File S2026

Royal Canadian Mounted Police

Geotechnical Report II
New RCMP Detachment
Maidstone, SK

Clifton Associates

Clifton Associates

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Attention: Mr. Corey Schneider Project Manager
Company: RCMP
Address: National Project Delivery Office
P.O. Box 6500
Regina SK S4P 3J7

Geotechnical Report **File S2026**
Proposed RCMP Detachment
Maidstone, SK

We are pleased to present to you our geotechnical report regarding the above subject.

We thank you for the opportunity to work with you on this project. If you have any questions regarding this report, please contact me.

Yours truly,

Clifton Associates Ltd.

Richard Yoshida PEng
Senior Geotechnical Engineer
RTY/djb

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1.0 Introduction

This report presents results of a geotechnical investigation conducted for the new RCMP Detachment Facility to be constructed in Maidstone, Saskatchewan. The site is located on the east end of 4th Avenue in Maidstone in Lot 51, Parcel C, Plan 85B12566 as shown on Drawing No. S2026-01. Authorization to proceed was received by RCMP Purchase Order No. 7196349 dated 15 April 2014, via email from Bonny Manz, Senior Contracting Officer, RCMP.

In general, the objectives of this work were:

- To define the subsurface soil strata and groundwater conditions in the area of the proposed development.
- To provide recommendations for suitable methods of foundation support for proposed structures.
- To provide pavement structure recommendations.
- To provide recommendations for excavations, backfill and drainage.
- To provide general site development criteria.
- To provide commentary on pertinent geotechnical issues identified during the subsurface investigation.

It should be noted that Clifton previously provided a geotechnical report to the RCMP for a different site in Maidstone in May 2013 (our file number L187). Recommendations provided in each report are site specific and should not be applied interchangeably without prior approval from this office.

2.0 Description of the Site and Proposed Structures

It is our understanding that the facility will consist of a one storey structure with a footprint of about 778 m^2, and a separate 60 m^2 storage building. The main building may have a mezzanine level, and may have a partial basement or crawlspace.
The site is currently an uncultivated agricultural field. Conditions are similarly undeveloped to the north and east of the site. The site is bordered on the south by 4th Avenue, and on the west by the right of way for the future expansion of 4th Street. There are no utilities on this site.

There appears to be a drainage divide across the site located approximately between Boreholes BH102 and BH108., with drainage to the east from Borehole BH108 and to the west from Borehole BH102. Drainage to the west appears to flow towards the ditch along 4th Avenue.

General foundation recommendations contained herein are provided for the proposed structure. These recommendations can be revised for specific loadings or configurations, if required, once additional details are known. This office must be advised of any changes so that the applicability of these recommendations can be assessed.

3.0 Field and Laboratory Investigation

Subsurface conditions were investigated by eight boreholes drilled at the site as shown on Drawing No. S2026-02. Boreholes were drilled on 9 May 2014 using a truck mounted MARL M10 drill rig using 150 mm diameter solid stem auger. The boreholes were drilled to a maximum depth of 13 m below surface.

Representative disturbed and undisturbed samples were recovered for laboratory analysis. Sampling was started at a depth of 0.75 m and continued at a 0.75 m interval to 4.6 m. After this depth, the sampling interval was increased to 1.5 m. Thin walled (Shelby) tube samples were collected in three boreholes. Disturbed cutting samples were collected in the remaining two boreholes.

One standpipe piezometer was installed in Borehole BH104 to monitor groundwater levels. The piezometer was constructed using 50 mm diameter Schedule 40 PVC pipe with a machined screen section. Filter sand was placed around the screen, and a bentonite seal placed on top of the sand. The remainder of the annulus was filled with cuttings.

Borehole locations were recorded using a handheld GPS unit. The accuracy of the measurements is not known. Relative borehole elevations were measured using the top of a fire hydrant at the south west of the site on the south side of 4th Ave. as a temporary benchmark with an assumed elevation of 100.000 m.

The natural water content of each sample was determined. Other testing included determination of Atterberg limits and water soluble sulphate content of selected representative samples. The undrained shear strength of undisturbed samples was estimated using laboratory vane shear and pocket penetrometer apparatus.
Observations made during the field investigation, visual descriptions and the results of laboratory tests are recorded in the Borehole Logs, and the Summary of Sampling and Laboratory Test Data which are appended to this report. An explanation of the symbols and terms used in the borehole logs is included in the Symbols and Terms section of this report.

Laboratory testing was conducted in accordance with procedures and methodologies described in ASTM standards. The determination of the Unified Soil Classification in accordance with ASTM D2487 includes the measurement of grain size distribution with respect to gravel, sand and silt and clay sized particles. It also includes the laboratory measurement of plasticity, including plastic limit and liquid limit in accordance with ASTM D4318. Atterberg limits and determination of the plasticity of soil provides more useful information on the effect of the clay sized fraction on soil behaviour.

4.0 Analysis

4.1 Stratigraphy

Stratigraphy generally consisted of varying deposits of sand, silt and clay overlying glacial till to the depth of exploration. The thickness of organic topsoil varied from 150 mm to 250 mm. Frost was occasionally encountered in the upper 1 m.

Fine grained, silty sand with some clay was encountered to a depth of 0.76 m to 2.5 m below ground surface. Sand was olive brown in colour and moist. Standard penetration test (SPT) N values in the sand ranged from 4 to 9 blows for 300 mm penetration, indicating a loose in situ density.

Sandy clay and silt was encountered in some boreholes in the upper 2.5 m. The thickness of these layers varied from approximately 0.3 m to 2 m. Clay and silt was olive brown, and was firm to stiff, with iron staining and salt inclusions.

Till was encountered to the depth of exploration. It had a sandy clay matrix with some silt and a trace of gravel, was moist, olive brown in colour, oxidized, and very stiff in consistency. The estimated undrained shear strength of oxidized till was 150 kPa. Below a depth of 5.6 m to 7.3 m, till was unoxidized, with an estimated undrained shear strength of 200 kPa. Although not encountered during drilling, cobbles and boulders are common within glacial till, and should be expected in excavations and during piling.

4.2 Groundwater Regime

Seepage was noted in most boreholes at the surface of the till. Clay and sand encountered near surface was wet, and significant sloughing was observed during drilling. Standpipe piezometers were installed in Boreholes BH104 and BH105, with the tips placed at a depth of 12.6 m and 4.2 m, respectively. Groundwater levels were measured on 28 April 2014, which was approximately two weeks after installation. Groundwater levels were measured as high as 1.7 m below ground surface.

Groundwater levels are expected to fluctuate with the level of development in the area, as well as seasonal changes in precipitation, infiltration and evaporation. It is not possible to predict increases in groundwater levels with precision; however, it is not unusual for groundwater levels to increase over time after development. Groundwater levels may rise temporarily due to irrigation or snowmelt as water infiltrates the surface and flows vertically and horizontally through the upper sands and clays, or through fissures and fractures within the till stratum, as well as through sandy laminations or lenses. This water may report to excavations or crawlspaces with time.

5.0 General Discussion

The major geotechnical issues associated with this project are:

- Seismic site characterization and design parameters.
- Frost penetration.
- Foundations to support the proposed structures.
- Site development criteria, including stable cut and fill slopes.
- Retaining walls.
- Excavations.

5.1 Seismic Site Response

The site classification for seismic site response, as described in NBCC 2010 (Table 4.1.8.4A), can be based on the average estimated undrained shear strength or average standard penetration test blow count in the upper 30 m. Shear wave velocity was not measured for this site. The undrained shear strength of soil encountered at this site was greater than 100 kPa. On this basis, design can assume Site Class C conditions for seismic response.

For Site Class C conditions, the acceleration based site coefficient, F_a = 1.0 and the velocity based site coefficient, F_v = 1.0. The peak ground acceleration (PGA) and the 5% damped spectral response acceleration values for 0.2, 0.5, 1.0, and 2.0 second periods, $S_a(T)$, for the site in Maidstone are summarized in Table 5.1.

Table 5.1 Seismic Data, Maidstone SK

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA
0.095	0.057	0.026	0.008	0.036

5.2 Frost

The depth of freezing will vary depending on air temperature, ground cover, the type of any fill material utilized during development and other factors. Surficial soil at this site consisted of clay.

The estimated freezing index for Lloydminster based on normal temperatures is 1,653°C-days. The estimated maximum depth of freezing for a severe winter is estimated to be 2.2 m to 2.5 m. The estimated depth of freezing for an average winter will be about 1.5 m to 2.1 m. The depth of freezing will be greatest in moist to dry sand and lowest in moist clay. There exists a risk of ice segregation and associated heave if soil under shallow spread footings, if constructed, is allowed since groundwater levels appear to be within 2 m to 3 m below ground surface. Good site drainage must be maintained after development to maintain low groundwater levels.

The depth of burial for water lines or other lines that cannot be allowed to freeze should consider local practice. In general, it is recommended that water lines be buried at least 2.4 m below ground surface or finished grade to reduce the risk of freezing. Shallower lines can be protected using heat trace or closed cell extruded polystyrene insulation. The amount and extent of insulation required will be dependent on several factors, particularly the thermal regime around the pipe, including the depth of burial, surface conditions and fluid temperature, if present.

5.3 Foundation Alternatives

The selection of a suitable foundation will depend on the magnitude of loading and the required performance. Foundation alternatives at this site include:

- Spread footings constructed on very stiff till.
- Augered cast-in-place concrete piles.

Issues related to foundation construction will include:

- Low bearing capacity and potential heave for shallow footings constructed on upper clay or sand.
- High bearing capacity on low plasticity clay till stratum.
- Cobbles and boulders within the till strata.
- Sloughing and seepage in excavations, originating from upper sand and clay, or occasional sand or sandy lenses or fractures within the till stratum.

A foundation consisting of augered cast-in-place concrete piles would provide the best performance with respect to vertical movement.

5.3.1 Spread Footings

Generally, spread footings must be constructed below the anticipated depth of freezing, which is about 1.5 m to 2.1 m for an average winter. At this site, relatively soft deposits of sand and clay exist as deep as 2.5 m below surface; therefore, we recommend that footings be constructed on a prepared subgrade consisting of very stiff till at a minimum depth of 2.5 m. Settlement at recommended bearing pressures will not exceed 25 mm.

5.3.2 Augered Cast-in-Place Concrete Piles

Augered cast-in-place concrete piles developing capacity on the basis of skin friction or end bearing may be considered for this site. Straight shaft piles may be designed on the basis of skin friction. Belled or under-reamed piles developing their capacity on the basis of end bearing on till may also be considered. It is likely that the majority of piles will require temporary sleeving, since some sloughing was observed in the upper sands and clays during the field investigation. Temporary sleeving may also be required where saturated sand or sandy lenses are encountered in the till to ensure that excavations are free of sloughing soil and water prior to concreting. Settlement of augered cast-in-place concrete piles developing their capacity on the basis of skin friction is expected to be less than about 5 mm to 10 mm. Settlement of piles developing their capacity on the basis of end bearing is expected to be less than 25 mm, depending on the contact pressure.

5.4 Coefficient of Earth Pressure

Active and passive earth pressure can be calculated using active earth pressure coefficients. Table 5.2 provides a summary of these properties.

Table 5.2 Earth Pressure Coefficients

Material	Angle of Internal Friction	Total Unit Weight	Earth Pressure Coefficients		
	(°)	(kN/m^3)	Active	At Rest	Passive
Clay	19	20	0.51	0.67	2.0
Till	32	20	0.30	0.47	3.3
Granular Fill	38	20	0.24	0.38	4.2

5.5 Coefficient of Friction for Sliding

The friction angle between concrete and soil for concrete poured directly on soil can be assumed to be equal to the angle of internal friction for soil provided in Table 5.2. This assumes a rough contact surface between soil and concrete. For smooth concrete against soil, the tangent of the angle of internal friction should be reduced by 20 percent.

5.6 Retaining and Basement Walls

Pressures on basements or retaining walls can be calculated using the appropriate active or at rest earth pressure coefficient as defined in Table 5.2. Pressures on retaining walls will be reduced if good quality granular fill is used. Clay or clay rich soil should be used for the upper 0.6 m of fill to minimize infiltration.

The performance of existing structures can be utilized to assess the necessity for water proofing. Based on the field investigation, it is likely that groundwater levels will be below a depth of 3 m, which will likely be below the base of a crawlspace or basement. Walls should be water proofed due to the presence of perched water.

Granular, free draining backfill is preferred because of its higher strength, which means that wall pressure will be reduced. For basement structures, a perimeter subdrainage system connected to a sump that is dewatered, or weep holes with appropriate provisions to prevent loss of ground from behind the walls should be installed to ensure that water does not accumulate against the wall. Weep holes with appropriate provisions to prevent loss of ground from behind the walls may be used for retaining walls to allow external drainage.

5.7 Floors

It is our understanding that a portion of the structure will have a crawlspace or basement. Commentary for a grade supported floor slab is provided.

Construction of grade supported floor slabs should avoid fill material of unknown composition and condition. If significant fill is contemplated, adequate compaction control and material selection criteria will be crucial to ensure suitable performance. Commentary regarding compaction is provided in later sections. Granular fill is preferred considering strength and the potential for vertical movement.

Any organic or soft material should be removed and the subgrade should be proof rolled to determine the location of any soft areas. These areas should be excavated and filled with a well graded, compacted granular fill. The subgrade should be compacted to at least 98% of the maximum dry density as determined in accordance with the standard Proctor test.

Silt and clay encountered in the upper 2.5 m may experience some heave or swell associated with seasonal changes in soil moisture, estimated to be less than about 50 mm. Potential volume changes in the underlying till stratum will not be significant. Differential movement is estimated to be about half of this amount. It is important to provide a uniform, well-constructed granular structure to support the concrete slab so that differential vertical movement is minimized.

5.8 Modulus of Subgrade Reaction

The modulus of subgrade reaction, k_s (MPa), can be estimated using values for the elastic modulus, E_s, a width B (m), and Poisson's ratio **u** = 0.45, as:

$$k_s = \frac{E_s}{B\left(1-\upsilon^2\right)}$$

For floor design, the value for 'B' can be the loaded area of the floor being examined. A value, E_s = 15,000 kPa may be used for clay. This can be increased to 20,000 kPa for very stiff till. The value for the modulus of subgrade reaction should be varied over a range of about ±50% to assess the sensitivity of performance to the assumed value.

5.9 Excavations

Seepage and sloughing should be expected in upper sand and clay. On the basis of observations in small diameter boreholes excavated for the field investigation, soil in the upper 2 m to 3 m is classified as 'type 4' in accordance with Occupational Health and Safety regulations. Shoring or relatively flat cut back angles will likely be required for excavations, and the requirement for pumping of water from excavations should be expected. Temporary sleeving will likely be required for piling. Some seepage may also occur from sand and sandy lenses, or fractures within the glacial till. This may change as a result of precipitation and infiltration, as water will move through fissures and fractures and sandy laminations or lenses.

For a ‘type 4’ soil, excavations should be no steeper than about 3 horizontal to 1 vertical (3:1) in the upper sand and clay. Although excavations through these materials may stand in the short term at near vertical angles, oversteepened slopes will slough and collapse if they are left open for long periods of time or if water is allowed to infiltrate. Failure may be sudden and may endanger personnel and equipment working in the vicinity.

5.10 Pavement Structures

The subgrade soil available at this site for pavement areas is silty sand or low plasticity sandy silt and clay. A design CBR value of 5.0 for this subgrade soil has been assumed. A design period of 20 years was used for all roadways and parking lots. We have made some assumptions regarding traffic.

Pavement structures are designed on the number and type of heavy trucks that are expected. Car and small truck traffic is almost insignificant, as one heavy semi-trailer truck is equivalent to perhaps 2,000 to 3,000 cars.

If traffic on the lot can be segregated into light and heavy traffic areas, there may be some economy in providing two different pavement structures. The actual traffic make-up is not known. For purposes of design, traffic has been classified as described below, assuming traffic in terms of a number of trucks on a daily or monthly basis, which can be:

- Heavy Pavements: The design is based on approximately 1×10^5 ESALs, which is equivalent to about 2 trucks per day. As a comparison, if the assumption is for about 6 trucks per month, the design traffic would be about 1×10^4 ESALs for a 20 year design period.
- Light Pavements: This includes any areas that are intended for a paved surface, but are not subject to any planned heavy truck haul. An example would be a parking lot adjacent to the office building. The structure here is nominal and design is based on the assumption that these areas could experience one loaded truck per week that may pass through or temporarily stop in these areas. The design traffic for these areas is 1×10^4 ESALs for a 20 year design period.

The recommended pavement structure thicknesses are presented in Table 5.3. They are based on a subgrade CBR of 5.0 and the design loadings described above.

A granular pavement structure can utilize the base course thickness shown in Table 5.3. The subbase thickness should be increased to 160 mm and 260 mm for light and heavy traffic areas, respectively. Alternately, the surface may consist of a 100 mm to 150 mm thickness of traffic gravel placed on the subbase material. This type of structure will require periodic maintenance, including blading and reapplication of a gravel surface.

A concrete slab may be considered for areas subject to heavy wheel loading and shearing stresses associated with turning of tires. The slab should be 200 mm in thickness and can be placed on a 25 mm to 50 mm thick levelling course of sand.

Table 5.3 Recommended Pavement Structure Thickness

	Thickness (mm)	
	Light Pavement Structures	Heavy Pavement Structures
Subbase	110	190
Crushed Base Course (Type 33)	150	150
Hot Mix Asphalt Concrete	40	60

5.11 General Site Development

5.11.1 Construction Equipment

Standard excavation equipment may be used for site development; no unusual excavation conditions are anticipated. Clay and till will become slippery when it is wet.

Large vibratory smooth steel drum compacting equipment should be used to compact granular soil. For large granular fills, test pads are recommended to evaluate the efficiency of the compaction process for the fill material and equipment being used. A maximum lift thickness of 200 mm is recommended initially.

A sheepsfoot or pad foot compactor is recommended where significant quantities of clay or clay till are present, or are being compacted in an embankment.

5.11.2 Topsoil, Cobbles and Boulders

Organic topsoil should be removed prior to placement of any fill to minimize the potential for settlement. The average topsoil thickness was estimated to be about 200 mm.

No cobbles and boulders were encountered within the upper 2 m at this site, although they are commonly found in glacial till.

5.11.3 Groundwater

Groundwater seepage was observed as high as about 1 m below surface during drilling; therefore, water is expected in excavations below this depth. Groundwater levels are expected to fluctuate seasonally and with precipitation.

5.11.4 Suitability of On-Site Soil for Compacted Fill

Surficial sand at this site may be frost susceptible. Clay till possesses low plasticity and is present at a water content close to optimum; it will be an acceptable material for construction of roads and embankments. Some moisture conditioning or drying may be required to aid in compaction. Clay till will be subject to some heave as its water content increases and will shrink if it is allowed to dry.

5.11.5 Shrinkage Factors

For estimates of earthwork volumes, a shrinkage factor of 15% to 20% may be used for clay.

5.11.6 Engineered Fill

If required, engineered fills supporting important structures should utilize pit run sand or gravel. Specifications for pit run gravel and sand, and crushed base course material are appended to this report.

5.11.7 Cut or Fill Slopes

Cut or fill slopes in clay or sand will possess long term stability at slopes of 2 horizontal to 1 vertical (2:1), but may be subject to increased rates of erosion. Flatter slopes are preferred for landscaping purposes. Vegetation can be used to maintain slopes. Where vegetation is not desirable, a gravel surface with a minimum thickness of 150 mm is recommended on these slopes to reduce the potential for erosion.

Drainage swales and ditches should be constructed with gentle slopes, if possible, as the soil will be easily eroded, particularly if water velocities are greater than 2 m/s.

It is desirable to have road subgrades at least 1.0 m above natural ground on fill sections or to have at least a 1.0 m ditch in cut-fill sections. The surface of the subgrade should have enough cross-slope to ensure positive surface drainage prior to surfacing, nominally 5%.

5.11.8 Site Grading

The site should be graded to ensure positive drainage throughout the construction phase. Grades should be created to direct water away from excavations and trenches. Within excavations, the subgrade should be graded with a cross slope so that any accumulated water can be removed by pumping.

Proper site grading design is critical to ensure good long term performance of shallow footings and mat foundations. Grades should ensure that water from precipitation or snowmelt does not accumulate near structures. A positive slope away from structures of at least 5% for about 3 m is recommended.

5.12 Compaction Specifications

Compaction specifications must consider the desired properties of the fill. Specifications will typically require compaction to a percentage of the maximum dry density determined in accordance with the standard Proctor test and may include a range of water contents that are desirable. Depending on the desired properties for the compacted soil, the water content is often provided as a guide to the contractor, since the compactive effort will usually be minimized if the soil is compacted close to the optimum water content determined in accordance with the standard Proctor test. If the soil is wet of optimum, it will be possible to attain a specified density if greater compactive effort or more work is applied to the soil.

The compaction water content will have an impact on the properties of the compacted soil. Soil strength and compressibility is better if the water content is lower than optimum. Soil compacted wet of optimum to the necessary density may be more compressible under low pressure and may have reduced strength. The swelling potential and permeability of a soil will generally be reduced; however, if the soil is compacted wet of optimum.

The following recommendations are provided for compaction.

- The excavated subgrade should be uniformly compacted to 95% of its maximum dry density determined in accordance with ASTM D698-00a, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)]. The water content of the subgrade should be close to optimum water content.
- Soft areas in the subgrade should be subcut and backfilled with well graded pit run gravel that is uniformly compacted to at least 100% of its maximum dry density determined in accordance with ASTM D698-00a, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)].
- If considered, granular pads for shallow spread footings should be constructed with a well graded pit run gravel that conforms to the recommended gradations for granular materials appended to this report. The material should be compacted to a minimum average 98% of maximum dry density for four (4) consecutive tests, with no single test less than 96%, determined in accordance with the standard Proctor test. Lift thickness should not exceed 200 mm.
- Crushed base course that will be under a floor slab, spread footing or paved areas should be compacted to a minimum 98% of its maximum dry density determined in accordance with the standard Proctor test.
- Fill material that will be under a paved area should be compacted to a minimum 98% of maximum dry density determined in accordance with the standard Proctor test in lifts no thicker than 150 mm in compacted thickness. Fill under landscaped areas does not generally required high density, although some compaction is required to reduce the amount of settlement. A suggested level of compaction is a minimum 90% of maximum dry density determined in accordance with the standard Proctor test.
- Backfill of trenches in areas that already have been compacted should be with new subbase material as specified previously and compacted to a minimum 98% of maximum dry density determined in accordance with the standard Proctor test.
- Backfill and compact simultaneously each side of walls in layers of 300 mm to ensure that excessive pressure is not applied to one side of the wall.

5.13 Potential for Sulphate Attack

Water soluble sulphate contents as high as 2.17% by dry weight of soil were measured in the laboratory. According to CSA A23.1, the potential for sulphate attack is very severe, corresponding to an S-1class of exposure. On this basis, sulphate resistant Type HS cement must be specified for all concrete in contact with the native soil. The maximum water to cement ratio should be 0.40, with a minimum specified compressive strength of 35 MPa at 56 days. Additional recommendations regarding sulphate resistant cement may be found in CSA A23.1.

6.0 Discussion of Foundations

Foundation alternatives at this site include shallow spread footings constructed on very stiff till below a depth of about 2.5 m, or augered cast-in-place concrete piles. A foundation system consisting of piles and grade beam will minimize settlement and will not be subject to vertical movement associated with seasonal changes in soil moisture.

6.1 Augered Cast-in-Place Concrete Piles

Augered cast-in-place concrete piles may be designed to develop their capacity on the basis of skin friction or end bearing, but not both. Piles developing their capacity on the basis of end bearing will undergo larger settlement than piles developing their capacity on the basis of skin friction.

The minimum length of pile is 6 m to ensure that a pile can resist any potential uplift forces associated with adfreeze forces or heave associated with an increase in water content.

Some seepage and sloughing was noted during the field investigation. Cobbles and boulders are common in glacial till, and should be expected in excavations. Cobbles and boulders that are smaller than the shaft diameter can be extracted on auger flights. Coring will be required to penetrate larger boulders.

For pile groups, a minimum centre to centre spacing of 2.5 times the pile diameter is recommended. A group efficiency of 1.0 is recommended for the determination of group capacity.

Ultimate skin friction values for pile foundations are summarized in Table 6.1. The skin friction contribution of the upper 2 m of a pile constructed below finished grade and the capacity of any portion of the pile penetrating fill, should be ignored in the determination of pile capacity. Geotechnical resistance factors for analyses have been provided in Table 6.2.

Table 6.1 - Summary of Ultimate Pile Design Parameters

Depth (m)		Soil	Ultimate Skin Friction (kPa)	Ultimate End Bearing (kPa)
From	To			
0	2	Clay / Sand	0	-
2	2.5	Clay / Sand	50	-
2	7	Oxidized Till	68	-
7	13	Unoxidized Till	80	1,800

Table 6.2 - Resistance Factors for Shallow and Deep Foundations

Case	Resistance Factor
o Shallow Foundations: Vertical resistance by semi-empirical analysis using laboratory and in situ test data	0.5
o Deep Foundation: Bearing resistance to axial load based on semi-empirical analysis using laboratory and in situ test data	0.4
o Deep Foundation: Analysis using dynamic monitoring results	0.5
o Deep Foundation: Analysis using static loading test results	0.6
o Uplift Analysis: By semi=empirical analysis	0.3
o Uplift Analysis: Using load test results	0.4
o Horizontal Load Resistance	0.5

6.1.1 Belled Piles

Piles can also be under-reamed or belled, with capacity calculated on the basis of end bearing only. The bell must be constructed at least 2.5 bell diameters below grade to allow development of capacity. The ultimate end bearing value bells have been summarized in Table 6.1. Geotechnical resistance factors for analyses have been provided in Table 6.2.

Bells should be left open for a minimum amount of time prior to concreting to minimize the risk of heave of the bottom associated with groundwater levels being above the base of the bell and from unloading associated with excavation.

6.1.2 Uplift Capacity

Uplift capacity of an augered cast-in-place concrete pile can be calculated on the basis of the ultimate skin friction values provided in Table 6.1 and the geotechnical resistance factors in Table 6.2. The weight of the pile can be included in the calculation. The end bearing component should not be included in the calculation of uplift capacity. The uplift capacity of a pile group will be the lesser of the sum of the uplift resistance of the piles in the group or the sum of the resistance mobilized on the surface perimeter of the group using the ultimate skin friction values provided in Table 6.1 and the geotechnical resistance factors in Table 6.2, plus the effective weight of the soil and piles enclosed within this perimeter.

6.1.3 Negative Skin Friction

Piles installed through a significant thickness of relatively unconsolidated fill material should be designed to accommodate negative skin friction which can develop as the fill settles. Pile capacity should consider negative skin friction plus dead load. It should not consider live load. Values of negative skin friction will be the same as ultimate skin friction values provided in Table 6.1.

Fill with a thickness of less than about 1 m placed adjacent the building is not expected to result in significant consolidation of soil around a pile foundation, since the surficial soil possesses a high preconsolidation pressure associated with desiccation. Negative skin friction will not have to be considered for pile design in this case.

6.1.4 Confirmation of Design

Pile design parameters or pile capacity may be confirmed by dynamic or static pile load tests in accordance with the following ASTM standards:

- ASTM D1143 Standard Test Methods for Deep Foundations Under Static Axial Compressive Load.
- ASTM D4945 Standard Test Method for High-Strain Dynamic Testing of Piles.

As illustrated in Table 6.2, conducting a static load test will allow the use of a higher resistance factor to determine pile capacity. Pile load tests may be conducted on production or prototype piles. The design pile capacity may influence the selection of the type of pile tested. If the design capacity of the production pile is high, it may be more economical to test a lower capacity prototype pile to confirm design parameters since it is desired to fail the pile during testing to assess ultimate design parameters. Alternately, the pile can be tested to confirm design capacity.

6.1.5 Settlement

Settlement of augered cast-in-place concrete piles developing their capacity on the basis of skin friction is expected to be less than about 5 mm to 8 mm. Piles developing their capacity on the basis of end bearing will settle approximately 15 mm to 25 mm. The amount of settlement for an end bearing pile will depend upon the amount of loosened material left on the base of the pile after construction of the bell. Bells must be well cleaned to limit settlement to these values. A suggested definition of ‘clean’ for specifications is as follows:

- The average thickness of loose soil at the base of the bell should be no more than 15 mm and should cover less than 50% of the base of the bell, with no more than 40 mm of loose spoil material at any point on the bearing surface.
- No more than 50 mm of water should be allowed to accumulate at the base of the bell prior to concreting.

6.1.6 Lateral Loads on Piles

The lateral load carrying capacity and deflection of a pile subjected to a lateral load is dependent on the stiffness of the pile and soil strength. The stiffness of a pile can be calculated using well defined properties of steel or concrete, or both; however, the response of soil under loading is subject to some variability. The best method to evaluate the performance of a pile subjected to a lateral load is a well-designed and executed lateral load test based on ASTM D3966-07, Standard Test Methods for Deep Foundations under Lateral Loads.

The performance of laterally loaded augered cast-in-place concrete piles may be analyzed using the software application LPILE. This program computes deflection, shear, bending moment and soil response with respect to depth in a nonlinear soil. Soil behaviour is modelled with *p-y* curves that are generated by the software following published recommendations for various types of soils. These relationships consider the relationship between undrained shear strength and soil modulus, as well as strain at 50% of the maximum stress.

The lateral load carrying capacity of pile groups will depend on the pile spacing and orientation of the piles. In general, pile spacing should be at least 2.5 pile diameters. For preliminary analyses, an efficiency of 0.70 may be used for a group loaded parallel to the piles. This can be increased to 0.90 for loading perpendicular to the piles. Specific configurations with specific lateral, vertical or moments can be analyzed using software applications such as GROUP. Analyses for this site can assume soil properties shown in Table 6.3. Analyses can be undertaken once the magnitude of applied pile loads has been assessed.

Table 6.3 - Soil Properties for Analyses of Laterally Loaded Piles Using LPile

Soil Strata	Depth (m)	Undrained Shear Strength (kPa)	Effective Unit Weight (kN/m^3)
Sand / Clay	0 to 17	45	19.0
Sand / Clay	1.7 to 2.5	45	9.0
Till	2.5 to 7	150	11.5
Till	7 to 13	200	11.5

Piles can be analyzed for a fixed or free pile head condition. The fixed condition maintains a zero slope at the top of the pile and the pile head is allowed to translate. A free pile head condition allows rotation at the head of the pile.

The performance of the pile subjected to a lateral load will be most sensitive to the properties of soil near the top of the pile. There will be a significant difference between deflection associated with a fixed head and a free head condition, with a reduction in pile head deflection for an increased pile diameter. Pile head deflection and moment is not expected to vary significantly for a reasonable range of applied vertical load.

Pile behaviour may be approximated using analysis that incorporates a coefficient of horizontal subgrade reaction, k_s. The coefficient of horizontal subgrade reaction is a rough approximation at best and includes a high degree of uncertainty due to the influence of stress level, pile geometry and empirical nature of expressions used to derive these values. Values for k_s are summarized in Table 6.4.

Table 6.4 - Coefficient of Horizontal Subgrade Reaction, k_3

Soil	Depth (m)	k_3 (kN/m^3)
Sand / Clay	0 to 10	0
Sand / Clay	1.5 to 2.5	2,000/B to 5,000/B
Till	2.5 to 8	10,000/B to 15,000/B
Till	8 to 13	15,000/B to 25,000/B

B – Pile Diameter (m)

6.2 Shallow Spread Footings

Generally, spread footings must be constructed below the anticipated depth of freezing, which is about 1.5 m to 2.1 m for an average winter. At this site, the upper sand/clay is relatively soft; therefore, the preferred subgrade soil for a spread footing will be the low plasticity till stratum below a depth of about 2.5 m.

Very stiff clay till possesses relatively high bearing capacity. The estimated net ultimate bearing capacity of the oxidized till stratum is 750 kPa. Resistance factors for shallow and deep foundations from NBCC 2010 have been summarized in Table 6.2. Settlement is expected to be predominantly elastic due to the overconsolidated nature of till. Some minor vertical movement associated with changes in soil moisture should be expected for lightly loaded structures supported on a shallow foundation. The amount of settlement will increase as the size of the footing increases. The estimated settlement for a footing designed on the basis of the bearing capacity. The bearing pressure utilized will be controlled by settlement rather than bearing failure.

For a spread footing, the geotechnical resistance calculated using the ultimate bearing capacity and appropriate resistance factor is utilized to ensure that a gross failure of the foundation does not occur. Settlement considerations will typically govern the selection of an appropriate bearing pressure. Consideration of serviceability utilizes working or services loads and unfactored geotechnical properties for soil strata.

6.2.1 Settlement

The amount of settlement will be dependent on factors such as the foundation size and applied pressure. The amount of settlement will increase for a larger foundation with no change in the bearing pressure. The estimated settlement for a spread footing with a width of about 450 mm to 1,000 mm will be about 25 mm.

6.2.2 Subgrade Preparation

The width of excavations for major foundations should extend a minimum 1.5 m plus the depth of excavation beyond the edge of the foundation to ensure that the subgrade can be prepared and fill can be properly placed and compacted.
Although the base of large excavations can be level, it is desirable to create a cross slope on the subgrade to encourage the flow of water away from structures during construction and after placement of fill.

The subgrade should be prepared by excavating to the design grade and proof rolling with a heavy roller or other equipment to verify uniformity of the subgrade. Soft material should be excavated an additional 600 mm, minimum and the area backfilled with compacted pit run gravel. Pit run gravel should be compacted to a minimum 100% of its maximum dry density to minimize the potential for differential settlement.

7.0 General Foundation Recommendations

7.1 Augered Cast-in-Place Concrete Piles

Augered cast-in-place piles developing their load carrying capacity on the basis of skin friction can be considered for structures at this site. If additional capacity is required, piles may be designed on the basis of end bearing. Our specific design criteria and recommendations for augered cast-in-place piles are as follows:

1. Foundation loads may be supported on piles designed as straight shafts, developing load carrying capacity on the basis of skin friction only. Values for ultimate skin friction value are summarized in Table 6.1. The geotechnical resistance factors have been summarized in Table 6.2. The skin friction contribution of the upper 2 m (minimum) below finished grade and any fill material should be ignored in the calculation of pile capacity.
2. On the basis of observations during the field investigation, significant seepage and some sloughing should be expected in the upper approximate 2.5 m, and some seepage may be encountered from sand or sandy lenses, or fractures and fissures in the till below 2.5 m. Temporary sleeving will likely be required for piling. Cobbles and occasional boulders can be expected in the till strata. Concrete should be placed in dry shafts within 2 hrs of excavation to minimize softening of the clay or clay till, which can reduce pile capacity and squeezing of soil, which can result in necking. Should seepage or sloughing occur, the hole should be pumped dry before concreting.
3. It is suggested that the aspect ratio of a pile, defined as the ratio between length and diameter, should not exceed 30. This should ensure that good contact is maintained between the concrete and soil and that no voids are created.
4. The use of water to facilitate excavation of piles should be avoided, since this will result in softening of the soil in contact with the concrete, reducing pile capacity. Inspection during construction is recommended to ensure compliance with specifications.
5. Pile shafts must be adequately reinforced to withstand the imposed stresses. Pile reinforcement should extend at least 5 m below finished grade and not less than two thirds the pile length.
6. If additional pile capacity is required, the piles may be belled out or expanded at the base. The bell must be constructed at least 2.5 bell diameters below grade to allow development of capacity. Belled piles constructed on very stiff to hard till will provide high capacity.

7. The ultimate end bearing values for a well-constructed, machine cleaned bell have been provided in Table 6.1. Geotechnical resistance factors for analyses have been provided in Table 6.2.
8. The base of the bell should be a minimum 500 mm below the top of the soil stratum upon which is designed to bear. This value and geotechnical resistance factors used for design may be revised on the basis of a pile load test.
9. Inspection by qualified geotechnical personnel is necessary to ensure that end bearing piles constructed in this manner will be capable of developing these capacities. Skin friction along the shafts of belled piles may not be used in the design of end bearing piles.
10. The average thickness of loose soil at the base of the bell should be no more than 15 mm and should cover less than 50% of the base of the bell, with no more than 40 mm of loose spoil material at any point on the bearing surface.
11. No more than 50 mm of water should be allowed to accumulate at the base of the bell prior to concreting.
12. The undrained shear strength of soil at the base of the bell may be verified using a pocket penetrometer, laboratory vane shear apparatus or other suitable tools. Soil at the base of the pile can be sampled using a thin walled tube sampler to ensure that no ‘build up’ is present.
13. If bells are to be inspected by down hole personnel, piles should have a minimum shaft diameter of 700 mm to allow installation of a sleeve for safety in accordance with Occupational Health and Safety guidelines. Such piles should be inspected by a qualified Geotechnical Engineer or personnel under the supervision of a qualified Geotechnical Engineer to confirm the soil strength parameters and approve the piling construction methods. Inspection will be limited to that area within the shaft so that personnel remain within the sleeved area.
14. Bells should be constructed with a sideslope not less than 45° and preferably 60° from the horizontal. The base of the bells should be excavated vertically a minimum of 200 mm to allow adequate load transfer to the soil. The base of the bell must be excavated into undisturbed foundation soils of adequate capacity as described in previous sections to carry the design loads. The area around the shaft extension should be carefully cleaned and the edges of the shaft extension beveled to reduce the risk of stress concentrations within the finished bell.

7.2 Shallow Spread Footing

The following recommendations are made for a shallow spread footing:

1. Footings should be constructed on very stiff till below a depth of about 2.5 m. In general, the surface should be prepared by removing any pockets of soft soil or soft fill to a uniform bearing surface. The surface must be maintained in an undisturbed state. The excavated surface can be protected with a mudslab placed within 24 hours of completion of excavation.
2. Seepage and sloughing should be expected in footing excavations, especially from the sands and clays in the upper 2.5 m. Flat cutback angles or shoring may be required. The requirement for pumping of water from excavations should be expected.
3. Spread footings founded on the glacial till below a depth of 2.5 m below existing grade should be below the depth of frost penetration.
4. Over excavated areas may be filled with a lean concrete mix or with a well graded pit run gravel that conforms to the Recommended Specifications for Granular Materials appended to this report. The material must be compacted to 100% of its maximum dry density determined in accordance with ASTM D698-00a, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft lbf/ft^3 (600 kN m/m^3)].

5. The foundation must be adequately reinforced to distribute the applied loads and also have sufficient stiffness to distribute local overstresses.
6. The minimum footing width is 450 mm.
7. A shallow spread footing constructed as specified above may be designed on the basis of an ultimate bearing capacity of 750 kPa, using the geotechnical resistance factors shown in Table 6.2. For serviceability criteria, bearing capacity can be selected on the basis of settlement or differential settlement as described in previous sections.

8.0 Floor Considerations

8.1 Grade Supported Floors

Our recommendations for a grade supported floor slab are as follows:

1. The subgrade soil below the proposed floor slab should be excavated to undisturbed soil. Construction on fill material of unknown quality and composition can result in uneven settlement or heave. All topsoil must be removed from the site during subgrade preparation for the grade supported floor slab. Care must be exercised to remove all loose soil and debris. Soft, wet areas, which do not have sufficient trafficability for construction purposes, may be further excavated and replaced with a pit run sand or gravel which complies with the attached specifications.
2. The excavated subgrade should be uniformly compacted to 98% of its maximum dry density determined in accordance with ASTM D698-00a, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)]. The water content of the subgrade should be adjusted to optimum water content ±2%.
3. Place a crushed base course which complies with the specifications given in the Recommended Specifications for Granular Materials appended to this report for Type 32 or 33 base course.
4. Compact the base course to a minimum average 98% of its maximum dry density for four (4) consecutive tests, with no single test less than 96%, as determined in accordance with ASTM D698-00a, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)]. Water may be used as an aid to compaction and vibratory compaction equipment is recommended.
5. A layer of polyethylene sheeting 150 μm (minimum) thick should be placed between the granular base and the concrete slab to deter the migration of moisture through the floor and loss of moisture from freshly placed concrete.
6. The floor must be structurally isolated from other building elements, service lines and appurtenant structures to prevent stresses caused by floor movement from being transmitted to these elements.
7. Positive site drainage around the building and control of roof drainage away from the building reduces the risk of volume change in grade supported floors.

8.2 Structurally Supported Floor

The following procedures are recommended for the construction of a structurally supported floor:

1. The subgrade should be positively graded to a sump to remove water, which may inadvertently pond beneath the floor.
2. Migration of moisture from the soil should be prevented by installing 150 m (minimum) thick polyethylene vapour barrier covered with 50 mm of sand.
3. Floors designed, as a structurally supported system with a crawl space between the floor and the subgrade should have some provision to ventilate the crawl space, particularly during the summer months.
4. As an alternative to a crawl space, the floor may be cast upon waxed cardboard carton ‘void form’ that is designed to degrade following the placement of the concrete. The cardboard cartons must have a strength sufficient to support the fresh concrete until it has sufficient strength to be self-supporting. Great care is required during construction of such floor systems to ensure that the collapse of the cartons does not take place, resulting in a grade supported slab. Careful inspection of these floors during construction is required to ensure that the void does not collapse during the placement of the floor. Further, care must be taken during selection of ‘void form’ used. Materials which depend upon biologic degradation should be avoided.

9.0 Excavation Considerations

The stability of cut slopes and the stability of any adjacent structure must be considered for any excavations on the site. The anticipated sideslopes for the excavation will depend on the soil texture, water content and length of time that the excavation is left open.

Seepage and sloughing was observed from sands and clays at the surface of the till, and is expected during excavation. Seepage may also originate from sand or sandy lenses or layers, or fractures within the till. Water can likely be collected in open sumps and pumped away from the excavation.

Excavations should be performed in compliance with provincial safety regulations. On the basis of observations in small diameter boreholes excavated for the field investigation, soil in the upper 2 m to 3 m is classified as ‘type 4’ in accordance with Occupational Health and Safety regulations. For a ‘type 4’ soil, excavations should be no steeper than about 3 horizontal to 1 vertical (3:1) in the upper sand and clay.

Although excavations through these materials may stand in the short term at near vertical angles, oversteepened slopes will slough and collapse if they are left open for long periods of time or if water is allowed to infiltrate. Failure may be sudden and may endanger personnel and equipment working in the vicinity.

The condition of the soil around an excavation should be carefully observed to ensure that excessive ravelling or sloughing does not occur in the upper sand and clay. All loose material on the sides of the excavation should be trimmed. The excavation should be left open for the minimum amount of time required for construction. Some loss of strength in the soil can be expected with the passing of time, resulting in sloughing and local slope failures.

As described in Occupational Health and Safety Regulations, a competent worker should be stationed on the surface to alert any worker in the excavation about the development of any potentially unsafe conditions. Machinery and heavy equipment should not be allowed closer to the excavation than one half of the depth of the excavation, unless precautions are implemented to ensure that workers in the excavation are safe. Spoil material should not be piled closer than 3 m from the edge of the excavation and with sideslopes no steeper than 1:1.

Infiltration of water into the soil around the excavation can result in loss of strength and collapse of the excavation walls. It is recommended that workers not be in the excavation during rainfall and that excavation walls be carefully inspected for cracking and potential failures after rainfall before work continues in the excavation.

10.0 Underground Walls

It is recommended that the underground walls should be designed to withstand the lateral earth pressure (p) at any depth (H) as estimated by the following expression:

$$p = K (H + q)$$

where: = unit weight of the wall backfill, provided in Table 5.2
q = the vertical pressure of any surcharge acting at ground surface near the wall
K = the active earth pressure coefficient provided in Table 5.2 for a wall that is allowed to rotate, and the at rest earth pressure coefficient for a rigid wall

This expression assumes that the wall will be backfilled with a free draining granular backfill and will not be subject to build up of water pressure behind the wall. If effective wall drainage cannot be guaranteed, full hydrostatic pressure, which may act on the wall, must be considered in the design.

Free draining backfill materials should be placed adjacent to the exterior underground walls. Free draining means that the granular material should be well graded and have less than 3 percent passing the 75 µm sieve. The upper 0.6 m of backfill should consist of local compacted soil or the surface must be covered with some other suitable impermeable material. The ground surface should be contoured away from the building to further discourage the entry of surface runoff into the backfill. Regardless of the type of backfill used behind the wall, it is recommended that the wall be effectively damp-proofed to prevent migration of moisture through the concrete. Damp-proofing also aids in reducing the rate of deterioration of the concrete due to chemical attack and weathering.

11.0 Recommendations for Pavement Structures

Recommended pavement structure thickness has been provided in Table 5.3. Our recommendations for pavement materials and construction of the pavement structure, including the subgrade, follow:

1. Excavate all topsoil, organic material, fill and soft or wet pockets of soil in the proposed pavement areas.
2. The surface of the subgrade should have enough cross-slope to ensure positive surface drainage prior to surfacing, nominally 2%.
3. Shape the subgrade to the design lines and grades. All fill areas should be placed and compacted in lifts not exceeding 150 mm compacted thickness and in compliance with compaction recommendations given below in Points 5 and 6.
4. Scarify and adjust the soil water content for the upper 150 mm of subgrade surface to optimum water content ±2% determined in accordance with ASTM D698-07e, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)].
5. Compact the upper 150 mm of subgrade surface uniformly to 96% of its maximum dry density determined in accordance with ASTM D698-07e, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)].
6. Where required, place subbase which is a well graded sandy gravel passing the 50 mm sieve and with less than 15% by weight passing the 75 μm sieve. Shape and compact the subbase. Additional compaction water or dilute asphalt emulsion may be required to stabilize the subbase surface.
7. Place a crushed, soil stabilized base course which complies with the specifications given for Type 33 base course in the Recommended Specifications for Granular Materials attached. The thickness of the base course is defined in the subsequent section. No single lift of base course may be greater than 200 mm compacted thickness.
8. Compact the base course to a minimum 98% of its maximum dry density determined in accordance with ASTM D698-07e, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 (600 kN-m/m^3)]. Water may be used as an aid to compaction and vibratory compaction equipment is recommended.
9. When the base course construction is completed to lines, grades and compaction specifications, apply a prime coat of liquid cutback asphalt at the rate of 0.5 L/m^2. No traffic should be allowed on the recently primed base course until the prime coat is fully cured.
10. Place a spreader-laid hot mix asphalt concrete having specifications meeting those described in the Saskatchewan Ministry of Highways and Infrastructure specification for Asphalt Concrete Mix Type 2 for heavy traffic areas, and Asphalt Concrete Mix Type 3 for light traffic areas.
11. The hot mix asphalt concrete supplied should have a minimum stability of 8,000 N for light traffic area, and 12,000 N for heavy traffic areas.
12. Placement of asphalt shall be in accordance with Saskatchewan Ministry of Highways and Infrastructure Specification 3.50. The hot mix asphalt concrete should be finished to a tight, smooth surface free from ruts, waves, roller marks, cracks or segregation.
13. The hot mix asphalt concrete should use AC 150-200(A) asphalt cement.
14. A flush coat may be required to seal the surface of the recently constructed asphalt concrete surface.

12.0 Closure

This report was prepared by Clifton Associates Ltd. for the use of the RCMP and their agents for specific application to the proposed RCMP Detachment to be located in Lot 51, Parcel C, Plan 85B12566 in Maidstone, SK. The material in it reflects Clifton Associates Ltd. best judgment available to it at the time of 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 Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report has been prepared with generally accepted engineering practices common to the local area. No other warranty, expressed 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 and groundwater 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 Associates Ltd. 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 investigation as well as certain recommendations arising out of such investigations. Our recommendations do not constitute a design, in whole or in part, of any 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 the 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.

Clifton Associates Ltd.

Richard T Yoshida PEng

Association of Professional
Engineers and Geoscientists of Saskatchewan
Certificate of Authorization No. 238

Appendix A

Drawings

Clifton Associates

Regina Office
340 Maxwell Crescent
Regina SK S4N 5Y5

Telephone 306-721-7611
Facsimile 306-721-8128

regina@clifton.ca
www.clifton.ca

SITE LOCATION PLAN

SCALE 1:7,500 APPROX.

LEGEND :

SITE BOUNDARY ━ · ━ · ━

NOTES :

1. BASE MAP DOWNLOADED FROM GOOGLE MAPS https://maps.google.ca
2. LEGAL DESCRIPTION :
   S.E.1/4 SEC.34-TWP.47-RGE.23-W.3Mer
   TOWN OF MAIDSTONE, SK

DRAWING REVISIONS

REV	DESCRIPTION	BY	DATE

ENGINEER
Clifton Associates

CLIENT
ROYAL CANADIAN MOUNTED POLICE

PROJECT
MAIDSTONE NEW DETACHMENT
GEOTECHNICAL INVESTIGATION II

TITLE
SITE LOCATION PLAN

DESIGNED CD	SCALE 1:7500	DATE 2014-05-26
DRAWN SP	PROJECT NO. S2026	DWG NO. 01
CHECKED RMM, CD	FILE NO. S2026	SHEET NO. 01 OF 02

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BORE HOLE LOCATION PLAN

SCALE 1:1,500 APPROX.

LEGEND :

SITE BOUNDARY	━ · ━
BOREHOLE LOCATION (APPROX.)	◕
MONITOR WELL LOCATION (APPROX.)	◕
BENCHMARK TOP OF FIRE HYDRANT BOLT (100.00m ASSUMED)	✦

NOTES :

1. BASE MAP DOWNLOADED FROM GOOGLE MAPS https://maps.google.ca
2. LEGAL DESCRIPTION : S.E.1/4 SEC.34-TWP.47-RGE.23-W.3Mer TOWN OF MAIDSTONE, SK

DRAWING REVISIONS

REV	DESCRIPTION	BY	DATE

ENGINEER

Clifton Associates

CLIENT

ROYAL CANADIAN MOUNTED POLICE

PROJECT

MAIDSTONE NEW DETACHMENT
GEOTECHNICAL INVESTIGATION II

TITLE

BOREHOLE LOCATION PLAN

DESIGNED CD	SCALE 1:1500	DATE 2014-05-26
DRAWN SP	PROJECT NO. S2026	DWG NO. 02
CHECKED RMM, CD	FILE NO. S2026	SHEET NO. 02 OF 02

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Appendix B

Borehole Logs and Laboratory Test Data

Clifton Associates

Regina Office
340 Maxwell Crescent
Regina SK S4N 5Y5

Telephone 306-721-7611
Facsimile 306-721-8128

regina@clifton.ca
www.clifton.ca

Soil Descriptive Terms

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

- texture
- color, 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 predominatly 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.	

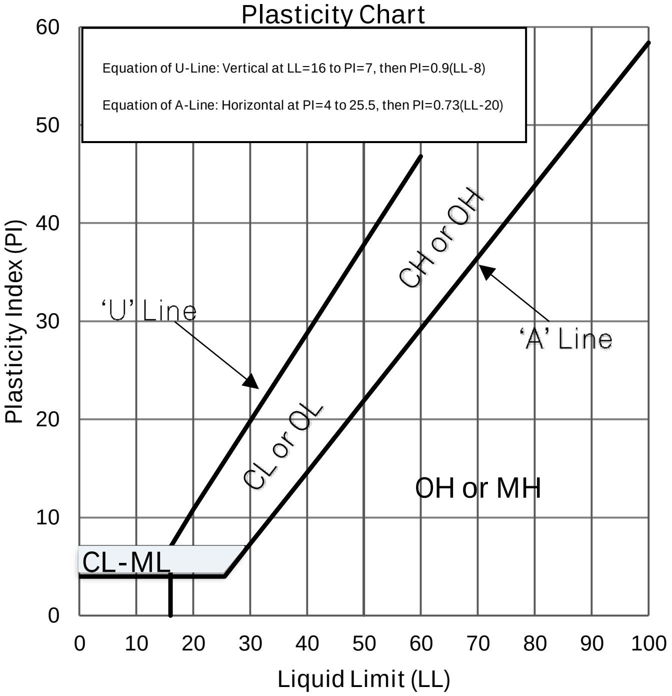
The term "TILL" may be used as a textural term to describe a soil which has been deposited by glaciers and contains an unsorted, wide range of particle sizes.

Colour and Oxidation

The soil color at its natural moisture content is described by common colors and, quantitatively, in terms of the Munsell color notation; (eg. 5Y 3/1). The notation combines three variables, hue, value and chroma to describe the soil color. 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 color from a neutral color indicates the soil has been oxidized. Oxidation of a soil occurs in a oxygen rich environment where most commonly metallic iron, oxidizes and turns a neutral colored 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: Less than 5% pass No. 200 sieve - GW, GP, SW, SP More than 12% pass No. 200 sieve - GM, GC, SM, SC 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 Cu or Cc 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 If fines are organic add "with orgnic 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 Cu or C ccriteria 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 If fines are organic add "with orgnic fines" to group name
			SC	Clayey sand			Atterberg limits on or above "A" line and PI > 7	
Fine-grained soils50% 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. If > 30% coarse-grained, add "sandy" or "gravelly" as appropriate. Class as organic when oven dried liquid limit is < 75% of undried liquid limit.	Plasticity Chart 		
			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 boulder`s" 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 Ceohesive 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, color 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 ($Na2Ca(So_4)_2$), 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
- ▨ Silt
- ▨ Sand
- ▨ Gravel
- ▨ Cobbles
- ▨ Till – oxidized
- ▨ Till – unoxidized
- ▨ Peat
- ▨ Topsoil or Organic Soil
- ▨ Coal
- ▨ Fill (undifferentiated)
- ▨ Concrete
- ■ Asphalt
- ▤ Clay Shale
- ▨ Sandstone
- ▨ Mudstone
- ▨ Bedrock (undifferentiated)

Borehole Completion and Backfill Materials

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

Soil Sample Type

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

Groundwater Symbols

▼ Piezometric elevation as determined by a piezometer installation.

▽ Water levels measured in borings at time and under the conditions noted.

Clifton Associates

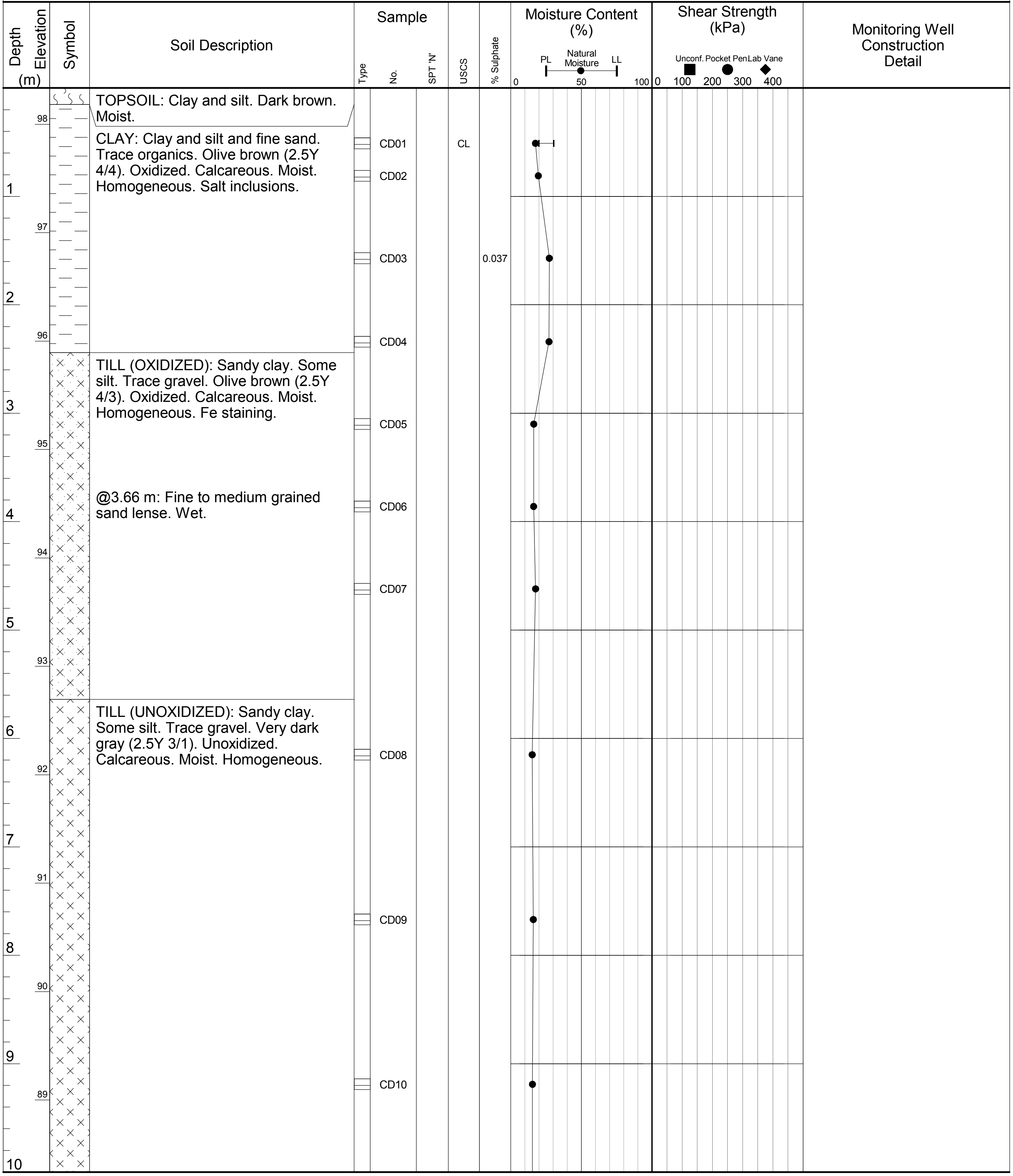
BOREHOLE LOG

BOREHOLE: 101

Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883626
Easting: 615167
Ground Elev.: 98.335
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD



TOPSOIL: Clay and silt. Dark brown. Moist.

CLAY: Clay and silt and fine sand. Trace organics. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Salt inclusions.

TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Olive brown (2.5Y 4/3). Oxidized. Calcareous. Moist. Homogeneous. Fe staining.

@3.66 m: Fine to medium grained sand lense. Wet.

TILL (UNOXIDIZED): Sandy clay. Some silt. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Homogeneous.

No.	SPT 'N'	USCS	% Sulphate
CD01		CL	
CD02			
CD03			0.037
CD04			
CD05			
CD06			
CD07			
CD08			
CD09			
CD10			

Clifton Associates

BOREHOLE LOG

BOREHOLE: 101

Page: 2 of 2

Client: RCMP	Northing: 5883626	Date Drilled: 09/05/2014
Project: New Detachment Geotech II	Easting: 615167	Drill:MARL M-10
Location: Maidstone, SK.	Ground Elev.: 98.335	Drilling Method: Solid Stem Auger
Project No.: S2026	Top Casing Elevation:	Logged by: CD

Depth (m)	Elevation (m)	Symbol	Soil Description	Sample Type	Sample No.	SPT 'N'	USCS	% Sulphate	Moisture Content (%) PL / Natural Moisture / LL 0 50 100	Shear Strength (kPa) Unconf. ■ Pocket Pen ● Lab Vane ◆ 0 100 200 300 400	Monitoring Well Construction Detail
	88		TILL (UNOXIDIZED): Sandy clay. Some silt. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Homogeneous. *(continued)*		CD11						
11	87										
			Notes: End of hole at 11.43 m. No sloughing. Water to 6.55 m. Seepage at 2.13 m.								
12	86										
13	85										
14	84										
15	83										
16	82										
17	81										
18	80										
19	79										
20											

Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.46	CD1	GB		17.5	19.9	30.4	10.5	CL	0.0	22.9	77.1						
0.76	CD2	GB		19.5	Non-plastic				0.0	41.2	58.8						
1.52	CD3	GB		27.3									0.037				
2.29	CD4	GB		27.1													
3.05	CD5	GB		16.3													
3.81	CD6	GB		16.2													
4.57	CD7	GB		17.6													
6.10	CD8	GB		15.2													
7.62	CD9	GB		16.0													
9.14	CD10	GB		15.4													
10.67	CD11	GB		15.4													

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project New Detachment Geotech II
Location Maidstone, SK
Project No. S2026

Borehole No.
BH101

BOREHOLE LOG

BOREHOLE: 102

Page: 1 of 2

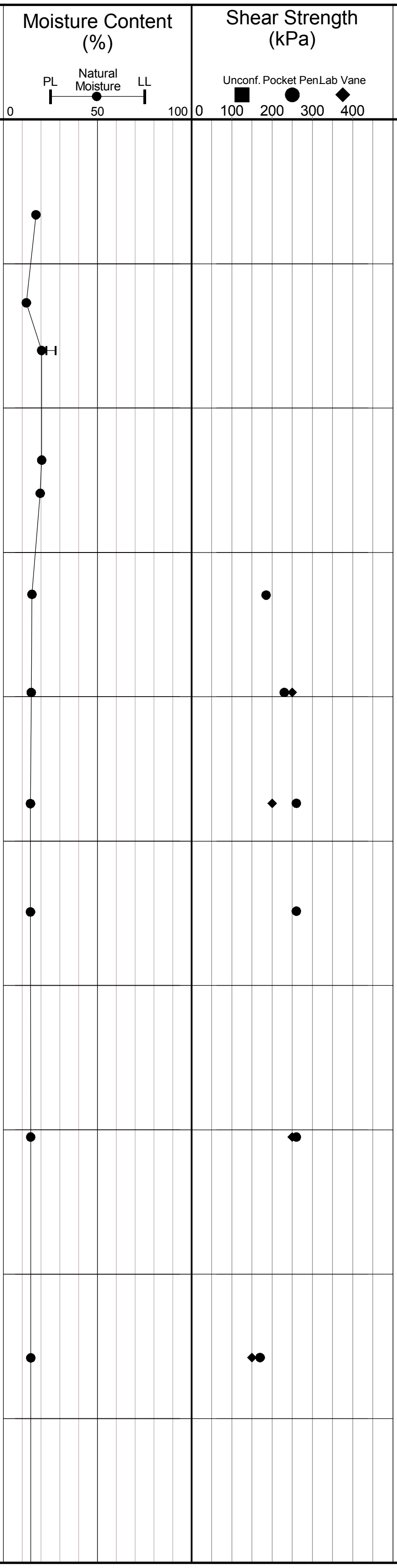
Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883624
Easting: 615206
Ground Elev.: 98.6
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD

Depth (m)	Elevation	Soil Description
0	98.6	TOPSOIL: Clay and silt. Dark brown. Moist..
	98	SAND: Silty fine sand. Some clay. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Loose. Homogeneous. @0.61 m: Frozen from 0.61 - 1.07 m.
2	97	CLAY: Silty clay. Some fine sand. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Salt inclusions.
3	96	TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Dark olive brown (2.5Y 3/3). Oxidized. Calcareous. Moist. Very stiff to hard. Homogeneous. Fe staining. Salt inclusions. @3.81 m: Mn staining. Fissured.
8	90	TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous.
10		

No.	SPT 'N'	USCS	% Sulphate
CD12			
CD13			
CD14	5/ /	CL-ML	2.167
CD15A	9/ /		
CD15B			
CD16			
CD17			
CD18			
CD19			
CD20			
CD21			



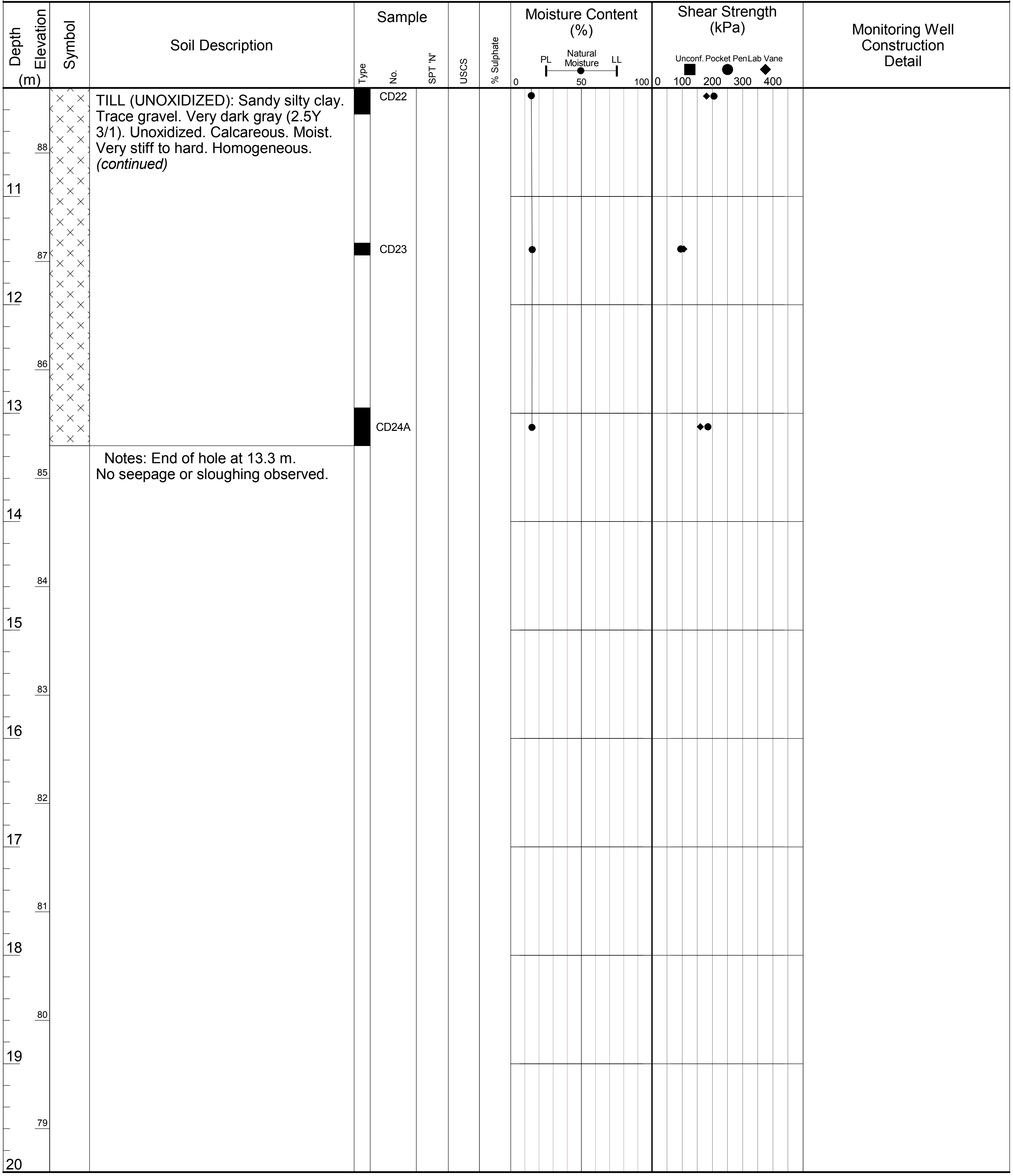
Monitoring Well Construction Detail

BOREHOLE LOG

BOREHOLE: 102

Page: 2 of 2

Client: RCMP	Northing: 5883624	Date Drilled: 09/05/2014
Project: New Detachment Geotech II	Easting: 615206	Drill:MARL M-10
Location: Maidstone, SK.	Ground Elev.: 98.6	Drilling Method: Solid Stem Auger
Project No.: S2026	Top Casing Elevation:	Logged by: CD



TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous. *(continued)*

Notes: End of hole at 13.3 m.
No seepage or sloughing observed.

Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.61	CD12	GB		17.3													
1.22	CD13	GB		12.2													
1.52	CD14	SS		20.3	22.9	27.6	4.7	CL-ML	0.0	13.2	86.8		2.167				
2.29	CD15A	SS		20.4													
2.51	CD15B	SS		19.6													
3.05	CD16	SY	490	15.2											185	185	
3.81	CD17	SY	320	14.8											230	250	
4.57	CD18	SY	335	14.4											260	200	
5.33	CD19	SY	310	14.4											260+	260	
6.86	CD20	SY	380	14.5											260+	250	
8.38	CD21	SY	395	14.6											170	150	
9.91	CD22	SY	330	14.6											205	180	
11.43	CD23	SY	110	15.2											95	105	
12.95	CD24A	SY	350	15.0											185	160	

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project New Detachment Geotech II
Location Maidstone, SK
Project No. S2026

Borehole No.
BH102

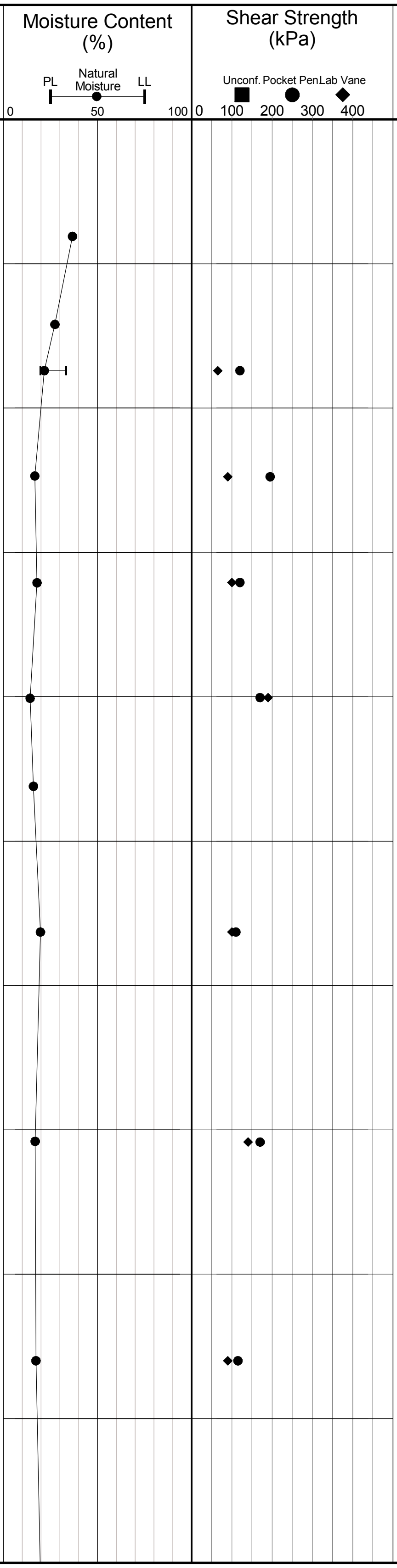
BOREHOLE LOG

BOREHOLE: 103
Page: 1 of 2

Client: RCMP	Northing: 5883590	Date Drilled: 09/05/2014
Project: New Detachment Geotech II	Easting: 615181	Drill:MARL M-10
Location: Maidstone, SK.	Ground Elev.: 98.165	Drilling Method: Solid Stem Auger
Project No.: S2026	Top Casing Elevation:	Logged by: CD

Depth (m)	Elevation	Soil Description	Sample Type	Sample No.	SPT 'N'	USCS	% Sulphate
	98	TOPSOIL: Clay and silt. Dark brown. Moist..					
		SAND: Silty fine sand. Some clay. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. @0.46 m: Frozen from 0.46 - 0.76 m.		CD24B			
1	97	CLAY: Silt and clay. Some fine sand. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Salt inclusions.		CD25			
		TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Dark olive brown (2.5Y 3/3). Oxidized. Calcareous. Moist. Very stiff to hard. Fe staining. Salt inclusions.		CD26		CL	0.05
2	96			CD27			
3	95			CD28			
4	94			CD29			
				CD30			
5	93			CD31			
6	92						
7	91	TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous.		CD32			
8	90			CD33			
9	89						
10							

Monitoring Well Construction Detail



Clifton Associates

BOREHOLE LOG

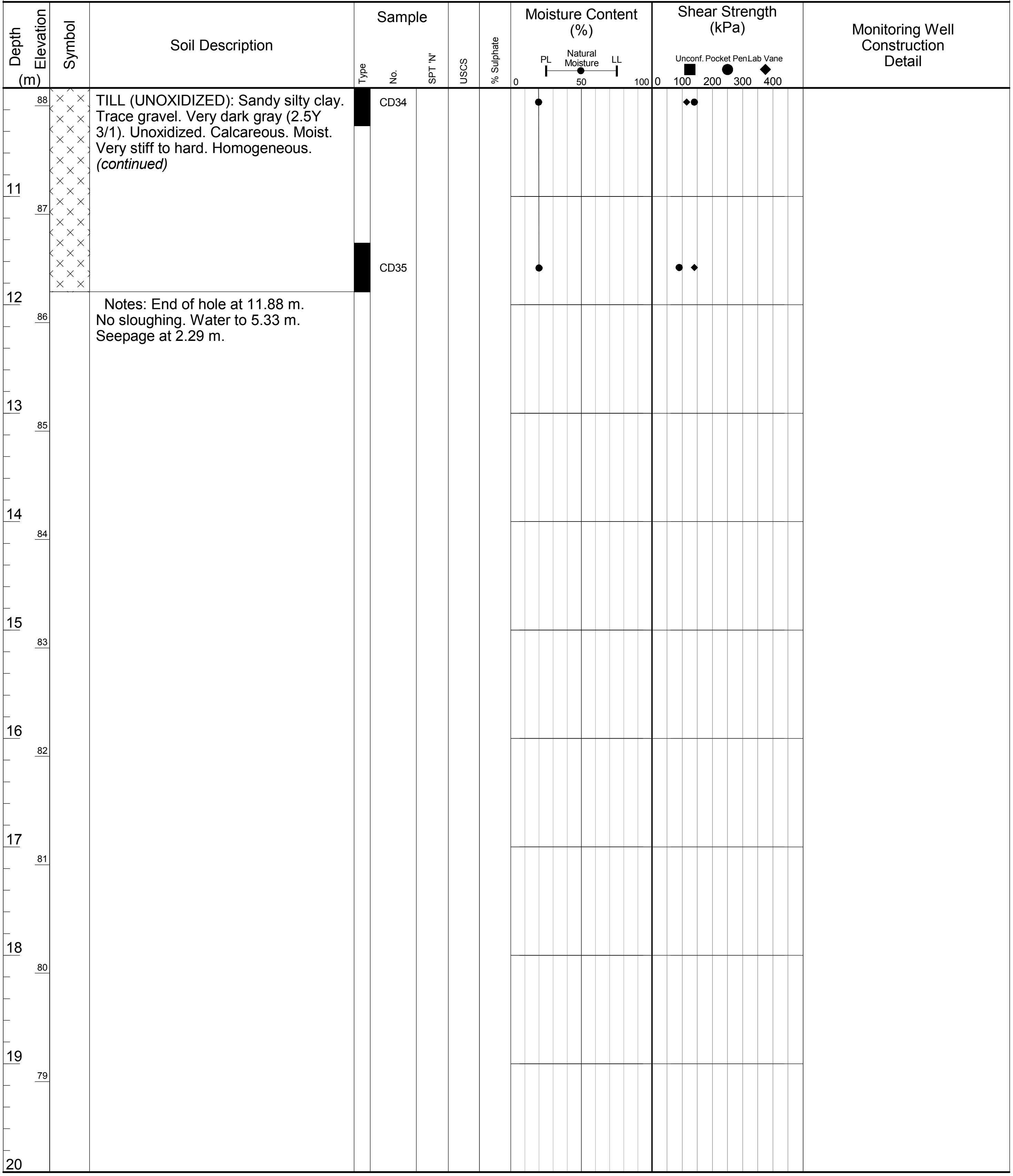
BOREHOLE: 103

Page: 2 of 2

Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883590
Easting: 615181
Ground Elev.: 98.165
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD



TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous. *(continued)*

Notes: End of hole at 11.88 m. No sloughing. Water to 5.33 m. Seepage at 2.29 m.

Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.76	CD24B	GB		36.7													
1.37	CD25	GB		27.4													
1.52	CD26	SY	440	21.8	19.6	33.2	13.6	CL	0.2	33.2	66.6		0.05		120	65	
2.29	CD27	SY	370	16.7											195	90	
3.05	CD28	SY	315	17.9											120	100	
3.81	CD29	SY	390	14.2											170	190	
4.57	CD30	GB		16.0													
5.33	CD31	SY	600	19.7											110	100	
6.86	CD32	SY	450	16.9											170	140	
8.38	CD33	SY	440	17.3											115	90	
9.91	CD34	SY	440	19.7											140	115	
11.43	CD35	SY	450	20.0											90	140	

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project	New Detachment Geotech II
Location	Maidstone, SK
Project No.	S2026

Borehole No.

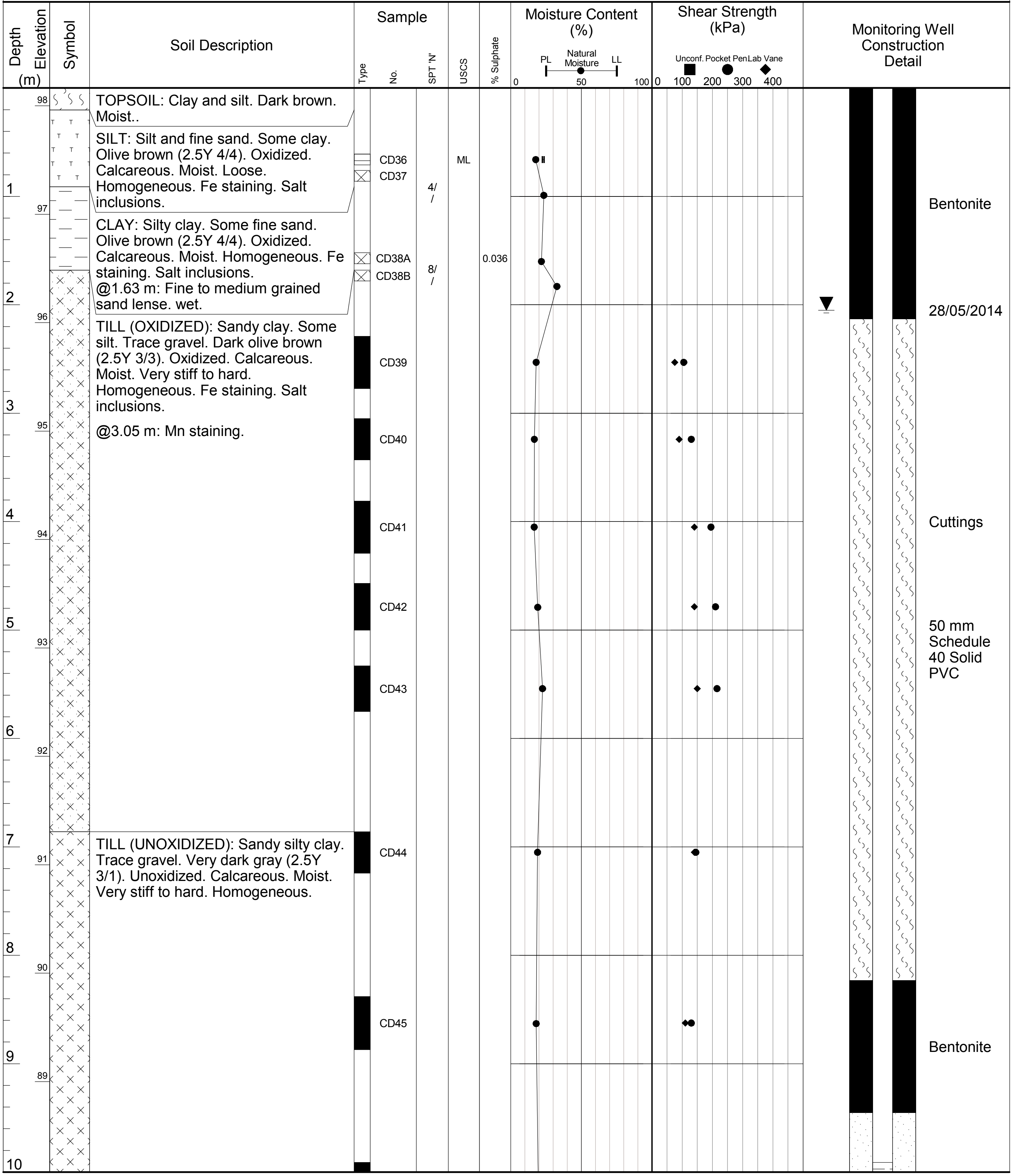
BH103

Clifton Associates

BOREHOLE LOG

BOREHOLE: 104
Page: 1 of 2

Client: RCMP	Northing: 5883590	Date Drilled: 09/05/2014
Project: New Detachment Geotech II	Easting: 615205	Drill:MARL M-10
Location: Maidstone, SK.	Ground Elev.: 98.165	Drilling Method: Solid Stem Auger
Project No.: S2026	Top Casing Elevation:	Logged by: CD



TOPSOIL: Clay and silt. Dark brown. Moist..

SILT: Silt and fine sand. Some clay. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Loose. Homogeneous. Fe staining. Salt inclusions.

CLAY: Silty clay. Some fine sand. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Fe staining. Salt inclusions.
@1.63 m: Fine to medium grained sand lense. wet.

TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Dark olive brown (2.5Y 3/3). Oxidized. Calcareous. Moist. Very stiff to hard. Homogeneous. Fe staining. Salt inclusions.

@3.05 m: Mn staining.

TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous.

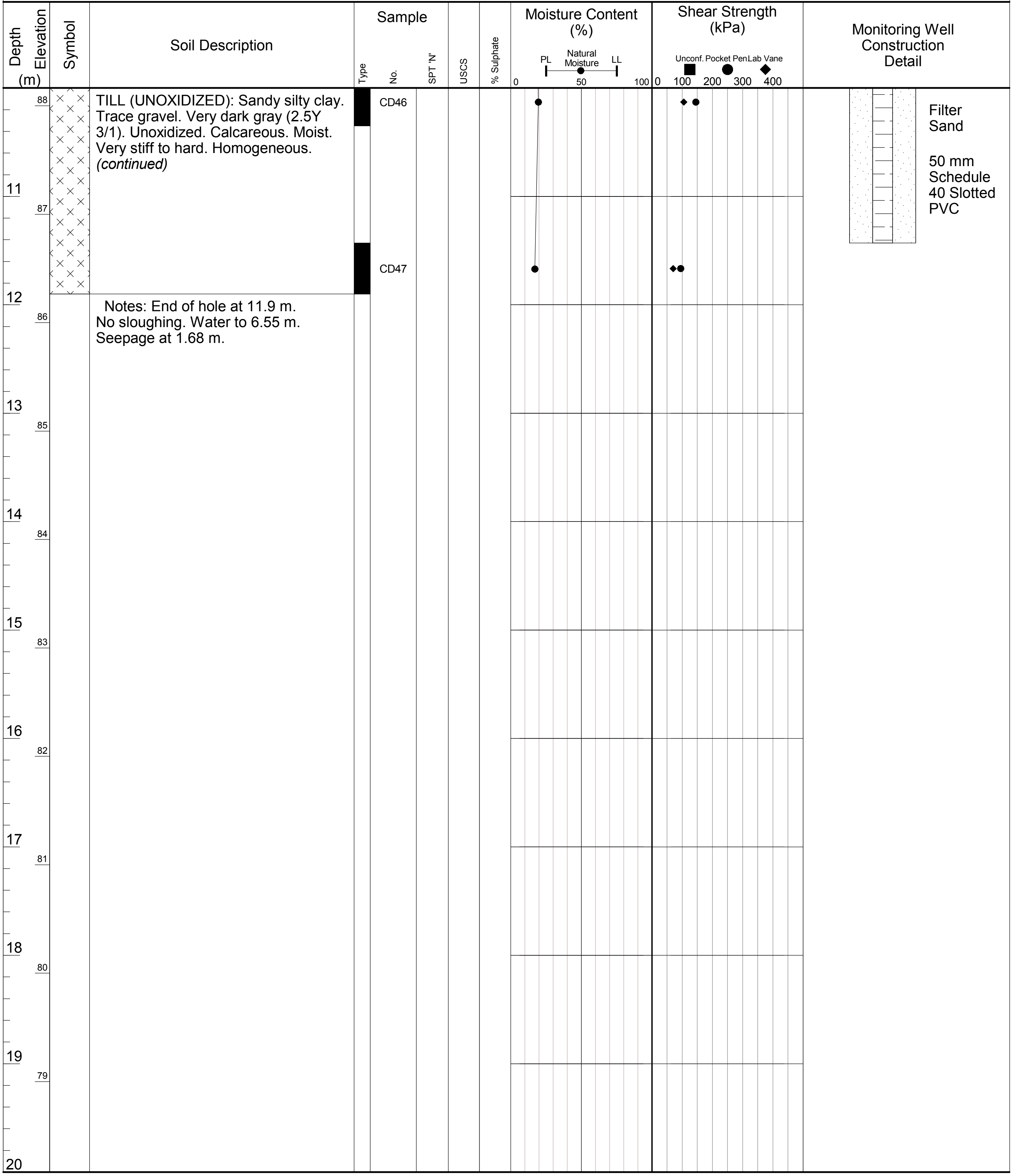
BOREHOLE LOG

BOREHOLE: 104

Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883590
Easting: 615205
Ground Elev.: 98.165
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD



TILL (UNOXIDIZED): Sandy silty clay. Trace gravel. Very dark gray (2.5Y 3/1). Unoxidized. Calcareous. Moist. Very stiff to hard. Homogeneous. *(continued)*

Notes: End of hole at 11.9 m.
No sloughing. Water to 6.55 m.
Seepage at 1.68 m.

Summary of Sampling and Laboratory Test Data

Sample				Water Content	Consistency				Gradation				Sulphate Content	Shear Strength			Dry Density
Depth	Number	Type	Recovery		Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay		Compression Test	Lab Vane	Pocket Penetrometer	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.61	CD36	GB		17.7	22.2	23.5	1.3	ML	0.0	46.8	53.2						
0.76	CD37	SS		23.4													
1.52	CD38A	SS		21.7									0.036				
1.68	CD38B	SS		32.7													
2.29	CD39	SY	480	18.0											105	75	
3.05	CD40	SY	380	16.7											130	90	
3.81	CD41	SY	480	16.6											195	140	
4.57	CD42	SY	430	19.1											210	140	
5.33	CD43	SY	420	22.5											215	150	
6.86	CD44	SY	380	19.0											145	140	
8.38	CD45	SY	490	18.0											130	110	
9.91	CD46	SY	440	19.6											145	105	
11.43	CD47	SY	470	17.1											95	70	

Remarks: USC required on CD37 however sample was too small to complete testing.

Approved by:

Clifton Associates Ltd.
engineering science technology

Project New Detachment Geotech II
Location Maidstone, SK
Project No. S2026

Borehole No.
BH104

Clifton Associates

BOREHOLE LOG

BOREHOLE: 105
Page: 1 of 1

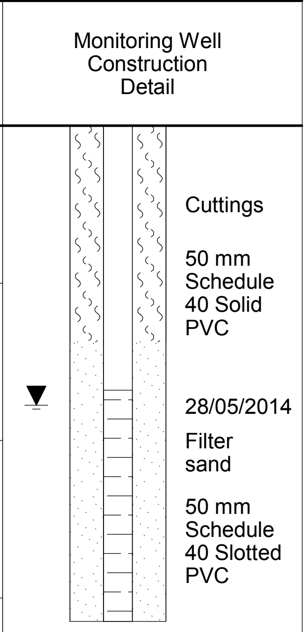
Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883615
Easting: 615151
Ground Elev.: 98.055
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD

Soil Description	Sample Type	Sample No.	SPT 'N'	USCS	% Sulphate
TOPSOIL: Silty fine sand. Trace organics. Dark brown. Moist.					
SAND: Silty fine sand. Clayey. Trace organics. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Fe staining. Salt inclusions. @0.91 m: Becomes wet.	☰	CD48			
TILL (OXIDIZED): Sand and clay. Silty. Trace gravel. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Stiff. Homogenous. Fe staining. Salt inclusions.	☰ ☰ ☰	CD49 CD50 CD51		CL	

Notes: End of hole at 3.15 m. Sloughing to 1.22 m. No seepage or groundwater observed.



Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.76	CD48	GB		21.5													
1.52	CD49	GB		17.4	18.1	31.3	13.2	CL	0.3	39.0	60.7						
2.29	CD50	GB		16.5													
3.05	CD51	GB		18.5													

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project	New Detachment Geotech II
Location	Maidstone, SK
Project No.	S2026

Borehole No.

BH105

Clifton Associates

BOREHOLE LOG

BOREHOLE: 106
Page: 1 of 1

Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883574
Easting: 615153
Ground Elev.: 98.55
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD

Soil Description	Sample Type	Sample No.	SPT 'N'	USCS	% Sulphate
TOPSOIL: Silty fine sand. Trace organics. Dark brown. Moist.					
SAND: Sand and silt. Some clay. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous.	☰	CD52			
CLAY: Silty clay. Some fine sand. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Wet. Homogeneous. Fe staining. Salt inclusions.	☰	CD53		CL-ML	
TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. Fe staining.	☰ ☰	CD54 CD55			

Notes: End of hole at 3.15 m.
No sloughing. Water to 2.74 m.
Seepage at 1.83 m.

Monitoring Well Construction Detail

Summary of Sampling and Laboratory Test Data

Sample				Water Content	Consistency				Gradation				Sulphate Content	Shear Strength			Dry Density
Depth	Number	Type	Recovery		Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay		Compression Test	Lab Vane	Pocket Penetrometer	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.76	CD52	GB		14.6	Non-plastic				0.0	56.8	43.2						
1.52	CD53	GB		26.1	21.5	28.3	6.8	CL-ML	0.0	14.3	85.7						
2.29	CD54	GB		16.8													
3.05	CD55	GB		17.5													

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project New Detachment Geotech II
Location Maidstone, SK
Project No. S2026

Borehole No.
BH106

Clifton Associates

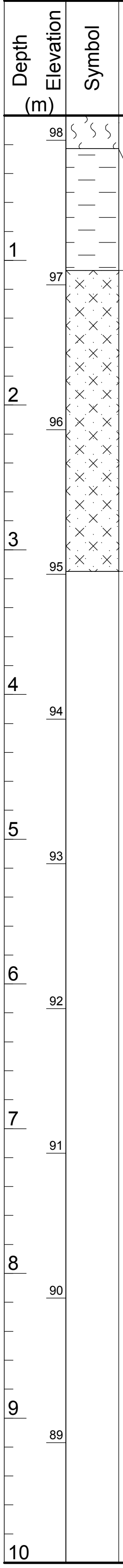
BOREHOLE LOG

BOREHOLE: 107
Page: 1 of 1

Client: RCMP
Project: New Detachment Geotech II
Location: Maidstone, SK.
Project No.: S2026

Northing: 5883565
Easting: 615220
Ground Elev.: 98.17
Top Casing Elevation:

Date Drilled: 09/05/2014
Drill:MARL M-10
Drilling Method: Solid Stem Auger
Logged by: CD



Soil Description	Sample Type	Sample No.	SPT 'N'	USCS	% Sulphate
TOPSOIL: Silty fine sand. Trace organics. Dark brown. Moist.					
CLAY: Sandy clay. Some silt. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous. @0.46 m: Frozen from 0.46 - 0.76 m.		CD56		CL	
		CD57			
TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Dark olive brown (2.5Y 3/3). Oxidized. Calcareous. Moist. Homogeneous. Fe staining. Salt inclusions.		CD58		CL	
		CD59			
		CD60			

Notes: End of hole at 3.15 m.
No sloughing. Seepage at 1.07 m.

Monitoring Well Construction Detail

Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.46	CD56	GB		22.1	19.5	31.1	11.7	CL	0.0	24.0	76.0						
0.76	CD57	GB		23.5													
1.52	CD58	GB		17.0	20.0	33.3	13.3	CL	2.7	35.8	61.5						
2.29	CD59	GB		18.5													
3.05	CD60	GB		17.2													

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

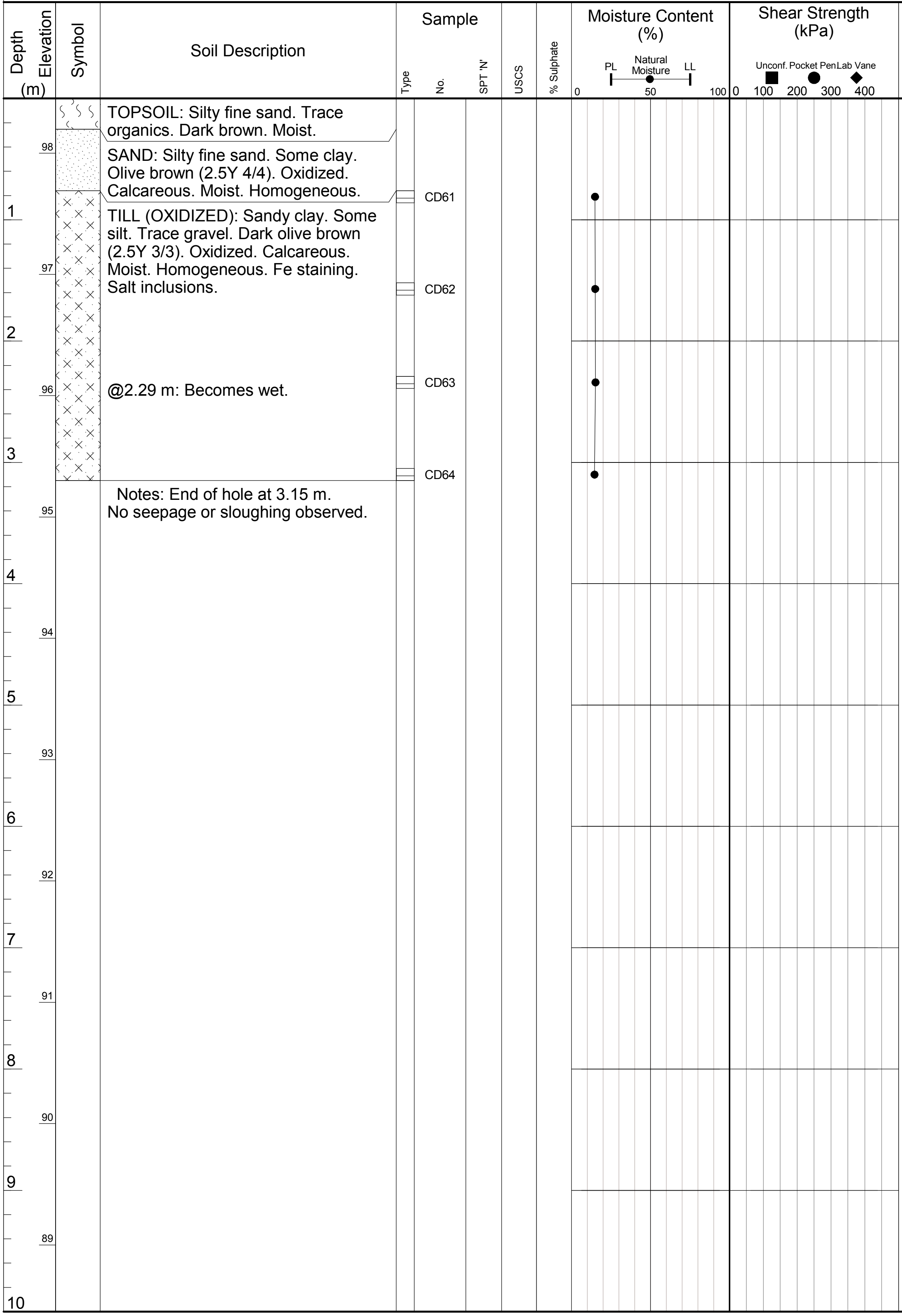
Project New Detachment Geotech II
Location Maidstone, SK
Project No. S2026

Borehole No.
BH107

BOREHOLE LOG

BOREHOLE: 108
Page: 1 of 1

Client: RCMP	Northing: 5883631	Date Drilled: 09/05/2014
Project: New Detachment Geotech II	Easting: 615220	Drill:MARL M-10
Location: Maidstone, SK.	Ground Elev.: 98.45	Drilling Method: Solid Stem Auger
Project No.: S2026	Top Casing Elevation:	Logged by: CD



TOPSOIL: Silty fine sand. Trace organics. Dark brown. Moist.

SAND: Silty fine sand. Some clay. Olive brown (2.5Y 4/4). Oxidized. Calcareous. Moist. Homogeneous.

TILL (OXIDIZED): Sandy clay. Some silt. Trace gravel. Dark olive brown (2.5Y 3/3). Oxidized. Calcareous. Moist. Homogeneous. Fe staining. Salt inclusions.

@2.29 m: Becomes wet.

Notes: End of hole at 3.15 m.
No seepage or sloughing observed.

Monitoring Well Construction Detail

Summary of Sampling and Laboratory Test Data

Sample					Consistency				Gradation					Shear Strength			
Depth	Number	Type	Recovery	Water Content	Plastic Limit	Liquid Limit	Plasticity Index	USC	Gravel	Sand	Silt	Clay	Sulphate Content	Compression Test	Lab Vane	Pocket Penetrometer	Dry Density
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.76	CD61	GB		14.9													
1.52	CD62	GB		15.0													
2.29	CD63	GB		15.2													
3.05	CD64	GB		14.6													

Remarks:

Approved by:

Clifton Associates Ltd.
engineering science technology

Project	New Detachment Geotech II
Location	Maidstone, SK
Project No.	S2026

Borehole No.

BH108

Appendix C

Recommendations for Granular Materials

Clifton Associates

Regina Office
340 Maxwell Crescent
Regina SK S4N 5Y5

Telephone 306-721-7611
Facsimile 306-721-8128

regina@clifton.ca
www.clifton.ca

Clifton Associates

Recommended Specifications for Granular Materials

1. Granular materials shall be composed of fragments of durable rock free from undesirable quantities of soft or flaky particles, topsoil, organic matter, clay or silt lumps, lumps of frozen granular soil, ice, snow or construction rubble.

2. The Pit Run Fill shall have a plasticity index less than 10 percent. The Crushed Base Course shall have a plasticity index less than 6 percent.

3. For Pit Run Sand, $\frac{D_{60}}{D_{10}} > 6$, and $1 < \frac{(D_{30})^2}{D_{10} x D_{60}} < 3$. For Pit Run Gravel, $\frac{D_{60}}{D_{10}} > 4$, and $1 < \frac{(D_{30})^2}{D_{10} x D_{60}} < 3$.

4. Granular materials shall be excavated, loaded, hauled, placed and levelled in such a manner to prevent contamination with undesirable materials described in Point 1 above and to prevent excessive segregation of coarse and fine particles.

5. Granular material shall conform to the following gradation specifications:

Percent by Weight Passing U.S. Standard Sieve Series

Sieve	Pit Run Gravel Fill	Pit Run Sand Fill	Crushed Base Course				
			32	33	34	35	36
50.0 mm	100						
25.0 mm	85 – 100		100				
18.0 mm	80 – 100		87 – 100	100	100	100	100
12.5 mm	70 – 100	100	79 – 93	81 – 100	91 - 100	81 - 100	91 – 100
5.0 mm	50 – 85	75 – 100	47 – 77	50 – 80	70 - 85	50 - 85	70 – 85
2.0 mm	35 – 75	50 – 90	29 – 56	32 – 52	45 - 65	32 - 65	45 – 70
900 µm	25 – 50	30 – 75	18 – 39	20 – 35	28 - 43	20 - 43	28 – 51
400 µm	15-35	15 – 50	13 – 26	15 – 25	20 - 30	15 - 30	20 – 35
160 µm	8 – 22	5 – 30	7 – 16	8 – 15	11 - 18	8 - 18	11 – 21
71 µm	0 - 13	0 – 15	6 - 11	7 – 10	8 - 12	7 - 12	8 – 13

Clifton Associates

Calgary Office

2222 30th Avenue NE
Calgary, AB T2E 7K9

T (403) 263-2556
F (403) 234-9033

Edmonton Office

4409 94th Street NW
Edmonton, AB T6E 6T7

T (780) 432-6441
F (780) 432-6271

Lloydminster Office

#10 – 6309 43rd Street W
Lloydminster, AB T9V 2W9

T (780) 872-5980
F (780) 872-5983

Regina Office

340 Maxwell Crescent
Regina, SK S4N 5Y5

T (306) 721-7611
F (306) 721-8128

Saskatoon Office

#4 – 1925 1st Avenue N
Saskatoon, SK S7K 6W1

T (306) 975-0401
F (306) 975-1076

North Battleford Office

#2 – 9802 27th Avenue
North Battleford, SK S9A 1K5

T (306) 445-1621
F (306) 937-3731

www.clifton.ca