363.7

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 29, 2021
DRILL RIG: CME 55
DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

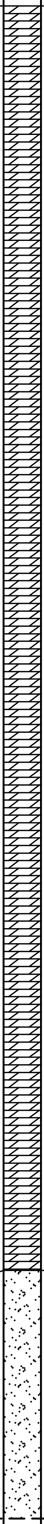
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

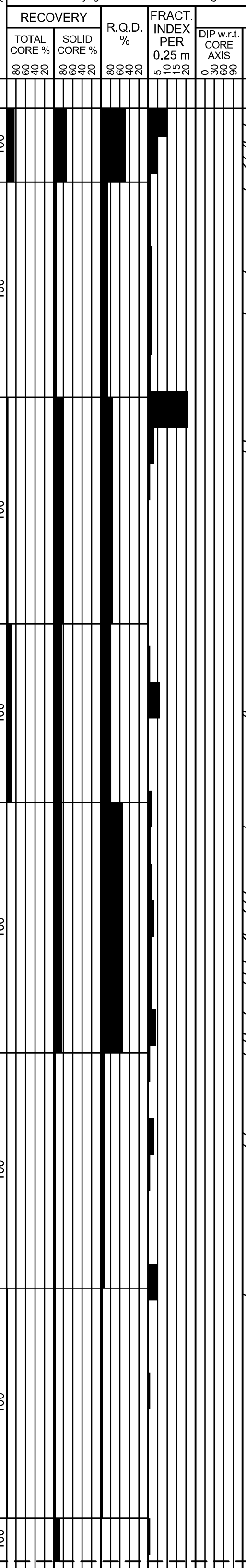
PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

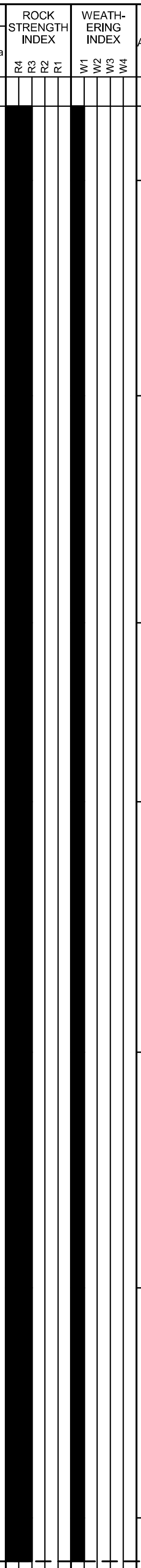
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN FLUSH	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	
		BEDROCK SURFACE	61.09 4.80				
5	Rotary Drill HQ3 Core	Fresh, medium to thickly bedded. medium grey, fine grained, non to faintly porous, medium strong DOLOSTONE, interbedded with shale, limestone and sandstone - Broken/lost core from 4.8 m to 4.88 m - Broken core from 5.03 m to 5.05 m		1	100	BD,PL,SM BD,CU,SM SO BD,CU,SM SO BD,UN,SM BD,PL,SM SO BD,PL,SM SO BD,UN,SM CC,CA <1 mm	
6				2	100	HJN,PL,H IN,CA <1 mm BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM HJN,PL,H IN BD,PL,SM Ca 3-5 mm BD,PL,SM	
7		- Broken/lost core from 6.79 m to 7.02 m - Broken core from 7.09 m to 7.16 m		3	100	BD,CU,SM BD,PL,SM DC,CL <1 mm BD,PL,RO BD,PL,SM BD,PL,SM	Bentonite Seal
8						BD,PL,SM	
9		- Broken/lost core from 8.72 m to 8.88 m - Broken core from 8.93 m to 8.97 m		4	100	BD,PL,RO BD,PL,SM BD,UN,SM BD,PL,SM	▽
10				5	100	BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,SM BD,PL,RO BD,PL,SM BD,CU,SM BD,CU,SM BD,UN,SM BD,PL,SM BD,CU,SM	
11						BD,PL,SM BD,UN,SM BD,PL,SM BD,UN,SM BD,PL,SM	Silica Sand
12				6	100	BD,PL,SM BD,CU,SM DC,SI <1 mm BD,CU,SM BD,UN,SM DC,SI <1 mm	
13		- Broken/lost core from 12.92 m to 12.96 m	52.73 13.16			BD,UN,SM BD,UN,SM	
		Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE with thin partings of shale		7	100	BD,PL,SM	52 mm Diam. PVC #10 Slot Screen
14						JN,PL,RO	
				8	100		





Jcon Jr Ja



Q AVG.

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

PROJECT: 21494078

RECORD OF DRILLHOLE: 21-10

SHEET 3 OF 3

LOCATION: N 5026360.8 ;E 361363.7

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 29, 2021

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
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PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25 m 5 10 15 20	DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	ROCK STRENGTH INDEX R4 R3 R2 R1	WEATHERING INDEX W1 W2 W3 W4	Q AVG.	
		--- CONTINUED FROM PREVIOUS PAGE ---																	
15	Rotary Drill HQ3 Core	Fresh, thinly to thickly bedded, light grey, fine to medium grained, non to faintly porous, medium strong SANDSTONE with thin partings of shale		50.44 15.45	8	100						JN,PL,RO							52 mm Diam. PVC #10 Slot Screen
		End of Drillhole Note(s): 1. Water level measured at a depth 8.85 m (Elev. 57.04 m) on October 5, 2021																	
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			
24																			

MIS-RCK 004 21494078.GPJ GAL-MISS.GDT 12/16/21 ZS

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RI
CHECKED: AG

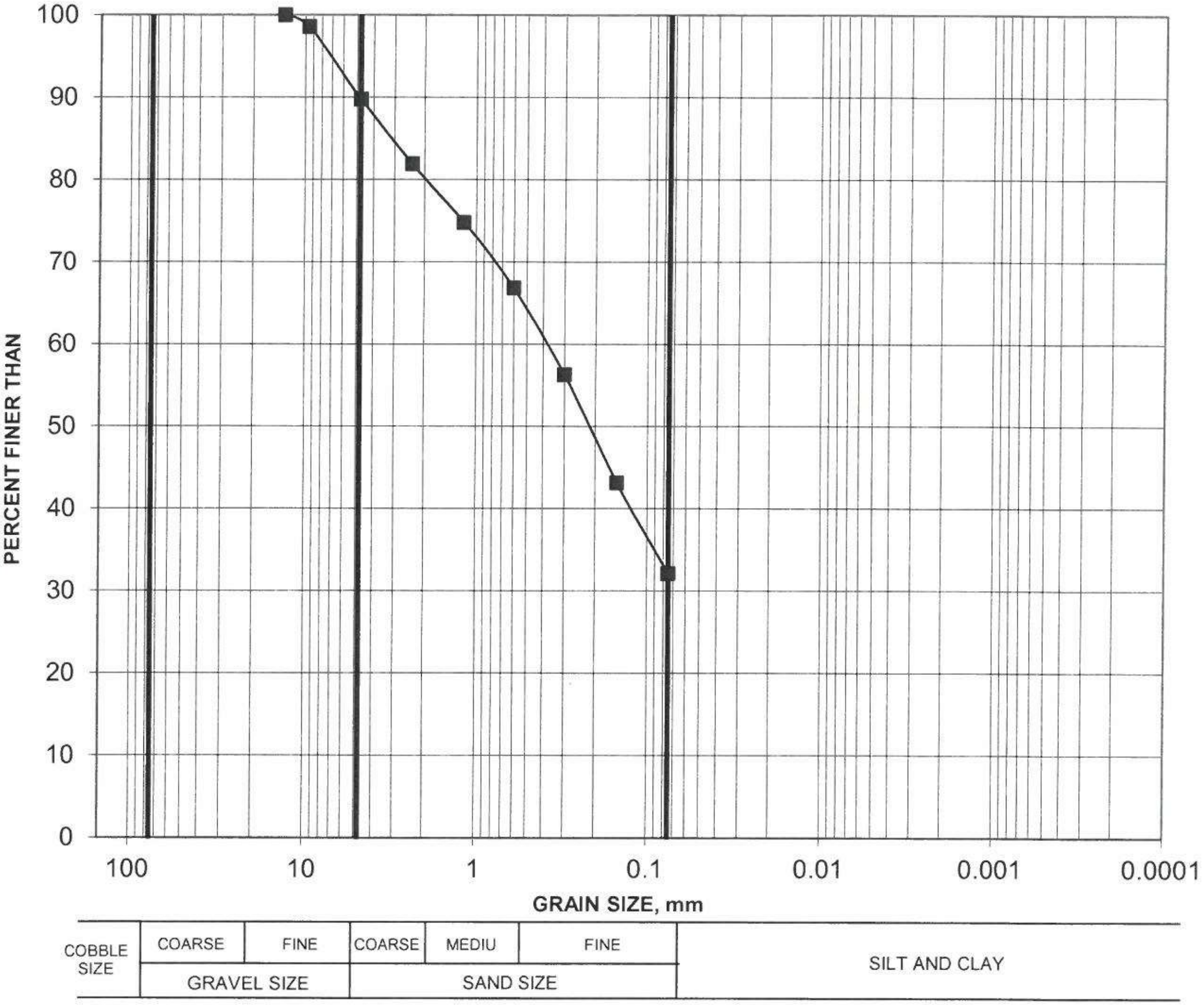
APPENDIX D

GEOTECHNICAL LABORATORY TEST RESULTS

GRAIN SIZE DISTRIBUTION

FIGURE B-1

SILTY SAND (FILL)



				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
■	21-01	2	0.61-1.22	10	58	32	

Project: 21494078/3000

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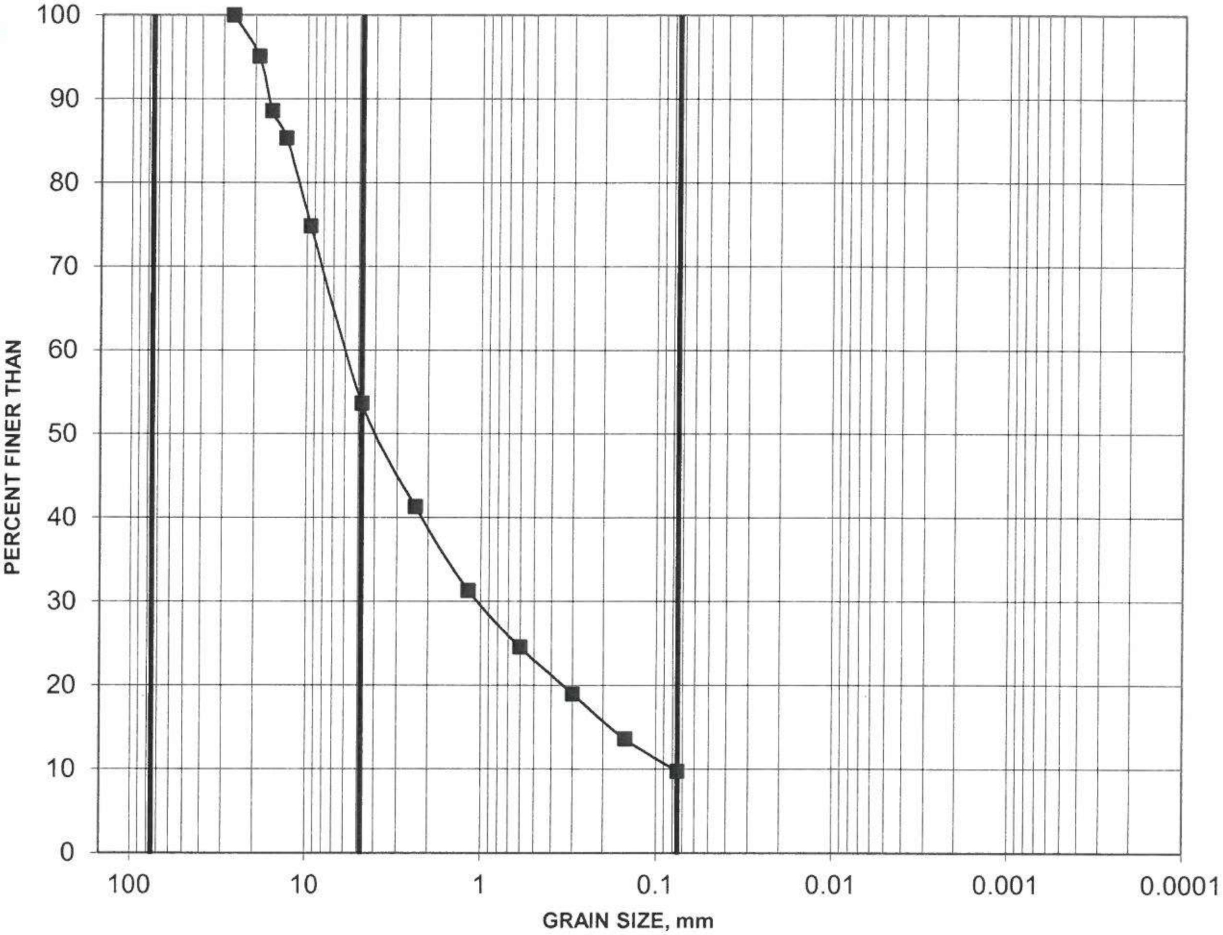
MEMBER OF WSP

Created by:
Checked by: SB

GRAIN SIZE DISTRIBUTION

FIGURE
B-2

GRAVELLY SAND (FILL)



COBBLE SIZE	COARSE	FINE	COARSE	MEDIU	FINE	SILT AND CLAY
	GRAVEL SIZE		SAND SIZE			

				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■—	21-02	3	1.22-1.83	46	44	10	

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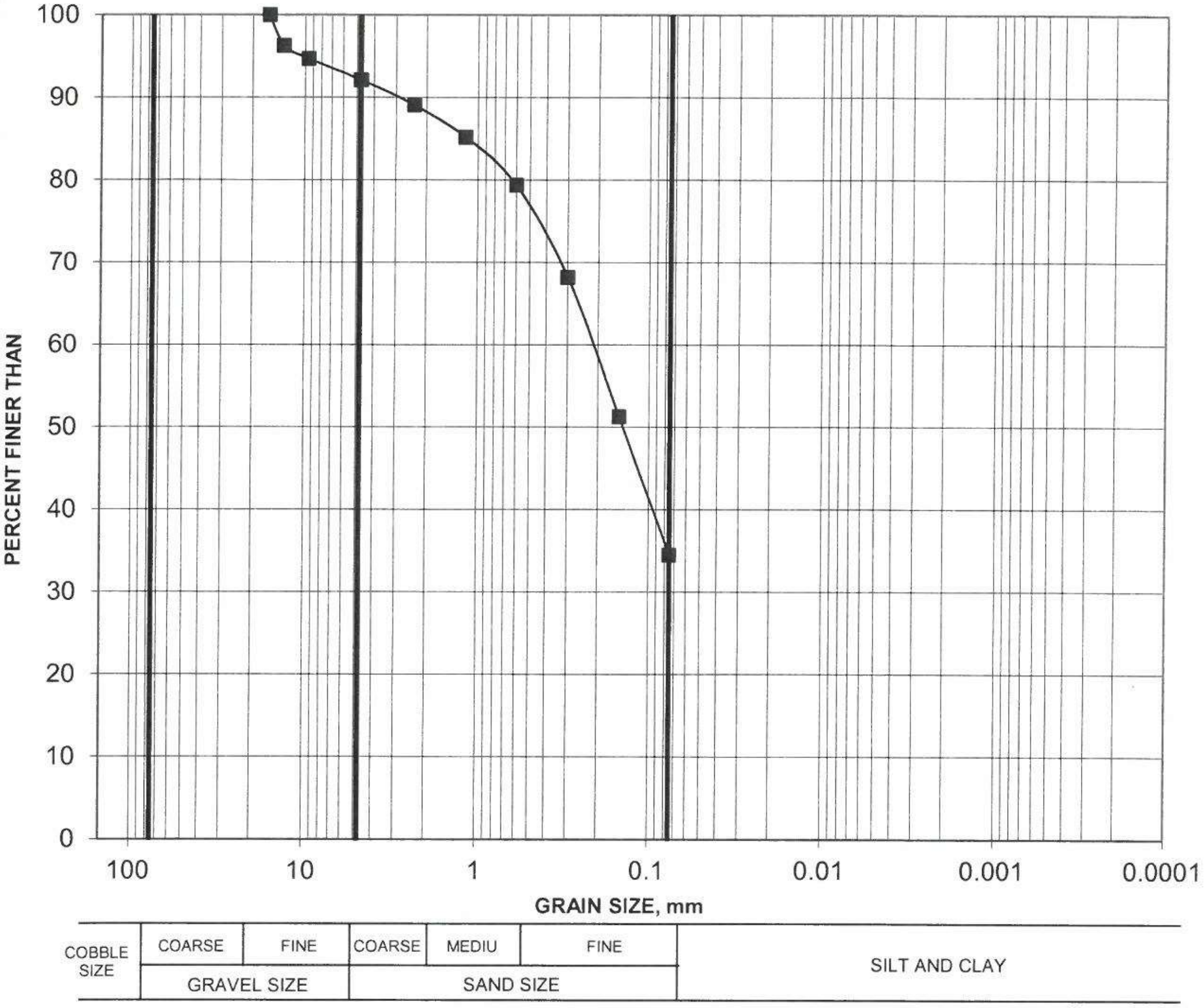
MEMBER OF WSP

Project: 21494078

Created by: CW
Checked by: JB

GRAIN SIZE DISTRIBUTION	FIGURE B-3

SILTY SAND (GLACIAL TILL)



				Constituents (%)		
Borehole		Sample	Depth (m)	Gravel	Sand	Silt	Clay
■	21-08	3A	2.29-2.44	8	57	35	

Project: 21494078

GOLDER
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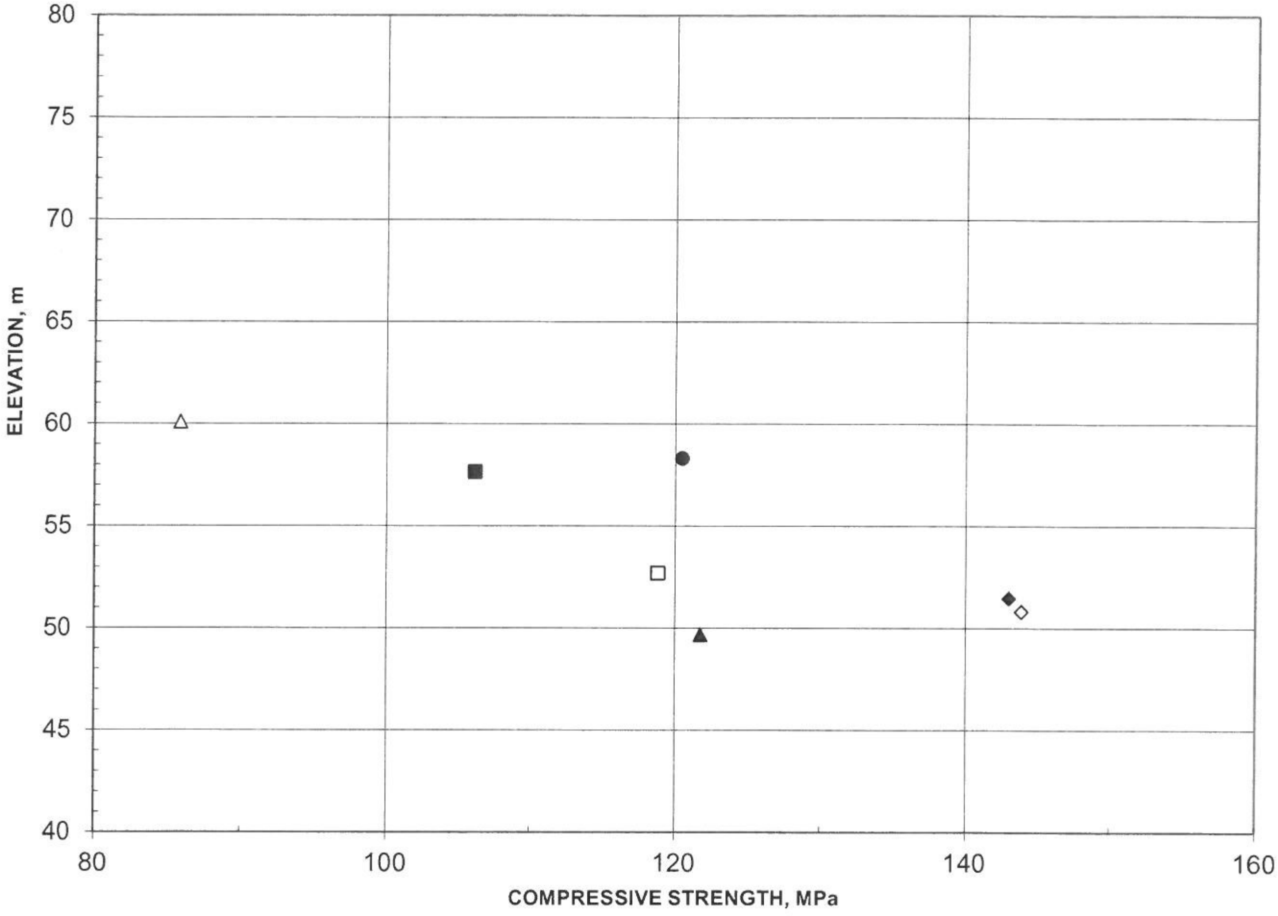
ASTM D7012 - Method C
UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE
SUMMARY OF LABORATORY TEST RESULTS

FIGURE
B-4



	Borehole	Depth (m)	L/D	Bulk Density (kg/m^3)	Lithology	UCS (MPa)	Failure Type
■	BH21-06 RC1	7.4	2.1	2669	shale/limestone	106	1
◆	BH21-08 RC1	13.2	2.1	2610	limestone	143	1
▲	BH21-08 RC2	15.0	2.1	2580	limestone	122	1
●	BH21-09 RC1	7.6	2	2640	limestone	120	1
□	BH21-09 RC2	13.2	2.0	2500	limestone	119	1
◇	BH21-09 RC3	15.1	2	2542	limestone	144	1
△	BH21-10 RC1	5.8	2.1	2671	shale/limestone	86	1

Notes:

Failure Types

1. Well formed cones on both ends
2. Well formed cones on one end, vertical cracks through cap
3. Columnar vertical craking through both ends
4. Diagonal fracture with no cracking through ends
5. Side fractures at top or bottom
6. Side fractures at both sides of top or bottom

Remarks

- Cores tested in vertical direction.
- Cores tested in air-dry condition.
- Time to failure > 2 and < 15 minutes.

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MEMBER OF WSP

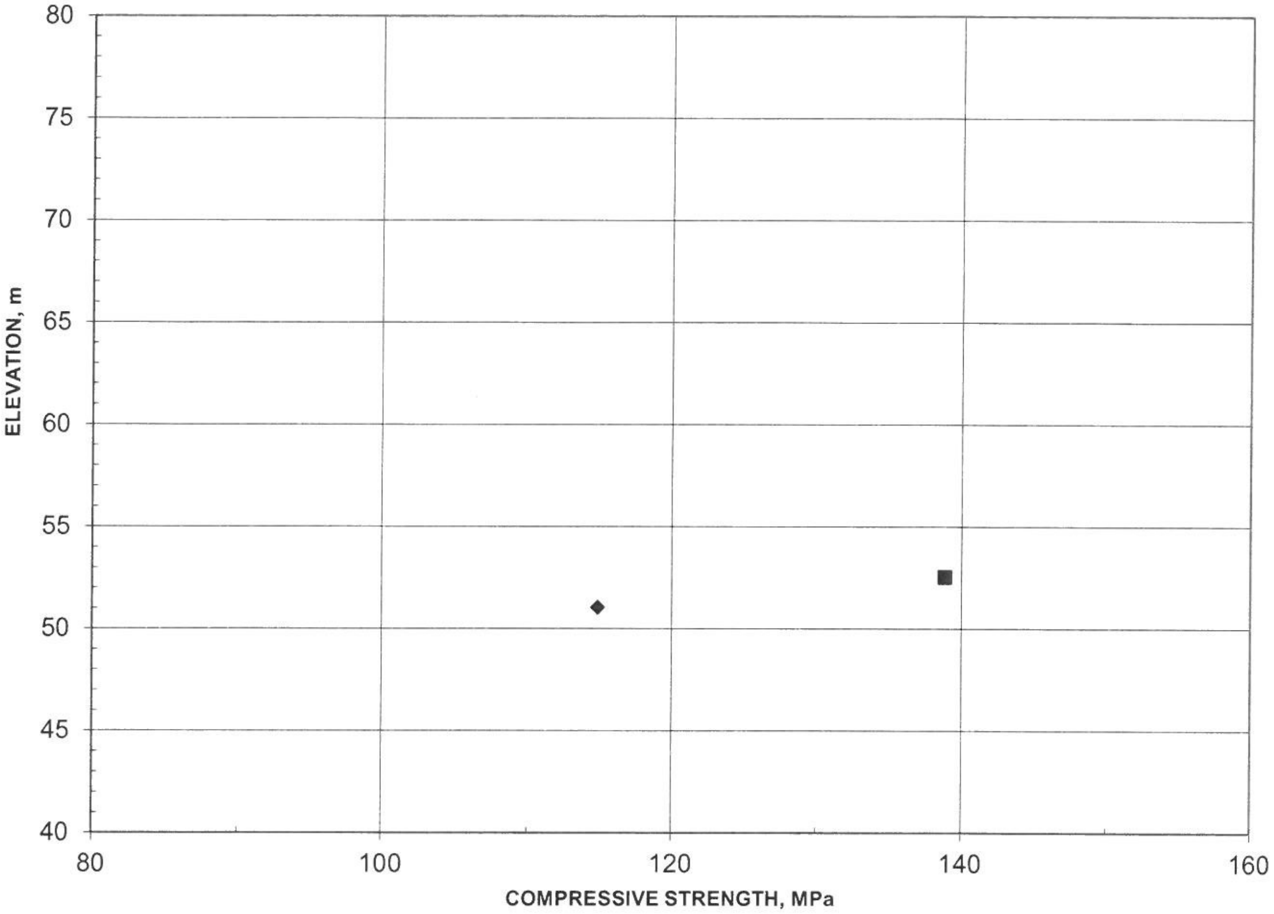
Created by:	CW
Checked by:	JB

Project: 21494078/3000

https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2021/21494078/

ASTM D7012 - Method C
UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE
SUMMARY OF LABORATORY TEST RESULTS

FIGURE
B-5



	Borehole	Depth (m)	L/D	Bulk Density (kg/m^3)	Lithology	UCS (MPa)	Failure Type
—■—	BH21-10 RC2	13.3	2.2	2550	limestone	139	1
—◆—	BH21-10 RC3	14.8	2.2	2543	limestone	115	1

Notes:

Failure Types

1. Well formed cones on both ends
2. Well formed cones on one end, vertical cracks through cap
3. Columnar vertical craking through both ends
4. Diagonal fracture with no cracking through ends
5. Side fractures at top or bottom
6. Side fractures at both sides of top or bottom

Remarks

- Cores tested in vertical direction.
- Cores tested in air-dry condition.
- Time to failure > 2 and < 15 minutes.

Project: 21494078/3000

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MEMBER OF WSP

Created by:	CW
Checked by:	JB

https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2021/21494078/

APPENDIX E

ROCK CORE PHOTOS

BH 21-06 (Dry)
Rock core from a depth of 1.9 m to 9.4 m
Core Box 1 to 3 of 3

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Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

Ottawa, ON

Project No.	21494078
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Date:	2021-10-08
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Review:	WC

BH 21-06
1 to 3 of 3

BH 21-06 (Wet)
Rock core from a depth of 1.9 m to 9.4 m
Core Box 1 to 3 of 3

1.9 m

9.4 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

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Ottawa, ON

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BH 21-06
1 to 3 of 3

BH 21-07 (Dry)
Rock core from a depth of 1.6 m to 9.7 m
Core Box 1 to 3 of 3

1.6 m

9.7 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

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BH 21-07
1 to 3 of 3

BH 21-07 (Wet)
Rock core from a depth of 1.6 m to 9.7 m
Core Box 1 to 3 of 3

1.6 m

9.7 m

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BH 21-07
1 to 3 of 3

BH 21-08 (Dry)
Rock core from a depth of 3.2 m to 11.2 m
Core Box 1 to 3 of 5

3.2 m

11.2 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

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Ottawa, ON

Project No.	21494078
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Date:	2021-10-08
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BH 21-08
1 to 3 of 5

BH 21-08 (Dry)
Rock core from a depth of 11.2 m to 15.5 m
Core Box 4 to 5 of 5

11.2 m

15.5 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

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Ottawa, ON

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Date:	2021-10-08
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Review:	WC

BH 21-08
4 to 5 of 5

BH 21-08 (Wet)
Rock core from a depth of 3.2 m to 11.2 m
Core Box 1 to 3 of 5

3.2 m

11.2 m

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BH 21-08
1 to 3 of 5

BH 21-08 (Wet)
Rock core from a depth of 11.2 m to 15.5 m
Core Box 4 to 5 of 5

11.2 m

15.5 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

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Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
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Review:	WC

BH 21-08
4 to 5 of 5

BH 21-09 (Dry)
Rock core from a depth of 1.6 m to 10.0 m
Core Box 1 to 3 of 5

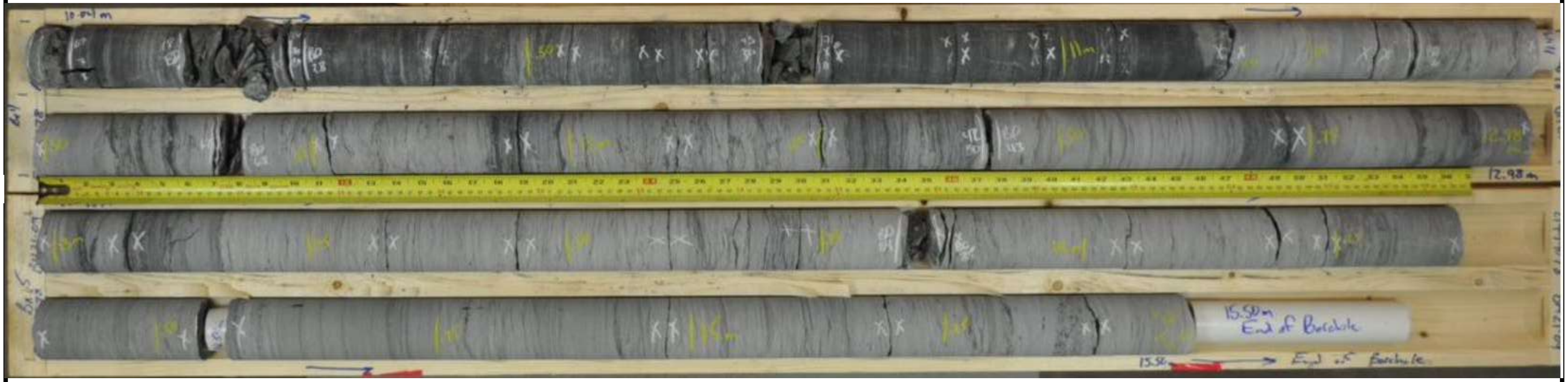
1.6 m

10.0 m

GOLDER	**Environmental Assessment, Geotechnical and Hydrogeological Investigation** **21494078- Fengate Ph One Two RSC Richmond** **Ottawa, ON**	Project No. 21494078 Drawn: AG Date: 2021-10-08 Checked: AG Review: WC	**BH 21-09** **1 to 3 of 5**

BH 21-09 (Dry)
Rock core from a depth of 10.0 m to 15.5 m
Core Box 4 to 5 of 5

10.0 m



15.5 m

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Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
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Review:	WC

BH 21-09
4 to 5 of 5

BH 21-09 (Wet)
Rock core from a depth of 1.6 m to 10.0 m
Core Box 1 to 3 of 5

1.6 m

10.0 m

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Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
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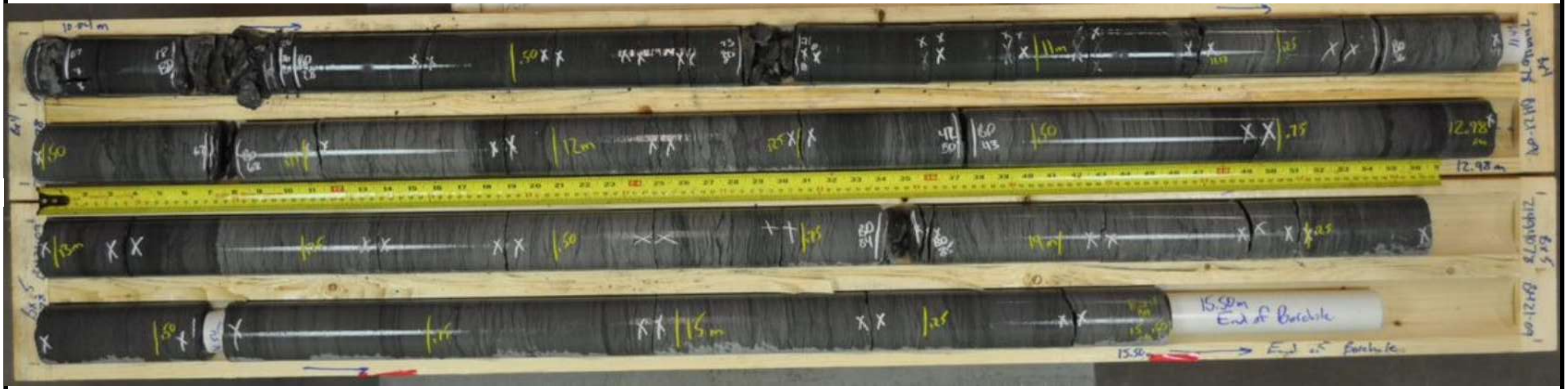
Review:	WC

BH 21-09
1 to 3 of 5

BH 21-09 (Wet)
Rock core from a depth of 10.0 m to 15.5 m
Core Box 4 to 5 of 5

10.0 m



15.5 m

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Date:	2021-10-08
Checked:	AG
Review:	WC

BH 21-09
4 to 5 of 5

BH 21-10 (Dry)
Rock core from a depth of 2.7 m to 12.1 m
Core Box 1 to 3 of 5

2.7 m

12.1 m

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Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

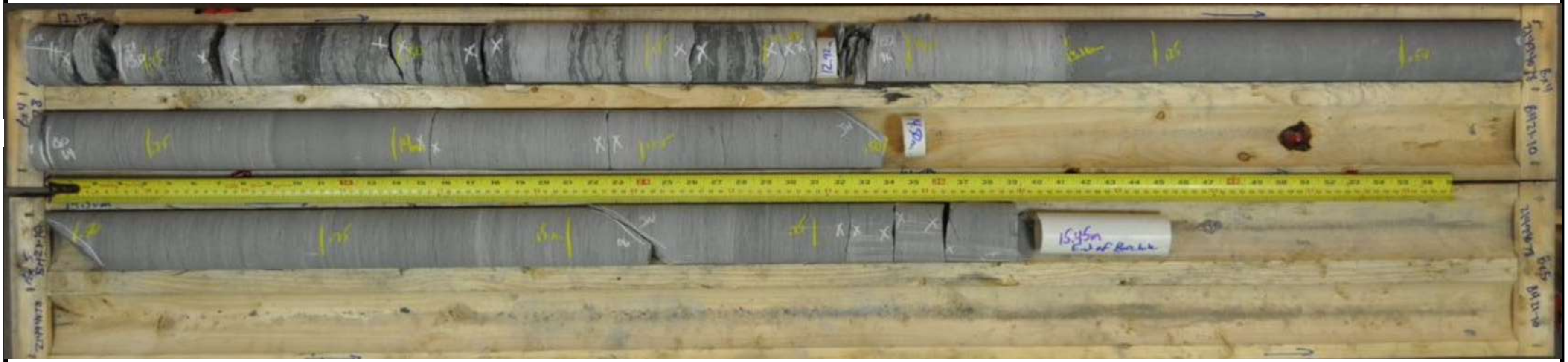
Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
Checked:	AG
Review:	WC

BH 21-10
1 to 3 of 5

BH 21-10 (Dry)
Rock core from a depth of 12.1 m to 15.4 m
Core Box 4 to 5 of 5

12.1 m



15.4 m

Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
Checked:	AG
Review:	WC

BH 21-10
4 to 5 of 5

BH 21-10 (Wet)
Rock core from a depth of 2.7 m to 12.1 m
Core Box 1 to 3 of 5

2.7 m

12.1 m

GOLDER

Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
Checked:	AG
Review:	WC

BH 21-10
1 to 3 of 5

BH 21-10 (Wet)
Rock core from a depth of 12.1 m to 15.4 m
Core Box 4 to 5 of 5

12.1 m

15.4 m

GOLDER

Environmental Assessment, Geotechnical and Hydrogeological Investigation

21494078- Fengate Ph One Two RSC Richmond

Ottawa, ON

Project No.	21494078
Drawn:	AG
Date:	2021-10-08
Checked:	AG
Review:	WC

BH 21-10
4 to 5 of 5

APPENDIX F

RESULTS OF GEOPHYSICS TESTING

GOLDER
MEMBER OF WSP

TECHNICAL MEMORANDUM

DATE October 27, 2021 21494078

TO Ali Ghirian
Golder Associates Ltd.

FROM Peter Giamou, Christopher Phillips **EMAIL pgiamou@golder.com; cphillips@golder.com**

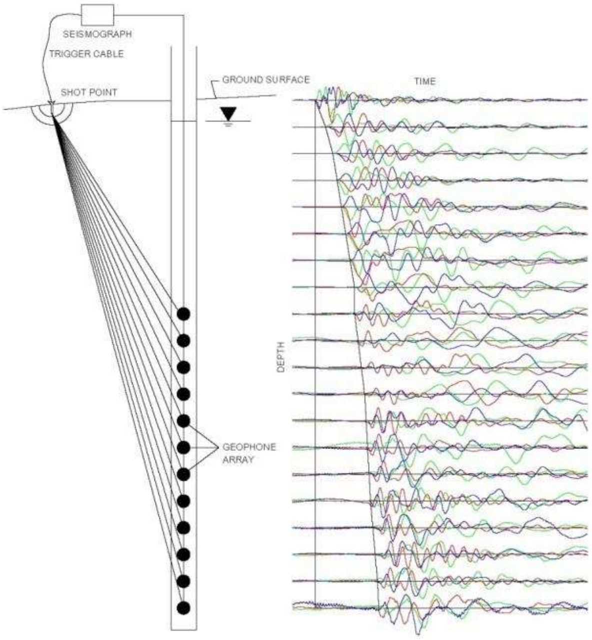
VERTICAL SEISMIC PROFILING RESULTS
1047 RICHMOND ROAD, OTTAWA, ONTARIO

This memorandum presents the results of two Vertical Seismic Profiling (VSP) testing carried out in Borehole 21-08 at 1047 Richmond Road, Ottawa, Ontario. VSP testing was carried out on October 6, 2021. Borehole 21-08 was drilled to an approximate depth of 15 m below the existing ground surface and then cased with a 2.5 inch PVC pipe grouted in place. The borehole consisted of approximately 3.2 m of sandy silt over dolostone and sandstone bedrock to the bottom of the borehole.

Methodology

For the VSP method, seismic energy is generated at the ground surface by an active seismic source and recorded by a geophone located in a nearby borehole at a known depth. The active seismic source can be either compression or shear wave. The time required for the energy to travel from the source to the receiver (geophone) provides a measurement of the average compression or shear-wave seismic velocity of the medium between the source and the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole.

The high-resolution results of a VSP survey are often used for earthquake engineering site classification, as per the National Building Code of Canada (NBCC).



Example 1: Layout and resulting time traces from a VSP survey.

Field Work

The field work was carried out on October 6, 2021, by personnel from the Golder Mississauga office.

At Borehole 21-08, compression and shear-wave seismic energy were generated from a sledge-hammer located 2.00 m from the borehole. The seismic source for the shear-wave test consisted of a 2.4-metre-long, 150 millimetre by 150 millimetre wooden beam, weighted by a vehicle and horizontally struck with a 9.9 Kg sledge-hammer on alternate ends of the beam to induce polarized shear waves. Test measurements started at ground surface and were recorded in the borehole with a 3-component receiver spaced at 1-metre intervals below the ground surface to the maximum depth of the casing (15 m).

The seismic records collected for each source location were stacked a minimum of three times to minimize the effects of ambient background seismic noise on the collected data. The data was sampled at 0.020833 millisecond intervals and a total time window of 0.341 seconds was collected for each seismic shot.

Data Processing

Processing of the VSP test results consisted of the following main steps:

1) Compilation of seismic records to present seismic traces for all depth intervals on a single plot for each seismic source and for each component;
2) Low Pass Filtering of data to remove spurious high-frequency noise;
3) First-break picking of the compression and shear-wave arrivals; and,
4) Calculation of the average compression and shear-wave velocity to each tested depth interval.

Processing of the VSP data was completed using the SeisImager/SW software package (Geometrics Inc.). The seismic records from Borehole 21-08 are presented on the following two plots and show the first-break picks of the compression wave (Figure 1) and shear wave arrivals (Figure 2) overlaid on the seismic waveform traces recorded at the different geophone depths. The arrivals were picked on the vertical component for the compression source and on the two horizontal components for the shear source.

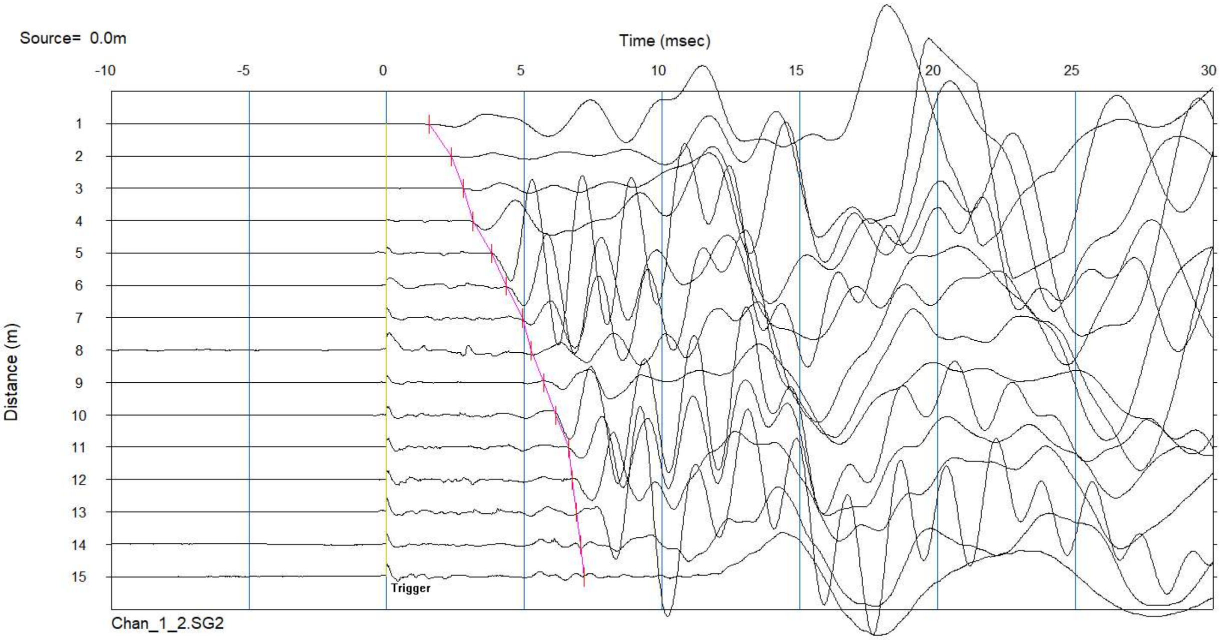


Figure 1: First-break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 21-08.

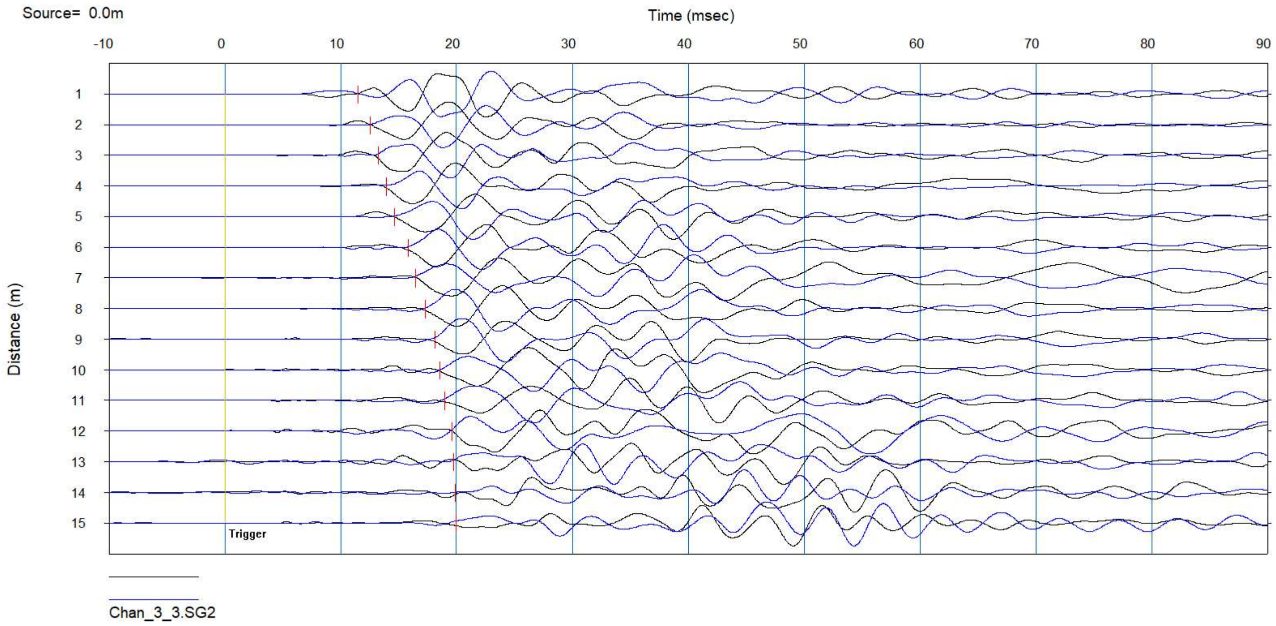


Figure 2: First-break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 21-08.

Results

The VSP results at Borehole 21-08 are summarized in Table 1. The shear wave and compression wave layer velocities were calculated by best-fitting a theoretical travel time model to the field data. The depths presented on the table are relative to ground surface.

The estimated dynamic engineering moduli, based on the calculated wave velocities, are also presented in Table 1. The engineering moduli were calculated using an estimated bulk density, based on the borehole log. An estimated bulk density of 2000 kg/m^3 was used for the overburden and an estimated bulk density of 2,600 kg/m^3 was used for the limestone bedrock.

At Borehole 21-08 the average shear wave velocity from ground surface to a depth of 30 metres was measured to be 1,171 metres per second. The average velocity at Borehole BH 21-08 was calculated assuming that the velocity from 15 metres to a depth of 30 metres was constant with an average shear-wave velocity value of 2,800 m/s which is equal to the velocity at the bottom of the borehole.

Limitations

This technical memorandum, which specifically includes all tables, figures and attachments, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

Closure

We trust that these results meet your current needs. If you have any questions or require clarification, please contact the undersigned at your convenience.

Golder Associates Ltd.

Peter Giamou, B.Sc.,P. Geo
Senior Geophysicst
PG/CRP/jl

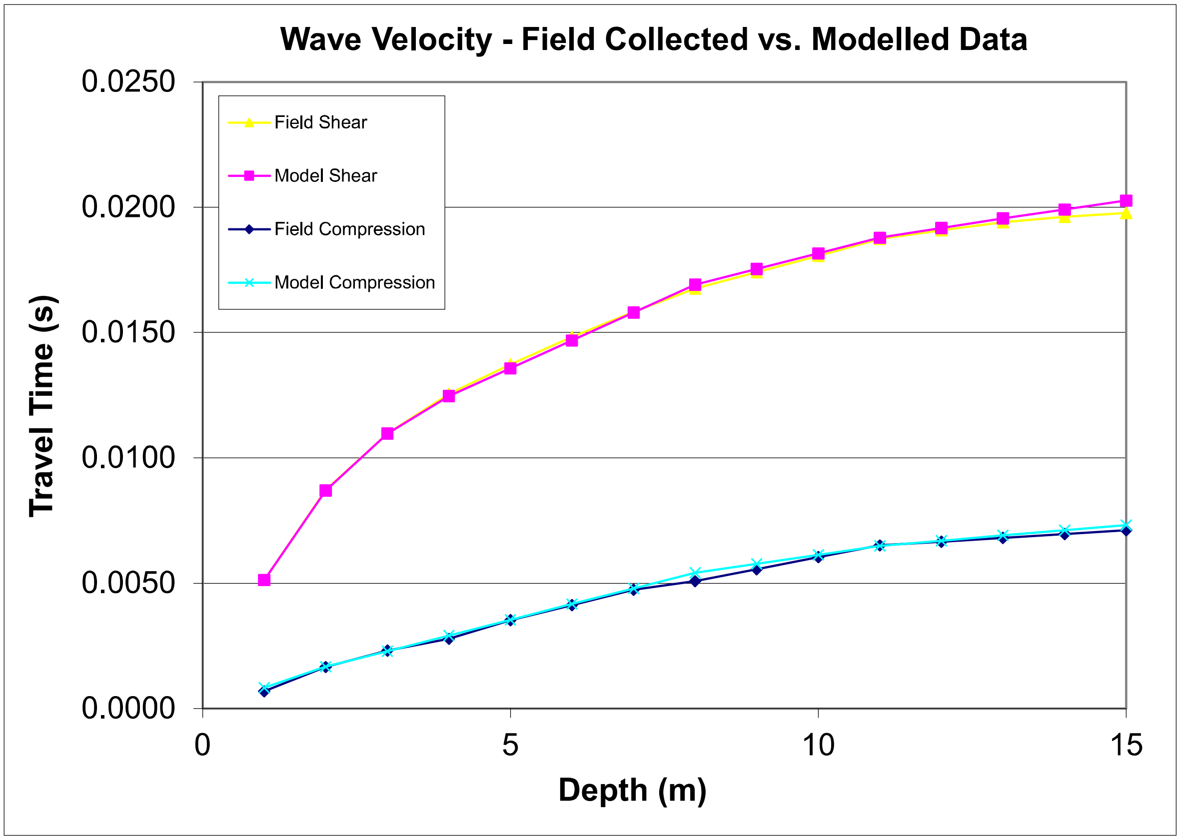
Christopher Phillips,M.Sc., P.Geo
Senior Geophysicist

Attachments: Table 1 – VSP Modeller BH 21-08

https://golderassociates.sharepoint.com/sites/152441/project files/5 technical work/geotechnical_1047 richmond rd/vsp survey/report/21494078 tech memo vsp model bh21-08 27oct2021.docx

TABLE 1
VSP VELOCITY PROFILE
BOREHOLE 21-08

Layer Depth (m)		Velocities (m/s)		Estimated Bulk Density (kg/m^3)	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave	Shear Wave		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	1.0	400	195	2000	0.34	76	204	219
1.0	2.0	1200	280	2000	0.47	157	461	2671
2.0	3.0	1600	440	2000	0.46	387	1130	4604
3.0	4.0	1600	670	2600	0.39	1167	3253	5100
4.0	5.0	1600	900	2600	0.27	2106	5343	3848
5.0	6.0	1600	900	2600	0.27	2106	5343	3848
6.0	7.0	1600	900	2600	0.27	2106	5343	3848
7.0	8.0	1600	900	2600	0.27	2106	5343	3848
8.0	9.0	2800	1600	2600	0.26	6656	16741	11509
9.0	10.0	2800	1600	2600	0.26	6656	16741	11509
10.0	11.0	2800	1600	2600	0.26	6656	16741	11509
11.0	12.0	4800	2600	2600	0.29	17576	45430	36469
12.0	13.0	4800	2600	2600	0.29	17576	45430	36469
13.0	14.0	4800	2800	2600	0.24	20384	50638	32725
14.0	15.0	4800	2800	2600	0.24	20384	50638	32725



Notes
1. Depth presented is relative to the ground surface.
2. This table shall be analyzed in conjunction with the accompanying report.

APPENDIX G

CERTIFICATE OF CHEMICAL ANALYSES

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Ali Ghirian
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1964465
Date Submitted: 2021-10-12
Date Reported: 2021-10-15
Project: 21494078
COC #: 881198

				Lab I.D.	1588443	1588444
				Sample Matrix	Soil	Soil
				Sample Type		
				Sampling Date	2021-09-30	2021-09-27
				Sample I.D.	21-06 sa2	21-10 sa3
Group	**Analyte**	**MRL**	**Units**	**Guideline**		
Anions	Cl	0.002	%		0.007	<0.002
	SO4	0.01	%		<0.01	0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.24	0.15
	pH	2.00			8.88	8.39
	Resistivity	1	ohm-cm		4350	6670

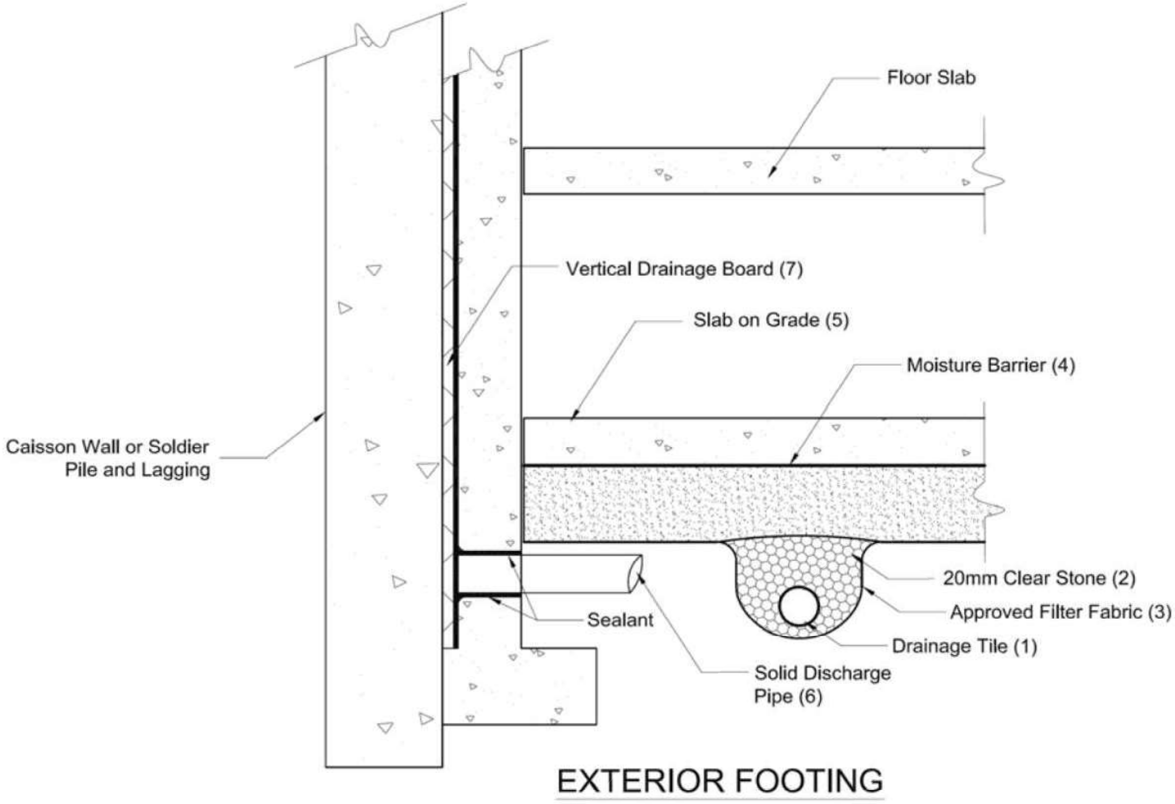
Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX H

PERMANENT DRAINAGE RECOMMENDATIONS



Notes

1. Drainage tile to consist of 100 mm (4") diameter weeping tile or equivalent perforated pipe leading to a positive sump or outlet.

2. 20 mm (3/4") Clear Stone – 150mm (6") top and side of drain, 100 mm (4") of stone below drain.

3. Wrap the clear stone with an approved filter membrane (Terrafix 270R or equivalent).

4. Moisture barrier to be at least 200 mm (8") of compacted clear 20 mm (3/4") stone or equivalent free draining material. A vapour barrier may be required for special floors.

5. Do not connect the underfloor drains to the perimeter drains.

6. Solid discharge pipe outletting into a solid pipe leading to a sump.

7. Vertical drainage board Terradrain 600 or equivalent with filter cloth should be continuous from bottom to 1.2 m below exterior finished grade.

8. Review the geotechnical report for specific details. Final detail must be approved before system is considered acceptable.

DRAINAGE RECOMMENDATIONS

Shored Basement wall with Underfloor Drainage System

(Not to Scale)