Ms. Shelley Tamelin
Canadian Rockies Hot Springs
Parks Canada Agency
PO Box 40
Radium Hot Springs, BC
V0A1M0

March 9, 2021

Project Number: 2020-036

RE: Geotechnical Investigation for Retaining Wall in Distress
Banff Upper Hot Springs, Banff National Park, AB

Dear Ms. Tamelin,

As requested, Taylor Geotechnical Ltd. (TGL) has conducted a geotechnical investigation for the retaining wall in distress at the Banff Upper Hot Springs located at 1 Mountain Ave. in Banff National Park, AB. The purpose of the investigation was to identify the subsurface soil and groundwater conditions at the project site, as well as to identify the possible mechanisms resulting in distress to the retaining wall. Based on our interpretation of this information, comments and recommendations for rehabilitation of the structure are provided herein.

The scope of work for this project was provided in the document "Statement of Work, Banff Upper Hot Springs, Retaining Wall Repair Project" version 2 emailed to TGL on August 11th, 2020 and TGL Proposal P2020-069 dated August 13th, 2020. Authorization to proceed was given by the client on August 17th, 2020. This report supersedes the previous version submitted on November 23, 2020 and incorporates comments and feedback provided by Parks Canada Agency (PCA) on December 8, 2020.

It should be noted that the scope of this report is limited to the geotechnical assessment of the existing retaining wall. It does not include any investigation, analytical testing or assessment of possible groundwater contamination, archeological or biological considerations, or sediment control measures. This report should be read in conjunction with the Disclaimer and Limitations which are appended following the text of this letter. The reader's attention is specifically drawn to this information as it is essential for the proper use and interpretation of this report.

1.0 PROJECT UNDERSTANDING

An overview of the project and current site conditions is presented below. Project information was provided by Ms. Tamelin prior to the geotechnical investigation. The purpose of this work is to provide a factual report of the current conditions of the in-situ materials and to provide recommendations for the rehabilitation or repair of the wall.

The Upper Hot Springs facility is located at 1 Mountain Ave, Banff, AB which is on the lower east-facing slope of Sulphur Mountain. The retaining wall is adjacent to the Hot Springs pool and is situated at the southeast corner of site. The retaining wall is approximately 15 m long and 3 m tall. The ground surface above the retaining wall is relatively flat-lying and is covered in asphalt. At the base of the retaining wall, the terrain slopes moderately steeply down to the east.

The retaining wall was constructed of stacked rock with mortar and was constructed by hand without specific direction from an engineer. From conversation with PCA, it is understood that the retaining wall was built during the 1930's and was likely constructed in two phases. Evidence of phased construction is visible in differing rock shape and placement as well as change in mortar colour and consistency. This change is apparent approximately 1.0 m to 1.5 m above the existing ground surface.

The retaining wall has experienced some settlement and deformation since its construction. It is understood that the area above the retaining wall has been recently used to stockpile snow during seasonal snow removal work.

2.0 DOCUMENT REVIEW

The following section summarizes the pertinent information captured from the document review. Documents and drawings were provided by the Parks Canada Agency upon initiation of the study.

Ripley, C. F. (1957). Foundation Conditions at Upper Hot Springs Pool Banff National Park (pp. 1-10, Rep. No. R-301). Vancouver, BC: Ripley and Associates.

- Report summarizes the geotechnical investigation carried out for the existing foundation conditions at the Upper Hot Springs pool. Comments and recommendations for the geotechnical aspects of design were provided within the document.
- Between June 7, 1957 and June 14, 1957 four test pits were excavated to expose the foundation material underlying the pool and surrounding retaining walls.
- It was discovered that the bath house and pool are founded entirely on excavated ground. The retaining walls at the northwest and northeast corners of the pool were founded on backfill material.
- Testpit 1 was excavated to a depth of 2.13 m. The excavated material mainly consisted of silt, sands and cobbles. Calcareous Tufa of varying hardness was encountered at the bottom of the testpit.
- Testpits 2, 3 and 4 were located in the tunnel of the facility and were excavated to a depths of 45 cm (or 15 cm below the bottom of the footings). Soft and moist Calcareous Tufa was encountered.

Saunders, R. (1994). Preliminary Geotechnical Assessment Banff Upper Hot Springs Redevelopment (pp. 1-4, Rep.). Calgary, AB: Geo-Engineering.

- Report summarizes the geotechnical investigation carried out for the proposed expansion/renovations of the existing pool facility. Comments and recommendations for the geotechnical aspects of design were provided within the document.
- On August 30, 1994, a Becker Hammer was used to drill one borehole on the approximate east-west centerline of the addition (near the crest of the slope).
- The borehole confirmed fractured limestone bedrock at a depth of 9.8 m. This was overlain by a layer of dense glacial till consisting of sand and gravel in a silty matrix. Sandy gravel was encountered above the glacial till. The upper layer extended to a depth of approximately 4.9 m.
- Groundwater was not encountered at the time of the investigation.

Choi, S. (2015). Geotechnical Assessment for Foundation Rehabilitation (pp. 1-34, Rep. No. 2341-01968-00). Prince George, BC: McElhanney.

- Report summarizes a geotechnical investigation carried out for the rehabilitation of the Caretakers Cottage located the Upper Hot Springs facility.
- On June 16, 2015, two boreholes were advanced using a truck mounted drill rig.
- Borehole 1 was drilled on the east side of the building. Topsoil was encountered to a depth of 0.1 m. A layer of sand and gravel with some silt and clay was encountered to a depth of 7.6 m. Bedrock was observed from 7.6 m to 12.9 m.
- Borehole 2 was drilled on the west side of the building. Bedrock was observed from ground surface and extending beyond the terminus of the borehole.
- Groundwater was not encountered.

Kleindienst, E. (2017). Slope Stability Assessment Banff Upper Hot Springs (pp. 1-29, Rep.). Cranbrook, BC: Vast Resource Solutions.

- Report summarizes the findings of a slope stability analysis for the slope located below the Banff Upper Hot Springs Pool.
- The surficial soils consist of silty sand, some gravel and trace to little clay and extend beyond 1.0 m.
- The factor of safety of the slope east of the retaining wall in question is 1.7 with trees and 1.8 without. The factor of safety was noted to decrease with trees along the slope because of their additional weight.

3.0 FIELD AND LABORATORY WORK

The geotechnical investigation was carried out on September 1st, 2020. At this time, four (4) boreholes were advanced at the site to determine subsurface soil and groundwater conditions, as well as to collect representative soil samples. Boreholes were augured using an excavator-based drill operated by TGL staff from Canmore, AB. The drilling work was carried out under the supervision of TGL geologist.

Boreholes were advanced to depths between 1.8 m to 3.2 m. The depth of testholes was limited to minimize impact on the underlying tufa deposits. Representative soil sample was collected for a detailed examination and laboratory testing. Upon completion, the boreholes were backfilled with the excavation soils. Borehole logs are provided within Appendix A of this report. Laboratory testing included moisture content determination. Testing was completed by Taylor Geotechnical in Canmore, AB. Results are presented in Appendix A.

On September 2nd, 2020, a distress survey was completed on the existing retaining wall and visible signs of deterioration were logged. Observations and measurements of the sloping terrain below the retaining wall was also carried out.

4.0 SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

The following section summarizes the observed subsurface soil and groundwater conditions at the time of the investigation. All boreholes were advanced along the ground surface behind the retaining wall. Please note variability in ground conditions may exist between boreholes and with depth. Borehole logs and laboratory testing results are presented in Figure 1. Approximate borehole locations are presented in Photo 10 of Appendix B.

- An asphalt layer was encountered in all four holes having an approximate thickness of 80 mm.
- BH-01 was drilled on top of a previous sinkhole patch. The upper 0.6 m was identified as fill material used for the sinkhole repair. This layer consisted of sandy gravel with some debris and tufa fragments. Underlaying this layer was a sandy gravel with some silt and cobbles to hole termination at 1.75m. The borehole was terminated due to auger refusal on cobbles.
- Within BH-02, a 0.3 m thick layer of gravely sand with trace to some silt was encountered below the asphalt surface layer. This layer was underlain by a sand with trace silt and trace gravel to a depth of 1.4 m.
- BH-03 and BH-04 encountered a gravelly sand with trace to some silt to a depth of 1.2m.
- Within BH-02, 3 and 4, sand, degraded tufa and trace silt was encountered following the upper granular layers. The sand and degraded tufa material extended beyond the terminus to the boreholes.
- Debris, cobbles and tufa fragments were noted in all the boreholes.

Groundwater was not encountered in the boreholes at the time of the investigation. The auger bit was observed to be wet when pulled out of BH-01. However, accumulation of groundwater was not observed at the bottom of the open borehole. Please note, groundwater levels are subject to seasonal variation with the highest water levels likely to occur during the late-Spring and Summer months.

5.0 CONDITION ASSESSMENT OF RETAINING WALL

The following section summarizes observed features of the retaining wall at the time of the investigation. Annotated photographs of the features described below are presented in Appendix B.

- Along the face of the retaining wall, the mortar was noted to be in poor condition with numerous crack features running vertically and horizontally around the stacked rocks.
  - Features 1, 2, 5 and 8 are vertical crack features that run from the top to bottom of the retaining wall. Typical thickness of the cracks are 1 cm to 2 cm.
  - Feature 7 is a horizontal crack that is approximately 1 cm wide that connects to the vertical crack identified as Feature 8.
  - In addition, visibly different mortar mixtures seem to be present over the entirety of the wall. It was most apparent between the upper and lower portions of the structure.
- Feature 3 consists of a clogged drain outlet.
- Feature 4 is bulging of the lower portion of the retaining wall. It starts 3.8 m from the south end of the wall and terminates 4.4 m from the north end. The bulge is noted at the base of the wall up to heights of 1.1 m to 1.8 m.
  - This feature appears to be mainly contained within the work completed in the presumed first construction phase.
  - It is considered unlikely that this feature was a deliberate construction choice and is likely more likely evident of distress and structural deterioration.
- Granular fill material was discovered at the toe of the retaining wall and at various places along Feature 4.
- Feature 6 is a void caused from the loss of the retaining wall material (mortar and rock). It is approximately 70 cm deep and 70 cm long and 15 cm tall.
- Feature 9 is on the asphalt surface on top of the retaining wall is a 15 cm wide crack that run approximately 1.5 m.

- Feature 10 is a noted 5° inwards lean in the top 0.5m of the retaining wall. This portion of retaining wall exists above the asphalt ground surface.
- Feature 11 is a 0.5m deep void running approximately 1.75m long. This void is at a low point in the current ground surface and is anticipated to be preferential path for surface water flow.
- No water of excess moisture was noted at the toe or along the face of the retaining wall.
- The ground surface below the retaining wall was observed to be moderately steeply sloping and covered in treed vegetation. The sloping terrain was relatively consistent and did not show signs of recent or historical slope movement.

6.0 MECHANISMS OF DISTRESS

Based on our review of the site and subsurface conditions, the following observations pertaining to stability of the current retaining wall configuration.

- Significant pavement distress occurred earlier in 2020 with development of open cracks and voids immediately behind the structure.
- Bulging of the lower portion of the retaining wall indicates that insufficient lateral support was provided by the retaining wall for the loading conditions. This is particularly apparent at and immediately above the base of the wall.
- It is TGL's opinion that a circular failure occurred from the asphalt surface extending through the lower portion of the retaining wall. The mobilized soil pushes against the lower portion of the retaining wall to form the bulge feature.
- Deterioration to the grout is anticipated to have occurred over the lifespan of the structure, however the significant cracking is likely more recent and in connection to failure of the structure. Deterioration of the mortar has resulted in loosening of the stacked rocks and lose of rocks in specific locations.
- As noted above, granular materials have mobilized behind the retaining wall. Due to degradation of the mortar, granular material has moved through the structure and has been deposited along the lower stacked rock and at the toe. Movement of soil likely accelerates at times of heavy surface water flow (e.g., rainfall events and during snow melt) as water can flow freely through the cracks along the asphalt surface. This has left significant voids behind the retaining wall.
- The observed drain feature along the face of the wall indicates that drainage of free water behind the retaining wall was a consideration to maintain the long-term stability of the structure.
- The ground surface below the retaining wall does not appear to have been impacted by failure of the structure. This indicates that the failure is confined the retaining wall structure and ground surface behind the structure.

7.0 GEOTECHNICAL COMMENTS AND RECOMMENDATIONS

Based on the results of the investigation, it is TGL's opinion that failure of the retaining wall has occurred. The structure is not stable in its current configuration. Replacement of the structure is required in order to regain access to the landing area behind the retaining wall. Immediate attention is required. This attention includes:

- Closing access to the landing above the retaining wall and leaving it closed until a stable site condition has been implemented through re-construction of the retaining wall.
- Consideration to closing walking path access below the trail.
- Planning and undertaking retaining wall reconstruction or decommissioning as soon as is practical.

To repair the structure to maintain the original esthetic would likely require void filling by grouting along with the installation of reinforcement and drainage. It is TGLs' opinion that repair of the structure is not a feasible option for the following reasons:

- Significant voids exist behind the retaining wall and cracking is present along the face of the retaining wall along with missing rocks.
- Grouting is likely the only means to fill these voids. However, this work would likely to result in significant grout loss through and beneath the structure.
- Grout loss could communicate with the neighbouring creek and under the pool structure. This posses significant environmental and operational risks.

An alternative repair option includes application of shotcrete along the face of the retaining wall along with the installation of soil nails to tie back the structure. This option would cover the stacked rock facing with concrete and is not believed to be viable as the esthetic nature of the current retaining wall would be lost.

Replacement with a cast-in-place concrete wall was initially considered. However, it is foreseeable that this type of rigid structure would experience cracking over its lifespan from exposure to freeze-thaw cycles as well as small amounts of ground movement that are typical for retaining wall structures.

Taylor Geotechnical recommends replacement with a more flexible multi-segmental retaining wall system. The following provides preliminary options replacement of the structure with multi-segmental retaining wall system.

1. Replacement of the Retaining Wall including Salvaged Pieces of the Stacked Rock using Maccaferri Terrawall product.
   - Remove asphalt surface.
   - Demolish existing retaining wall while stockpiling the stacked rock units.
   - Existing stones would be stacked as facing stone placed within the wire mesh baskets.
   - Construct replacement structure including appropriate drainage.
2. Replacement of the Retaining wall with a new multi-segmental design.
   - This option involves complete replacement.
   - Salvaging the rock from the existing structure could be used as a decorative feature on top of the retaining wall, if desired.
   - Multi-segmental retaining walls can be constructed of various styles of concrete or masonry units to tie into the aesthetic style of the facility.

Following submission of the draft report, discussion on the preferred retaining wall replacement option was had with Parks Canada Agency. It was determined that the MagnumStone product was desired option for the replacement multi-segmental retaining wall.

From discussion with PCA on December 8, 2020, it was determined that retaining wall removal is also being considered as PCA evaluates the associated costs and benefits with retaining wall construction. Removal of the existing retaining wall would require reshaping of the ground surface to a stable sloping configuration.

8.0 ANALYSIS AND DESIGN

Taylor Geotechnical Ltd. has undertaken analysis of the proposed replacement retaining wall constructed of MangnumStone units. Additionally, TGL undertook analysis of the slope regrading option following retaining wall remove. The following section describes the analyses completed as well as provides a design information. Measurements of the critical slope section were taken during the site investigation and used in the analyses.

Geotechnical assessment of the retaining wall included review of global stability, as well as external and internal stability of the retaining wall. Global stability analysis was undertaken for the slope regarding option.

8.1 SUMMARY OF INPUT PARAMETERS

Global stability analysis was undertaken using Slide2 software by Rocscience Inc. The limit equilibrium method was used with Morgenstern-Price analysis method. The following material parameters were applied using the Mohr Coulomb failure criterion.

Table 1: Summary of Material Parameters for Upper Hot Springs Retaining Wall

Material Description	Unit Weight, kN/m^3	Internal Angle of Friction, degrees	Cohesion, kPa
Retained Soil (Gravely Sand)	18	30	0
Retained Soil (Degraded Tufa)	15	32	0
Reinforced Soil (Angular Rock Fill)	21	37	0
Foundation Soil (Glacial Till/Intact Tufa)	18	37	7

8.2 SUMMARY OF RESULTS FOR MAGNUMSTONE RETAINING WALL (OPTION 1)

Considering the global stability of the proposed retaining wall configuration at the critical section, failure was noted within the retained soils behind the retaining wall, as well as global failure within the native foundation material. See Figure 1 appended to the text of this memorandum for reference. Minimum factor of safety (FOS) values of 1.5 are required for dry conditions.

To review external failure modes included sliding, overturning and bearing, as well as internal failure modes including overstress, pullout and shear, SRWall proprietary software was used. The above material parameters were incorporated in the analysis; however, cohesion was neglected within backfill materials. Additionally, the retaining wall batter of 4.8 degrees was applied as well as a minimum embedment depth of 510 mm for an overall wall height of 3.04 m (or 5 units). Use of geogrid reinforcement (i.e., Tensar Biaxial Geogrid BX1500) between units was considered. Table 2 summarizes the factor of safety results for the above listed failure modes. See Figure 2 for reference.

Table 2: Summary of Geogrid Requirements and Calculated FOS Values for External Failure Modes, Upper Hot Springs Replacement Retaining Wall

Scenario	Geogrid Reinforcement	Factor of Safety (FOS)		
		Sliding (FOS > 1.5)	*Overturning (FOS > 3.0)*	*Bearing Capacity (FOS > 3.0)*
MangnumStone Retaining Wall	Between… Units 4/5 – 2.5 m Units 3/4 – 2.0 m Units 2/3 – 2.0 m Units 1/2 – 2.0 m Ground/Unit 1 – none	2.4	3.4	5.2

The geogrid reinforcement lengths prescribed in Table 2 were found to meet the minimum factor of safety requirements for overstress, pullout and sliding. FOS values greater than 1.5 were achieved for each reinforcement length in the above scenarios.

Based on the results of the assessment completed, the above retaining wall designs satisfy the requirements for internal and external stability as well as global slope stability.

8.3 SUMMARY OF RESULTS FOR SLOPE REGRADING (OPTION 2)

TGL undertook a global stability analysis for option 2 which includes removal of the existing retaining wall and regrading the area with an engineered slope. Figure 3A and 3B presents the global stability analysis completed using Slide2 (Rocscience Inc.). The following points summarize the analyses findings.

- The slope was configured at an angle of 2 horizontal to 1 vertical (or 26.6 degrees measured from horizontal). This configuration moves the crest of the slope back approximately 4.9 m from the face of the existing retaining wall.
- The re-grade slope starts at the location of the existing base of the retaining wall and was analyzed with the retaining wall removed.
- Two scenarios were assessed.
    - Figure 3A depicts the condition with the existing fill materials left in place with negligible effort to replace and recompact. The minimum factor of safety in this case was 1.2 (for a surficial failure surface). FOS results of 1.4 to 1.5 were observed for material failure modes.
    - Figure 3B presents the condition where an existing deleterious fills are removed with angular rock or engineered sand and gravel fill materials. The minimum FOS was 1.5 for a surficial failure. FOS values of 1.7 to 1.8 were observed for material failure modes.

From this analysis it was determined that removal of the existing retaining wall and regrading the slope to an angle of 26.6 degrees (or 2 horizontal to 1 vertical) would provide a stable configuration.

9.0 RECOMMENDATIONS FOR CONSTRUCTION

The following sections provide input for construction for the two foreseeable options: 1) construction of a new segmental retaining wall using MagnumStone; and 2) removal of the existing retaining wall and re-grading the terrain.

9.1 RETAINING WALL CONSTRUCTION

It is recommended that the following comments be incorporated into construction of the multi-segmental retaining wall. See Figure 2 for reference.

Stripping:

- All organic, deleterious materials and construction waste from the existing retaining wall must be subexcavated and removed from beneath the retaining wall footprint in preparation for construction.
- Consideration can be given to leaving the bottom of the existing retaining wall in place (truncated to approximately 0.2 m above the existing ground surface) and constructing the MagnumStone wall behind the stack rock. The bottom MagnumStone unit will be required to be set back 1.0 m from the front face of the stacked rock.

Temporary Excavations:

- Based on the anticipated conditions, temporary cut slope angles of 1 vertical to 1 horizontal may be used for dry conditions.
- Temporary cut slopes should be flattened to 1 vertical to 1.5 horizontal if excavations are to be left open for a prolong period, rainfall is anticipated, and/or ground conditions vary to warrant shallower excavations. It is recommended that Taylor Geotechnical is contacted to review the site conditions in these cases.

Retaining Wall Construction:

- MagnumStone units are to be constructed in accordance with the manufacturer's recommendations.
- A minimum batter of 4.8 degrees shall be applied to the entire height of the retaining wall. This is equivalent to maintaining a setback of 50 mm between units, as per the manufacturer's recommendations.
- MangnumStone units must be placed on a prepared level surface that consists of 25 mm minus crushed gravel placed in a 100 mm thick lift compacted to 98% of Standard Proctor maximum dry density (SPMDD).
- A minimum depth of burial of 0.51 m shall be applied to ensure adequate resistance is maintained against sliding and overturning. The top of the bottom block shall be installed a minimum horizontal distance of 1.0 m from the existing soil slope (e.g., a thickness of 1.0 m of soil is required in front of the bottom unit). See Figure 2 for reference.

- The minimum geogrid requirements listed in Table 2 shall be applied. Biaxial geogrid equivalent or better than Tensar BX1500 should be used. Geogrid lengths are measured from the front face of the retaining wall into backfill. Careful installation is required to ensure reinforcement is within the direction of pull and negligible damage occurs. Geogrid shall be installed as per the manufacturer's specifications.

Backfill:

- TGL recommends the use of 150 mm minus pit run sand and gravel with less than 10% passing the 0.075 mm sieve size. Backfill should be placed in loose lifts not exceeding 300 mm in thickness and compacted using suitable equipment to 98% SPMDD.
- If construction occurs when temperatures are below freezing, and moisture conditioning is not feasible, Taylor Geotechnical recommends the use of angular rock fill with maximum particles sizes of 100 mm in nominal diameter. Less than 5% of material passing the 0.075 mm sieve size is allowed by weight.
- Angular rock backfill should be placed in loose lifts not exceeding 300 mm in thickness and compacted using suitable equipment. A minimum of 6 passes with compaction equipment is recommended per lift.
- Placement and compaction of backfill should be reviewed by geotechnical personnel in the field.

Quality Control/Quality Assurance:

- It is recommended that Taylor Geotechnical staff carry out periodic inspections throughout the building process for verification that retaining wall construction meets the requirements outlined by Taylor Geotechnical and for quality assurance purposes. The following inspections are recommended.
    - Participation in start-up meeting.
    - An initial inspection at the start of construction following demolition to verify the ground conditions and review the retaining wall construction requirements with the contractor and project staff.
    - Periodic inspections to review backfill placement and compaction, as well as adequate installation of geogrid including the following:
        - Compaction testing on prepared base and review of block placement.
        - Compaction testing on backfill behind first row of blocks (first 2 lifts).
        - Review of geogrid installation (between first and second rows of blocks).
        - Ad hoc inspections following to confirm adequate compaction of backfill and geogrid installation.

9.2 REMOVAL OF EXISTING RETAINING WALL AND TERRAIN REGRADING

The following points summarize the construction recommendations for retaining wall removal and terrain regrading.

- All organic, deleterious materials and construction waste from the existing retaining wall must be subexcavated and removed.
- Consideration can be given to leaving the bottom of the existing retaining wall in place (truncated to approximately 0.3 m above the existing ground surface) and then constructing the engineered slope behind the truncated stack rock wall.
- Removal of any existing unsuitable fill materials will be required (to be confirmed with geotechnical personnel on site).
- Based on the anticipated conditions, temporary cut slope angles of 1 vertical to 1 horizontal may be used for dry conditions.
- Temporary cut slopes should be flattened to 1 vertical to 1.5 horizontal if excavations are to be left open for a prolong period, rainfall is anticipated, and/or ground conditions vary to warrant shallower excavations. It is recommended that Taylor Geotechnical is contacted to review the site conditions in these cases.
- TGL recommends the use of 150 mm minus pit run sand and gravel with less than 10% passing the 0.075 mm sieve size. Backfill should be placed in loose lifts not exceeding 300 mm in thickness and compacted using suitable equipment to 98% SPMDD.
- If construction occurs when temperatures are below freezing, and moisture conditioning is not feasible, Taylor Geotechnical recommends the use of angular rock fill with maximum particles sizes of 100 mm in nominal diameter. Less than 5% of material passing the 0.075 mm sieve size is allowed by weight.
- Angular rock backfill should be placed in loose lifts not exceeding 300 mm in thickness and compacted using suitable equipment. A minimum of 6 passes with compaction equipment is recommended per lift.
- Placement and compaction of backfill should be reviewed by geotechnical personnel in the field.
- A permanent slope angle of 26.6 degrees measured from horizontal (or 2 horizontal to 1 vertical) should be constructed.
- It is recommended that the slope be seeded to promote growth of a vegetive cover. This will protect from surficial ravelling from surface run off.
- The following inspections and testing are recommended from a quality control/quality assurance point of view
    - Participation in start-up meeting.
    - An initial inspection at the start of construction following demolition to verify the ground conditions, review existing fill materials, and construction requirements with the contractor and project staff.
    - Periodic inspections to review backfill placement and compaction.

10.0 COST ESTIMATES

The following sections provide a cost estimate for the two foreseeable construction options: 1) construction of a new segmental retaining wall using MagnumStone; and 2) removal of the existing retaining wall and re-grading the terrain.

10.1 REMOVAL OF EXISTING WALL AND CONSTRUCTION OF SEGMENTAL RETAINING WALL

Course of Action:

Work detailed in 9.1 should be completed. Foundation level surface shall be prepared such that it is of competent materials, hard and compact. First row of blocks shall be placed, and fill shall be placed and compacted. Geogrid reinforcement shall be placed and followed by second row of block and fill.

Assumptions:

Mobilization/Demobilization is $2000 total. 9 Days with ½ day on each end for mobilization, or two weeks of full-time employment for 3. Excavator is 15 ton class (e.g., CAT 315). Compaction is done with 1 ton vibrating walk behind compactor or better. Hauling is done as required in a tandem with no trailer. No road weight bans are in place during the work. Supervisor is on site and available during the project. Does not include paving. Magnumstone blocks are used, cost $220 each F.O.B. in Calgary, and cover 0.75 m^2. 80 mm crushed gravel sourced in Bow Valley.

Cost:

$63,800.

10.2 REMOVAL OF EXISTING WALL AND REGRADING THE TERRAIN

Course of Action:

Asphalt shall be saw cut to provide a clean edge to the existing facility. Asphalt shall be broken and removed in pieces with dimensions no greater than 1000 mm. Fill behind the wall shall be removed such that no more than 1000 mm of wall remain unsupported. The suggested procedure would be to remove 1000 mm of wall stone, then remove 1000 mm of fill, repeated until final grade is achieved. Material is shipped to Francis Cooke in tandem dump trucks.

Assumptions:

Mobilization/Demobilization is $2000 total. 4 Days with ½ day on each end for mobilization, or one week of full-time employment for 3. Excavator is 15 ton class (e.g., CAT 315). Hauling is done as required in a tandem with no trailer. No road weight bans are in place during the work. Supervisor is on site and available during the project. Does not include seeding.

Cost:

$17,000.

Potential Cost Savings:

Asphalt smaller than 1 m in dimension cost $30/tonne to tip at Francis Cooke Regional Waste Centre, greater than cost $100/tonne. Clean fill can be dumped at $17/tonne or can be repurposed within Banff. Stone could be saved for reuse or sold at a premium (due to origin).

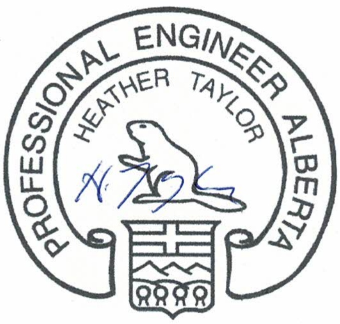
11.0 CLOSURE

It is trusted that this letter report meets your present requirements. Should you have any questions or need additional information, please do not hesitate to contact Heather Taylor at 403-707-5082 or heather@taylorgeotechnical.com to discuss.

Kind Regards,

TAYLOR GEOTECHNICAL LTD.

Prepared By:



2021-03-09

Heather Taylor, MSc, P.Eng.
Senior Geotechnical Engineer

Reviewed By:

Jon Taylor, MA, P.Eng.
Senior Geotechnical Engineer

PERMIT TO PRACTICE
TAYLOR GEOTECHNICAL LTD.
RM SIGNATURE: H. Taylor
RM APEGA ID #: 169143
DATE: 2021-03-09
PERMIT NUMBER: P014061
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

DISCLAIMER AND LIMITATIONS

This report is delivered subject to the expressed condition that the following disclaimers and limitations concerning use of the report and the liability of Taylor Geotechnical are accepted by the reader.

BASIS OF THE REPORT

This report was prepared for the Client for the purpose of providing geotechnical investigation for the specific site, development, and design described to Taylor Geotechnical by the Client.

The findings, opinions and recommendations in this report are only valid to the extent that the report addresses these specifics and remain subject to the limits described herein.

The opinions and recommendations in this report are based on geotechnical investigation work carried out on site in accordance with the Standard of practice described herein.

The report does not include any investigation, analytical testing or assessment of possible soil and groundwater contamination, archeological or biological considerations or sediment control measures.

The Client should provide Taylor Geotechnical with notice any material changes to the site, development, design and objectives, and provide Taylor Geotechnical with opportunity to revise the report accordingly. Any special concerns or circumstances not contemplated at the time of the report should be communicated so that Taylor Geotechnical may conduct further investigations not otherwise within the scope of services provided.

STANDARD OF PRACTICE

This report has been prepared with reasonable care and skill in accordance with the generally accepted practices for geotechnical services. This report makes no expressed or implied warranties other than being prepared according to the standards of practice described herein.

USE OF THE REPORT

This report is intended for the exclusive use and sole benefit of the Client, its successors and assigns. It makes no representations of fact, opinion or recommendations whatsoever to any other persons ("Third Parties"). No Third Party may use, rely upon or reproduce this report in whole or in part without the written consent of Taylor Geotechnical and on the terms and conditions set by Taylor Geotechnical.

Any use of the report by a Third Party is the sole responsibility of that Third Party. Taylor Geotechnical is not responsible for any damages suffered by Third Parties as a result of this report or decisions made based on this report. This limitation includes no responsibility for changes in real estate values that may occur as a consequence of this report.

All intellectual property and any copyrights in this report belong to Taylor Geotechnical.

Taylor Geotechnical shall keep a paper copy of this report on file and that copy shall take precedence in the event of discrepancy with any circulated or electronic copies.

THE COMPLETE REPORT

The complete report includes all information generated and reported to the client through Taylor Geotechnical's services on this assignment. The report document does not stand alone from Client instructions, communications and other reporting by Taylor Geotechnical to the Client, all of which form part of the report. Taylor Geotechnical is not responsible for use of portions of the report without reference to the whole report.

RELIANCE ON INFORMATION PROVIDED

In preparing this report, Taylor Geotechnical has relied in good faith on information from the Client and further persons. Taylor Geotechnical is entitled to rely on such information and is not required to independently verify the truth of information provided. Taylor Geotechnical accepts no responsibility for any misstatements in the report resulting from the misinformation, misstatements, omissions, misrepresentations or fraudulent acts by the Client or other persons.

INTERPRETATION OF SITE CONDITIONS
The interpretations of site conditions in this report are based on the conditions at sample locations on a specific site at one point in time, and the opinions and recommendations provided are only valid to that extent.

The interpretation of site conditions involves inherent and unavoidable risks. The identification and classification of soils, rocks, geological units, materials and quantities of the same is inherently judgemental in nature. The investigative practice means that some conditions may not be detected or that actual conditions may vary from sample points. Comprehensive investigations conducted according to the applicable standards by experienced personnel with appropriate equipment can still fail to locate some site conditions.

As conditions may change over time, this report is intended for immediate use. The Client should provide Taylor Geotechnical with any changes to site conditions or new information that becomes available after the date of this report and have Taylor Geotechnical re-consider its opinions and recommendations prior to the Client or Third Parties making decisions based on this report.

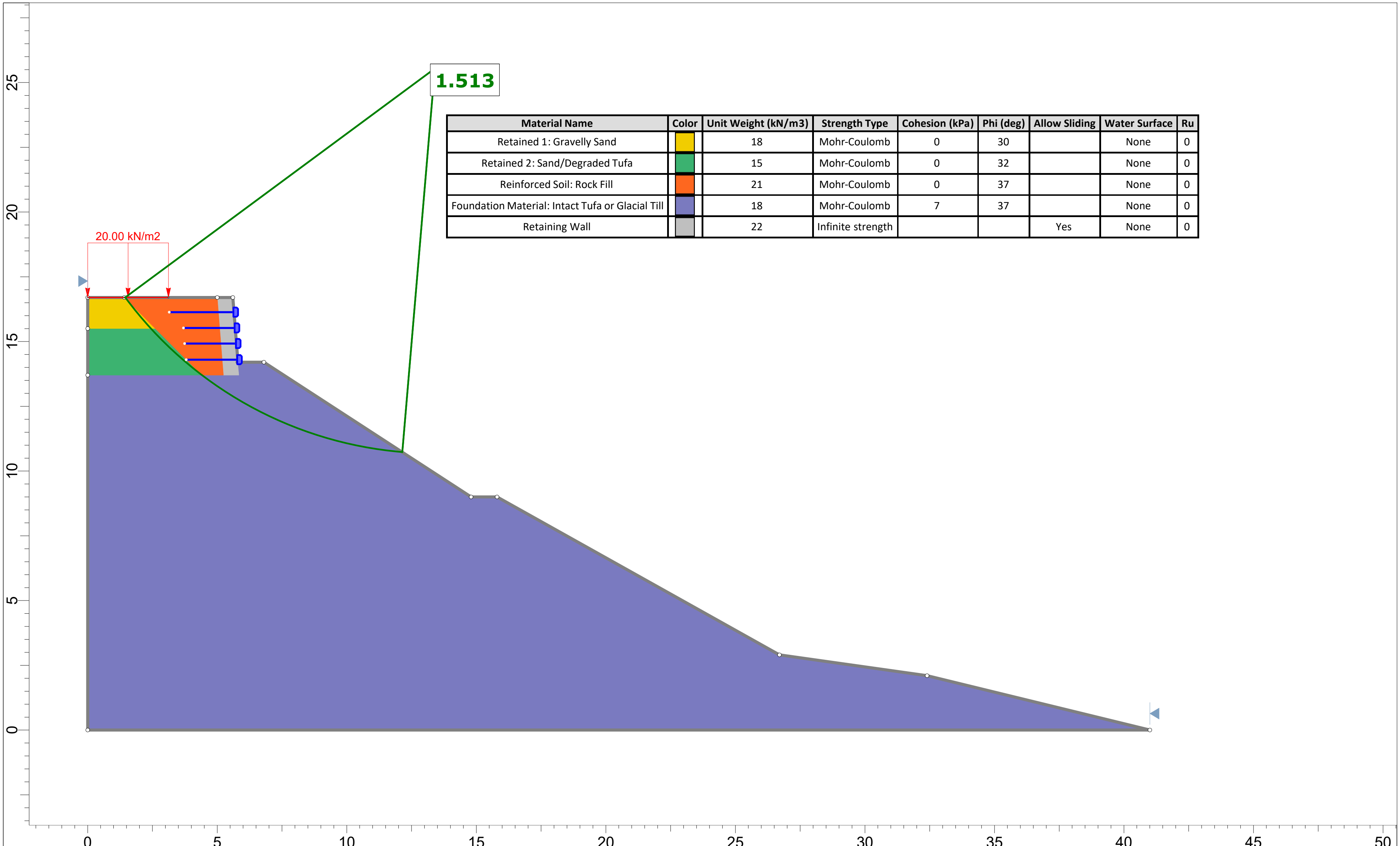
REGULATORY CONTEXT
This report was prepared in the context of government regulations and policies in effect and generally promulgated at the time and, unless specifically noted, does not consider any government regulations or policies that were not in effect and generally promulgated at the time it was prepared. Unless specifically stated, this report provides no advice on regulatory issues associated with the site or project.

INDEPENDENT JUDGEMENT OF CLIENT
Opinions and recommendations in this report are based on Taylor Geotechnical's interpretations of information obtained through a limited investigation within a defined scope of services. Taylor Geotechnical is not liable for the independent conclusions, interpretations and decisions of the Client or any Third Parties based on this report. This limitation includes any decisions to purchase, sell, develop, lease or rent land or buildings.

RELEASE OF POLLUTANTS
Geotechnical engineering and environmental consulting work involves risks of encountering and causing the release of pollutants or hazardous substances. Taylor Geotechnical shall have no liability to the Client or Third Parties for such releases unless the substance is specifically identified by the Client prior to the performance of services.

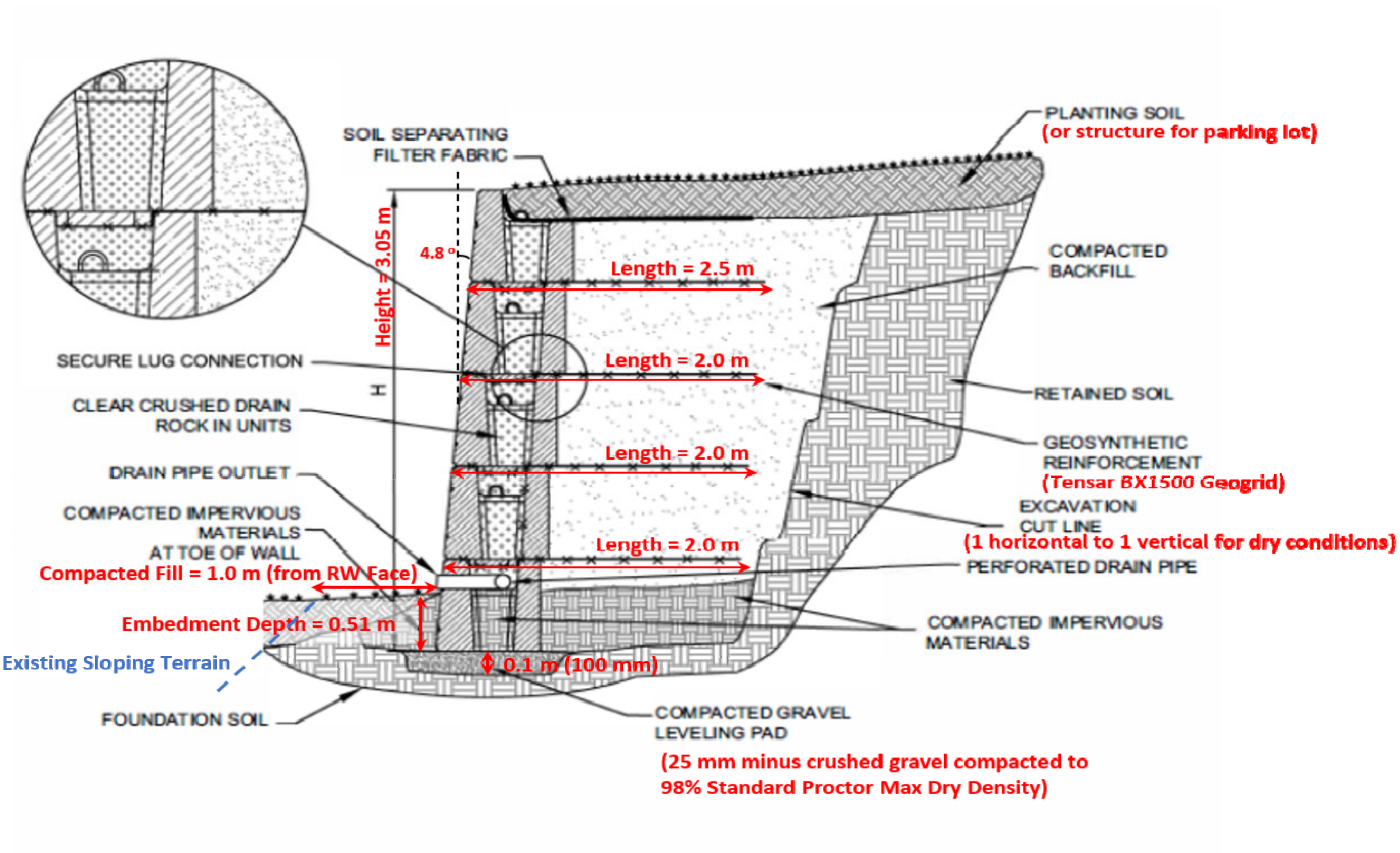
DESIGN AND CONSTRUCTION SERVICES
Where consented to by Taylor Geotechnical, this report may form part of design and construction documents for information purposes even though issued prior to final design. Any differences between the recommendations in this report and the final design should be reported to Taylor Geotechnical, and Taylor Geotechnical to review the final design for consistency with the recommendations prior to proceeding to construction. All recommendations remain subject to field review by Taylor Geotechnical during the construction phase, and Taylor Geotechnical should be retained to conduct such field review to confirm that the site conditions do not materially differ from the interpreted conditions at the time the report was prepared.

These further services may be necessary for Taylor Geotechnical to provide letters of assurance as required by regulatory bodies in some jurisdictions.



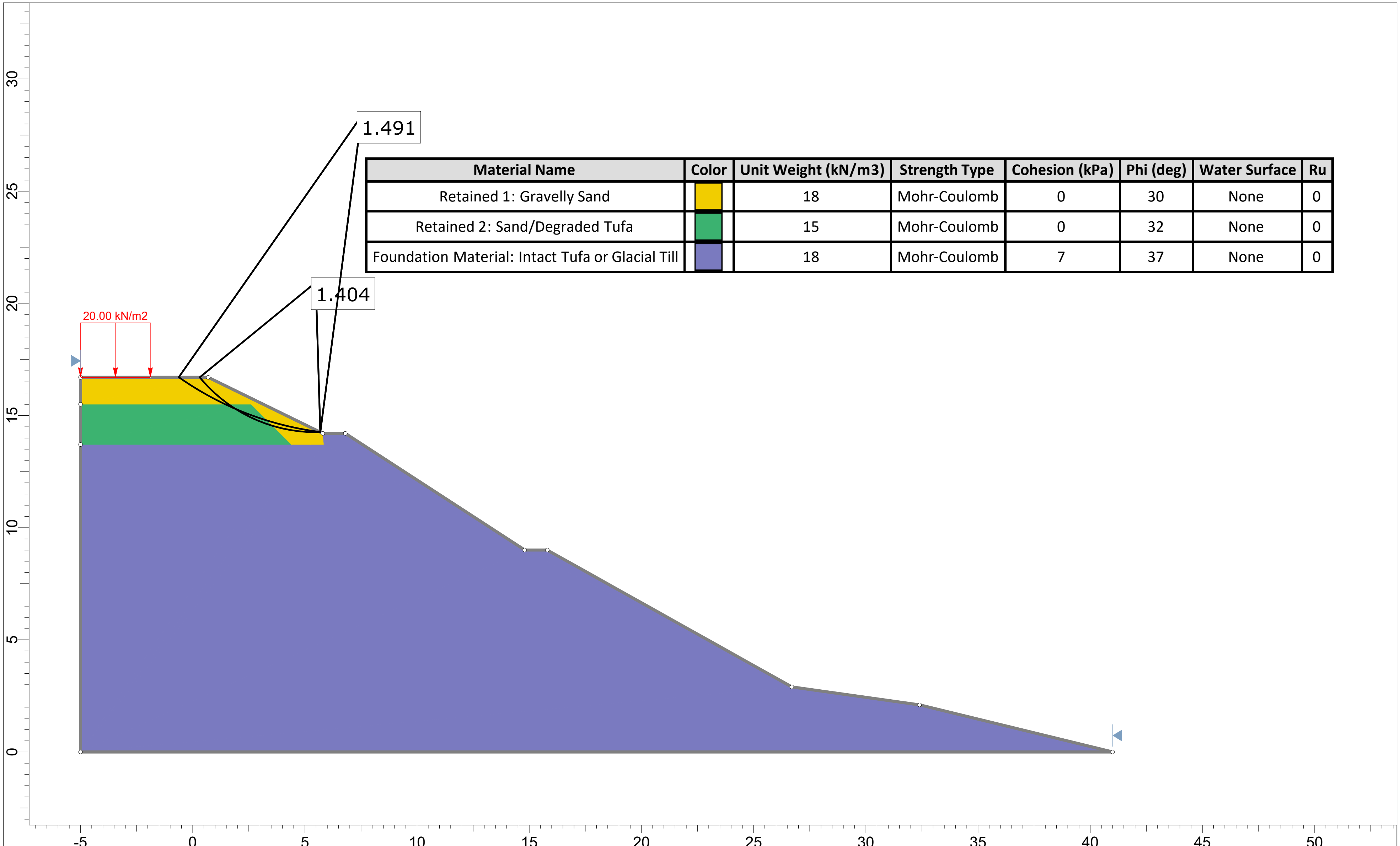
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Allow Sliding	Water Surface	Ru
Retained 1: Gravelly Sand		18	Mohr-Coulomb	0	30		None	0
Retained 2: Sand/Degraded Tufa		15	Mohr-Coulomb	0	32		None	0
Reinforced Soil: Rock Fill		21	Mohr-Coulomb	0	37		None	0
Foundation Material: Intact Tufa or Glacial Till		18	Mohr-Coulomb	7	37		None	0
Retaining Wall		22	Infinite strength			Yes	None	0

rocscience	*Project* Upper Hot Springs		
	Group Group 1	*Scenario* Master Scenario	
	Drawn By Heather Taylor	*Company* Taylor Geotechnical	
SLIDEINTERPRET 9.009	*Date* 2020-11-22	*File Name* 2020-036 Global Stability Analysis.slmd	



Reference: Cornerstone Wall Solutions Inc. (2020)

DATE: 2020-12-21	TAYLOR GEOTECHNICAL	PROJECT: **Upper Hot Springs**	
DRAWN: HT			
DESIGNED: HT		TITLE: **MagnumStone Retaining Wall Section**	
CHECKED: JT	CLIENT: **Shelley Tamelin**		
APPROVED: JT	**Canadian Rockies Hot Springs**	PROJECT #: 2020-036	FIGURE: 2 REV.: 0

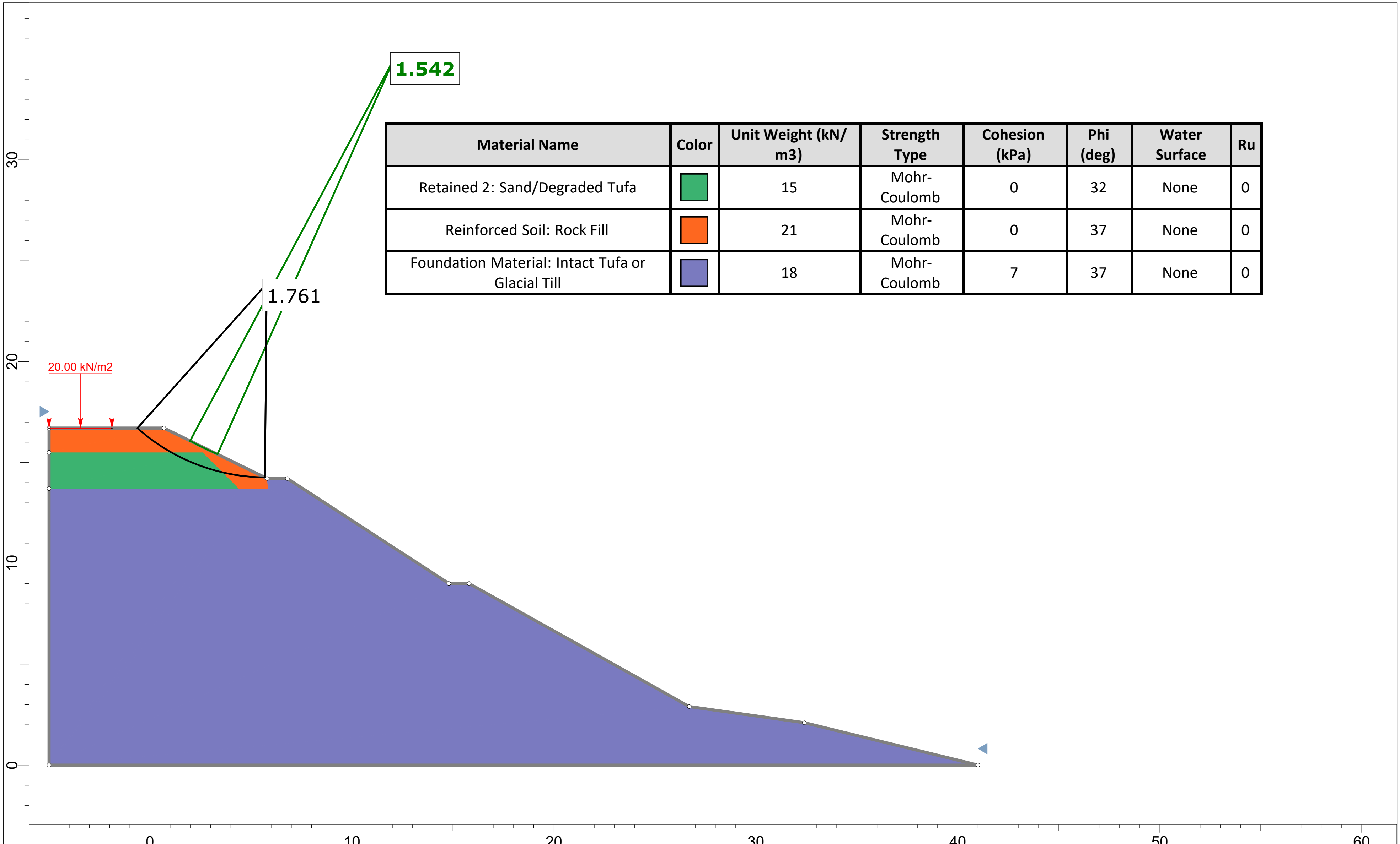


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Retained 1: Gravelly Sand		18	Mohr-Coulomb	0	30	None	0
Retained 2: Sand/Degraded Tufa		15	Mohr-Coulomb	0	32	None	0
Foundation Material: Intact Tufa or Glacial Till		18	Mohr-Coulomb	7	37	None	0

rocscience

SLIDEINTERPRET 9.010

Project	Upper Hot Springs		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	Heather Taylor	*Company*	Taylor Geotechnical
Date	2020-12-21	*File Name*	2020-036 Global Stability Analysis - Slope Section.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Retained 2: Sand/Degraded Tufa		15	Mohr-Coulomb	0	32	None	0
Reinforced Soil: Rock Fill		21	Mohr-Coulomb	0	37	None	0
Foundation Material: Intact Tufa or Glacial Till		18	Mohr-Coulomb	7	37	None	0

rocscience

SLIDEINTERPRET 9.010

Project	Upper Hot Springs		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	Heather Taylor	*Company*	Taylor Geotechnical
Date	2020-12-21	*File Name*	2020-036 Global Stability Analysis - Slope Section.slmd

APPENDIX A: BOREHOLE LOGS AND LAB TESTING RESULTS

12-109 Bow Meadows Crescent, Canmore, AB, T1W 2W8.
T: (403) 707-6185
www.taylorgeotechnical.com

TAYLOR GEOTECHNICAL

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT LOGS

Terminology describing common soil genesis:	
Rootmat	Vegetation, roots and mass with organic matter and topsoil typically forming a mattress at the ground surface.
Topsoil	Mixture of soil and humus capable of supporting vegetative growth.
Peat	Mixture of visible and invisible fragments of decaying organic matter.
Till	Unstratified glacial deposit which may range from clay to boulders.
Fill	Material below the surface identified as placed by humans.

Terminology describing soil types:

Major Divisions			Group Symbols	Typical Names
Coarse-grained Soils: More than half material is larger than No. 200 sieve size.	Gravels: More than half coarse fraction is larger than No. 4 sieve size.	Clean Gravels (little or no fines)	GW	Well-graded gravels, gravel sand mixtures, little or no fines.
			GP	Poorly-graded gravels or gravel sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size.	Clean Sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly-graded sands or gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands , sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
Fine-grained Soils: More than half of material is smaller than No. 200 sieve size.	Silts and Clays: Liquid limit is less than 50.		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity. Quick to slow dilatancy.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. None to slow dilatancy.
			OL	Organic silts and organic silty clays of low plasticity. Slow to no dilatancy.
	Silts and Clays: Liquid limit is greater than 50.		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays and silts of medium to high plasticity.
Highly Organic Soils			Pt	Peat and other highly organic soils.

Coarse Grain Soils Particle Sizes

Constituent		Particle Sizes (mm)	Particle Sizes (Inches & Sieve Size)
Boulders		>300	>12"
Cobbles		60 – 300	3" – 12"
Gravel	Coarse	20 – 60	3/4" – 3"
	Medium	6 – 20	No 4. – 3/4"
	Fine	2 – 6	No.8 – No. 4
Sand	Coarse	0.6 – 2	No. 20 – No. 8
	Medium	0.2 – 0.6	No. 60 – No. 20
	Fine	0.06 – 0.2	No.200 – No. 60.
Silt		Not visible to naked eye	

NOTES: Cobbles and Boulders are individually noted and recorded at the depth which they occur. Dimensions of boulders should be recorded if possible.

Classification Terminology	
AND	35% – 50%
Adjective (.....Y)	20% – 35%
SOME	10% – 20%
TRACE	1% – 10%

Plasticity

A qualitative measure of the effect that water has on the consistency of the material in question. It can be estimated on the field as low, medium or high. High plastic clays are also referred to as swelling clays. It can be quantitatively determined using the Atterberg Limit test procedure in lab (ASTM D4318).

12-109 Bow Meadows Crescent, Canmore, AB, T1W 2W8.
T: (403) 707-6185
www.taylorgeotechnical.com

TAYLOR GEOTECHNICAL

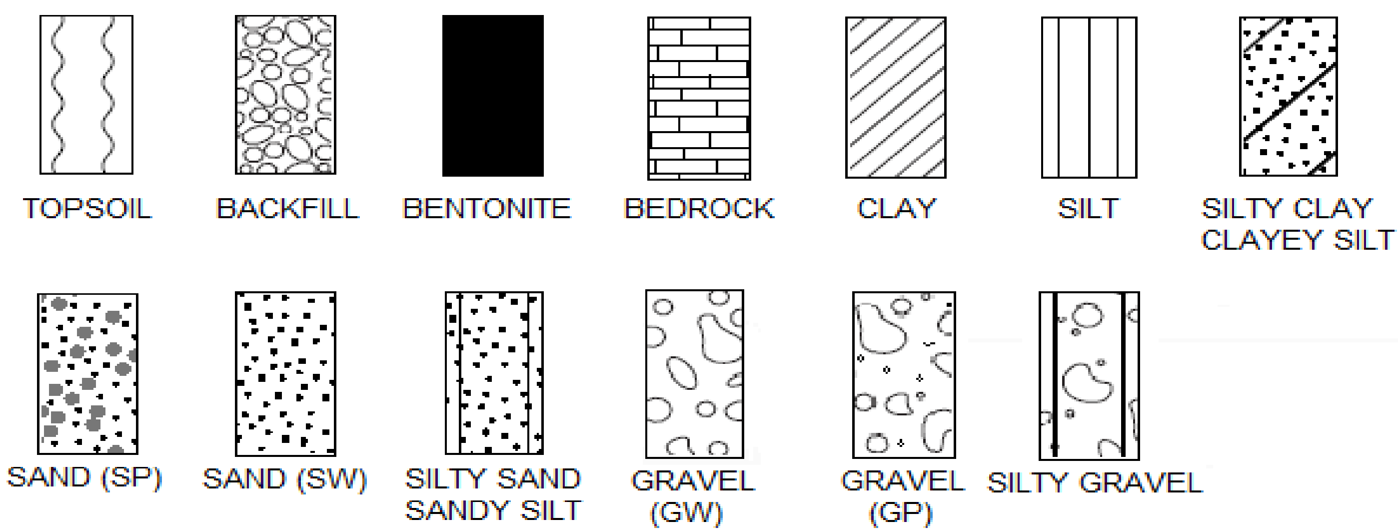
SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT LOGS

Terminology describing the compactness of soils				
Non-Cohesive Soils		**Cohesive Soils**		
Description	**N-Value**	**Description**	**Undrained Shear Strength (kPa)**	**N-Value**
Very Loose	0 – 4	Very Soft	< 12.5	0 – 2
Loose	4 – 10	Soft	12.5 – 25	2 – 4
Compact	10 – 30	Firm	25 – 50	4 – 8
Dense	30 – 50	Stiff	50 – 100	8 – 15
Very Dense	> 50	Very Stiff	100 – 200	15 – 30
		Hard	> 200	>30

N Value

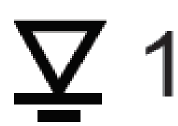
N-Value numbers are the field results of the Standard Penetration Test (SPT). N-Value represents the number of blows a 140 lb. (63.5kg) hammer falling 30 inches (300mm) required to drive a 2 inch (50.8mm) O.D. split spoon sampler one foot (300m) into the soil. The N-Value equals the number to drive the sampler over the interval of 6 to 18 inches (300 to 610mm).

GRAPHIC LOG/STRATA PLOT SYMBOLS



SAMPLE TYPE	
GRAB	Grab sample off augers or samples taken while test pitting.
SPT	Split spoon sample from standard penetration test.
BS	Bulk sample.
ST	Shelby tube.
DP	Direct push sample.

WATER LEVEL MEASUREMENT



- Measured in standpipe, piezometer, well or observed while drilling or test pitting.
- Number denotes successive readings.

TAYLOR GEOTECHNICAL

Upper Hot Springs Retaining Wall: BH-01

PROJECT NUMBER: 2020-036
PROJECT NAME: Upper Retaining Wall
CLIENT: Parks Canada
HOLE NUMBER: BH-01

DRILLING DATE: September 1, 2020
TOTAL DEPTH: 1.75 m
HOLE DIMENSIONS: 80 mm
TIME START: 10:51
TIME END: 12:00

COORDINATES: 11 UTM 0600676/5667560
ELEVATION: N/A
CONTRACTOR: Taylor Geotechnical Ltd.
METHOD: Testpit & 80mm Solid Stem Auger
EQUIPMENT: CanDig Mini Excavator

COMMENTS: Testpit dug on top of previous sinkhole patch. Testpit dug to 0.6 m, 80 mm auger hole drilled to 1.75 m.

LOGGED BY: Lee Mueller
CHECKED BY: Heather Taylor

Depth (m)	Samples	Moisture (%)	Water Level	Graphic Log	Material Description	Remarks & Testing
					ASPHALT	
0.2					SANDY GRAVEL (FILL); GW, trace to some silt, dark greyish brown, damp, with occasional cobbles, debris and tufa fragments. -Old Asphalt encountered from 0.3 m to 0.5 m.	
0.4						
0.6					SANDY GRAVEL; GW-GM, some silt to silty, dark greyish brown, damp to moist, with occasional cobbles,	
0.8	SA#1	11.7%				
1						
1.2	SA#2					
1.4						
1.6	SA#3	11.6%				
1.8					End of Hole at 1.75 m. - Auger refual @ 1.75 m. - Auger bit wet @ 1.75 m. - Hole sloughed to 1.45 m upon completion. - No visible groundwater in hole upon completion. - Backfilled with cuttings from hole.	
2						
2.2						
2.4						
2.6						
2.8						
3						
3.2						
3.4						
3.6						
3.8						
4						
4.2						
4.4						
4.6						
4.8						

TAYLOR GEOTECHNICAL

Upper Hot Springs Retaining Wall: BH-02

PROJECT NUMBER: 2020-036
PROJECT NAME: Upper Retaining Wall
CLIENT: Parks Canada
HOLE NUMBER: BH-02

DRILLING DATE: September 1, 2020
TOTAL DEPTH: 3.2 m
HOLE DIMENSIONS: 80 mm
TIME START: 12:20
TIME END: 12:45

COORDINATES: 11 UTM 0600680/5667564
ELEVATION: N/A
CONTRACTOR: Taylor Geotechnical Ltd.
METHOD: 80mm Solid Stem Auger
EQUIPMENT: CanDig Mini Excavator

COMMENTS: Closest hole to stairs leading to pool deck.

LOGGED BY: Lee Mueller
CHECKED BY: Heather Taylor

Depth (m)	Samples	Moisture (%)	Water Level	Graphic Log	Material Description	Remarks & Testing
0.0–0.1					ASPHALT	
0.1–0.3	SA#1	14.3%			GRAVELLY SAND; SW, trace to some silt, dark greyish brown, with occasional debris and rootlets.	
0.3–1.4	SA#2	17.7%			SAND; SW, trace silt, trace gravel, dark grey, damp to moist.	
1.4–3.2	SA#3	10.9%			SAND; SW, degraded Tufa, trace silt, damp, light brown to tan.	
3.2					End of Hole at 3.2 m. - Hole sloughed to 2.2 m upon completion. - No seepage. - Backfilled with cuttings from hole.	

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8, 2, 2.2, 2.4, 2.6, 2.8, 3, 3.2, 3.4, 3.6, 3.8, 4, 4.2, 4.4, 4.6, 4.8

TAYLOR GEOTECHNICAL

Upper Hot Springs Retaining Wall: BH-03

PROJECT NUMBER: 2020-036	**DRILLING DATE:** September 1, 2020	**COORDINATES:** 11 UTM 0600682/5667564
PROJECT NAME: Upper Retaining Wall	**TOTAL DEPTH:** 2.4 m	**ELEVATION:** N/A
CLIENT: Parks Canada	**HOLE DIMENSIONS:** 80 mm	**CONTRACTOR:** Taylor Geotechnical Ltd.
HOLE NUMBER: BH-03	**TIME START:** 13:10	**METHOD:** 80mm Solid Stem Auger
	TIME END: 13:35	**EQUIPMENT:** CanDig Mini Excavator

COMMENTS:

LOGGED BY: Lee Mueller
CHECKED BY: Heather Taylor

Depth (m)	Samples	Moisture (%)	Water Level	Graphic Log	Material Description	Remarks & Testing
					ASPHALT	
0.2					GRAVELLY SAND; SW, trace to some silt, dark greyish brown, with occasional debris and rootlets.	
0.4	SA#1					
0.6, 0.8, 1						
1.2, 1.4, 1.6, 1.8, 2, 2.2					SAND; SW, degraded Tufa, trace silt, damp, light brown to tan.	
2.4, 2.6, 2.8, 3, 3.2, 3.4, 3.6, 3.8, 4, 4.2, 4.4, 4.6, 4.8					End of Hole at 2.4 m. - Hole sloughed to 1.6 m upon completion. - No seepage. - Backfilled with cuttings from hole.	

Upper Hot Springs Retaining Wall: BH-04

PROJECT NUMBER: 2020-036
PROJECT NAME: Upper Retaining Wall
CLIENT: Parks Canada
HOLE NUMBER: BH-04

DRILLING DATE: September 1, 2020
TOTAL DEPTH: 2.4 m
HOLE DIMENSIONS: 80 mm
TIME START: 13:15
TIME END: 13:45

COORDINATES: 11 UTM 0600680/5667567
ELEVATION: N/A
CONTRACTOR: Taylor Geotechnical Ltd.
METHOD: 80mm Solid Stem Auger
EQUIPMENT: CanDig Mini Excavator

COMMENTS:

LOGGED BY: Lee Mueller
CHECKED BY: Heather Taylor

Depth (m)	Samples	Moisture (%)	Water Level	Graphic Log	Material Description	Remarks & Testing
					ASPHALT	
0.2					GRAVELLY SAND; SW, trace to some silt, dark greyish brown, with occasional debris and rootlets.	
0.4						
0.6						
0.8						
1	SA#1					
1.2					SAND; SW, degraded Tufa, trace silt, damp, light brown to tan.	
1.4						
1.6						
1.8						
2						
2.2						
2.4					End of Hole at 2.4 m. - Hole sloughed to 1.8 m upon completion. - No seepage. - Backfilled with cuttings from hole.	
2.6						
2.8						
3						
3.2						
3.4						
3.6						
3.8						
4						
4.2						
4.4						
4.6						
4.8						

APPENDIX B: SITE PHOTOGRAPHS

Photo 1: Looking NW towards the retaining wall.

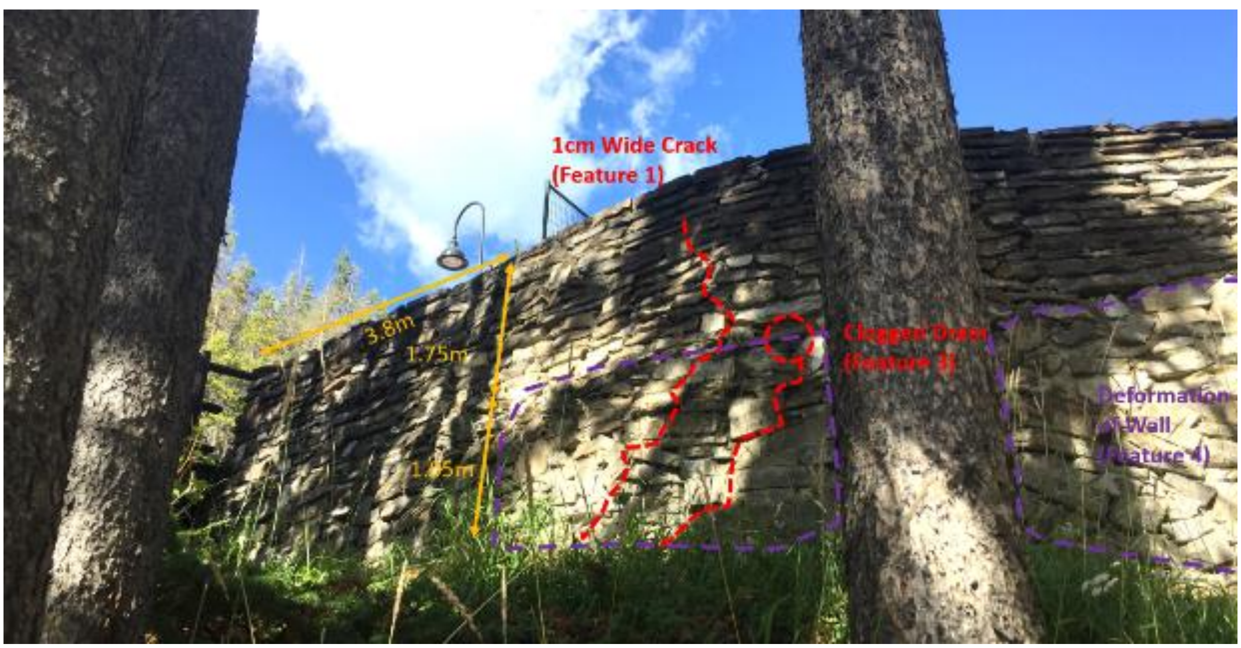


Photo 2: West end of retaining wall

Photo 3: Middle left section of retaining wall. Photo taken looking north/northwest.

Photo 4: Middle right section of retaining wall. Photo taken looking west.

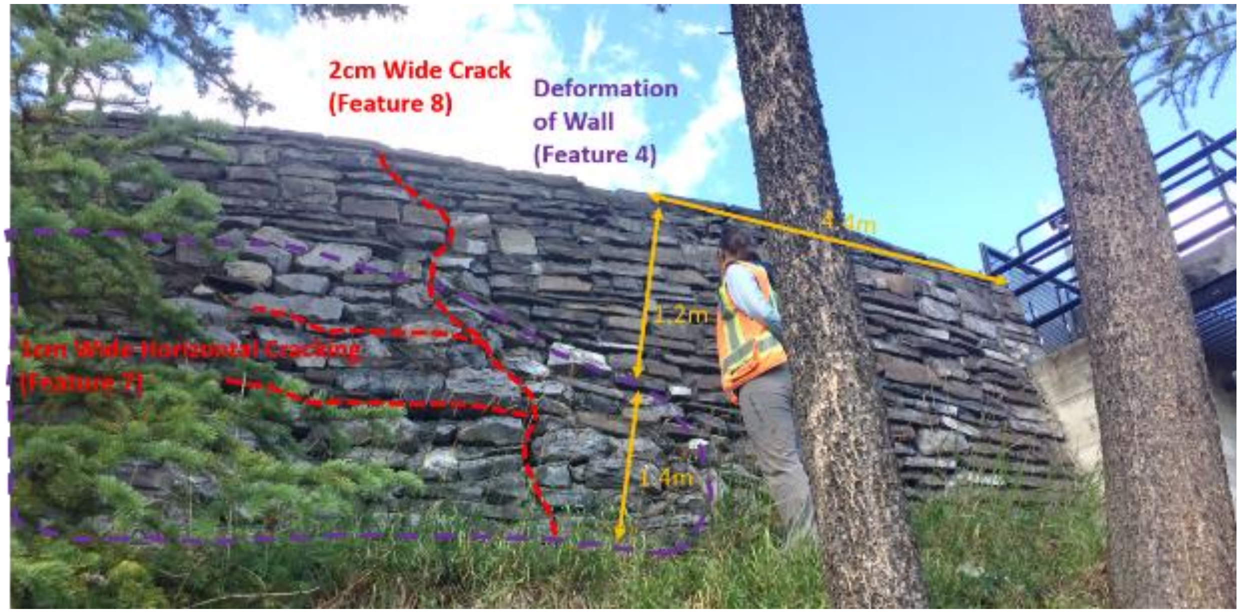


Photo 5: North end of retaining wall.

Photo 6:West end of retaining wall. Photo taken from the upper pathway looking east.

Photo 7: Asphalt deformations located approximately at the center of the wall.

Photo 8: Void and asphalt degradation.

Photo 10: Location of the boreholes. Photo taken looking south.