File CG3608

# ISL Engineering & Land Services Ltd.

# Canmore Bow River Pathway Geotechnical Investigation

Clifton

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**24 June 2022** **File CG3608**

# ISL Engineering & Land Services Ltd.

## Canmore Bow River Pathway
## Geotechnical Investigation
## Canmore, AB

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ID#124269
2022-06-24

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The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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# 1.0 Introduction

Clifton Engineering Group Inc. (Clifton) was retained by ISL Engineering & Land Services Ltd. (ISL) to complete a geotechnical investigation for the Canmore Bow River Pathway Project located in Canmore, Alberta. Authorization to proceed for the investigation was provided by David Breu of ISL via signed contract on 12 March 2022. The geotechnical investigation was performed as per the scope of work outlined in Clifton's proposal PC3858 dated 28 February 2022. The investigation was intended to assess the geotechnical properties, groundwater conditions, and to provide comments and recommendations pertaining to geotechnical design for the proposed pedestrian bridges.

# 2.0 Site Description

The site is located along the Bow River Pathway in West Canmore Park, Canmore, Alberta. A review of the surficial geology[1] indicates that at the soil conditions will consist of flood plain deposits including gravel, minor sand, silt, and clay.

Based on the information received from ISL, the Town of Canmore will be upgrading the existing pathway including asphalt overlays, construction of a new prefabricated 35 m span pedestrian bridge, a pedestrian bridge upgrade near Sta.1+400, and retaining wall reconstruction near Sta. 0+700. It is our understanding that geotechnical recommendations are required for those upgrades. For the pedestrian bridge upgrade near Sta.1+400, it was communicated that the abutment will be constructed using a Lock-Block™ system. The stability analysis and the design of this system were not included in the original scope of work; therefore, this report does not provide any detail on the system.

# 3.0 Field and Laboratory Investigation

## 3.1 Geotechnical Investigation

The field drilling was completed on 17 and 18 March 2022 and hand augering was completed on 26 May 2022. The boreholes were drilled in the following locations:

- BH22-01 – pedestrian bridge upgrade over the stormwater outlet; drilled to 10.7 m.
- BH22-02 – pathway upgrade; drilled to 1.5 m.

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[1] Geological Survey of Canada, 1972. *Surficial Geology Banff Area West of Fifth Meridian Sheet 2*. Geological Survey of Canada. Map 1324A Scale 1:50,000.

- BH22-03 and BH22-04 – pedestrian bridge crossing Canmore Creek; drilled to depths of 15.3 m and 15.2 m, respectively.
- BH22-05 – retaining wall on the pathway; drilled to 6.2 m.
- HA22-01 – pathway upgrade; hand excavated to 0.3 m.
- HA22-02 and HA22-03 – retaining wall base; hand excavated to 0.5 m.

A borehole location plan showing the five (5) boreholes and three (3) hand auger holes can be seen in **Error! Reference source not found.**. The borehole locations were adjusted in the field based on the existing buried utilities. One planned borehole not included in the above list was cancelled because of a sanitary sewer line in the area that could not be accurately located. The borehole locations were surveyed by Clifton staff with a handheld GPS unit with an accuracy of ±3 m.

The drilling was performed using a track mounted drill rig equipped with solid stem augers and ODEX. The rig was owned and operated by All Service Drilling Ltd. The hand excavations were completed using a hand auger and shovel to the termination depth.

Observations made during the field investigation, visual descriptions according to the Unified Soil Classification System (USCS), and the results of laboratory tests are recorded on the borehole logs in Appendix B. For boreholes, subsurface soil and bedrock conditions were logged based on disturbed samples collected at selected depth intervals for laboratory testing. Where possible, Standard Penetration Testing (SPT) was conducted in all boreholes starting from a depth of 1.5 m and continued at 1.5 m intervals. Representative disturbed, and SPT samples were recovered for laboratory analyses.

Standpipes consisting of solid and slotted 25 mm diameter polyvinyl chloride (PVC) pipe were installed in boreholes BH22-01, BH22-03, and BH22-04 to monitor the groundwater. Clifton staff returned to site on 01 April 2022 to monitor the standpipes.

### 3.2 Geotechnical Laboratory Testing

All laboratory testing, except water-soluble sulphate, were carried out at Clifton's geotechnical laboratories. The water-soluble sulphates were tested by Bureau Veritas Laboratories in Calgary, Alberta. The laboratory testing included:

- Water content on all samples
- Two (2) sieve analyses
- Two (2) organic content tests
- Three (3) water-soluble sulphate content tests

The results of the water content, organic contents and water-soluble sulphate content tests are provided on the borehole logs in Appendix B. The results of the sieve analyses are in Appendix C.

# 4.0 Site Conditions

### 4.1 Surface Conditions

At the time of the geotechnical investigation, all borehole locations were located on the existing Bow River Pathway except for BH22-03 which was in a grassed area covered with snow. Hand auger locations were on side slope of the existing pathway and retaining wall.

### 4.2 Subsurface Conditions

The subsurface strata and groundwater conditions encountered in each borehole is described in detail in the borehole logs provide in Appendix B, with additional information provided in this section and subsections below.

#### 4.2.1 Gravel

Gravel was encountered in each borehole at the surface. BH22-02 and BH22-03 were terminated in the gravel layer at 1.5 m and 15.3 m. All hand auger holes are terminated in the gravel layer at 0.3 m to 0.5 m. The gravel was primarily sandy with variable amounts of silt and clay. In general, it was brown in colour and oxidized. The SPT N values ranged from 7 to over 50 with an indicating that the gravel was loose to very dense. The SPT N values generally increased with depth.

Water contents of the gravel samples ranged from 0.1% to 12.9% with an average moisture content of 6.2%. The soluble sulphate test results for the gravel samples tested were <0.1% indicating negligible sulphate exposure.

#### 4.2.2 Coal

Two coal layers were encountered in BH22-05, one at 3.4 m (0.3 m thick) and the other at 4.8 m (the borehole was terminated in this layer). The water contents were 11.8%, 15.3% and 15.7% with an organic content of 15.4%.

#### 4.2.3 Sand

A 1.2 m thick sand layer was encountered in BH22-03 at a depth of 0.9 m. The water content in this layer was 25.8%. One SPT was completed in this layer and the N value was 12 indicating that the layer was compact.

#### 4.2.4 Clay

A 0.9 m thick clay layer was encountered in BH22-03 at a depth of 2.1 m. The water content was 20.5%. A sulphate test completed in this layer indicated a soluble sulphate content of <0.1%.

### 4.2.5 Bedrock

Bedrock was encountered underlying the gravel deposit in boreholes BH22-01 and BH22-04. Where encountered, the top of the bedrock was 6.7 m and 3.4 m below existing ground. The bedrock was mudstone and dark grey to black in colour. The SPT N-values were over 50 indicating that the bedrock was hard. The water content values in the bedrock were between 2.6% and 15.7%.

### 4.3 Groundwater Conditions

Seepage was observed in boreholes BH22-01, BH22-03, and BH22-04 at depths of 3.0 m to 6.1 m. Groundwater measurements were completed on 01 April 2022 which is presented in Table 4.1.

**Table 4.1 – Groundwater Levels – 01 April 2022**

| Borehole Number | Groundwater Depth (m) |
|---|---|
| BH22-01 | 4.5 |
| BH22-03 | 2.4 |
| BH22-04 | 5.1 |

It should be noted that groundwater levels can be influenced by many variables and may not be representative of long-term stabilized groundwater conditions. Variables which affect groundwater readings include amongst others: surface infiltration, puncture of perched water horizons, and inadequate time for stabilization of groundwater pressures.

# 5.0 Comments and Recommendations

### 5.1 Geotechnical Concerns

Based on the results of the drilling, geotechnical conditions are suitable for each of the proposed projects. The primary geotechnical condition that will affect all three projects is the coarse gravel, cobbles, and boulders that comprise the majority of the site soils. These soils will influence not only the bridge foundations but the reconstruction of the pathway.

For the pedestrian bridges, coarse gravel, cobbles, and boulders were not observed during drilling as the drilling was completed using ODEX drill rig. However, based on our experience in this area and the surrounding environment at surface, it is likely that they will be encountered during construction. Although coarse gravel, cobbles and boulders would not generally be a major concern when using shallow foundations, they may cause uneven bearing surfaces. Other factors that must be considered in the design and construction for the bridges are the shallow bedrock, the coal, and the existing foundations. Deep foundations are not recommended due to the shallow bedrock in both bridge locations. Construction of deep foundations to the minimum embedment depth required for resistance to adfreeze forces may not be possible because of the shallow bedrock. Therefore, the proposed pedestrian bridges may be supported by shallow footing foundations founded on the shallow bedrock. However, the foundations should not bear on any coal layers encountered during construction. If the existing stormwater outfall bridge foundation is within the footprint of the new bridge foundation, it must be removed entirely prior to construction of the new foundation. If not removed, the subsurface conditions below the foundation could be highly variable, which could lead to differential settlements and cracking in the new foundation. Voids from the removed foundation must be backfilled with properly compacted engineered fill.

For the pathway, the coarse gravel, cobbles, and boulders are the only significant geotechnical condition affecting the design and construction for the rehabilitation. The coarse material at the surface may impact the integrity of asphalt pavement structure after the construction.

For the retaining wall, there are several issues that may have caused the failure of the retaining wall. The possible failure mode will be discussed in detail in Section 5.4 of this report.

## 5.2 Bridge Foundations

As indicated earlier, the geotechnical conditions are suitable for shallow foundations. Based on the type of proposed development and the soils encountered, it is anticipated that shallow foundations will also be the most economical foundation system. Therefore, the recommendations provided in the following subsections are for shallow foundations only. For the Lock-Block™ system, bearing resistance provided for shallow foundation can be used.

### 5.2.1 Site Preparation

Any existing foundations and utilities that are not being reused must be removed. If not removed, the subsurface conditions below the foundation will be highly variable, which could lead to differential settlements and cracking.

It is recommended that the exposed subgrade be inspected by Clifton's geotechnical personnel. This inspection would be intended to identify areas containing near-surface deleterious material prior to placement of engineered fill, foundation forms, or concrete. All unsuitable and deleterious material must be removed from beneath foundations, and where engineered fill is needed to bring the site elevation to final grade. If cobbles and boulders are encountered at footing elevation where a flat surface cannot be achieved for the footings, it is recommended to over-excavate and pour mud-slab to provide a flat surface for the footing construction. Voids found in the native gravel and within the foundation area should be backfilled with lean mix concrete.

Subgrade surfaces should be protected from freezing. In addition, the subgrade should be protected from wetting or dying, both before and after the placement of fill. Subgrade surfaces that are allowed to dry or become wet must be scarified, moisture conditioned, and recompacted. It should be recognized that even for properly compacted engineered fill, differential consolidation may occur over time which can result in some settlement of surface supported structures. If fill thickness over 1 m is placed, it is anticipated that engineered fill soil may exhibit post-construction settlement of approximately 1% to 3% of the placed fill thickness.

### 5.2.2 Limit States Design

Ultimate Limit States are primarily concerned with collapse mechanisms for the structure and, hence, safety. Foundation designs using a limit states design approach should satisfy the following design equation[2]:

$$\Phi R_n \geq \Sigma \alpha_i S_{ni}$$

Where:

$\Phi R_n$ - Factored geotechnical resistance

$\Phi$ - Geotechnical resistance factor

$R_n$ - Nominal (ultimate) geotechnical resistance determined using unfactored geotechnical parameters

$\Sigma \alpha_i S_{ni}$ - Summation of the factored overall load effects (e.g., dead load due to weight of structure or live load due to wind)

$\alpha_i$ - Load factor corresponding to a particular load

$S_{ni}$ - Specified load component of the overall load effects (e.g., dead load due to weight of structure or live load due to wind)

I - Various types of loads such as dead load, live load, wind load, etc.

Geotechnical resistance factors should be as provided by Table 6.2 of the Canadian Highway Bridge Design Code and as outlined in the following subsections. The critical design events and their corresponding load combinations and load factors should be assessed and determined by the structural engineer.

**<u>Serviceability Limit State (SLS)</u>**

Serviceability Limit States (SLS) are primarily concerned with mechanisms that restrict or constrain the intended use, occupancy, or function of the structure. For foundation design, SLS are usually associated with excessive foundation movements (e.g., settlement, differential settlement, heave, etc.) or unacceptable foundation vibrations.

In general, the formal criteria for SLS can be expressed as follows:

*Serviceability Limit ≥ Effect of Service Load*

SLS are evaluated using unfactored geotechnical settlement properties (i.e., compressibility, Young's Modulus, etc.) to determine an SLS bearing reaction which, when applied to the foundation soil, will not exceed a specified serviceability criterion. However, the load-settlement behaviour of foundations is

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[2] Canadian Geotechnical Society. 2006.*Canadian Foundation Engineering Manual – 4th Edition*

complex and, not withstanding the non-linear nature of the soil, depends on the foundation type and foundation configuration.

As required by the Canadian Highway Bridge Design Code, foundations are required to be designed in terms of Limit States Design (LSD). The resistance factor for shallow foundations is 0.5 from Canadian Highway Bridge Design Code.

### 5.2.3 Shallow Foundations

Based on the results of the drilling and the lab testing, the bridge foundations can be spread footings for the proposed pedestrian bridges. Footings should be founded on native gravel or bedrock.

The recommended unfactored bearing resistance footing widths ranging from 1.0 m to 2.0 m can be taken as 950 kPa. A resistance factor of 0.5 as per Canadian Highway Bridge Design Code should be applied to obtain the factored bearing resistance at ULS. For the Serviceability Limit State (SLS), a bearing reaction of 475 kPa may be used for strip footings up to 2.0 m in width.

Bearing surfaces should be protected from ingress of free water, typically resulting in softening of soils. Footings must not be placed on disturbed, or frozen soil. Bearing soil that becomes frozen, dried, or softened must be removed and replaced with concrete, or footings should be extended to reach soil in an unaffected condition. As well, the bearing surface should be free of cobbles or boulders that may extend above the bearing surface and could interfere with the reinforcing in the bottom of the footing.

It is recommended that the prepared bearing surfaces for footings shall be inspected by a qualified geotechnical engineer or technician to identify areas containing near-surface deleterious material or cobbles and boulders. Soft or wet areas detected should be examined and removed; and cobbles or boulders above the bearing surface should be pried out and the area backfilled with finer gravel.

### 5.2.4 Lateral Earth Pressure for Bridge Abutments

The lateral earth pressure acting on the foundations will depend on the type and method of placement of backfill materials, the nature of soil, and the magnitude of surface loading including construction loading, freedom of lateral movement of the structure and the drainage conditions. Pressure on underground structures can be calculated using the appropriate active, at rest, or passive earth pressure coefficients as defined in Table 5.1.

**Table 5.1 – Earth Pressure Coefficients**

| Material | Angle of Internal Friction (°) | Total Unit Weight (kN/m³) | Earth Pressure Coefficients | | |
|---|---|---|---|---|---|
| | | | Active | At-Rest | Passive |
| Gravel | 31 | 21 | 0.32 | 0.48 | 3.12 |

### 5.2.5 Sulphate Exposure

To determine the potential of sulphate attack on concrete in contact with soils at the site, two samples of gravel were tested for water-soluble sulphate content. The result indicated that the concentration of water-soluble sulphates in the soil was <0.1%. The value indicates that the potential sulphate for attack on concrete is negligible for this site. As per Canadian Standard Association, Type GU cement should be used for concrete mix. All imported soils should be tested to determine water soluble sulphate concentration and associated sulphate exposure classification.

### 5.2.6 Seismic Site Response

The site classification for seismic site response as described in Table 4.1 of the Canadian Highway Bridge Design Code is based on the soil types, shear wave velocity, the undrained shear strength, or SPT results in the upper 30 m. Measurement of shear wave velocity was not within the scope of this work. On this basis, the design can assume Site Class C.

### 5.2.7 Frost Susceptibility

Frost susceptibility of soil characterizes the tendency of the soil to grow ice lenses and heave during freezing. As per the Canadian Foundation Engineering Manual (CFEM)[3] soils are classified as F1 to F4 showing F1 as the least and F4 as the most frost-susceptible soil that would lose strength during spring thaw. The near-surface soil unit encountered at the project site was gravel or sand that is classified as a frost group F2 based on the Unified Soil Classification System.

The maximum seasonal frost penetration depth was calculated for the near-surface soils using the procedure described in CFEM[4]. The surface freezing index of 1000°C degree days was used for the location. The average seasonal frost penetration depth is estimated to be approximately 3.3 m. The frost depth is deeper than cohesive soil as granular soil has lower heat latency which can transfer frost deeper. The site has lower water content in gravel which contributed the deeper frost depth as well. Therefore, shallow foundation structures should have a minimum soil cover of at least 3.3 m for frost protection purposes. Buried utilities should have a minimum soil cover of at least 3.3 m for frost protection purposes.

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[3] Canadian Geotechnical Society. 2006.*Canadian Foundation Engineering Manual – 4th Edition*, Table 13.1, Page 189

[4] Canadian Geotechnical Society. 2006.*Canadian Foundation Engineering Manual – 4th Edition*, Section 13.4

Insulation may be used to protect the concrete foundations. As a general guide, 25 mm of insulation may be assumed to provide approximately 0.3 m of equivalent soil cover. Insulation used for frost protection should be placed at a minimum depth of 0.6 m below the finished ground surface and the top 0.6 m of backfill should be ignored for equivalent frost penetration calculation purposes. The insulation supplier should be consulted for the detailed design of insulation.

The Town of Canmore's Engineering Design and Construction Guidelines' minimum soil cover is 3.3 m for public utilities. If the minimum soil cover of 3.3 m is provided, an air-entrained concrete should be used for the foundations.

## 5.3 Pathways

The existing gravel surface and subgrade gravel can be used as sub-base material if organics or deleterious material are removed. The subgrade and existing gravel surface must be scarified and re-compacted to a minimum of 95% SPMDD. Based on Figure STR 7.9 of Town of Canmore's Engineering Design & Construction Guidelines, the pathway should be a minimum 150 mm above the surrounding grades. As recommended by "the City of Calgary Roads Construction 2015 Standard Specifications" Section 302.06.02, proof rolling is recommended to detect soft areas in a subgrade. It is usually accomplished with the use of heavily (8200 kg axle load) loaded single axle truck. While the passes are being made, any softened, rutted, or displaced areas detected should be examined and either re-compacted or the existing material removed and replaced with suitable quality material. If granular material is used to replace the soft soil, positive drainage must be provided to prevent accumulation of water.

The pavement surface and the underlying subgrade should be graded to direct runoff water towards suitable drainage. It is essential to establish the positive drainage throughout the site as the existing gravel surface is experiencing ruts and soft spots due to accumulated surface water.

All granular materials should conform to the City of Calgary Road Specifications and should be tested and approved by a geotechnical engineer prior to delivery to the site. The base material should be compacted to 95% SPMDD. Asphalt should be compacted to a minimum of 93% of its Maximum Theoretical Density.

**Table 5.2 – Recommended Asphalt Pavement Structure for Pathways**

| Layer | Thickness (mm) |
|---|---|
| Asphalt (City of Calgary B-Mix) | 75 mm |
| Base – 20 mm Minus Crushed Gravel[1] | 100 mm |
| Sub-base - Existing gravel surface, subgrade gravel or 75 mm Minus Pitrun | 200 mm |

Notes: [1] 25 mm Crushed Gravel as per the City of Calgary Road Specification

### 5.3.1 Site Drainage

It is recommended that the final grading of the site be designed such that surface water is directed away from all structures. Surface water should not be permitted to pond or flow adjacent to foundations.

## 5.4 Retaining Wall

It is our understanding that the existing retaining wall will be replaced with a new retaining wall due to failure of the existing wall. BH22-05, HA22-02 and HA22-03 were drilled and the site visit was conducted to assess the condition of the existing retaining wall and to determine the possible failure mode. There were several potential issues identified from the results of the drilling and from visual observations of the retaining wall. Photographs showing the issues are presented in Appendix D.

Combining these four possible issues, the existing retaining wall had instability over time and likely had movement at the base of the wall.

### 5.4.1 Issues

**Geogrid Reinforcement**

The visual observation shows that the retaining wall has been designed using uniaxial geogrid with boulder facing. The uniaxial geogrid provides tensile strength in one direction which is not ideal for the retaining wall. As well, the irregular surfaces of the boulder facing does not provide continuous mechanical connection between the geogrid and the facing. This would likely prevent full mobilization of the geogrid and thus stabilization of the entire wall. As such, movement of the boulder facing is likely not prevented.

**Unstable Base**

The base of the retaining wall was easily hand augered to 0.5 m, indicating the soil was very loose. This could lead to excessive movements of the boulders due to settlement or frost action. As well, it could make the subgrade susceptible to erosion. A competent base should be prepared to have long term performance of the retaining wall. The Photograph 1 and Photograph 2 shows the base of the retaining wall where erosion and seepage have caused the movement of the base.

**Seepage**
The existing retaining wall showed seepage path signs in the wall where fines were washed away from the backfill gravel. It has also possibly created seepage paths at the base. Photograph 2 shows the seepage path at the base of the wall. Photograph 5 shows the gravel has washed out fines. Erosion from behind the wall could further reduce the effectiveness of the geogrid reinforcement.

**Coal Layer**
In BH22-05, 0.3 m and 1.4 m thick coal layer was encountered. Coal fragments were found at the base of the retaining wall during the site visit. The coal layer is compressible and can easily decompose. Therefore, if the retaining wall was founded in the coal layer, this may have further reduced the stability of the retaining wall over time.

### 5.4.2 Recommendations

The possible suitable retaining wall options are a cantilever retaining wall and a mechanically stabilized earth (MSE) retaining wall.

The site is very limited due to the river to the north and the residential houses to the south. A cantilever wall may provide better stability as the retaining wall foundation base can be designed to have an extension or to buried deeper to provide additional support. If an MSE wall is proposed, a detailed analysis of the retaining wall is recommended prior to the design to see if the site has enough space for the reinforced soil mass.

For both systems, proper drainage through the wall is essential. This will reduce the hydrostatic pressure behind the wall and will reduce the potential for erosion of the backfill.

The design and analysis of the retaining wall is not included in the scope of work in this report.

## 5.5 General Recommendations

### 5.5.1 Engineered Fill

The native sandy gravel on site can be considered as an engineered fill. All engineered fill material required to bring the area to designed grade must be free from oversized material (cobbles and boulders over 150 mm in size), organics, roots, debris, and other deleterious material. Cohesive fill should be placed in lifts not exceeding 300 mm thickness in loose measure, at a water content of 0 to +3% of its optimum moisture content (OMC). Granular fill should be placed at a moisture content of ±3% of its OMC. Each lift should be compacted to a minimum of 98% of the Standard Proctor Maximum Dry Density (SPMDD) around and beneath structures. Moisture conditioning may be required during compaction to achieve the required density.

Any excavated areas should be graded to ensure positive drainage throughout the construction phase. Grades should be created to direct water away from excavations and trenches. In excavations, the subgrade should be graded with a cross slope so that accumulated water can be removed by pumping. Adequate site grading design is critical to ensure long term performance of the bridges and pathway. Grades should also ensure that water from precipitation or snowmelt does not accumulate near the foundations.

### 5.5.2 Excavation and Underground Utilities

Temporary excavations at the site should be sloped or shored for worker and foundation protection. Construction must conform to good practice and comply with regulations, such as the Alberta Building Code and Occupational Health and Safety.

The subsurface soil that underlies the site may be excavated using conventional hydraulic excavation equipment. A variable deposit of sandy gravel was encountered throughout the site. According to the field investigation and Occupational Health and Safety Code Part 32, compact soils are to be classified as “soft, sandy, or loose”; therefore, excavation walls must be from the bottom of the excavation at an angle of not less than 45 degrees measured from the vertical. Clifton should be given the opportunity to review the proposed excavation layout and to provide further guidance if steeper cut slopes are desired.

Excavations must be protected from rain, snow, or ingress of free water. Prolonged exposure of excavated areas should be avoided to prevent deterioration of exposed soil with resultant slope instability. Similarly, excavated materials should be stockpiled away from the excavations to avoid slope instability and to prevent materials from falling into excavations. Temporary surcharge loads, such as stockpiles of material or heavy equipment, should be kept back from excavation faces a distance equal to at least one-half the excavation depth.

Additionally, all underground pipes must be placed on competent ground. Soft, loose, organic, or otherwise deleterious soil existing below the pipes must be over-excavated and replaced with well-compacted material. The subgrade soil and bedding gravel beneath the pipes should not be allowed to freeze. All backfill material in the trench should be free of wet, organic, or frozen soil.

Based on the measured groundwater levels, seepage is expected during excavation of foundations. Construction dewatering is likely to be required. If seepage is encountered during construction, groundwater may be controlled by sump and pump methods, although it may require larger than typical pumps running 24 hours per day, 7 days a week because of the soil type. The groundwater level should be maintained at a minimum of 0.5 m below excavation grade at all times. During construction, the prepared subgrade surface should be shaped to prevent ponding of water on the site. Excess water should not be allowed to pond and should be drained or pumped from within the foundations and areas subject to surface improvements as quickly as possible.

### 5.6 Review of Design and Construction Inspection

Clifton should be given the opportunity to review final designs, drawings, and specifications related to the geotechnical aspects of the proposed development to ensure that our comments and recommendations have been properly interpreted and implemented. Inspection by Clifton geotechnical representatives during foundation installation is required to ensure the required bearing values for foundation bearing surface is achieved. Construction review and inspection of foundation installations will be carried out in accordance with the Canadian Highway Bridge Design Code.

# 6.0 Closure

This report was prepared by Clifton Engineering Group Inc. for the use of ISL Engineering & Land Services Ltd. and their agents for specific application to the proposed Canmore Bow River Pathway Project that will be located in Canmore, Alberta.

The discussion and recommendations within this report were prepared in accordance with the standard care of geotechnical practice at the time of the report preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Clifton Engineering Group Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report has been prepared in accordance with generally accepted standard engineering practice common to the local area. No other warranty, express or implied is made.

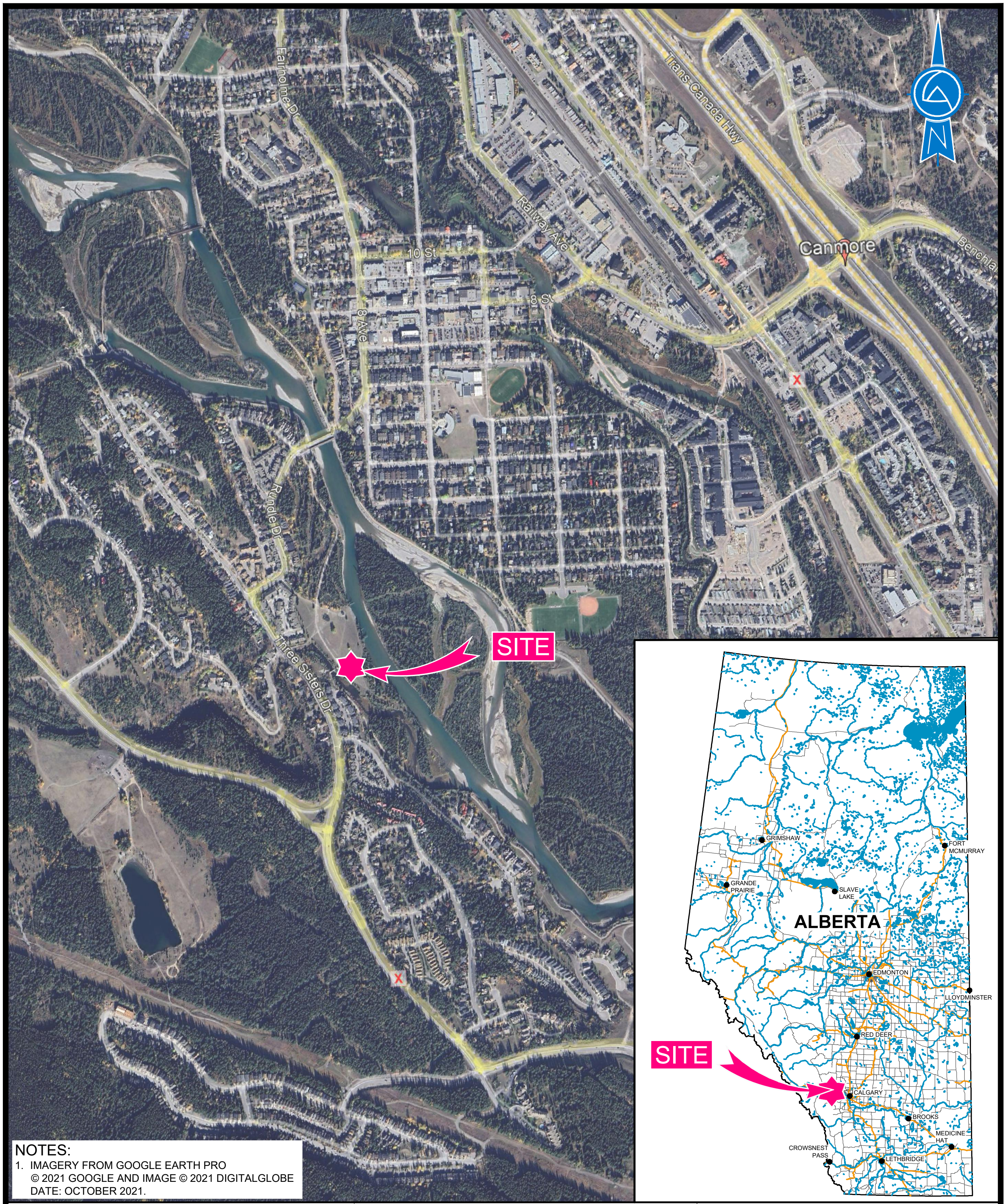
Our conclusions and recommendations are preliminary and based upon the information obtained from the referenced subsurface exploration. The borings and associated laboratory testing indicate subsurface and groundwater conditions only at the specific locations and times investigated, only to the depth penetrated and only for the soil properties tested. The subsurface conditions may vary between the boreholes and with time. The subsurface interpretation provided is a professional opinion of conditions and not a certification of the site conditions. The nature and extent of subsurface variation may not become evident until construction or further investigation. If variations or other latent conditions do become evident, Clifton Engineering Group Inc. should be notified immediately so that we may re-evaluate our conclusions and recommendations. Although subsurface conditions have been explored, we have not conducted analytical laboratory testing on samples obtained nor evaluated the site with respect to the potential presence of contaminated soil or groundwater.

The enclosed report contains the results of our investigations as well as certain recommendations arising out of such investigations. Our recommendations do not constitute a design, in whole or in part, of any of the elements of the proposed work. Incorporation of any or all of our recommendations into the design of any such element does not constitute us as designers or co-designers of such elements, nor does it mean that such design is appropriate in geotechnical terms. The designers of such elements must consider the appropriateness of our recommendations in light of all design criteria known to them, many of which may not be known to us. Our mandate has been to investigate and recommend, which we have completed by means of this report. We have had no mandate to design or review the design of any elements of the proposed work and accept no responsibility for such design or design review.

# Appendix A

## Drawings

Clifton



NOTES:
1. IMAGERY FROM GOOGLE EARTH PRO
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DATE: OCTOBER 2021.

LEGEND SYMBOL DESCRIPTION

BAR SCALE
0 1:15,000 500
LETTER SIZE DRAWING

PROJECT
CANMORE BOW RIVER PATHWAY GEOTECHNICAL

CLIENT
ISL ENGINEERING AND LAND SERVICES INC.

ENGINEER
Clifton

TITLE
SITE LOCATION PLAN

| | | |
|---|---|---|
| DSGN. BY | PROJECT NO.<br>CG3608 | SCALE<br>1:15,000 |
| DWN. BY<br>IW | FILE NO.<br>CG3608-01 | DWG. NO.<br>01 |
| REV. BY<br>RC | ISSUED DATE<br>2022-05-27 | |

LEGEND

SYMBOL ⊕

DESCRIPTION BOREHOLE LOCATION

BAR SCALE

100 METERS 0 1:4000 100

LETTER SIZE DRAWING

PROJECT

CANMORE BOW RIVER PATHWAY GEOTECHNICAL

CLIENT

ISL ENGINEERING AND LAND SERVICES INC.

ENGINEER

Clifton

TITLE

BOREHOLE LOCATION PLAN

DSGN. BY

PROJECT NO. CG3608

SCALE 1:4000

DWN. BY IW

FILE NO. CG3608-02

DWG. NO. 02

REV. BY RC

ISSUED DATE 2022-05-27

| LEGEND | SYMBOL | DESCRIPTION |
|---|---|---|
| | ● | HAND AUGER LOCATION |

BAR SCALE
25 0 25
METERS 1:2500
LETTER SIZE DRAWING

PROJECT
CANMORE BOW RIVER PATHWAY GEOTECHNICAL

CLIENT
ISL ENGINEERING AND LAND SERVICES INC.

ENGINEER
Clifton

TITLE
HAND AUGER LOCATION PLAN

| DSGN. BY | PROJECT NO. | SCALE |
|---|---|---|
| | CG3608 | 1:2500 |
| DWN. BY | FILE NO. | DWG. NO. |
| IW | CG3608-03 | 03 |
| REV. BY | ISSUED DATE | |
| RC | 2022-05-27 | |

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# Appendix B

## Borehole Logs

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## Soil Descriptive Terms

A soil description for geotechnical applications includes a description of the following properties:

- texture
- colour, oxidation
- consistency and condition
- primary and secondary structure

## Texture

The soil texture refers to the size, size distribution and shape of the individual soil particles which comprise the soil. The Unified Soil Classification System (ASTM D2487-00) is a quantitative method of describing the soil texture. The basis of this system is presented on the following page. The following terms are commonly used to describe the soil texture.

| Particle Size (ASTM D2487-00) | |
|---|---|
| Boulder | 300 mm plus |
| Cobble | 75 – 300 mm |
| Gravel | 4.75 – 75 mm |
| Coarse | 19 – 75 mm |
| Fine | 4.75 – 19 mm |
| Sand | 0.075 – 4.75 mm |
| Coarse | 2 – 4.75 mm |
| Medium | 0.425 – 2 mm |
| Fine | 0.075 – 0.425 mm |
| Silt and Clay | Smaller than 0.075 mm |

| Relative Proportions (CFEM, 4th Ed., 2006) | |
|---|---|
| Trace | 1 – 10 % |
| Some | 10 - 20 % |
| Gravelly, sandy, silty, clayey, etc. | 20 – 35 % |
| And | >35 % |
| Gravel, Sand, Silt, Clay, etc. | 35% and main fraction |

| Gradation | |
|---|---|
| Well Graded | Having a wide range of grain sizes and substantial amount of all intermediate sizes. |
| Uniform or Poorly Graded | Possessing particles of predominantly one size. |
| Gap Graded | Possessing particles of two distinct sizes. |

| Particle Shape | |
|---|---|
| Angular | Sharp edges and relatively plane sides with unpolished face. |
| Subangular | Similar to 'angular' but have rounded edges. |
| Subrounded | Well-rounded corners and edges, nearly plane sides. |
| Rounded | No edges, has smoothly curved sides. |
| Also may be flat, elongated, or both. | |

The term "TILL" may be used as a textural term to describe a soil which has been deposited by glaciers and contains an unsorted, wide range of particle sizes.

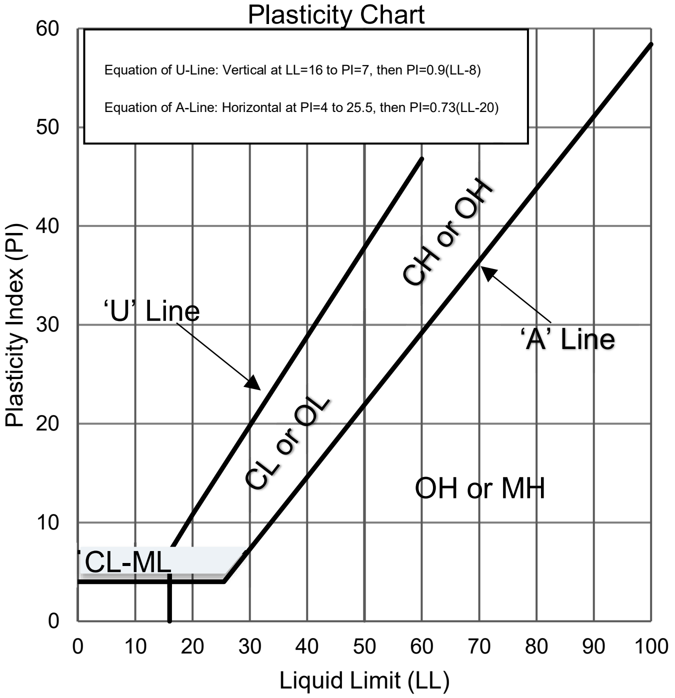
## Colour and Oxidation

The soil colour at its natural moisture content is described by common colours and, quantitatively, in terms of the Munsell colour notation; (eg. 5Y 3/1). The notation combines three variables, hue, value and chroma to describe the soil colour. The hue indicates its relation to red, yellow, green, blue and purple. The value indicates its lightness. The chroma indicates its strength of departure from a neutral of the same lightness.

Departure of the soil colour from a neutral colour indicates the soil has been oxidized. Oxidation of a soil occurs in an oxygen rich environment where iron-bearing minerals oxidize and turn a neutral coloured soil 'rusty' or reddish brown. Oxidized manganese gives a purplish tinge to the soil. Oxidation may occur throughout the entire soil mass or on fracture/joint/fissure surfaces.

## Classification of Soils for Engineering Purposes

ASTM Designation D 2487-00 (Unified Soil Classification System)

| Major Divisions | | | Group Symbol | Typical Names | Classification Criteria | | | |
|---|---|---|---|---|---|---|---|---|
| Coarse grained soils more than 50% retained on No. 200 sieve* (>0.075 mm) | Gravels More than 50% of coarse fraction retained on No. 4 sieve (4.75 mm) | Clean gravels <5% fines | GW | Well-graded gravel | If 15% sand add "with sand" to group name. | Classification on basis of percentage of fines:<br>Less than 5% pass No. 200 sieve - GW, GP, SW, SP<br>More than 12% pass No. 200 sieve - GM, GC, SM, SC<br>5 to 12% pass No. 200 sieve - Borderline classifications, use of dual symbols | $C_u = \frac{D_{60}}{D_{10}} \geq 4$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 | |
| | | | GP | Poorly graded gravel | | | Not meeting either $C_u$ or $C_c$ criteria for GW | |
| | | Gravels with >12% fines | GM | Silty gravel | | | Atterberg limits below "A" line or PI less than 4 | Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols<br>If fines are organic add "with organic fines" to group name |
| | | | GC | Clayey gravel | | | Atterberg limits on or above "A" line and PI > 7 | |
| | Sands 50% or more of coarse fraction passes No. 4 sieve (<4.75 mm) | Clean sands <5% fines | SW | Well-graded sand | If 15% gravel add "with gravel" to group name | | $C_u = \frac{D_{60}}{D_{10}} \geq 6$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 | |
| | | | SP | Poorly graded sand | | | Not meeting either $C_u$ or $C_c$ criteria for SW | |
| | | Sands with >12% fines | SM | Silty sand | | | Atterberg limits below "A" line or PI less than 4 | Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols<br>If fines are organic add "with organic fines" to group name |
| | | | SC | Clayey sand | | | Atterberg limits on or above "A" line and PI > 7 | |
| Fine-grained soils 50% or more passes No. 200 sieve* (<0.075 mm) | Silts and Clays Liquid Limit <50% | Inorganic | ML | Silt | If 15 to 29% coarse grained, add "with sand" or "with gravel" as appropriate.<br>If > 30% coarse grained, add "sandy" or "gravelly" as appropriate.<br>Class as organic when oven dried liquid limit is < 75% of undried liquid limit. |  | | |
| | | | CL | Lean clay -low plasticity | | | | |
| | | Organic | OL | Organic clay or silt (Clay plots above 'A' Line) | | | | |
| | Silts and Clays Liquid Limit >50% | Inorganic | MH | Elastic silt | | | | |
| | | | CH | Fat Clay -high plasticity | | | | |
| | | Organic | OH | Organic clay or silt (Clay plots above 'A' Line) | | | | |
| | Highly Organic Soils | | PT | Peat, muck and other highly organic soils | | | | |

*Based on the material passing the 3 in.(75 mm) sieve. If field samples contain cobbles or boulders, add "with cobbles or boulders" to group name

## Consistency and Condition

The consistency of a cohesive soil is a qualitative description of its resistance to deformation and can be correlated with the undrained shear strength of the soil. The condition of a coarse grained soil qualitatively describes the soil compactness and can be correlated with the standard penetration resistance (ASTM D1586-99).

### Consistency of Cohesive Soil (CFEM, 4th Edit., 2006)

| Consistency | Undrained Shear Strength (kPa) (CFEM, 4th Edit., 2006) | Field Identification (ASTM D2488-00) |
|---|---|---|
| Very Soft | <12 | Thumb will penetrate soil more than 25 mm. |
| Soft | 12 – 25 | Thumb will penetrate soil about 25 mm. |
| Firm | 25 – 50 | Thumb will indent soil about 6 mm. |
| Stiff | 50 – 100 | Thumb will indent, but penetrate only with great effort (CFEM). |
| Very Stiff | 100 – 200 | Readily indented by thumbnail (CFEM). |
| Hard | >200 | Thumb will not indent soil but readily indented with thumbnail. |
| Very Hard | N/A | Thumbnail will not indent soil. |

### Consistency of Coarse grained Soil (CFEM, 4th Edit., 2006)

| Compactness Condition | SPT N – Index (Blows/300mm) |
|---|---|
| Very Loose | 0 – 4 |
| Loose | 4 – 10 |
| Compact | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | Over 50 |

### Moisture Conditions (ASTM D2488-00)

| Description | Criteria |
|---|---|
| Dry | Absence of moisture, dusty, dry to touch. |
| Moist | Damp but no visible water. |
| Wet | Visible, free water, usually soil is below water table. |

## Structure

The soil structure is the manner in which the individual soil particles are assembled to form the soil mass. The primary soil structure is the arrangement of soil particles as originally deposited. The secondary soil structure refers to any rearrangement of the soil such as deformation and cracking which has taken place since deposition.

### Primary Soil Structure (Depositional)

**Geometry**

| | |
|---|---|
| Stratum | - A single sedimentary 'layer', greater than 10 mm in thickness, visibly separable from other strat by a discrete change in lithology and/or sharp physical break. |
| Homogeneous | - Same colour and appearance throughout. |
| Stratified | - Consisting of a sequence of layers which are generally of contrasting texture or colour. |
| Laminated | - Stratified with layer thickness between 2 – 10 mm. |
| Thinly Laminated | - Stratified with layer thickness less than 2 mm. |
| Bedded | - Stratified with layer thickness greater than 10 mm. |
| Very Thinly Bedded (Flaggy) | - Stratified with layer thickness between 10 – 50 mm. |
| Thinly Beddy (Slabby) | - Stratified with layer thickness between 50 – 600 mm. |
| Thickly Beddy (Blocky) | - Stratified with layer thickness between 600 – 1200 mm. |
| Thick-Bedded (Massive) | - Stratified with layer thickness greater than 1200 mm. |
| Lensed | - Inclusions of small pockets of different soil, such as small lenses of sand material throughout a mass of clay. |

**Bedding Structures**

| | |
|---|---|
| Cross-bedding | - Internal 'bedding' inclined to the general bedding plane. |
| Ripple-bedding | - Internal 'wavy bedding'. |
| Graded-bedding | - Internal gradation of grain size from coarse at base to finer at top of bed. |
| Horizontal bedded | - Internal bedding is parallel and flat lying. |

### Secondary Soil Structure (Post-Depositional)

**Accretionary Structures**

Includes nodules, concretions, crystal aggregates, veinlets, colour banding, and:

| | |
|---|---|
| Cementation | - Chemically precipitated material, commonly calcite ($CaCO_3$), binds the grains of soil, usually sandstone. Described as weak, moderate, or strong (ASTM D2488-00). |
| Salt Crystals | - Groundwater flowing though the soil/rock often precipitates visible amounts of salts. Calcite ($CaCO_3$), Glauber salts ($Na_2Ca(SO_4)_2$), and gypsum ($CaSO_4*2H_2O$) are common. |

**Fracture Structures**

| | |
|---|---|
| Fracture | - A break or discontinuity in the soil or rock mass caused by stress exceeding the materials strength. |
| Joint | - A fracture along which no displacement has occurred. |
| Fissure | - A gapped fracture, which may open and close seasonally. Usually an extensive network of closely spaced fractures, giving the soil a 'nuggetty' structure. |
| Slickensides | - Fractures in clay that are slick and glossy in appearance, caused by shear movements. |
| Brecciated | - Contains randomly orientated angular fragments of a finer mass, usually associated with shear displacement in soils. |
| Fault | - A fracture or fracture zone along with displacement has occurred. |
| Blocky | - A cohesive soil that can be broken down into small angular lumps which resist further break down. |

## Symbols Used on Borehole Logs

### Lithology Type

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ▨ | Clay | ▨ | Till – oxidized | ▨ | Coal | ▤ | Clay Shale |
| ▨ | Silt | ▨ | Till – unoxidized | ▨ | Topsoil or Organic Soil | ▨ | Sandstone |
| ▨ | Sand | ▨ | Peat | ▨ | Concrete | ▨ | Mudstone |
| ▨ | Gravel | ▨ | Fill (undifferentiated) | ■ | Asphalt | ▨ | Bedrock (undifferentiated) |
| ▨ | Cobbles | | | | | | |

### Borehole Completion and Backfill Materials

| | | | | | |
|---|---|---|---|---|---|
| ■ | Bentonite | ▨ | Cuttings | ▧ | Slough |
| ▨ | Concrete | ▨ | Grout | □ | Solid Pipe |
| ▦ | Cover | ▨ | Sand | ▯ | Slotted Pipe |

### Soil Sample Type

| | | | | | |
|---|---|---|---|---|---|
| ■ | Thin Walled Tube | ▤ | Disturbed | ▨ | No Recovery (NR) |
| ▩ | Driven Spoon | ▥ | Core (any type) | | |

### Groundwater Symbols

| | |
|---|---|
| ▼ | Piezometric elevation as determined by a piezometer installation. |
| ▽ | Water levels measured in borings at time and under the conditions noted. |

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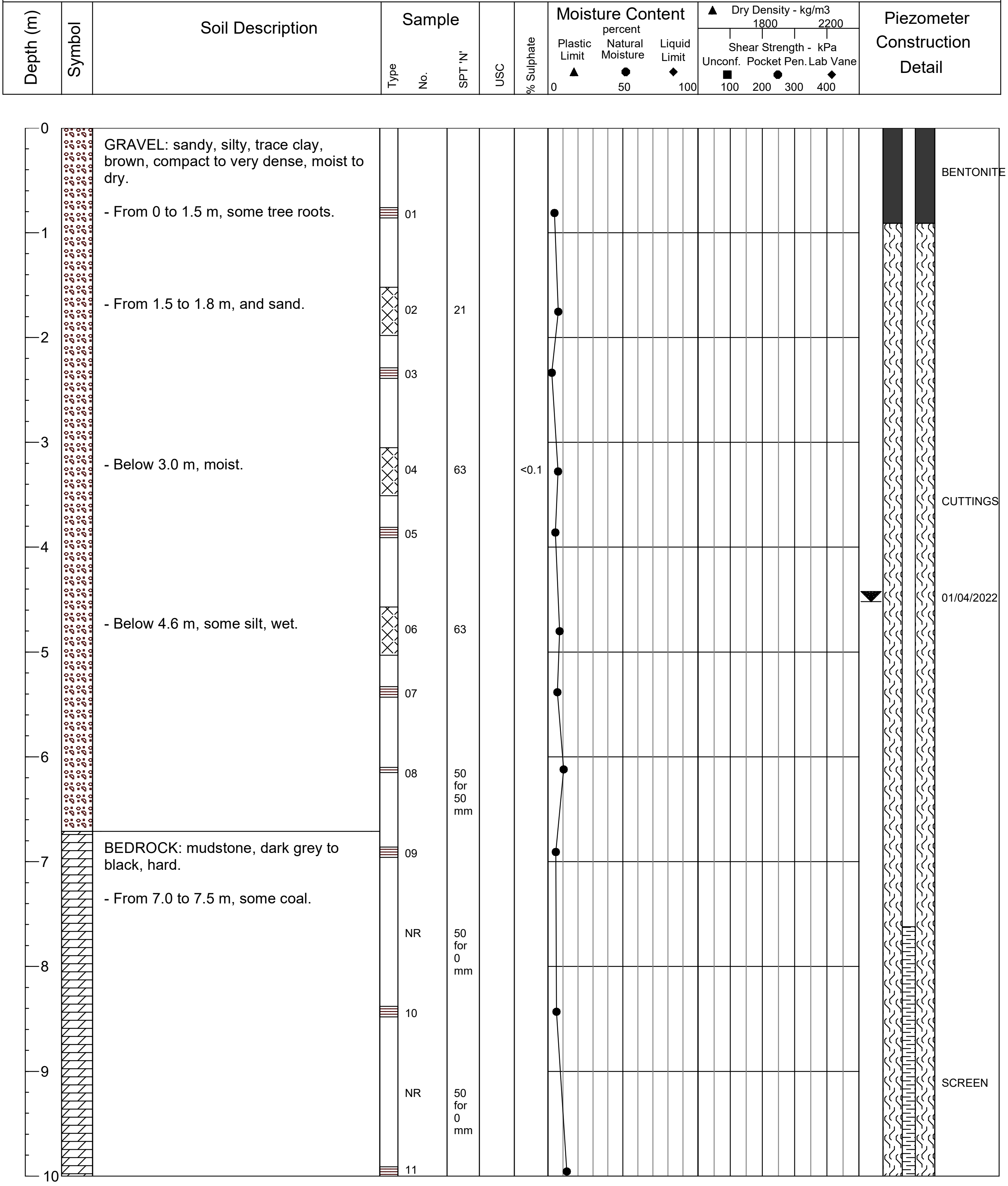
# BOREHOLE LOG

**Borehole:** BH22-01
**Page:** 1 of 2

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659551
Easting: 614984
Ground Elev.:
Top Casing Elev.:

Date Drilled: 18 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



GRAVEL: sandy, silty, trace clay, brown, compact to very dense, moist to dry.

- From 0 to 1.5 m, some tree roots.
- From 1.5 to 1.8 m, and sand.
- Below 3.0 m, moist.
- Below 4.6 m, some silt, wet.

BEDROCK: mudstone, dark grey to black, hard.

- From 7.0 to 7.5 m, some coal.

| Type | No. | SPT 'N' | USC | % Sulphate |
|---|---|---|---|---|
| ▤ | 01 | | | |
| ☒ | 02 | 21 | | |
| ▤ | 03 | | | |
| ☒ | 04 | 63 | | <0.1 |
| ▤ | 05 | | | |
| ☒ | 06 | 63 | | |
| ▤ | 07 | | | |
| ▤ | 08 | 50 for 50 mm | | |
| ▤ | 09 | | | |
| | NR | 50 for 0 mm | | |
| ▤ | 10 | | | |
| | NR | 50 for 0 mm | | |
| ▤ | 11 | | | |

Geotech BH m Elev CAL v13.ldf

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# BOREHOLE LOG

**Borehole:** **BH22-01**

**Page:** 2 of 2

| | | | | | |
|---|---|---|---|---|---|
| Client: | ISL Engineering & Land Services Ltd. | Northing: | 5659551 | Date Drilled: | 18 March 2022 |
| Project: | Canmore Bow River Pathway GEO | Easting: | 614984 | Drill: | Track |
| Location: | Canmore, AB | Ground Elev.: | | Drilling Method: | Odex |
| Project No.: | CG3608 | Top Casing Elev.: | | Logged by: | AH |

| Depth (m) | Symbol | Soil Description | Sample Type | Sample No. | SPT 'N' | USC | % Sulphate | Moisture Content (percent): Plastic Limit ▲, Natural Moisture ●, Liquid Limit ◆ (0 / 50 / 100) | ▲ Dry Density - kg/m3 (1800 / 2200); Shear Strength - kPa: Unconf. ■, Pocket Pen. ●, Lab Vane ◆ (100 / 200 / 300 / 400) | Piezometer Construction Detail |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | ▨ | BEDROCK: mudstone, dark grey to black, hard. | | NR | 50 for 0 mm | | | | | |

Notes:
- End of borehole at 10.7 m.
- Seepage observed at 3.0 m.
- No sloughing observed.

11 12 13 14 15 16 17 18 19 20

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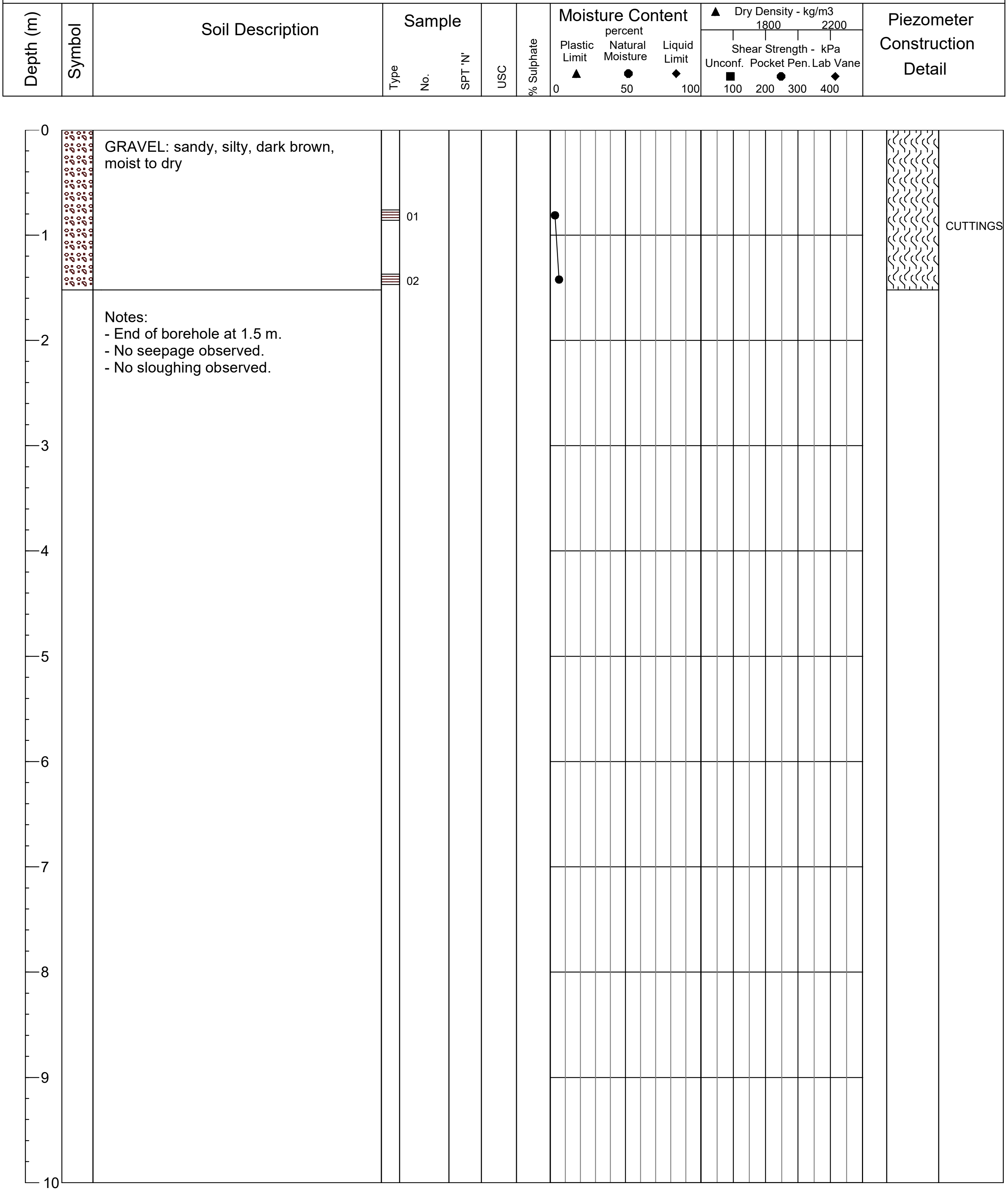
# BOREHOLE LOG

**Borehole:** **BH22-02**

**Page:** 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Client: | ISL Engineering & Land Services Ltd. | Northing: | 5660137 | Date Drilled: | 17 March 2022 |
| Project: | Canmore Bow River Pathway GEO | Easting: | 614484 | Drill: | Track |
| Location: | Canmore, AB | Ground Elev.: | | Drilling Method: | Solid Stem Auger |
| Project No.: | CG3608 | Top Casing Elev.: | | Logged by: | AH |



GRAVEL: sandy, silty, dark brown, moist to dry

Notes:
- End of borehole at 1.5 m.
- No seepage observed.
- No sloughing observed.

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# BOREHOLE LOG

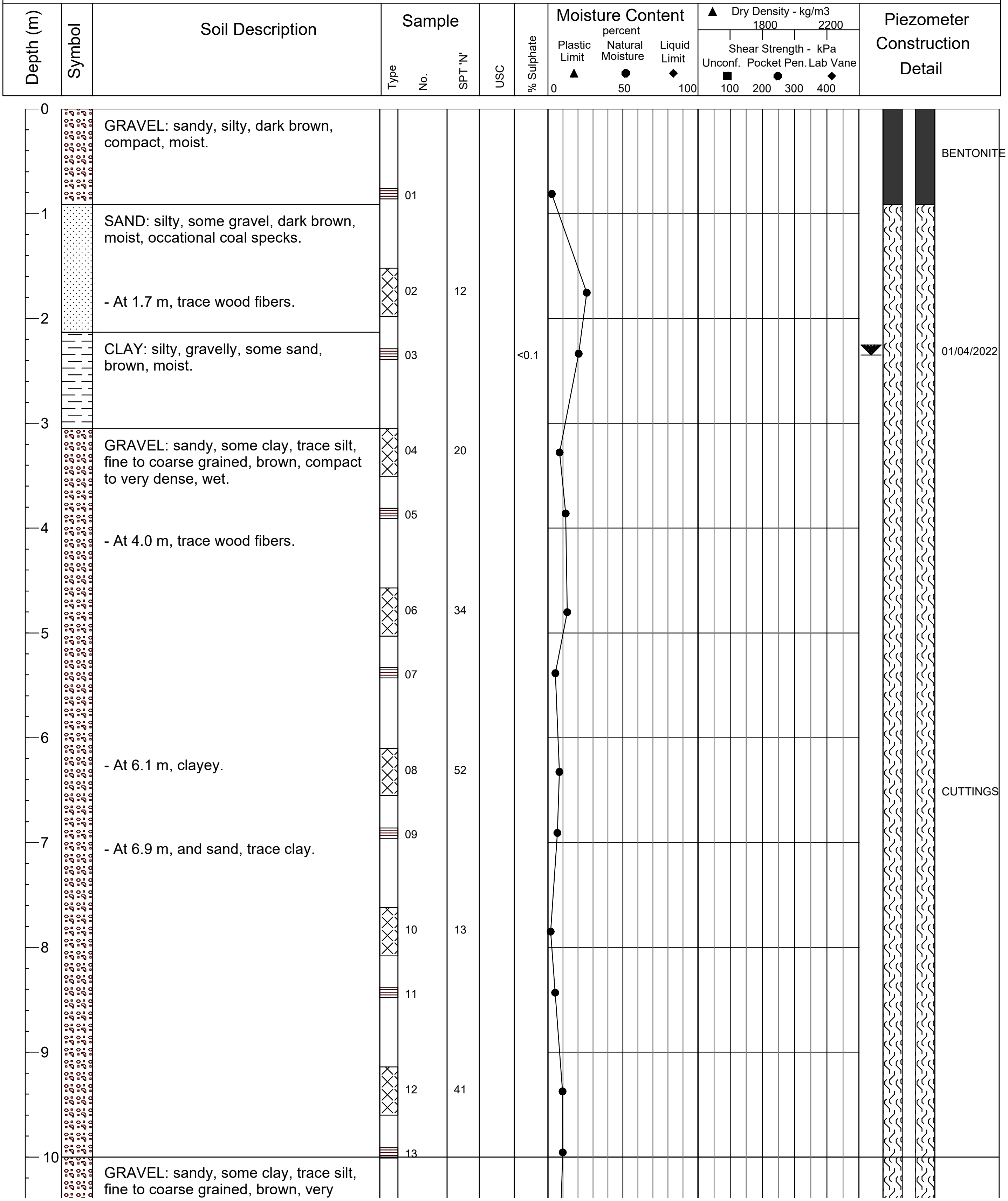
**Borehole:** **BH22-03**

**Page:** 1 of 2

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659969
Easting: 614601
Ground Elev.:
Top Casing Elev.:

Date Drilled: 17 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



GRAVEL: sandy, silty, dark brown, compact, moist.

SAND: silty, some gravel, dark brown, moist, occational coal specks.

- At 1.7 m, trace wood fibers.

CLAY: silty, gravelly, some sand, brown, moist.

GRAVEL: sandy, some clay, trace silt, fine to coarse grained, brown, compact to very dense, wet.

- At 4.0 m, trace wood fibers.

- At 6.1 m, clayey.

- At 6.9 m, and sand, trace clay.

GRAVEL: sandy, some clay, trace silt, fine to coarse grained, brown, very

| No. | SPT 'N' | % Sulphate |
|---|---|---|
| 01 | | |
| 02 | 12 | |
| 03 | | <0.1 |
| 04 | 20 | |
| 05 | | |
| 06 | 34 | |
| 07 | | |
| 08 | 52 | |
| 09 | | |
| 10 | 13 | |
| 11 | | |
| 12 | 41 | |
| 13 | | |

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# BOREHOLE LOG

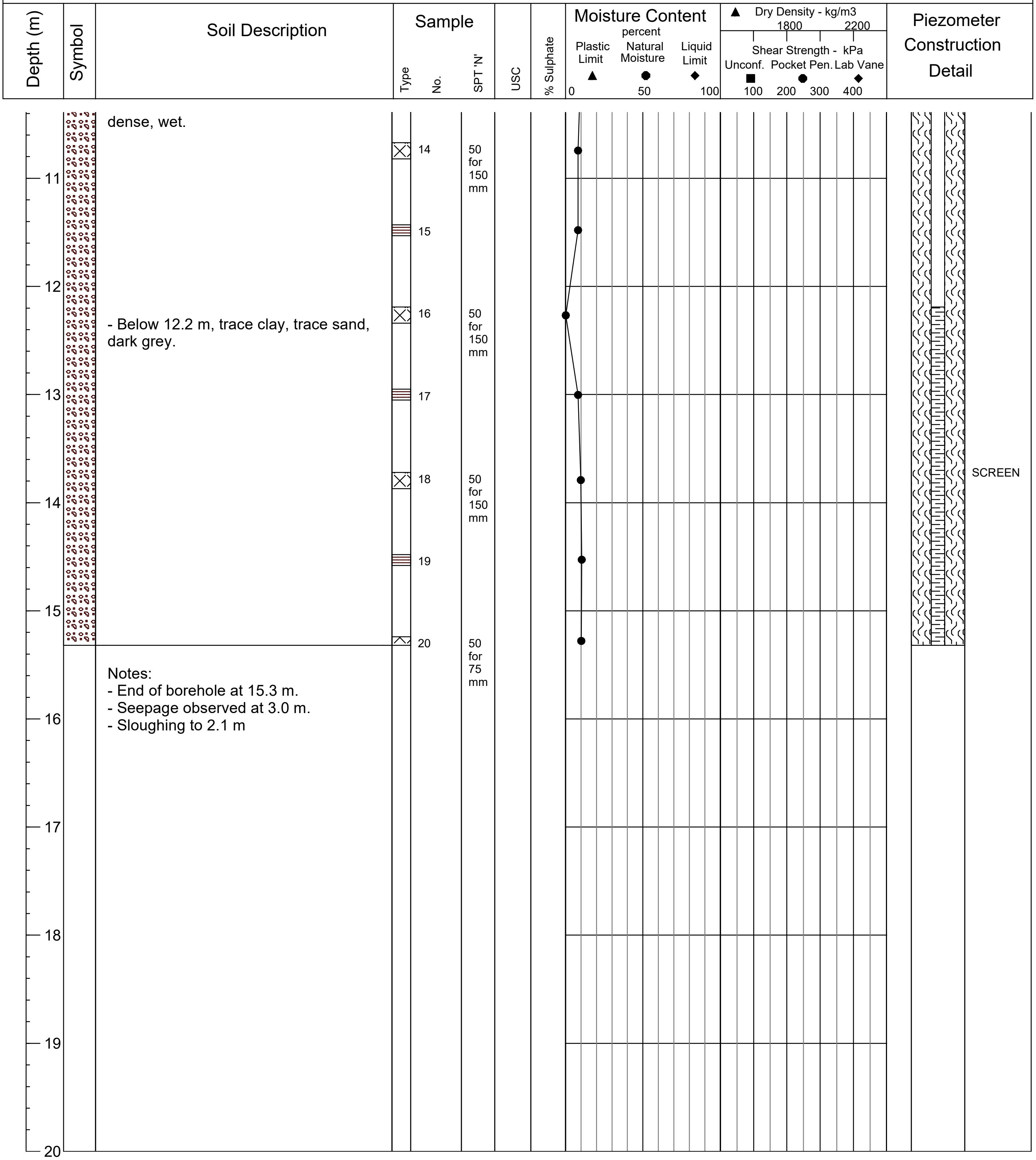
**Borehole:** **BH22-03**

**Page:** 2 of 2

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659969
Easting: 614601
Ground Elev.:
Top Casing Elev.:

Date Drilled: 17 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



dense, wet.

- Below 12.2 m, trace clay, trace sand, dark grey.

| Type | No. | SPT 'N' |
|---|---|---|
| ☒ | 14 | 50 for 150 mm |
| ▤ | 15 | |
| ☒ | 16 | 50 for 150 mm |
| ▤ | 17 | |
| ☒ | 18 | 50 for 150 mm |
| ▤ | 19 | |
| ☒ | 20 | 50 for 75 mm |

Notes:
- End of borehole at 15.3 m.
- Seepage observed at 3.0 m.
- Sloughing to 2.1 m

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# BOREHOLE LOG

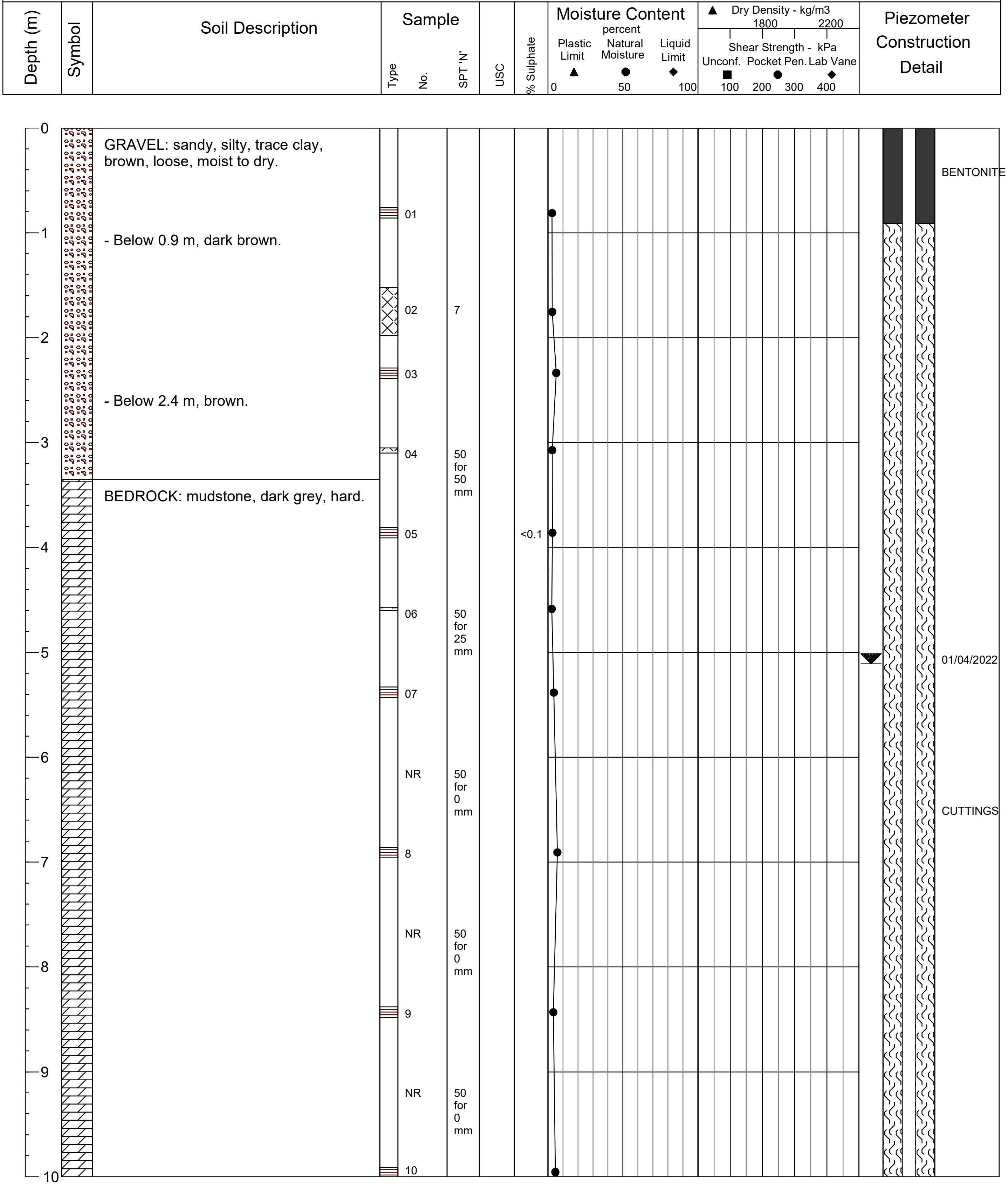
**Borehole:** **BH22-04**

**Page:** 1 of 2

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659933
Easting: 614570
Ground Elev.:
Top Casing Elev.:

Date Drilled: 18 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



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# BOREHOLE LOG

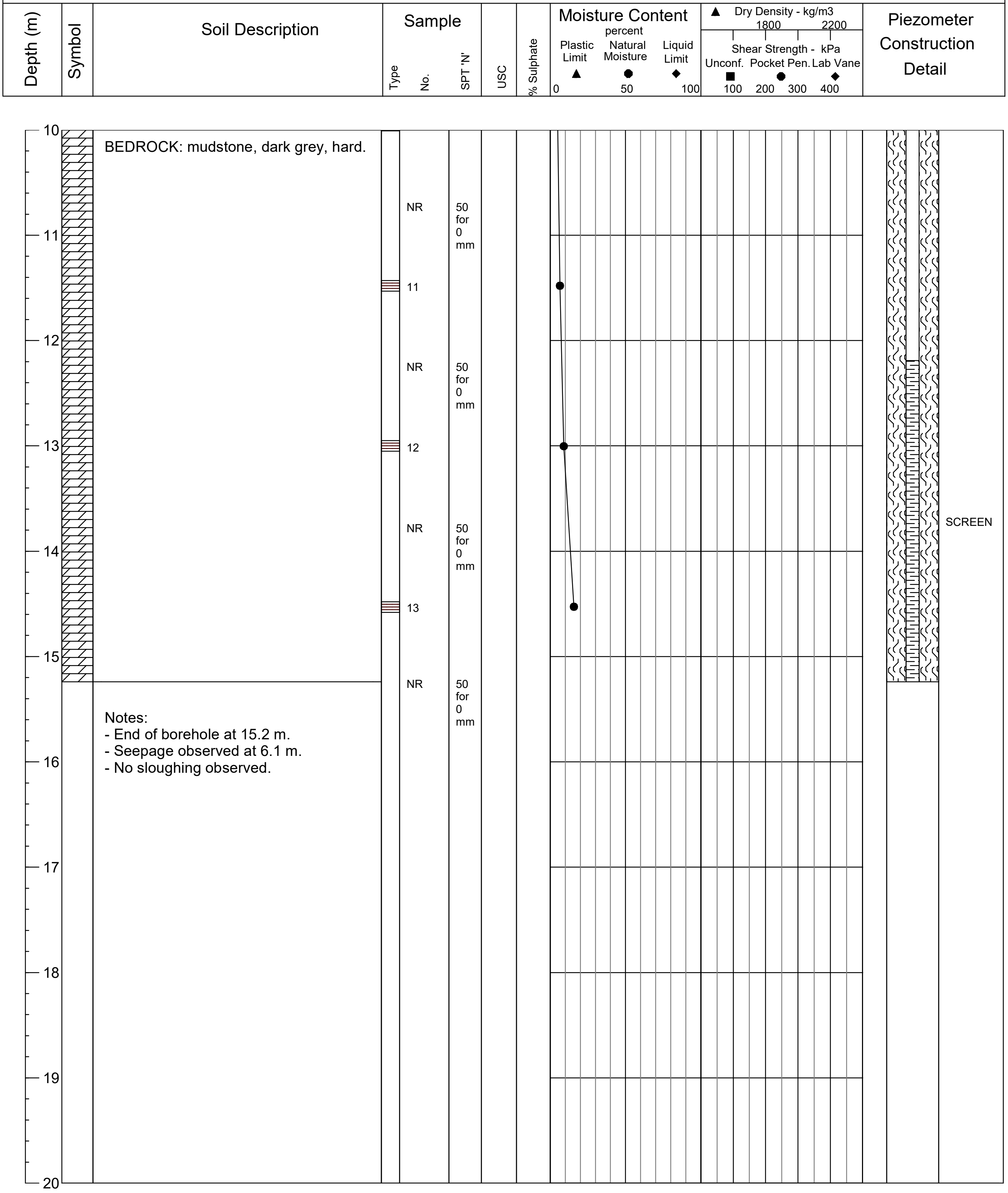
**Borehole:** **BH22-04**

**Page:** 2 of 2

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659933
Easting: 614570
Ground Elev.:
Top Casing Elev.:

Date Drilled: 18 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



BEDROCK: mudstone, dark grey, hard.

| Type | No. | SPT 'N' |
|---|---|---|
| NR | | 50 for 0 mm |
| | 11 | |
| NR | | 50 for 0 mm |
| | 12 | |
| NR | | 50 for 0 mm |
| | 13 | |
| NR | | 50 for 0 mm |

Notes:
- End of borehole at 15.2 m.
- Seepage observed at 6.1 m.
- No sloughing observed.

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# BOREHOLE LOG

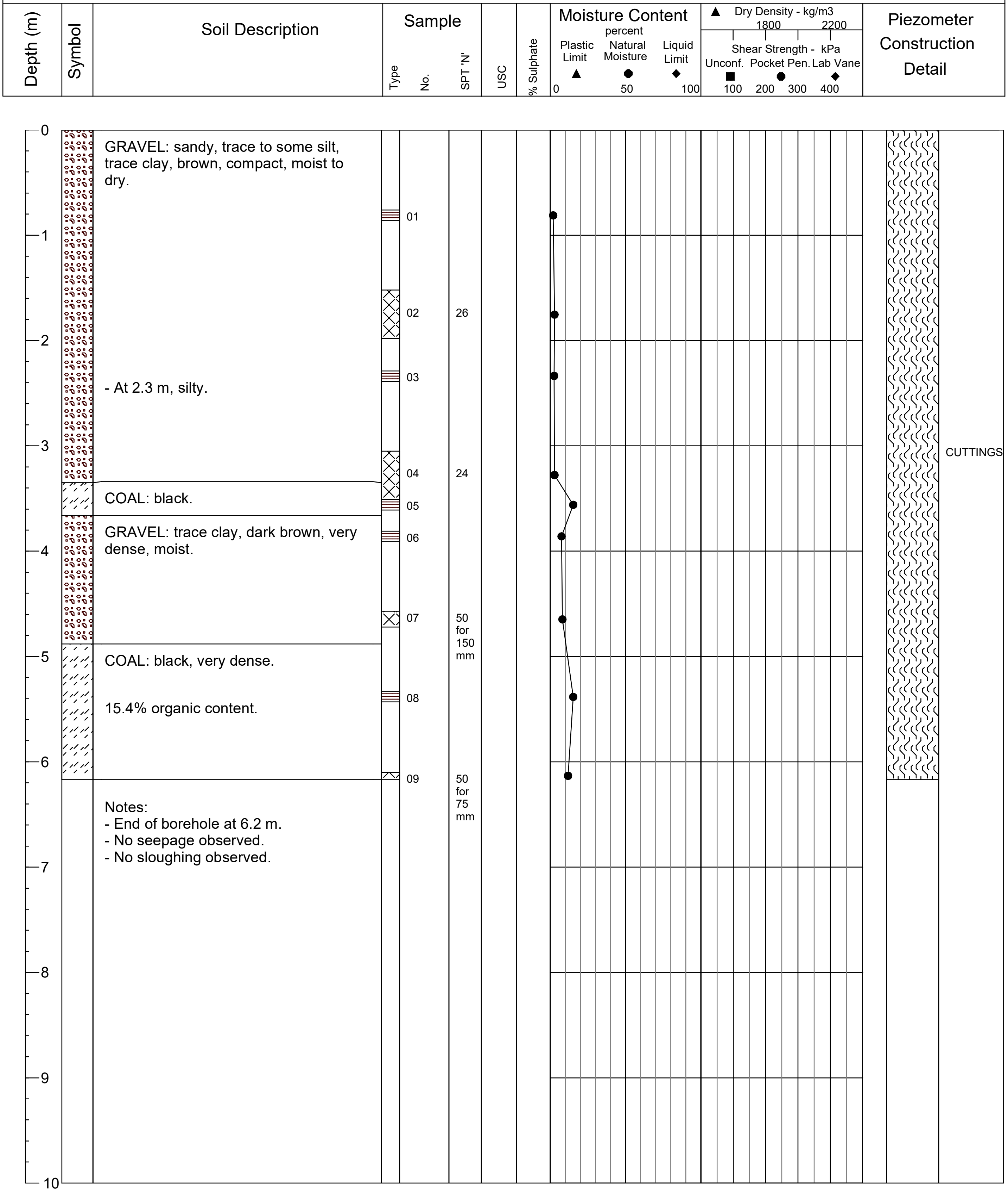
**Borehole:** **BH22-05**

**Page:** 1 of 1

Client: ISL Engineering & Land Services Ltd.
Project: Canmore Bow River Pathway GEO
Location: Canmore, AB
Project No.: CG3608

Northing: 5659933
Easting: 614570
Ground Elev.:
Top Casing Elev.:

Date Drilled: 17 March 2022
Drill: Track
Drilling Method: Odex
Logged by: AH



GRAVEL: sandy, trace to some silt, trace clay, brown, compact, moist to dry.

- At 2.3 m, silty.

COAL: black.

GRAVEL: trace clay, dark brown, very dense, moist.

COAL: black, very dense.

15.4% organic content.

Notes:
- End of borehole at 6.2 m.
- No seepage observed.
- No sloughing observed.

| No. | SPT 'N' |
|---|---|
| 01 | |
| 02 | 26 |
| 03 | |
| 04 | 24 |
| 05 | |
| 06 | |
| 07 | 50 for 150 mm |
| 08 | |
| 09 | 50 for 75 mm |

Geotech TP m Elev CAL v09.ldf

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# TEST PIT LOG

**Test Pit:** HA22-01

**Page:** 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Client: | ISL Engineering & Land Services Ltd. | Northing: | 5660284 | Date: | 26 May 2022 |
| Project: | Canmore Bow River Pathway GEO | Easting: | 614490 | Excavator: | Hand Auger and Shovel |
| Location: | Canmore, AB | Ground Elev.: | | Logged by: | RC |
| Project No.: | CG3608 | | | | |

| Depth (m) | Symbol | Soil Description | Sample Type | Sample No. | SPT 'N' | USC | % Sulphate | Moisture Content percent<br>Plastic Limit ▲ Natural Moisture ● Liquid Limit ◆<br>0 50 100 | ▲ Dry Density - kg/m3 1800 2200<br>Shear Strength - kPa<br>Unconf. ■ Pocket Pen. ● Lab Vane ◆<br>100 200 300 400 | Piezometer Construction Detail |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | GRAVEL: rounded, up to 70 mm in size, sandy, brown, moist, trace rootlets. | | | | | | | | |
| | | Notes:<br>- End of borehole at 0.3 m.<br>- No seepage observed.<br>- No sloughing observed. | | | | | | | | |
| 1 | | | | | | | | | | |

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**Clifton**

# TEST PIT LOG

**Test Pit:** **HA22-02**
**Page:** 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Client: | ISL Engineering & Land Services Ltd. | Northing: | 5659978 | Date: | 26 May 2022 |
| Project: | Canmore Bow River Pathway GEO | Easting: | 614546 | Excavator: | Hand Auger and Shovel |
| Location: | Canmore, AB | Ground Elev.: | | Logged by: | RC |
| Project No.: | CG3608 | | | | |

| Depth (m) | Symbol | Soil Description | Sample Type | Sample No. | Sample SPT 'N' | USC | % Sulphate | Moisture Content percent<br>Plastic Limit ▲ Natural Moisture ● Liquid Limit ◆<br>0 50 100 | ▲ Dry Density - kg/m3<br>1800 2200<br>Shear Strength - kPa<br>Unconf. ■ Pocket Pen. ● Lab Vane ◆<br>100 200 300 400 | Piezometer Construction Detail |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | GRAVEL: rounded, up to 80 mm in size, sandy, dark brown, moist, trace organics. | | | | | | | | |
| | | Notes:<br>- End of borehole at 0.5 m.<br>- No seepage observed.<br>- Sloughing during hand augering. | | | | | | | | |
| 1 | | | | | | | | | | |

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Clifton

# TEST PIT LOG

**Test Pit:** HA22-03
**Page:** 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Client: | ISL Engineering & Land Services Ltd. | Northing: | 5659972 | Date: | 26 May 2022 |
| Project: | Canmore Bow River Pathway GEO | Easting: | 614551 | Excavator: | Hand Auger and Shovel |
| Location: | Canmore, AB | Ground Elev.: | | Logged by: | RC |
| Project No.: | CG3608 | | | | |

| Depth (m) | Symbol | Soil Description | Sample Type | Sample No. | Sample SPT 'N' | USC | % Sulphate | Moisture Content percent: Plastic Limit ▲, Natural Moisture ●, Liquid Limit ◆ (0, 50, 100) | ▲ Dry Density - kg/m3 (1800, 2200); Shear Strength - kPa: Unconf. ■, Pocket Pen. ●, Lab Vane ◆ (100, 200, 300, 400) | Piezometer Construction Detail |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | GRAVEL: rounded, up to 80 mm in size, sandy, dark brown, moist, trace organics. | | | | | | | | |
| | | Notes:<br>- End of borehole at 0.5 m.<br>- No seepage observed.<br>- Sloughing during hand augering. | | | | | | | | |
| 1 | | | | | | | | | | |

# Appendix C

## Laboratory Results

Clifton

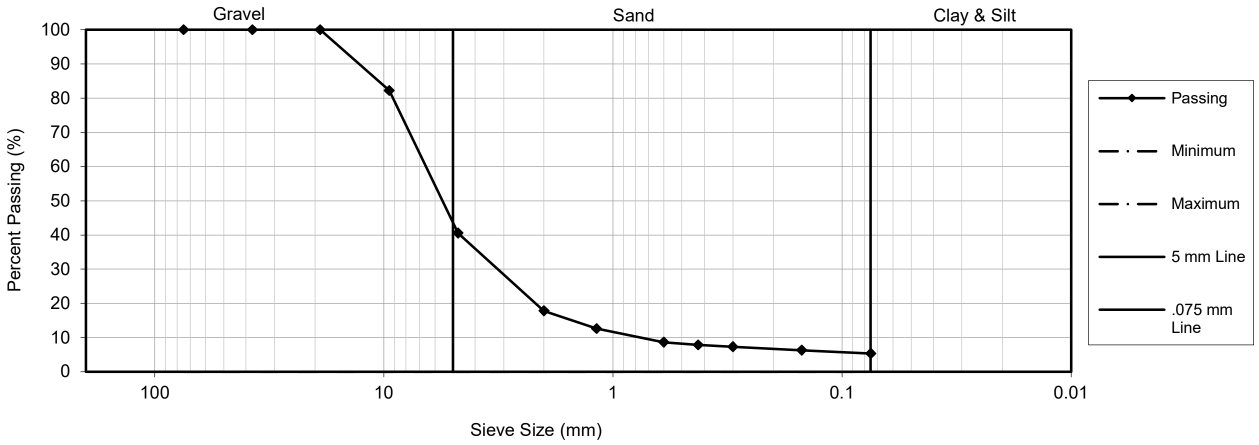
# Mechanical Sieve Analysis

ASTM C117, C136

| | | | |
|---|---|---|---|
| Sample No. | - | Supplied by | - |
| Date Sampled | 17-Mar-22 | Date Received | 17-Mar-22 |
| Time Sampled | - | Date Tested | 22-Mar-22 |
| Sampled by | AH | Tested by | KD |
| Sample Description | Gravel and sand trace silt/clay | | |
| Sample Location | BH22-03, Sample #9 @ 6.9m | | |

| | | | |
|---|---|---|---|
| Moisture Content (%) | 6.3 | Gravel PI (%) | |
| Lightweights (%) | | Fineness Modulus (%) | |
| Fracture Aggregate (%) | | Sand Equivalent (%) | |

| Sieve Size (mm) | Percent Passing | Sieve Size (mm) | Spec. Minimum % | Spec. Maximum % |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 75 | 100.0 | | | |
| 37.5 | 100.0 | | | |
| 19 | 100.0 | | | |
| 9.5 | 82.2 | | | |
| 4.75 | 40.5 | | | |
| 2 | 17.8 | | | |
| 1.18 | 12.5 | | | |
| 0.6 | 8.6 | | | |
| 0.425 | 7.8 | | | |
| 0.3 | 7.3 | | | |
| 0.15 | 6.3 | | | |
| 0.075 | 5.3 | | | |



| | |
|---|---|
| Approved By | Ashley Hermanson |

Clifton

| | |
|---|---|
| Project No. | CG3608 |
| Client | ISL Engineering & Land Services Ltd. |
| Project | Canmore Bow River Pathway GEO |
| Location | Canmore, AB |

# Mechanical Sieve Analysis

## ASTM C117, C136

| | | | |
|---|---|---|---|
| Sample No. | - | Supplied by | - |
| Date Sampled | 18-Mar-22 | Date Received | 18-Mar-22 |
| Time Sampled | - | Date Tested | 22-Mar-22 |
| Sampled by | AH | Tested by | KD |
| Sample Description | Sandy gravel some silt/clay | | |
| Sample Location | BH22-06, Sample #7 @ 5.3m | | |

| | | | |
|---|---|---|---|
| Moisture Content (%) | 6.3 | Gravel PI (%) | |
| Lightweights (%) | | Fineness Modulus (%) | |
| Fracture Aggregate (%) | | Sand Equivalent (%) | |

| Sieve Size (mm) | Percent Passing | Sieve Size (mm) | Spec. Minimum % | Spec. Maximum % |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 75 | 100.0 | | | |
| 37.5 | 100.0 | | | |
| 19 | 100.0 | | | |
| 9.5 | 68.1 | | | |
| 4.75 | 42.4 | | | |
| 2 | 32.3 | | | |
| 1.18 | 28.3 | | | |
| 0.6 | 22.0 | | | |
| 0.425 | 19.5 | | | |
| 0.3 | 17.5 | | | |
| 0.15 | 13.7 | | | |
| 0.075 | 11.1 | | | |

| | |
|---|---|
| Approved By | Ashley Hermanson |

| | |
|---|---|
| Project No. | CG3608 |
| Client | ISL Engineering & Land Services Ltd. |
| Project | Canmore Bow River Pathway GEO |
| Location | Canmore, AB |

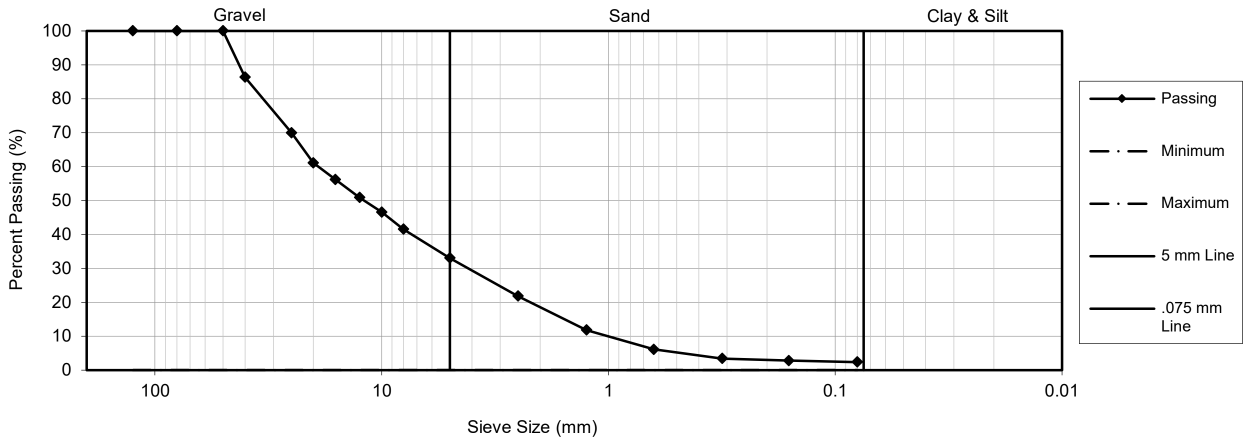
# Mechanical Sieve Analysis

ASTM C117, C136

| | | | |
|---|---|---|---|
| Sample No. | | Supplied by | RC |
| Date Sampled | 26-May-22 | Date Received | 26-May-22 |
| Time Sampled | - | Date Tested | 30-May-22 |
| Sampled by | RC | Tested by | KD |
| Sample Description | Sandy Gravel | | |
| Sample Location | HA-02 @ 0.3m | | |

| | | | |
|---|---|---|---|
| Moisture Content (%) | 1.9 | Gravel PI (%) | |
| Lightweights (%) | | Fineness Modulus (%) | |
| Fracture Aggregate (%) | | Sand Equivalent (%) | |

| Sieve Size (mm) | Percent Passing | Sieve Size (mm) | Spec. Minimum % | Spec. Maximum % |
|---|---|---|---|---|
| 125 | 100.0 | | | |
| 80 | 100.0 | | | |
| 50 | 100.0 | | | |
| 40 | 86.3 | | | |
| 25 | 69.9 | | | |
| 20 | 61.1 | | | |
| 16 | 56.2 | | | |
| 12.5 | 50.8 | | | |
| 10 | 46.5 | | | |
| 8 | 41.5 | | | |
| 5 | 33.0 | | | |
| 2.5 | 21.8 | | | |
| 1.25 | 11.8 | | | |
| 0.63 | 6.1 | | | |
| 0.315 | 3.4 | | | |
| 0.16 | 2.8 | | | |
| 0.08 | 2.4 | | | |



| | |
|---|---|
| Approved By | Rocky Cho |

| | |
|---|---|
| Project No. | CG3608 |
| Client | ISL Engineering & Land Services Ltd. |
| Project | Canmore Bow River Pathway GEO |
| Location | Canmore, AB |

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# Appendix D

## Photographs

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**Photograph 1**
Base of retaining wall facing East

**Photograph 2**
Base of retaining wall facing at the failed section

**Photograph 3**
Washed out fines from the retaining wall

**Photograph 4**
Close up of the retaining wall

**Photograph 5**
Failed retaining wall section

**Photograph 6**
Coal fragment at the base

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