Preliminary
Geotechnical Site Investigation

Proposed Rural Residential Subdivision
NE-27-83-23-W5M
Grimshaw, Alberta

E20170510-01 **July 2017**

Prepared For:

DGE Civil Engineering Consultants
Edmonton, Alberta

Prepared By:

Alpha Adroit Engineering Ltd
Edmonton, Alberta

Alpha Adroit

File No.: E20170510-01

July 10, 2017

DGE Civil Engineering Consultants
221, 9223 – 28 Avenue NW
Edmonton, AB T6N 1N1
Via Email: rfenton@dgeinc.ca | CC: mgillett@dgeinc.ca

Attention: Mr. Read Fenton, B.Sc., MBA, Project Manager

Dear Mr. Fenton,

Re: Preliminary Geotechnical Site Investigation
Proposed Rural Residential Subdivision
NE-27-83-23-W5M
Grimshaw, Alberta

Please find enclosed a copy of our preliminary geotechnical site investigation report for the above referenced proposed project.

Please contact the undersigned at 780-708-4110 or mkia@alphaadroit.ca should you have any enquiries. We thank you for choosing **Alpha Adroit Engineering Ltd**. for providing services in this project.

Respectfully Submitted,

ALPHA ADROIT ENGINEERING LTD
APEGGA Permit to Practice P12379

Mohammadali Kia, Ph.D., P.Eng.
Senior Geotechnical Engineer

1 EXECUTIVE SUMMERY

The investigation included drilling eight boreholes, visual classification of observed subsoil conditions, field strength testing, groundwater observations, and laboratory testing on select soil samples, which together with an engineering assessment are presented in this report.

The subsoil conditions generally consisted of a layer of topsoil over clay till. The site is generally considered to be buildable and can be used for rural residential land development if recommendations provided in this report are followed. Preliminary recommendations for shallow and deep foundations, as well as, other general geotechnical recommendations are provided in section 6.0 entitled "Geotechnical Evaluation and Recommendations ".

It should be noted that the results obtained during this study are only preliminary. It is recommended to have individual lots to be assessed by Alpha Adroit Engineering Ltd once specific building locations have been identified.

TABLE OF CONTENTS

PAGE

LIST OF TABLES **PAGE**

2 Introduction

This report presents the results of a preliminary geotechnical investigation undertaken at the above referenced Proposed Rural Residential Subdivision located at NE-27-83-23-W5M, Grimshaw, Alberta. The land currently is forested and never developed before, except for some trail tree clearing.

The purpose of this investigation was to determine the preliminary soil and groundwater conditions at the site and to provide general geotechnical engineering recommendations for the design and construction of foundations. Field drilling was carried out on June 3, 2017.

3 Site and Background Information

The legal land description of the site was provided by the client as NE-27-83-23-W5M, Grimshaw, Alberta.

It was understood that the site has never been developed before and the total area of the site is approximately 120 acres (to be confirmed by the client) and the investigation area was limited to where there was access for drilling. The client indicated that it is intended to develop the site into 13 residential lots, each having 6.9 to 10.7 acres area.

The client requested that Alpha Adroit advance eight (8) boreholes to a depth of 6 m below the existing ground surface at borehole locations that their locations was determined by the owner, to provide general indications of the subsoil and groundwater conditions at the above referenced property and provide the following geotechnical recommendations for the general area of investigation:

1. Sub surface geotechnical conditions
2. Site preparation
3. Foundation recommendations for residential family houses with basement
4. Permanent sub floor drainage systems
5. Lateral earth pressure for basement walls
6. Geotechnical recommendation for storm pond
7. Flexible pavement design
8. Site grading around proposed residential family homes
9. Underground utility trenches and backfilling requirements

It is understood that the development area will comprise of family homes that may include one level of underground basement.

The scope of Alpha Adroit's work did not include slope stability analysis. Even though Alpha Adroit Engineering Ltd (Alpha Adroit) conducted geotechnical drilling on the site, Alpha Adroit's scope of work did not include any environmental assessments. Alpha Adroit shall not be responsible for any environmental matters whatsoever. Alpha Adroit can conduct Environmental Site Assessment (ESA) Phase I and Phase II if required by the client.

4 Investigation Procedure

On June 3, 2017, eight boreholes (Boreholes BH17-01 to BH17-08) were drilled at the above-mentioned site to a maximum depth of 6.45 m below the existing ground surface, using a drill rig equipped with continuous flight, 150 mm diameter, solid-stem augers with Standard Penetration Testing (SPT) capability.

Supervision of drilling, soil sampling, and logging of the various soil strata was conducted by a senior geotechnical engineer of Alpha Adroit Engineering Ltd. The soil conditions encountered during drilling were described in accordance with the Modified Unified Soil Classification System. Approximate borehole locations are presented on Figure 1, Appendix A. The soil and groundwater conditions encountered during the fieldwork are presented on the borehole logs in Appendix B.

Soil sampling for the boreholes generally consisted of disturbed auger samples at 0.75 m intervals or as necessary. In addition, to obtain an indication of the Unconfined Compressive Strength of cohesive soils, pocket penetrometer (PP) readings were taken on intact cohesive soil samples from all boreholes. SPT tests were conducted at all borehole locations as deemed necessary.

Frost penetration depths are provided in Table 1. The groundwater conditions were monitored during drilling, after drilling completion, and the next day after drilling. The client also provided groundwater level readings (not conducted by Alpha Adroit or its supervision) for date June 26, 2017 to be included and considered in the report. The results of groundwater monitoring are presented on the borehole logs in Appendix B and are summarized in Table 2.

In addition to the routine moisture tests, the laboratory program consisted of three Atterberg limits tests (Liquid Limit and Plastic Limit). The results of these tests are presented on the borehole logs in Appendix B.

5 Subsurface Conditions

The soil profile at the borehole locations and within the depth of investigation generally consisted of a layer of Topsoil over clay till , or clay till at the cleared ground surface, which extended beyond the termination depth of the boreholes. The thickness of Topsoil is expected to vary across the site. The soil strata are shown on the borehole logs in Appendix B and are described in the following sections.

5.1 Topsoil

Topsoil was observed at the ground surface at all borehole locations except at borehole BH17-01, BH17-02, and BH17-04 locations, where it appeared that it had been cleared from the ground surface.

Topsoil was generally described as black and mainly consisted of decayed plant matters or a mix of black decayed organics mixed with clay, with organic odor, root smell, trace of roots, and moist to damp that generally crumbles with finger pressure (except at BH17-05 location).

Thickness of the Topsoil was generally between 0.4 to 0.75 m at borehole locations.

5.2 Clay Till

Clay till was observed at all borehole locations under Topsoil or at the ground surface and extended to the termination depth of the boreholes at all borehole locations.

Clay till was generally described as brown to dark brown in color, with organic odor and root smell, stiff to firm, low to medium plastic, moist, sandy with trace to some small gravel up to 1" in size, trace of sand pockets, trace of white staining, and trace of cobbles up to 3" in size. Liquid Limits ranged from 31% to 39.3% and Plastic Limits ranged from 12.6% to 20.6% measured on select samples of clay till material, confirming the low to medium plastic nature of the clay till material.

In-situ moisture contents within clay till ranged from 4.0 % to 23.5%, with an average of 15.3 %. Pocket penetrometer readings taken on intact auger samples of clay till material revealed unconfined compressive strengths, Qu, of less than 25 to 350 kPa, with a nominal value of 120 kPa.

5.3 Frost penetration

The expected maximum depth of frost penetration for various soil types observed at site is given in Table 1. The penetration is based on a freezing index for a 25-year return period of 2200 degrees-days Celsius. The depth of frost penetration assumes a uniform soil type without topsoil or snow cover.

Table 1. Estimated depth of frost penetration

Soil Type		Depth of Frost Penetration (m)
In-situ	Clay Till	2.8
Compacted Backfill (95 % SPMDD*)	Clay and Clay Till	2.5
	Silt and Sand	2.9
	Gravel	3.5

*SPMDD- Standard Proctor Maximum Dry Density

The low to medium plastic clayey soils encountered at the site are not considered frost susceptible; however, if it is exposed to extended freezing periods, it can exhibit frost heave in excess of 9% of its volumetric water contents.

Design frost penetration depth of 1.5 m below the existing ground surface can be used for heated buildings at this site. For unheated buildings, design frost penetration depth of 2.8 m can be used for this site. Properly designed and installed horizontal and vertical insulation can be used to control frost penetration depth and heat transfer in foundation soils of the proposed building. Insulation design was not part of the current scope of work; Alpha Adroit can provide insulation design if required by the client.

5.4 Groundwater conditions

It should be recognized that the level of the groundwater table is dependent on meteorological cycles and surface drainage on a regional scale as well as human activities. Higher groundwater levels than those observed in this investigation may be encountered following spring thaw and periods of prolonged precipitation.

The groundwater conditions in the boreholes were observed during drilling and 24 days following drilling completion. A summary of the groundwater observations is shown in Table 2.

Table 2. Summary of groundwater and sloughing observations

Borehole Number	Depth of Sloughing (m)	Depth of Water (m)		
		After completion	After 1 day	After 24 days
BH17-01	NA	Dry	NA	NA
BH17-02	NA	5.85	3.11	1.29
BH17-03	NA	Dry	2.9	1.38
BH17-04	NA	NA	NA	NA
BH17-05	NA	Dry	NA	NA
BH17-06	NA	Dry	4.75	2.97
BH17-07	NA	NA	NA	NA
BH17-08	NA	NA	NA	NA

The site is large and it is advisable that design groundwater level to be determined for smaller parcels of the land for geotechnical engineering purposes. If an overall groundwater level is required for the geotechnical design purposes outlined in this report, the groundwater table can be assumed to be at the current ground surface. It should be noted that depth of groundwater may change over time due to human activities, new developments, climate change, and other factors.

6 Geotechnical Evaluation and Recommendations

It is understood that the proposed development will consist of single family and multi-family homes which may also have one level of underground basement. The scope of this report is to provide general preliminary geotechnical recommendations for the site.

It is strongly recommended that individual home constructions consider seeking individual geotechnical engineering investigation and report for their specific application and location as glacial geology and human activities might present different subsoil and groundwater conditions at their specific building/development location. Both pile and footing foundations can be used for this development (subject to individual geotechnical investigation at individual lots).

Use of moisture barrier or geo-membranes are recommended to promote dry underground spaces. Raising of the site and road access areas via construction of engineered fill is recommended to promote trafficable areas and reduce difficulties associated with freeze-thaw cycles.

Surface waters shall not be allowed to ingress in bearing soils and should be drained away from the building footprints and roads both during construction and afterwards. Geotechnical recommendations are given in the following sections.

6.1 Site preparation

Site preparation will include removing any uncontrolled fill (if any present), top soil, and organic soil from the building and structural element footprints and the created excavations should be backfilled with engineered fill such as pitrun gravel or low plastic clay compacted to at least 98% of Standard Proctor Maximum Dry Density (SPMD). Alpha Adroit can provide construction quality control of compacted earthworks using nuclear densometer and field monitoring with prior arrangement.

If temporary excavations deeper than 1.5 m are expected to be left open for an extended period of time (more than two weeks), Alpha Adroit recommends that a separate slope stability analysis to be conducted. In the absence of a separate slope stability analysis, these slopes can be cut back at 1.25 H:1V for short term (less than two weeks) and a setback distance of at least 1.5 times of the depth of the excavation shall be considered. All such slopes and trenching shall be inspected by a qualified geotechnical engineer to assess the stability of such slopes. Steeper excavation wall slopes might be considered for short term if permitted by on-site competent geotechnical engineer. Alternatively, shoring systems can be used to retain the excavated walls of the basement areas and other trenching requirements. The bottom of the temporary excavation area shall be graded such that any surface water or groundwater seeped into the excavation area is drained to a ditch and sump area and is pumped out of the excavation area during construction to promote a workable surface area and prevent softening of the foundation soils. Water shall not be allowed to pond in the excavation areas. The bearing soils shall not be allowed to soften by water ingress or undergo freeze-thaw or drying-wetting cycles. A qualified geotechnical engineer should be on site, inspect the slopes, and monitor the construction on a full time basis during excavations over 1.5 meter deep, deeper than the depth of the foundation of the neighboring properties, and during placement of engineered backfills. Any ground cracking, ground deformation, or signs of slope movements or concentrated water seepage around or within the excavation area shall be reported to Alpha Adroit immediately and recommendations provided herein will be revised if required.

6.2 Cast-in-place concrete piles

Friction and end-bearing concrete cast-in-place piles can be used to support the proposed structures. Competent bedrock was not observed within the depth of investigation of this preliminary geotechnical investigation and hence recommendations for end bearing piles are not provided. The depth of the competent bedrock can be determined through individual geotechnical investigations for individual lots.

A competent and experienced inspector should be on site during the entire duration of the pile installation. The inspector shall keep complete and accurate records of the pile installation operation and confirm the depth of competent clay till layer per this report's requirements. Concrete should be poured immediately after drilling of the pile hole to reduce the risk of groundwater seepage and sloughing/softening of the soils and bearing layers. Use of casing (and pumping of groundwater) might be required due to high groundwater conditions encountered at the site. It is recommended that all final construction plans and schedules for foundations and earth works to be communicated and reviewed by the geotechnical engineering firm responsible for construction quality control and quality assurance (QA/QC) or acting as Professional Geotechnical Engineer of Record (Alberta Building Code) for this project.

6.2.1 Friction piles

A foundation system of cast-in-place concrete friction shaft piles could be considered for the proposed structures. Geotechnical bearing resistance may be taken as given in Table 3. Friction piles should be designed solely on the basis of skin friction, and no extra capacity from end bearing should be added to the pile capacity.

Table 3. Geotechnical bearing resistance values for designing cast-in-place concrete friction shaft piles

Depth below existing ground surface (m)	Layer	ULS (kPa)*	Factored ULS (kPa)*
0.0 to 1.5	0	0	0
1.5 to 12.0	Clay Till/ Sand Till	38	15

* No load eccentricity has been assumed for

ULS is the Un-factored Ultimate Resistance. Factored ULS is the Factored Ultimate Resistance; i.e. ULS that has been reduced by a geotechnical resistance factor.

The values in Table 3 are for Load and Resistance Factor Design (LRFD). For Working Stress Design (WSD) a Global Factor of Safety (FS) of 2 or higher can be used for friction piles.

Due to the shrinkage and other effects that would otherwise not provide intimate contact between the soil and concrete pile, the skin friction for that portion of the pile shaft within the upper 1.5 m should be discounted as zero. The load end bearing capacity that could be derived from end bearing should be ignored for two reasons: firstly, the base of the bored straight-shaft pile usually contains disturbed soil created by the pile auger; and secondly, the pile displacements required to attain end-bearing are much greater than those required for mobilize shaft friction.

Piles supporting grade beams should be embedded at least 9.0 m below the finished exterior grade for this site. Further, for unheated parts of the building, the piles should be embedded to a minimum of 9.0 m. A minimum pile shaft diameter of 400 mm is recommended to minimize void formation during pouring of the concrete. The minimum centre-to-centre spacing of straight-shaft piles should be 3 pile diameters. A nominal percentage of longitudinal steel reinforcement (0.50 percent of the cross sectional area of the pile) should be provided in the upper 6.0 m of the pile to counter potential uplift forces due to frost action and seasonal moisture variations. If the piles are designed as tension elements, longitudinal reinforcing steel should extend into the bottom of the piles, and the piles should be designed to resist the anticipated uplift stresses using the design values for uplift stresses.

6.3 General recommendations for pile foundations

6.3.1 Pile uplift resistance

The uplift resistance for straight shaft piles or driven steel pipe piles could be calculated as follows. For sustained uplift loads (other than those due to frost action), the allowable skin friction should be taken as 75% of the skin friction values given for compressive loading above. For short-term transient uplift loads, the allowable skin friction against uplift loads may be taken as 90% of the value presented for downward compressive loads.

6.3.2 Pile caps

Precautions should be taken to minimize the potential of heaving of the pile caps due to frost penetration or swelling of the underlying soil. For unheated structures, the frost heaving pressures on the underside of the pile caps should be taken as 65 kPa or greater for the native soils on this site. The potential for frost heaving forces can be greatly reduced by the placement of a compressible material or by providing a void between the underside of the pile cap and the soil.

A product such as Voidform (or equivalent) is recommended. The minimum thickness of the void shall be 150 mm. Should a compressible material be used as an alternative to Voidform, the uplift pressure acting on the underside of the pile caps may be taken as the crushing strength of the compressible medium. The finished grade adjacent to each pile cap should be capped with clay and sloped away so the surface runoff is not allowed to accumulate in the void space or in the compressible medium. If water is allowed to accumulate in the void spaces, the beneficial effect of the void space will be negated and frost-heaving pressures acting on the underside of the pile caps will occur.

6.4 Strip and square footings

Strip and square footings may be considered for the proposed buildings (subject to individual geotechnical investigation at individual lots) provided that foundation soils are not allowed to undergo excessive moisture change. A minimum depth of 1.5 m and 2.8 m is recommended for adequate frost protection for heated and unheated buildings, respectively. Alternatively, the client may choose to use insulation as a mean to reduce frost penetration depth. Adequate design can be provided by Alpha Adroit if required by the client.

If the footing level is below ground water level, dewatering of footing trenches might be necessary. For excavations that are open for long-term and are deeper than 1.5 m, proper slope stability analysis is required. The analysis can be carried out by Alpha Adroit Engineering Ltd upon request. Bearing pressure resistance at different depths for different aspect ratio of footing are given in Table 4.

Table 4. Bearing resistance for footings at different depths

Depth of the bottom of the footing (m)	Layer	Strip footing*		Square footing	
		ULS (KPa)	Factored ULS (KPa)	ULS (KPa)	Factored ULS (KPa)
1.5 to 2.8	Clay Till	210	105	240	120

- No load eccentricity has been assumed
- ULS is the Un-factored (Nominal) Ultimate Resistance. Factored ULS is the Factored Ultimate Resistance; i.e. ULS that has been reduced by the geotechnical resistance factor in accordance with NBCC 2005 and CHBDC 2000.
* The effective width to effective length ratio of the footing (B'/L') is assumed to be 0.1

For the interior footings, the footings should be founded at least 1.5 m below the interior or exterior floor slab. Footings must not be placed in any topsoil, uncontrolled fill, organic soils or loose, disturbed or frozen soils.

Footing excavations must be protected from frost, desiccation, or ingress of water. Bearing soils, which become frozen, dried, or softened, should be removed and replaced with concrete or the footings should be extended to reach soil in an unaffected condition. It is essential that the foundation soils not be allowed to freeze at any time before or after concrete for the footings have been placed. The footings shall be inspected by a qualified geotechnical engineer to confirm bearing capacity.

6.4.1 Footing uplift resistance

The uplift resistance of a footing to transient uplift loads can be calculated as the effective weight of a prism of soil formed by lines rising at an angle of 23 degrees to the vertical from the top of the footing, provided all backfill is compacted to a minimum field density of 98% of Standard Proctor Maximum Dry Density (SPMDD), for the material. In addition, the buoyant weight of the footing should be considered. For permanent uplift loads, it is recommended that the prism be assumed as rising vertically from the edge of the footing. A unit weight of 18.5 kN/m^3 may be used in calculations for re-compacted clay. A minimum factor of safety of 1.5 should be applied.

6.5 Floor slabs

6.5.1 Floor slab subgrade preparation

All soils containing organic compressible soils or fill should be removed from under the floor slab area. Following the removal, the building footprint area should be proof rolled to identify soft areas. The entire area of the subgrade should be scarified to a depth of minimum 300 mm, moisture conditioned, and re-compacted to at least 98 percent of Standard Proctor Maximum Dry Density (SPMDD). If required, cement stabilization might be used to stabilize soft soils. Such need can be verified during field inspection by a qualified geotechnical engineer through proof rolling.

Any backfill required to raise the sub-grade elevation should be completed using gravel or low plastic clay compacted to at least 98 percent of SPMDD, at moisture content within 2 percent of the Optimum Moisture Content (OMC). Imported fill or potential existing soils should be placed in lifts not exceeding 150 mm in compacted thickness.

A minimum of 200 mm of clean, well-graded crushed gravel is recommended beneath floor slab. Coarse material greater than 20 mm in diameter should be avoided directly beneath the floor slab to prevent stress concentrations in the slab. The granular coarse material should be compacted to a uniform dry density of at least 100 percent of SPMDD. A recommended typical gradation for stable granular material for use under the floor slab is provided in Table 5.

Table 5. Gradation requirements for granular backfill

Sieve opening size (mm)	Passing (%)
20	100
10	35-77
5	15-55
1.25	0-30
0.08	0-5

The percent fracture by weight (2 faces) should be at least 50 percent. Other appropriate materials, which fall outside the above recommended gradation limits, may be suitable but should be evaluated by a geotechnical engineer prior to use.

Excess water should be drained from the site as quickly as possible both during and after construction. The finished grade should be laid out so that the surface water drains away from the building by the shortest route.

6.6 Lateral earth pressure on basement walls

It is understood that the basement walls will be constructed using reinforced concrete and are considered rigid structural elements. It is understood that a subfloor drainage system and also vertical drainage surrounding the entire basement walls will be installed (two separate systems, not connected) and hence no hydrostatic pressure due to groundwater is expected to be exerted to the foundation walls. It is also understood that the excavation around the foundation walls will be backfilled with engineering fill comprising of crushed gravel. For these conditions and with rigid concrete walls, K_0 stress-state (at-rest lateral earth pressures) provides a good estimate for evaluating lateral earth pressures:

$$K_0 = \frac{\sigma_h'}{P_0'}$$

in which:

K_0= coefficient of earth pressure at-rest

σ'_h= horizontal effective stress

P'_0= vertical effective stress

For crushed gravel, K_0= 0.4 can be used (assuming ϕ' =35°). If low-plastic clay is used for backfilling, K_0= 0.6 can be used (assuming ϕ' =23°). Alpha Adroit shall be retained to examine the backfill soils to verify these assumptions. In addition, these estimates assume nominal compaction of up to 95% of SPMDD (Standard Proctor Maximum Dry Density) adjacent to the wall. If a higher degree of compaction is proposed, the design of lateral earth pressure shall adopt a triangular-trapezoidal direction. Alpha Adroit can provide further details upon request.

If surcharge loading, hydrostatic water pressures, or frost forces exist, the lateral earth pressures shall be adjusted to account for the same. Backfill around base walls should not commence until walls have reached adequate strength (at least 80% of their 28-day strength) and framing for lateral resistance shall remain in place.

6.7 Subfloor drainage System

It is recommended that a subfloor drainage system be installed below the concrete floor slab of any underground spaces to preclude development of hydrostatic uplift pressure on the slab and to promote a dry space. The drainage system would include excavating a series of trenches spaced maximum 4.0 m apart within the basement portion of the building and installing perforated weeping tile/filter sock and drainage gravel wrapped in filter geotextile. These pipes would then run to a header pipe (at a slope of at least 2.5%), which in turn, would drain (at a slope of at least 2.5%) to one or more internal sump/pump system(s) or storm sewer system. An exterior weeping system should also be provided. The exterior weeping tile system should be independent of the interior system.

A minimum of 200 mm of clean, well-graded crushed gravel is recommended beneath the floor slab. Coarse material greater than 20 mm in diameter should be avoided directly beneath the floor slab to prevent stress concentrations in the slab. The granular coarse material should be compacted to a uniform dry density of at least 98 percent of SPMDD. A recommended typical gradation for stable granular material for use under the floor slab is provided in Table 5.

6.8 Site grading and drainage

The finished grade around the buildings should be such that the surface water drains away from the building. The upper 0.3 m of backfill around the building should consist of compacted low plastic clay to act as a seal against the ingress of runoff water. The clay should extend for a distance of at least 3.5 m around the building and should be graded at a slope of minimum 2.5 percent away from the building. No concentrated roof drains shall be allowed to drain near building envelopes and it is recommended that such drains to be connected to storm water management pipes inside the building connected to the municipality's storm water management system. Design for surface water or roof drain management is not part of Alpha Adroit's scope of work for this project.

6.9 Preliminary geotechnical recommendations for storm pond slopes

This report does not provide analysis or recommendations regarding environmental aspects for storm water retention ponds for the proposed project. Such recommendations were not part of the current scope of work for this project and could be provided by Alpha Adroit if required by the client.

The location of the storm water retention pond is not known at this time. A subsurface soil encountered in the majority of boreholes is comprised of clayey soils, which should yield sufficiently low permeability characteristics for water retention purposes. Although, boreholes should be drilled in the proposed pond location to confirm this.

Groundwater observations indicated that groundwater was near surface at all locations measured except at BH17-06. Determination of the location of the storm water pond shall consider effects of groundwater seepage (if liner is not sued) and hydrostatic groundwater pressures on liner (if liner is used).

If storm water pond is constructed at locations where groundwater level is adequately deep to accommodate a storm water pond, and provided all peat, organic material and topsoil is removed, no liner is considered necessary from preliminary geotechnical engineering point of view, at this time, subject to further geotechnical investigation, environmental aspects, and confirmation during construction. Environmental matters are not within the scope of the current work and have not been considered in this preliminary geotechnical investigation report.

Side slope stability is a critical issue at this site due high groundwater table. The following table summarizes the approximate preliminary stable angles expected for the side slopes in various conditions:

Table 6. Preliminary Recommended Storm Pond Side Slope Angles

Material and Respective Location	Preliminary Recommended Storm Pond Side Slope Angle
Upper Clay Till, above the high water level	2 to 2.5 H:1V
Upper Clay Till, in the drawdown zone or below normal water level	3.7H:1V
Very Silty Clay Till, above the high water level	6H:1V
Very Silty Clay Till, below the high water level	10 to 12H:1V

Some form of erosion and ice protection will be required for the side slopes of the storm water retention pond. This can be accomplished by a rip-rap cover extending along the slope. It is recommended to place a filter geo-textile under the rip-rap to minimize fine soil erosion into the storm water pond. The rip-rap should be placed at least 1.0 meters (measured vertically) above and below the normal water level (subject to flood calculations as well). The silty soils are susceptible to erosion, and therefore the erosion protection should be placed as early as possible. Extensive erosion design of the storm water retention pond is beyond the scope of the current preliminary geotechnical investigation. Refined analysis can be provided after the location of the storm pond is finalized.

6.10 Site classification for seismic site response

Based on the observed soil conditions, Site Class "E" can be used for site classification for seismic site response.

6.11 Flexible pavement design

6.11.1 Subgrade preparation

It is understood that the pavement structure will be classified as both light duty and heavy duty. All fill soils as well as loose, soft, or organic soils should be removed from beneath the proposed pavement areas. The final subgrade surface should be compacted to 98 percent of SPMDD at

moisture content within 2% of the optimum moisture content to a depth of at least 300 mm in automobile parking areas and at least 450 mm in truck traffic areas. Prior to placement of the pavement structure, the entire surface should be proof rolled with a fully loaded tandem axle or single axle dump truck to detect any soft area. Stabilization of the subgrade with Portland cement (or in combination with geogrid) may be required in areas where the subgrade soils are too wet or too soft. The need for stabilization and its extent can be determined after proof rolling of the area. Drainage ditches along the roads shall drain the soils under the road to a depth of at least 1.5 meters below the final grade of the road (the elevation of the surface of the roads to be at least 1.5 m above the elevation of the bottom of the drainage ditches) and drainage ditches to have a positive gradient of at least 1.2% for positive drainage.

6.11.2 Flexible pavement sections

The pavement sections given in are the minimum requirements to accommodate the assumed traffic loading conditions and frequencies for the project site. These sections are designed based on a design period of 20 years and a maximum axle load of 80 kN (18 kips).

For areas subjected to automobile and light truck traffic only, the pavement structure is assumed to be used only by cars and light trucks (i.e. vans and ½ ton pickups), the pavement section given in Table 7 may be used, or a structurally equivalent section.

Table 7. Flexible pavement section thickness (light traffic areas)

Layer	Minimum Thickness (mm)
Asphalt concrete (50 blows)	120 mm
Gravel Base	250 mm
Subgrade	Stabilized, as necessary

In areas subjected to heavy traffic, (entrance, access ways, lay-down and heavy truck parking), the pavement section given in Table 8 may be used, or a structurally equivalent section.

Table 8. Flexible pavement section thickness (heavy traffic areas)

Layer	Minimum Thickness (mm)
Asphalt concrete (50 blows)	140 mm
Gravel Base	300 mm
Subgrade	Stabilized, as necessary

The granular base material should be hard, clean, well graded, crushed aggregate, free of organics, coal, clay lumps, and other deleterious material. The minimum sand equivalent should be 40 and the maximum percent passing the 80-micrometer screen should be 5 percent. Each mat of hot-mix asphalt should be compacted to at least 100 percent of maximum Marshall density.

It is recommended that concrete pads for garbage bins be constructed for use by garbage trucks. During the garbage bin pickup and removal, the loading intensity of front axle of the garbage truck may exceed the capacity of the recommended asphalt pavement structure. Accordingly, it is recommended that for all such bins, a minimum 200-mm thick reinforced concrete pad be constructed on at least 300 mm of compacted 20-mm granular base material (such as Table 5). The pads should be of sufficient size to ensure that both front and rear axles of the garbage truck rest on the pad while raising the garbage bin. Recommendations for subgrade stabilization might be required if site and construction procedures necessitate. Such necessity shall be determined by a qualified geotechnical engineer from Alpha Adroit during construction.

7 Closure and Disclaimer

The report has been prepared for the exclusive use of DGE Civil Engineering Consultants (the client) for the specific application to the preliminary geotechnical site investigation for the proposed Rural Residential Subdivision located at NE-27-83-23-W5M, Grimshaw, Alberta.

This report is an instrument of service of Alpha Adroit Engineering Ltd (Alpha Adroit). The report's contents are Copy Rights of Alpha Adroit and may not be copied or relied upon by any other party without the express written permission and consent of Alpha Adroit. In this report, Alpha Adroit has endeavored to comply with generally-accepted professional practices common to the local area, advanced methods, its own methods, or state of the art practices. Alpha Adroit makes no warranty, express or implied.

It should be noted that the results obtained during this study are only preliminary. It is recommended to have individual lots to be assessed by Alpha Adroit Engineering Ltd once specific building locations have been identified. Alpha Adroit may revise or provide lot-specific recommendations after such refined geotechnical assessment.

The analyses, conclusions, and recommendations contained in this report are based on data derived from a limited number of test holes obtained from widely spaced subsurface explorations or information provided by others. The methods used generally indicate subsurface conditions

only at the specific locations where samples were obtained or where in-situ tests would infer, only at the time they were obtained, and only to the depths penetrated. The samples and tests may not accurately reflect the nature and extent of strata variations that usually exist between sampling or testing locations. The accuracy of information provided by others have not been verified or reviewed for their accuracy by Alpha Adroit. If variations or other latent conditions become evident during construction, Alpha Adroit shall be notified immediately and Alpha Adroit will re-evaluate this report's recommendations. Alpha Adroit shall not be held responsible or liable for the adequacy of its recommendations when they are used in the field without Alpha Adroit being retained to observe and monitor the construction and provide recommendations as deemed necessary.

In consideration of the provision of the services by Alpha Adroit, such as this report, or the client relying on recommendations provided by Alpha Adroit, the client agrees that the liability of, and the client's recourse against Alpha Adroit with respect to this report, this project, and any services provided by Alpha Adroit, whether such liability arises in contract, negligence or other tort and/or any other cause of action in law, and whether arising directly, indirectly, in whole or in part by reason of any negligence of Alpha Adroit or its employees or agents, shall be absolutely limited to thirty percent of the fees received by Alpha Adroit, for all claims in aggregate. In the case of indirect or consequential loss, including without limitation, loss of earnings, profits, business opportunity, or otherwise, Alpha Adroit shall have no liability whatsoever. Alpha Adroit's liability in connection with its services is only to its clients, and does not extend to the clients' or Alpha Adroit's successors, assigns, associates, affiliates, officers, employees, directors, contractors, customers, clients, or to any other third party. Any action or claim by the client against Alpha Adroit in contract, negligence or other tort in connection, or arising out of the services provided by Alpha Adroit shall be commenced within and not later than one year from the date of this report.

Appendix A Site Plan Sketch

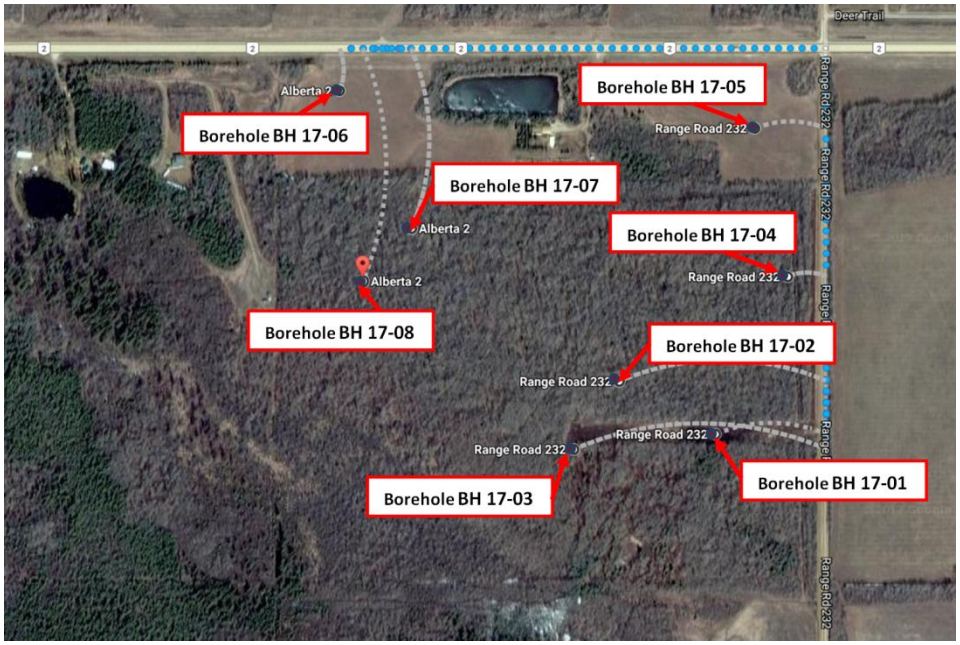


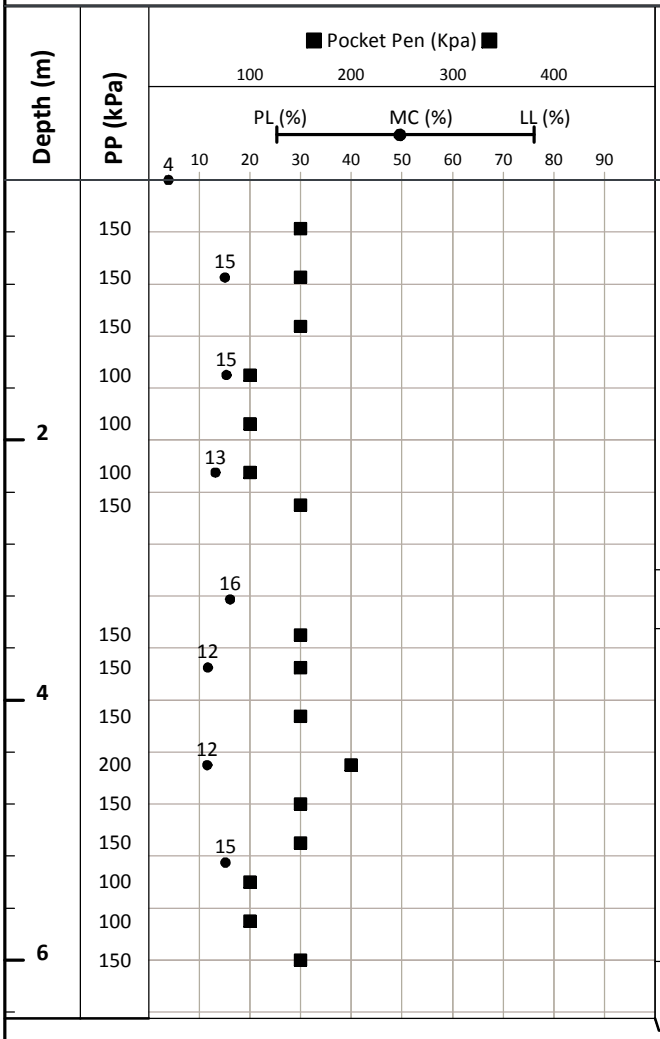
Figure 1. Sketch showing approximate borehole locations— not to scale

Appendix B Borehole Logs

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-01
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



SPT (N)	Material Description	Sample Type	Soil Symbol	Water Level	Piezometer
	CLAY TILL (0.0 m - 6.45 m) Brown to dark brown, orgainc odor, root smell, stiff to firm, sandy with small gravel up to 1" in size, low plastic, moist, trace of sand pockets, trace of white staining, trace of cobbles upto 3" in size				
3-6-7 (13)					
6-10-11 (21)					

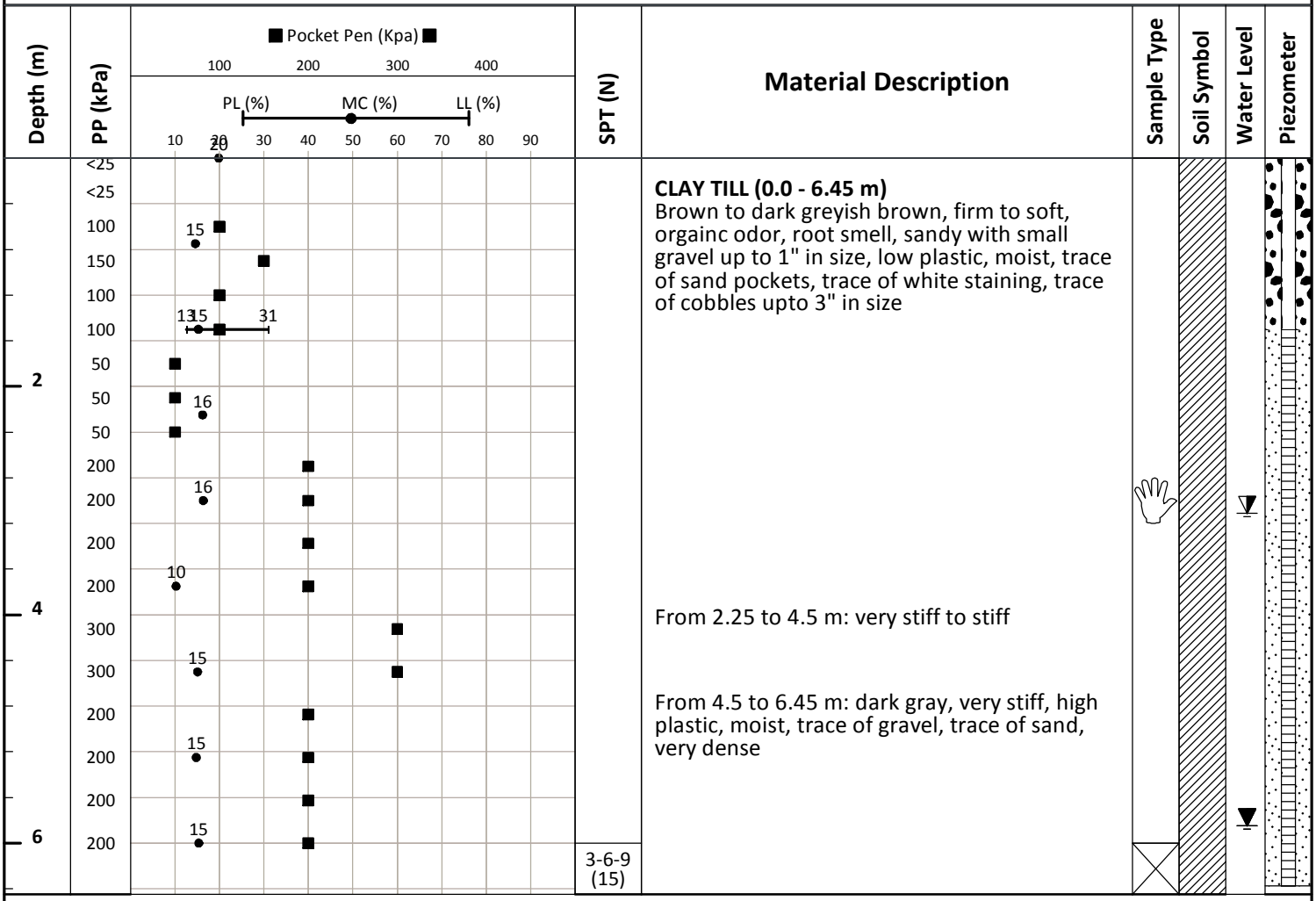
Bottom of borehole at 6.45 meters.

Topsoil
Clay
Grab Sample
Standard Penetration Test

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-02
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



CLAY TILL (0.0 - 6.45 m)
Brown to dark greyish brown, firm to soft, orgainc odor, root smell, sandy with small gravel up to 1" in size, low plastic, moist, trace of sand pockets, trace of white staining, trace of cobbles upto 3" in size

From 2.25 to 4.5 m: very stiff to stiff

From 4.5 to 6.45 m: dark gray, very stiff, high plastic, moist, trace of gravel, trace of sand, very dense

Bottom of borehole at 6.45 meters.

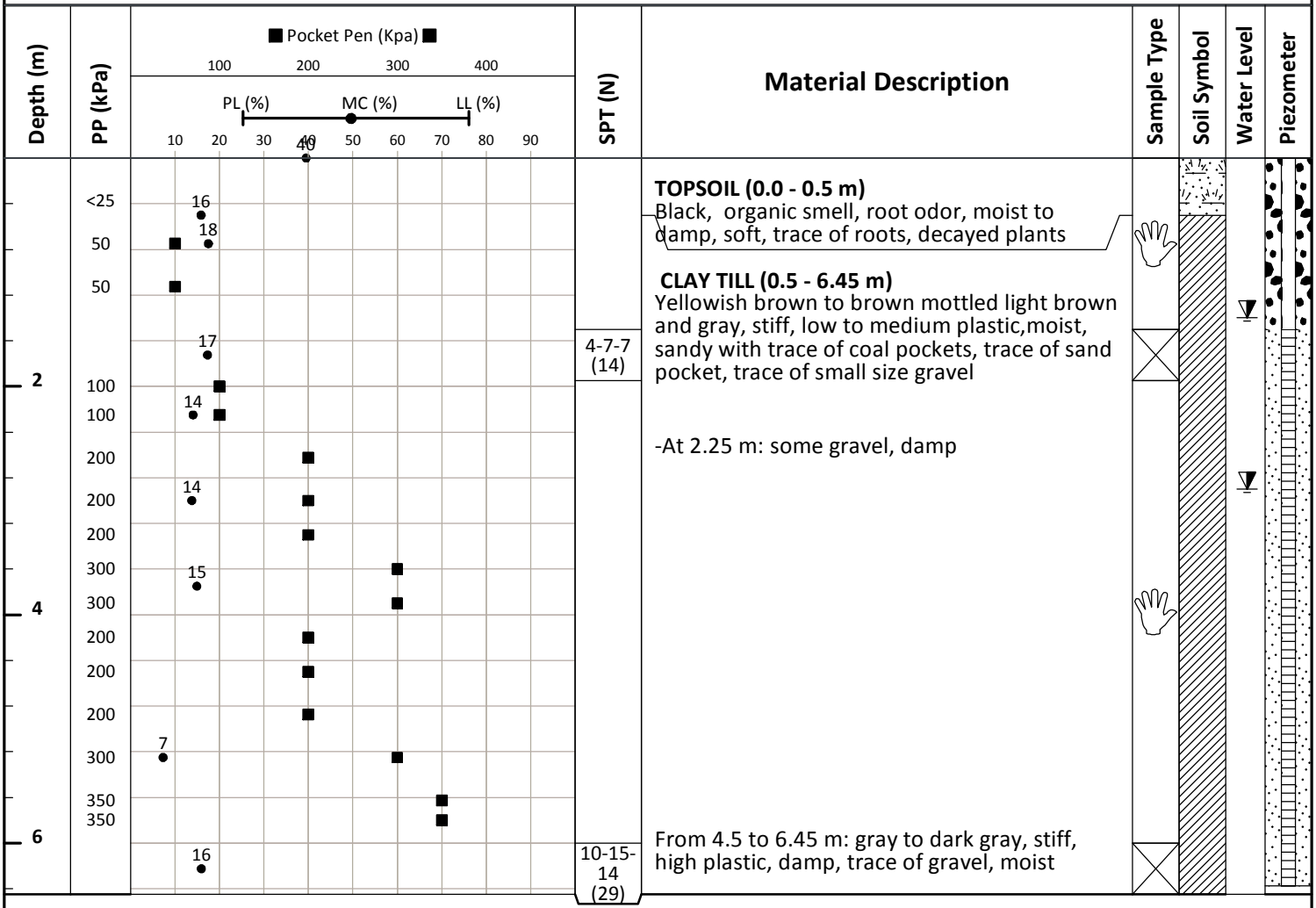
Water level at completion = 5.85 m BGS on June 3, 2017
On June 4, 2017, Water level = 3.11 m BGS
On June 26, 2017, Water level = 1.29 m BGS

Topsoil
Clay
Grab Sample
Standard Penetration Test
Cuttings Backfill
Slotted Pipe: 1 pipe group, 1 pipe

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-03
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



Bottom of borehole at 6.45 meters.

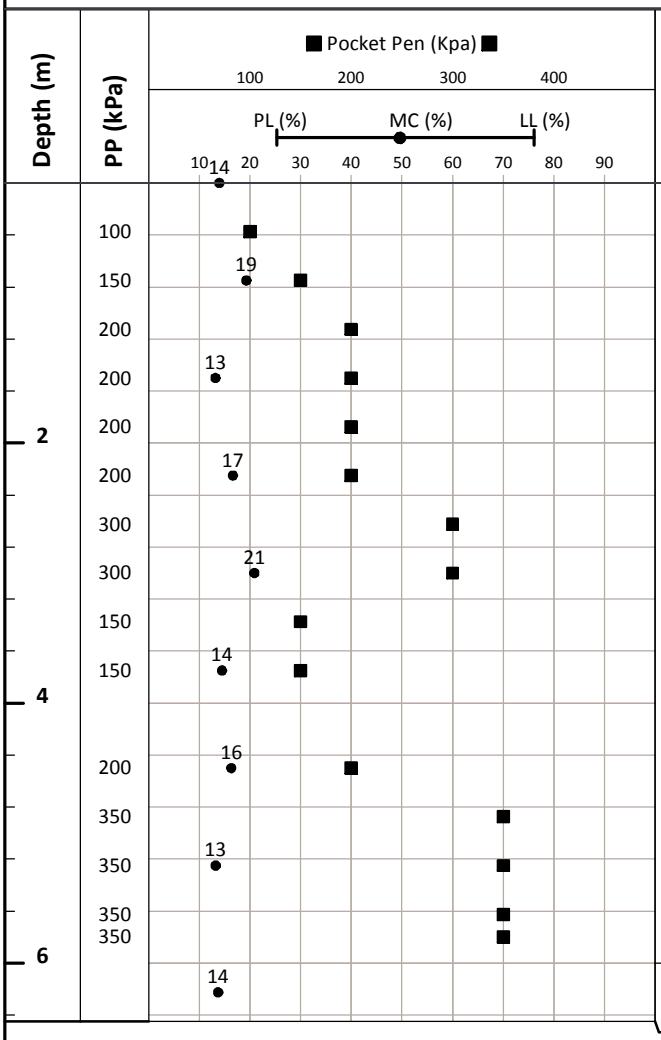
No water at completion on June 3, 2017 at 4:00 PM
Water level on June 4, 2017 at 7:37 AM = 2.9 m BGS
Water level on June 26, 2017 = 1.38 m BGS

Topsoil
Clay
Grab Sample
Standard Penetration Test
Cuttings Backfill
Slotted Pipe: 1 pipe group, 1 pipe

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-04
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



SPT (N)	Material Description	Sample Type	Soil Symbol	Water Level	Piezometer
	CLAY TILL (0.0 - 6.45 m) Yellowish brown, very stiff to stiff, medium plastic, sandy, moist, trace of gravel				
	From 1.5 to 3.75 m: some coal				
	From 5.25 to 6.45 m: gray to dark gray, hard to very stiff, high plastic, damp, trace of gravel, moist				
4-10-14 (24)					

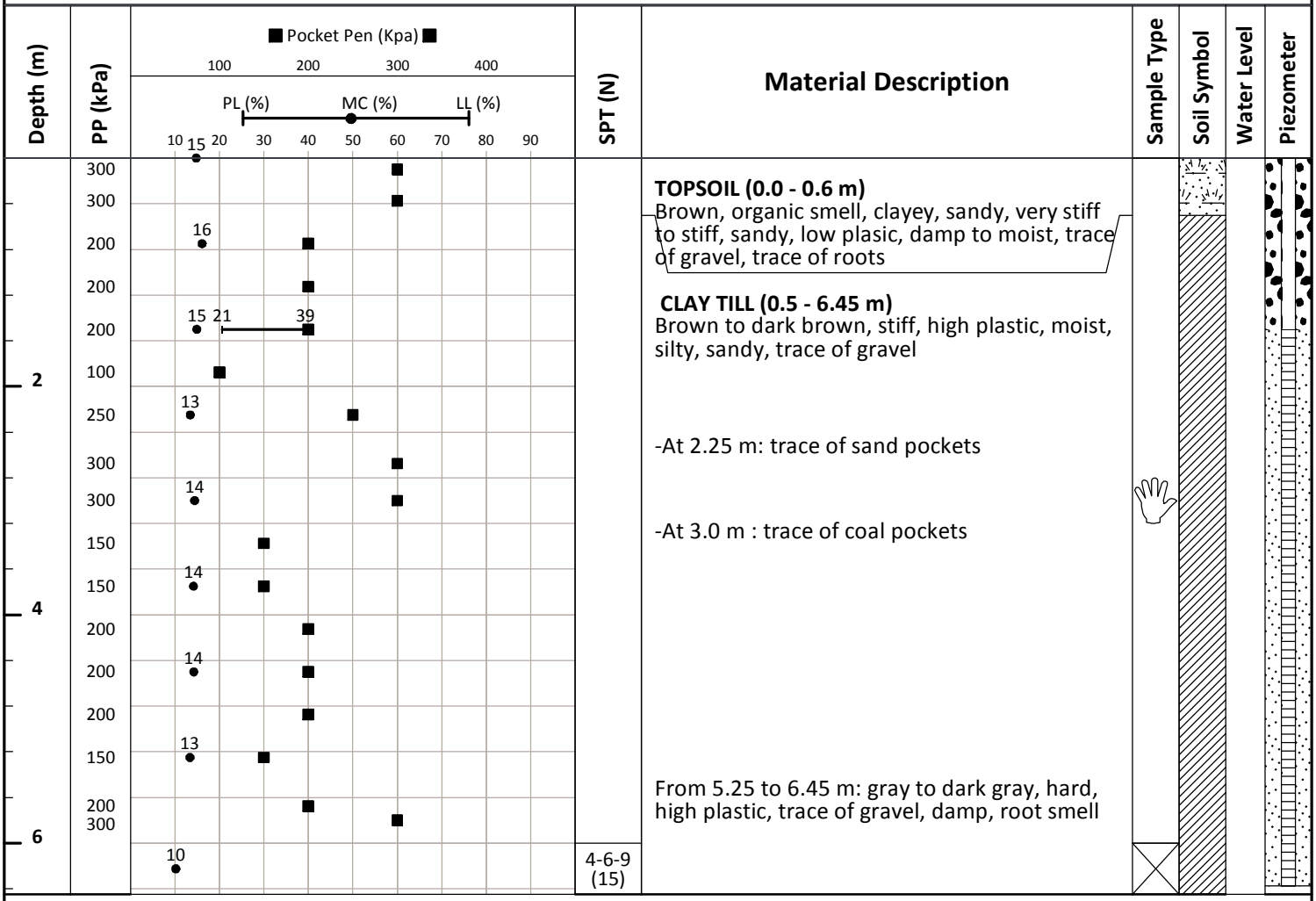
Bottom of borehole at 6.45 meters.

Topsoil
Clay
Grab Sample
Standard Penetration Test

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-05
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



Bottom of borehole at 6.45 meters.

No water at completion on
June 03, 2017

Topsoil
Clay

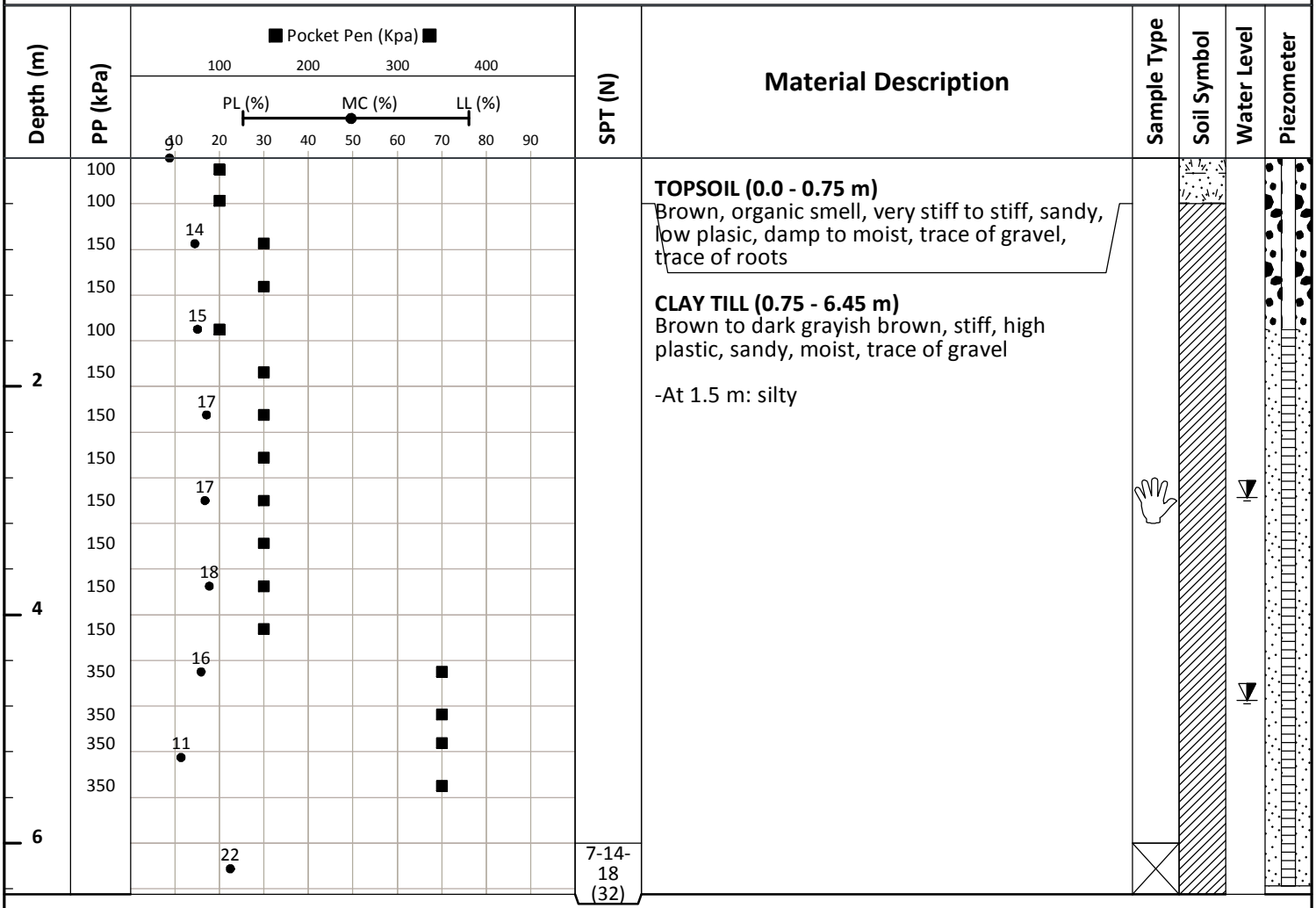
Grab Sample
Standard Penetration Test

Cuttings Backfill
Slotted Pipe: 1 pipe group, 1 pipe

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-06
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



TOPSOIL (0.0 - 0.75 m)
Brown, organic smell, very stiff to stiff, sandy, low plasic, damp to moist, trace of gravel, trace of roots

CLAY TILL (0.75 - 6.45 m)
Brown to dark grayish brown, stiff, high plastic, sandy, moist, trace of gravel

-At 1.5 m: silty

Bottom of borehole at 6.45 meters.

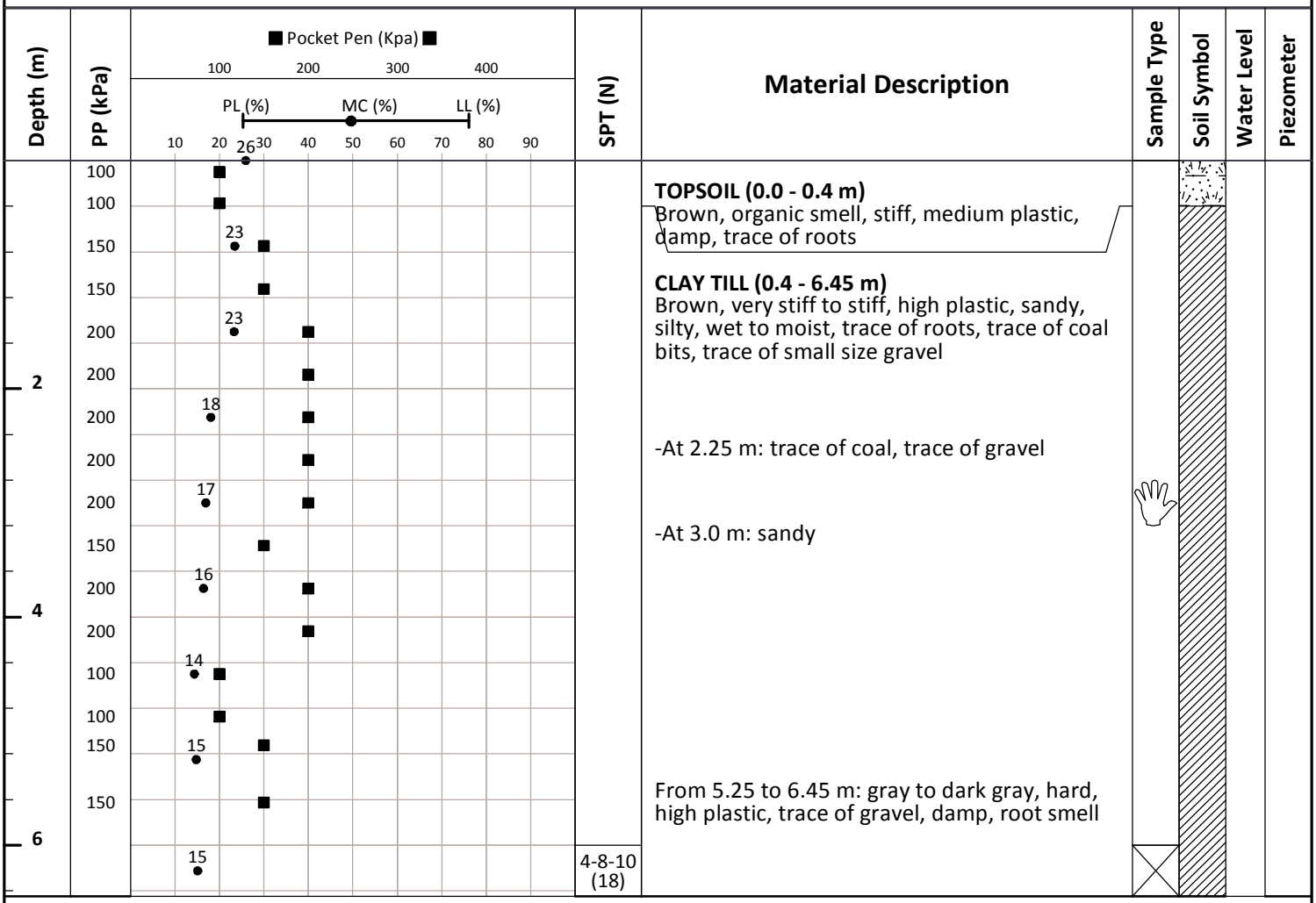
No water at completion on June 03, 2017
On June 4, 2017 Water level = 4.75 m BGS
On July 4, 2017 Water Level = 2.97 m BGS

Topsoil
Clay
Grab Sample
Standard Penetration Test
Cuttings Backfill
Slotted Pipe: 1 pipe group, 1 pipe

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-07
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



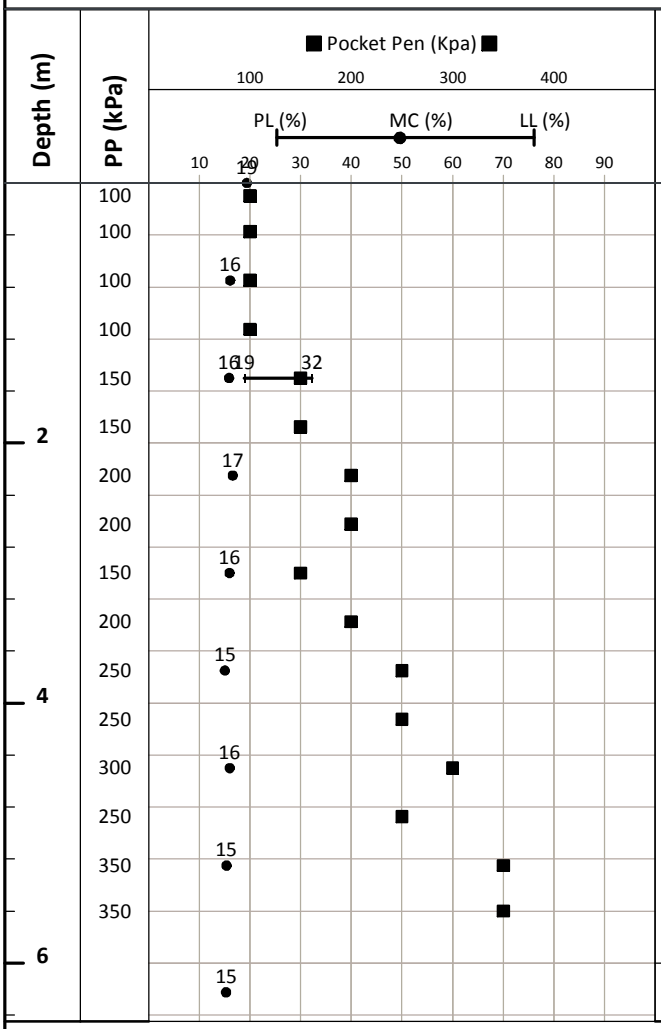
Bottom of borehole at 6.45 meters.

Topsoil
Clay
Grab Sample
Standard Penetration Test

Alpha Adroit

Borehole Log

Project No:	E20170209-01	**Borehole No:**	BH17-08
Project Location:	NE-27-83-23-W5M	**Date Started:**	2017-06-03
Client:	DGE Civil Engineering Consultants	**Date Completed:**	2017-06-03
Logged By:	F.Y.	**Drill Type:**	Solid Stem Auger and SPT
Sheet No:	1 of 1	**Elevation:**	NA



Material Description	Sample Type	Soil Symbol	Water Level	Piezometer
TOPSOIL (0.0 - 0.6 m) Brown, stiff to soft, high plastic, moist, trace of gravel				
CLAY TILL (0.6 - 6.45 m) Greenish brown, stiff to soft, sandy, silty, moist, trace of gravel				
From 2.25 to 4.5 m: brown, stiff, medium to high plastic				
-At 3.0 m: trace of coal pockets				
From 4.5 to 6.45 m: dark gray, hard, high plastic, damp, root smell, trace of gravel, trace of black sand pocket, trace of black and white gravel, trace of black coal chips				

Bottom of borehole at 6.45 meters.

Topsoil
Clay
Grab Sample
Standard Penetration Test