Geotechnical Engineering

Environmental Engineering

Hydrogeology

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Preliminary Geotechnical Investigation

Proposed Residential Development
Summerside West - Phase 4 and 5
Tenth Line Road - Ottawa

Prepared For

2447591 Ontario Inc.

Paterson Group Inc.
Consulting Engineers
154 Colonnade Road South
Ottawa (Nepean), Ontario
Canada K2E 7J5

Tel: (613) 226-7381
Fax: (613) 226-6344
www.patersongroup.ca

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Report: PG4049-1

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Appendices

1.0 Introduction

Paterson Group (Paterson) was commissioned by 2447591 Ontario Inc. to conduct a preliminary geotechnical investigation for the proposed residential development to be located between Mer Bleue Road and Tenth Line Road, in the City of Ottawa (refer to Figure 1 - Key Plan presented in Appendix 2). The objective of the investigation was to:

❏ determine the subsurface soil and groundwater conditions by means of a boreholes and a monitoring well program.

❏ provide geotechnical recommendations for the foundation design for the proposed buildings and pavement structure design of the proposed development including construction considerations which may affect the design.

The following report has been prepared specifically and solely for the aforementioned project which is described herein. The report contains our findings and includes geotechnical recommendations pertaining to the design and construction of the proposed development as understood at the time of this report.

Investigating the presence or potential presence of contamination on the subject property was not part of the scope of work of this present investigation. Therefore, the present report does not address environmental issues.

2.0 Proposed Development

It is understood that the proposed development will consist of low rise residential dwellings and townhouse style housing. Local roadways and residential driveways are also anticipated for the proposed development. It is further anticipated that the site will be serviced by future municipal services.

3.0 Method of Investigation

3.1 Field Investigation

The field program for the current investigation was carried out on February 27 and 28, 2017. At that time, 14 boreholes were completed to a maximum depth of 6.1 m below existing ground surface. The test hole locations were placed in a manner to provide general coverage of the subject site taking into consideration site features and underground utilities. The test hole locations for the current investigation are presented on Drawing PG4049-1 - Test Hole Location Plan included in Appendix 2.

The boreholes were completed using a track-mounted auger drill rig operated by a two person crew. All fieldwork was conducted under the full-time supervision of Paterson personnel under the direction of a senior engineer from the geotechnical division. The testing procedure consisted of augering to the required depths and at the selected locations sampling the overburden.

Sampling and In Situ Testing

Soil samples were collected from the boreholes using a 50 mm diameter split-spoon (SS) sampler, or from the auger flights. The depths at which the auger and split spoon samples were recovered from the test holes are shown as AU, and SS, respectively, on the Soil Profile and Test Data sheets in Appendix 1.

A Standard Penetration Test (SPT) was conducted in conjunction with the recovery of the split spoon samples. The SPT results are recorded as "N" values on the Soil Profile and Test Data sheets. The "N" value is the number of blows required to drive the split spoon sampler 300 mm into the soil after a 150 mm initial penetration using a 63.5 kg hammer falling from a height of 760 mm. This testing was done in general accordance with ASTM D1586-11 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.

Undrained shear strength testing was carried out in cohesive soils using a field vane apparatus.

The overburden thickness was evaluated by a dynamic cone penetration test (DCPT) completed at MW 3B. The DCPT consists of driving a steel drill rod, equipped with a 50 mm diameter cone at the tip, using a 63.5 kg hammer falling from a height of 760 mm. The number of blows required to drive the cone into the soil is recorded for each 300 mm increment.

Subsurface conditions observed in the test holes were recorded in detail in the field. Reference should be made to the Soil Profile and Test Data sheets presented in Appendix 1 for specific details of the soil profile encountered at the test hole locations

Groundwater

Groundwater monitoring wells were installed in all the boreholes to monitor the longterm groundwater level subsequent to the completion of the sampling program. The groundwater observations are discussed in Subsection 4.3 and presented in the Soil Profile and Test Data sheets in Appendix 1.

Sample Storage

All samples from the current investigation will be stored in the laboratory for a period of one month after issuance of this report. They will then be discarded unless we are otherwise directed.

3.2 Field Survey

The test hole locations were determined by Paterson personnel and were located and surveyed in the field by JD Barnes Limited. The locations of the boreholes are presented on Drawing PG4049-1 - Test Hole Location Plan in Appendix 2.

3.3 Laboratory Testing

The soil samples recovered from the our field investigation were examined in our laboratory.

3.4 Analytical Testing

One (1) soil sample was submitted for analytical testing to assess the corrosion potential for exposed ferrous metals and the potential of sulphate attacks against subsurface concrete structures. The sample was submitted to determine the concentration of sulphate and chloride, the resistivity and the pH of the sample. The results are presented in Appendix 1 and are discussed further in Subsection 6.7.

4.0 Observations

4.1 Surface Conditions

The subject site is currently undeveloped, agricultural land and is grass covered. McKinnons Creek transects the eastern portion of the property. Several shallow drainage ditches were also observed along the property lines and throughout the site for agricultural drainage purposes. The subject site is relatively flat and slightly below grade of Mer Bleue Road and Tenth Line Road. The site is bordered to the north by a residential development currently under construction, to the east by Tenth Line Road, to the West by Mer Bleue Road and to the south by mostly vacant land and some treed areas. Various piles of fill, topsoil and construction debris were observed along the north perimeter of the subject site.

4.2 Subsurface Profile

Generally, the soil profile encountered at the test hole locations consists of an agriculturally disturbed organic layer overlying a stiff brown silty clay crust followed by a deep, firm grey silty clay deposit. A silty sand layer approximately 1 m in thickness was present between the topsoil layer and silty clay deposit at MW 3A. A DCPT was completed at MW 3B with no practical refusal to a depth of 30 m below the existing ground surface. Reference should be made to the Soil Profile and Test Data sheets in Appendix 1 for the details of the soil profile encountered at each test hole location.

Based on available geological mapping, the bedrock in the area is part of the Lindsay formation, which consists of interbedded limestone and shale. Also, based on available geological mapping, the overburden thickness is expected to range from 25 to 50 m.

Silty Clay

Silty clay was encountered immediately beneath the topsoil at all test hole locations with the exception of MW 3A. The upper portion of the silty clay has been weathered to a firm to very stiff brown crust. The crust extends to depths varying between 1.5 and 3 m. In situ shear vane field testing carried out within the silty clay layer in the lower portion of the weathered crust yielded undrained shear strength values ranging from approximately 31 to 140 kPa. These values are indicative of a firm to very stiff consistency. In situ shear vane field testing carried out within the grey silty clay yielded undrained shear strengths ranging from approximately 24 to 39 kPa. These values are indicative of a soft to firm consistency.

4.3 Groundwater

Groundwater level readings were recorded on May 2, 2017 at the monitoring well locations. The groundwater level readings are presented in the Soil Profile and Test Data sheets in Appendix 1, and in Table 1 below. Long-term groundwater level can also be estimated based on the observed colour, moisture levels and consistency of the recovered soil samples. Based on these observations, the long-term groundwater level is expected between 1.5 to 2.5 m depth. It should be noted that groundwater levels are subject to seasonal fluctuations, therefore the groundwater levels could vary at the time of construction.

It should be noted that groundwater levels presented in the following table were recorded after heavy rain events and spring melting. Therefore, the groundwater levels within the monitoring wells had not stabilized at the time of recording. To accurately assess the groundwater levels, quarterly monitoring events will be completed to establish the long-term groundwater levels.

Table 1 - Summary of Groundwater Level Readings

Test Hole Number	Ground Elevation, m	Groundwater Levels, m		Recording Date
		Depth	Elevation	
MW 1A	88.76	0.19	88.57	May 2, 2017
MW 1B	86.76	0.20	86.56	May 2, 2017
MW 2A	86.40	0.29	86.11	May 2, 2017
MW 2B	86.40	0.30	86.10	May 2, 2017
MW 3A	86.82	0.12	86.70	May 2, 2017
MW 3B	86.82	0.28	86.54	May 2, 2017
MW 4A	86.41	0.48	85.93	May 2, 2017
MW 4B	86.41	0.34	86.07	May 2, 2017
MW 5A	86.55	0.60	85.95	May 2, 2017
MW 5B	86.55	0.38	86.17	May 2, 2017
MW 6A	86.17	0.62	85.55	May 2, 2017
MW 6B	86.17	0.10	86.07	May 2, 2017
MW 7A	86.60	0.38	86.22	May 2, 2017
MW 7B	86.60	0.17	86.43	May 2, 2017

5.0 Discussion

5.1 Geotechnical Assessment

From a geotechnical perspective, the subject site is satisfactory for the proposed residential development. However, due to the presence of the sensitive silty clay layer, the proposed development will be subjected to grade raise restrictions.

The above and other considerations are further discussed in the following sections.

5.2 Site Grading and Preparation

Stripping Depth

Topsoil and deleterious fill, such as those containing organic materials, should be stripped from under any buildings, paved areas, pipe bedding and other settlement sensitive structures.

Fill Placement

Fill used for grading beneath the building areas should consist, unless otherwise specified, of clean imported granular fill, such as Ontario Provincial Standard Specifications (OPSS) Granular A or Granular B Type II. Granular material should be tested and approved prior to delivery to the site. The fill should be placed in loose lifts of 300 mm thick or less and compacted using suitable compaction equipment for the lift thickness. Fill placed beneath the building areas should be compacted to at least 98% of the Standard Proctor Maximum Dry Density (SPMDD).

Non-specified existing fill along with site-excavated soil can be used as general landscaping fill and beneath parking areas where settlement of the ground surface is of minor concern. In landscaped areas, these materials should be spread in thin lifts and at least compacted by the tracks of the spreading equipment to minimize voids. If these materials are to be used to build up the subgrade level for areas to be paved, they should be compacted in thin lifts to a minimum density of 95% of the SPMDD. Non-specified existing fill and site-excavated soils are not suitable for use as backfill against foundation walls unless a composite drainage blanket connected to a perimeter drainage system is provided.

5.3 Foundation Design

Bearing Resistance Values

Using continuously applied loads, footings for the proposed buildings can be designed using the bearing resistance values presented in Table 2. The bearing resistance values provided have been designed in consideration of a 0.5 m long-term groundwater lowering and the permissible grade raise recommendations presented in the subsections of Section 5.3 on the following pages.

Table 2 - Bearing Resistance Values

Bearing Surface	Bearing Resistance Value at SLS (kPa)	Factored Bearing Resistance Value at ULS (kPa)
Stiff Silty Clay	75	140
Firm Silty Clay	60	125

Note: Strip footings, up to 1.5 m wide, and pad footings, up to 3 m wide, can be designed using the above noted bearing resistance values.

The bearing resistance values are provided on the assumption that the footings will be placed on undisturbed soil bearing surfaces. An undisturbed soil bearing surface consists of one from which all topsoil and deleterious materials, such as loose, frozen or disturbed soil, whether in situ or not, have been removed, prior to the placement of concrete for footings.

Bearing resistance values for footing design should be determined on a per lot basis at the time of construction.

Lateral Support

The bearing medium under footing-supported structures is required to be provided with adequate lateral support with respect to excavations and different foundation levels. Adequate lateral support is provided to the in-situ bearing medium soils above the groundwater table when a plane extending down and out from the bottom edge of the footing at a minimum of 1.5H:1V passes only through in situ soil of the same or higher capacity as the bearing medium soil.

Settlement/Grade Raise

Consideration must be given to potential settlements which could occur due to the presence of the silty clay deposit and the combined loads from the proposed footings, any groundwater lowering effects, and grade raise fill. The foundation loads to be considered for the settlement case are the continuously applied loads which consist of the unfactored dead loads and the portion of the unfactored live load that is considered to be continuously applied. For dwellings, a minimum value of 50% of the live load is recommended by Paterson.

Generally, the potential long term settlement is evaluated based on the compressibility characteristics of the silty clay. A test fill settlement monitoring program is currently underway for the subject site to accurately model the site permissible grade raise recommendations. For preliminary design purposes, a permissible grade raise of **1 m** above existing ground surface is recommended. It should be noted that the abovenoted permissible grade raise value will be updated upon completion of our test fill settlement monitoring program.

The total and differential settlements will be dependent on characteristics of the proposed buildings. For design purposes, the total and differential settlements are estimated to be 25 and 20 mm, respectively. A post-development groundwater lowering of 0.5 m was assumed.

The potential post construction total and differential settlements are dependent on the position of the long term groundwater level when buildings are situated over deposits of compressible silty clay. Efforts can be made to reduce the impacts of the proposed development on the long term groundwater level by placing clay dykes in the service trenches, reducing the sizes of paved areas, leaving green spaces to allow for groundwater recharge or limiting planting of trees to areas away from the buildings. However, it is not economically possible to control the groundwater level.

To reduce potential long term liabilities, consideration should be given to accounting for a larger groundwater lowering and to provide means to reduce long term groundwater lowering (e.g. clay dykes, restriction on planting around the dwellings, etc). Building on silty clay deposits increases the likelihood of movements and therefore of cracking. The use of steel reinforcement in foundations placed at key structural locations will tend to reduce foundation cracking compared to unreinforced foundations.

5.5 Design for Earthquakes

A seismic site response **Class E** should be used for design of the proposed buildings at the subject site according to the OBC 2012. The soils underlying the site are not susceptible to liquefaction.

5.6 Basement Slab

With the removal of all topsoil and deleterious fill, containing organic matter, within the footprints of the proposed buildings, the native soil surface will be considered an acceptable subgrade on which to commence backfilling for floor slab construction. Any soft areas should be removed and backfilled with appropriate backfill material. OPSS Granular B Type II, with a maximum particle size of 50 mm, are recommended for backfilling below the floor slab. It is recommended that the upper 200 mm of sub-slab fill consist of 19 mm clear crushed stone.

5.7 Pavement Structure

For design purposes, the pavement structure presented in the following tables could be used for the design of driveways, local residential streets and roadways with bus traffic. It should be noted that for residential driveways and car only parking areas, an Ontario Traffic Category A is applicable. For local roadways and roadways with bus traffic, an Ontario Traffic Category B and Category D should be used for design purposes, respectively.

Table 5 - Recommended Pavement Structure - Driveways

Thickness (mm)	Material Description
50	**Wear Course** - HL 3 or Superpave 12.5 Asphaltic Concrete
150	**BASE** - OPSS Granular A Crushed Stone
300	**SUBBASE** - OPSS Granular B Type II
SUBGRADE - Either fill, in situ soil or OPSS Granular B Type I or II material placed over in situ soil or fill	

Table 6 - Recommended Pavement Structure - Local Residential Roadways	
Thickness (mm)	**Material Description**
40	**Wear Course -** Superpave 12.5 Asphaltic Concrete
50	**Binder Course -** Superpave 19.0 Asphaltic Concrete
150	**BASE** - OPSS Granular A Crushed Stone
400	**SUBBASE** - OPSS Granular B Type II
SUBGRADE - Either fill, in situ soil or OPSS Granular B Type I or II material placed over in situ soil or fill	

Table 7 - Recommended Pavement Structure - Roadways with Bus Traffic	
Thickness mm	**Material Description**
40	**Wear Course -** Superpave 12.5 Asphaltic Concrete
50	**Upper Binder Course** - Superpave 19.0 Asphaltic Concrete
50	**Lower Binder Course** - Superpave 19.0 Asphaltic Concrete
150	**BASE** - OPSS Granular A Crushed Stone
600	**SUBBASE** - OPSS Granular B Type II
SUBGRADE - Either fill, in situ soil or OPSS Granular B Type I or II material placed over in situ soil or fill	

If soft spots develop in the subgrade during compaction or due to construction traffic, the affected areas should be excavated and replaced with OPSS Granular B Type II material. Weak subgrade conditions may be experienced over service trench fill materials. This may require the use of a geotextile, thicker subbase or other measures that can be recommended at the time of construction as part of the field observation program.

Minimum Performance Graded (PG) 58-34 asphalt cement should be used for driveways and local roadways and PG 64-34 asphalt cement should be used for roadways with bus traffic. The pavement granular base and subbase should be placed in maximum 300 mm thick lifts and compacted to a minimum of 100% of the material's SPMDD using suitable vibratory equipment.

Pavement Structure Drainage

Satisfactory performance of the pavement structure is largely dependent on the contact zone between the subgrade material and the base stone in a dry condition. Failure to provide adequate drainage under conditions of heavy wheel loading can result in the fine subgrade soil being pumped into the voids in the stone subbase, thereby reducing load carrying capacity.

Due to the low permeability of the subgrade materials consideration should be given to installing subdrains during the pavement construction as per City of Ottawa standards. The subdrain inverts should be approximately 300 mm below subgrade level. The subgrade surface should be crowned to promote water flow to the drainage lines.

6.0 Design and Construction Precautions

6.1 Foundation Drainage and Backfill

A perimeter foundation drainage system is recommended for proposed structures. The system should consist of a 100 to 150 mm diameter, geotextile-wrapped, perforated, corrugated, plastic pipe, surrounded on all sides by 150 mm of 10 mm clear crushed stone, placed at the footing level around the exterior perimeter of the structure. The pipe should have a positive outlet, such as a gravity connection to the storm sewer.

Backfill against the exterior sides of the foundation walls should consist of free-draining, non frost susceptible granular materials. The site materials will be frost susceptible and, as such, are not recommended for re-use as backfill unless a composite drainage system (such as system Platon or Miradrain G100N) connected to a drainage system is provided.

6.2 Protection Against Frost Action

Perimeter footings of heated structures are required to be insulated against the deleterious effect of frost action. A minimum 1.5 m thick soil cover (or equivalent) should be provided in this regard.

A minimum of 2.1 m thick soil cover (or equivalent) should be provided for other exterior unheated footings.

6.3 Excavation Side Slopes

The excavations for the proposed development will be mostly through a sensitive grey silty clay. Where excavation is above the groundwater level to a depth of approximately 3 m, the excavation side slopes should be stable in the short term at 1H:1V. Flatter slopes could be required for deeper excavations or for excavation below the groundwater level. Where such side slopes are not permissible or practical, temporary shoring should be used. The subsoil at this site is considered to be mainly a Type 2 or 3 soil according to the Occupational Health and Safety Act and Regulations for Construction Projects.

The slope cross-sections recommended above are for temporary slopes. Excavated soil should not be stockpiled directly at the top of excavations and heavy equipment should be kept away from the excavation sides.

It is recommended that a trench box be used at all times to protect personnel working in trenches with steep or vertical sides. It is expected that services will be installed by "cut and cover" methods and excavations will not be left open for extended periods of time.

It is expected that deep service trenches in excess of 3 m will be completed using a temporary shoring system designed by a structural engineer, such as stacked trench boxes in conjunction with steel plates. The trench boxes should be installed to ensure that the excavation sidewalls are tight to the outside of the trench boxes and that the steel plates are extended below the base of the excavation to prevent basal heave (if required).

Slopes in excess of 3 m in height should be periodically inspected by the geotechnical consultant in order to detect if the slopes are exhibiting signs of distress.

Excavation Base Stability

The base of supported excavations can fail by three (3) general modes:

☐ Shear failure within the ground caused by inadequate resistance to loads imposed by grade difference inside and outside of the excavation,
☐ Piping from water seepage through granular soils, and
☐ Heave of layered soils due to water pressures confined by intervening low permeability soils.

Shear failure of excavation bases is typically rare in granular soils if adequate lateral support is provided. Inadequate dewatering can cause instability in excavations made through granular or layered soils. The potential for base heave in cohesive soils should be determined for stability of flexible retaining systems.

The factor of safety with respect to base heave, FS_b, is:

$$FS_b = N_b s_u / \sigma_z$$

where:

N_b - stability factor dependent upon the geometry of the excavation and given in Figure 1 on the following page.
s_u - undrained shear strength of the soil below the base level
σ_z - total overburden and surcharge pressures at the bottom of the excavation

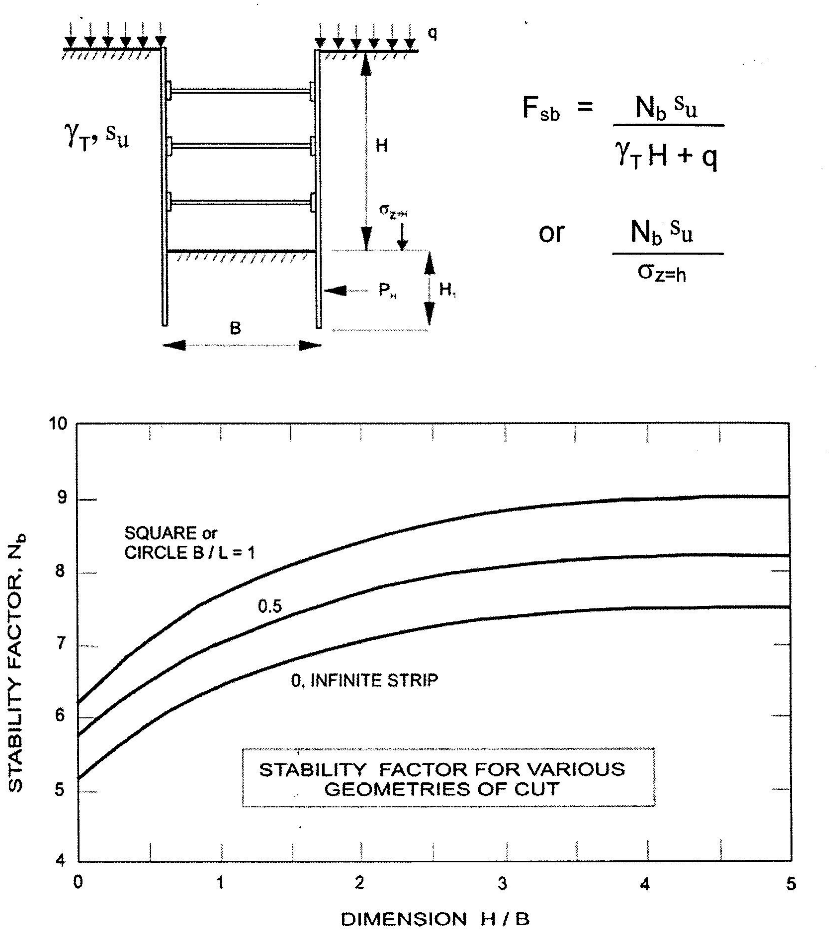


Figure 1 - Stability Factor for Various Geometries of Cut

In the case of soft to firm clays, a factor of safety of 2 is recommended for base stability.

6.4 Pipe Bedding and Backfill

Bedding and backfill materials should be in accordance with the most recent Material Specifications and Standard Detail Drawings from the City of Ottawa. These recommendations are for standard, open cut excavation placed services.

The pipe bedding for sewer and water pipes should consist of at least 150 mm of OPSS Granular A material. Where the bedding is located within the firm grey silty clay, the thickness of the bedding material should be increased to a minimum of 300 mm. The material should be placed in maximum 300 mm thick lifts and compacted to a minimum of 95% of its SPMDD. The bedding material should extent at least to the spring line of the pipe.

The cover material, which should consist of OPSS Granular A, should extend from the spring line of the pipe to at least 300 mm above the obvert of the pipe. The material should be placed in maximum 300 mm thick lifts and compacted to a minimum of 95% of its SPMDD.

Generally, it should be possible to re-use the moist (not wet) brown silty clay above the cover material if the excavation and filling operations are carried out in dry weather conditions. Wet silty clay materials will be difficult to re-use, as the high water contents make compacting impractical without an extensive drying period.

Where hard surface areas are considered above the trench backfill, the trench backfill material within the frost zone (about 1.8 m below finished grade) should match the soils exposed at the trench walls to minimize differential frost heaving. The trench backfill should be placed in maximum 300 mm thick loose lifts and compacted to a minimum of 95% of the material's SPMDD.

To reduce long-term lowering of the groundwater level at this site, clay seals should be provided in the service trenches. The seals should be at least 1.5 m long (in the trench direction) and should extend from trench wall to trench wall. The seals should extend from the frost line and fully penetrate the bedding, subbedding and cover material. The barriers should consist of relatively dry and compactable brown silty clay placed in maximum 225 mm thick loose layers and compacted to a minimum of 95% of the SPMDD. The clay seals should be placed at the site boundaries and at strategic locations at no more than 60 m intervals in the service trenches. Periodic inspection of the clay seal placement work should be completed by Paterson personnel during servicing installation work.

Bedding for Thrust Blocks

To increase the vertical allowable bearing capacity to 100 kPa or greater, Paterson suggests the following alternative bedding changes at the thrust block locations:

- ❑ Place a granular bedding to a minimum thickness of 400 mm using OPSS Granular A or OPSS Granular B, Type II compacted to 95% of the material's standard Proctor maximum dry density.

The bearing medium under the thrust blocks is required to be provided with adequate lateral support with respect to excavations and different foundation levels. Adequate lateral support is provided to the engineered fill and/or in-situ bearing medium soils when a plane extending down and out from the bottom edge of the thrust block at a minimum of 1.5H:1V passes only through in situ soil of the same or higher capacity as the bearing medium soil.

6.5 Groundwater Control

Due to the relatively impervious nature of the silty clay materials, it is anticipated that groundwater infiltration into the excavations should be low and controllable using open sumps. Pumping from open sumps should be sufficient to control the groundwater influx through the sides of shallow excavations.

Permit to Take Water

A temporary Ministry of the Environment and Climate Change (MOECC) permit to take water (PTTW) may be required for this project if more than 400,000 L/day of ground and/or surface water is to be pumped during the construction phase. A minimum 4 to 5 months should be allowed for completion of the PTTW application package and issuance of the permit by the MOECC.

For typical ground or surface water volumes, being pumped during the construction phase, between 50,000 to 400,000 L/day, it is required to register on the Environmental Activity and Sector Registry (EASR). A minimum of two to four weeks should be allotted for completion of the EASR registration and the Water Taking and Discharge Plan to be prepared by a Qualified Person as stipulated under O.Reg. 63/16. If a project qualifies for a PTTW based upon anticipated conditions, an EASR will not be allowed as a temporary dewatering measure while awaiting the MOECC review of the PTTW application.

The contractor should be prepared to direct water away from all bearing surfaces and subgrades, regardless of the source, to prevent disturbance to the founding medium.

6.6 Winter Construction

The subsurface conditions at this site mostly consist of frost susceptible materials. In presence of water and freezing conditions ice could form within the soil mass. Heaving and settlement upon thawing could occur. Precautions should be taken if winter construction is considered for this project.

In the event of construction during below zero temperatures, the founding stratum should be protected from freezing temperatures by the use of straw, propane heaters, tarpaulins or other suitable means. In this regard, the base of the excavations should be insulated from sub-zero temperatures immediately upon exposure and until such time as heat is adequately supplied to the building and the footings are protected with sufficient soil cover to prevent freezing at founding level.

The trench excavations should be constructed in a manner that will avoid the introduction of frozen materials into the trenches. As well, pavement construction is difficult during winter. The subgrade consists of frost susceptible soils which will experience total and differential frost heaving as the work takes place. In addition, the introduction of frost, snow or ice into the pavement materials, which is difficult to avoid, could adversely affect the performance of the pavement structure. Additional information could be provided, if required.

6.7 Corrosion Potential and Sulphate

One (1) sample was submitted for testing. The analytical test results of the soil sample indicate that the sulphate content is less than 0.01%. These results along with the chloride and pH value are indicative that Type 10 Portland cement (normal cement) would be appropriate for this site. The results of the resistivity indicate the presence of a moderate to very aggressive environment for exposed ferrous metals at this site, which is typical of silty clay samples submitted for the subject area. It is anticipated that standard measures for corrosion protection are sufficient for services placed within the silty clay deposit.

6.8 Landscaping Considerations

Tree Planting Restrictions

The proposed residential dwellings are located in a moderate to high sensitivity area with respect to tree plantings over a silty clay deposit. It is recommended that trees placed within 7.5 m of the foundation wall consist of low water demanding trees with shallow roots systems that extend less than 1.5 m below ground surface. Trees placed greater than 7.5 m from the foundation wall may consist of typical street trees, which are typically moderate water demand species with roots extending to a maximum 2 m depth.

It is well documented in the literature, and is our experience, that fast-growing trees located near buildings founded on cohesive soils that shrink on drying can result in long-term differential settlements of the structures. Tree varieties that have the most pronounced effect on foundations are seen to consist of poplars, willows and some maples (i.e. Manitoba Maples) and, as such, they should not be considered in the landscaping design.

Swimming Pools, Aboveground Hot Tubs, Decks and Additions

The in-situ soils are considered to be acceptable for swimming pools. Above ground swimming pools must be placed at least 5 m away from the residence foundation and neighbouring foundations. Otherwise, pool construction is considered routine, and can be constructed in accordance with the manufacturer`s requirements.

Additional grading around the hot tub should not exceed permissible grade raises. Otherwise, hot tub construction is considered routine, and can be constructed in accordance with the manufacturer’s specifications.

Additional grading around proposed deck or addition should not exceed permissible grade raises. Otherwise, standard construction practices are considered acceptable.

7.0 Recommendations

It is recommended that the following be completed once the master plan and site development are determined:

- Complete a supplemental geotechnical investigation.
- Review detailed grading plan(s) from a geotechnical perspective.
- Observation of all bearing surfaces prior to the placement of concrete.
- Periodic observation of the condition of unsupported excavation side slopes in excess of 3 m in height, if applicable.
- Observation of all subgrades prior to placing backfilling materials.
- Observation of clay seal placement at specified locations.
- Field density tests to ensure that the specified level of compaction has been achieved.
- Sampling and testing of the bituminous concrete including mix design reviews.

A report confirming that these works have been conducted in general accordance with Paterson's recommendations could be issued upon request, following the completion of a satisfactory material testing and observation program by the geotechnical consultant.

8.0 Statement of Limitations

The recommendations made in this report are in accordance with Paterson's present understanding of the project. Paterson requests permission to review the grading plan once available. Paterson's recommendations should be reviewed when the drawings and specifications are complete.

The client should be aware that any information pertaining to soils and the test hole log are furnished as a matter of general information only. Test hole descriptions or logs are not to be interpreted as descriptive of conditions at locations other than those of the test holes.

A soils investigation is a limited sampling of a site. Should any conditions at the site be encountered which differ from those at the test locations, Paterson requests to be notified immediately in order to permit reassessment of the recommendations.

The present report applies only to the project described in this document. Use of this report for purposes other than those described herein or by person(s) other than 2447591 Ontario Inc. or their agent(s) is not authorized without review by this firm for the applicability of our recommendations to the altered use of the report.

Paterson Group Inc.

LICENSED PROFESSIONAL ENGINEER
Aug. 4-2017
D. J. GILBERT
100116130
PROVINCE OF ONTARIO

Colin Belcourt, M.Eng.

David J. Gilbert, P.Eng.

Report Distribution:

- ☐ 2447591 Ontario Inc. (4 copies)
- ☐ Paterson Group (1 copy)

APPENDIX 1

SOIL PROFILE AND TEST DATA SHEETS

SYMBOLS AND TERMS

ANALYTICAL TEST RESULTS

patersongroup Consulting Engineers

154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. **PG4049**

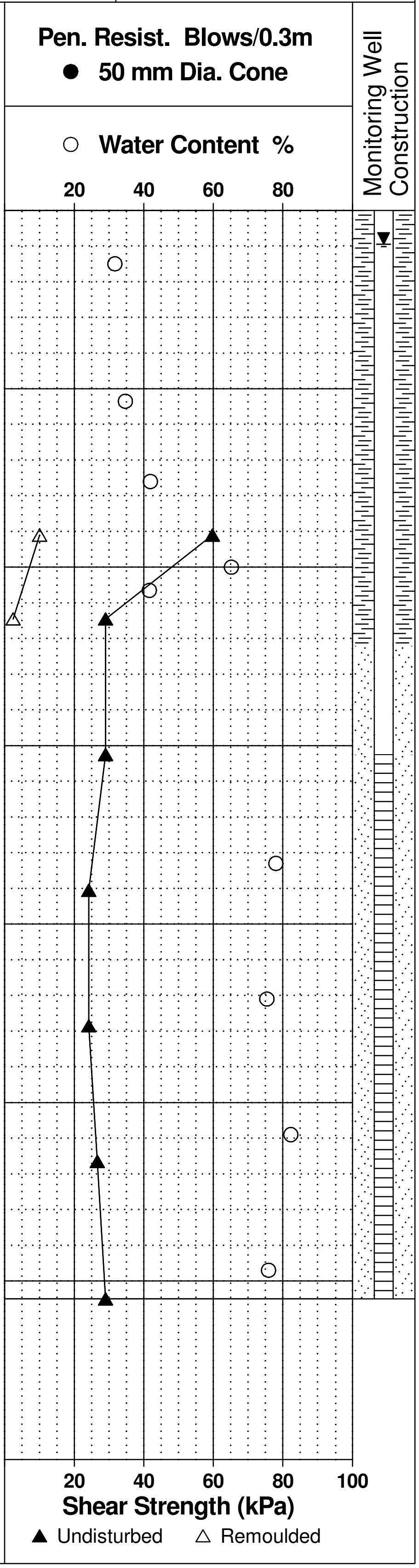
REMARKS

HOLE NO. **MW 1A**

BORINGS BY CME 55 Power Auger

DATE February 27, 2017

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE					0	86.76
TOPSOIL 0.28	AU	1				
Very stiff to stiff, brown **SILTY CLAY,** trace sand	SS	2	100	4	1	85.76
1.80	SS	3	92	P	2	84.76
Firm, grey **SILTY CLAY,** trace sand					3	83.76
					4	82.76
					5	81.76
6.10					6	80.76
End of Monitoring Well (GWL @ 0.19m - May 2, 2017)						



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

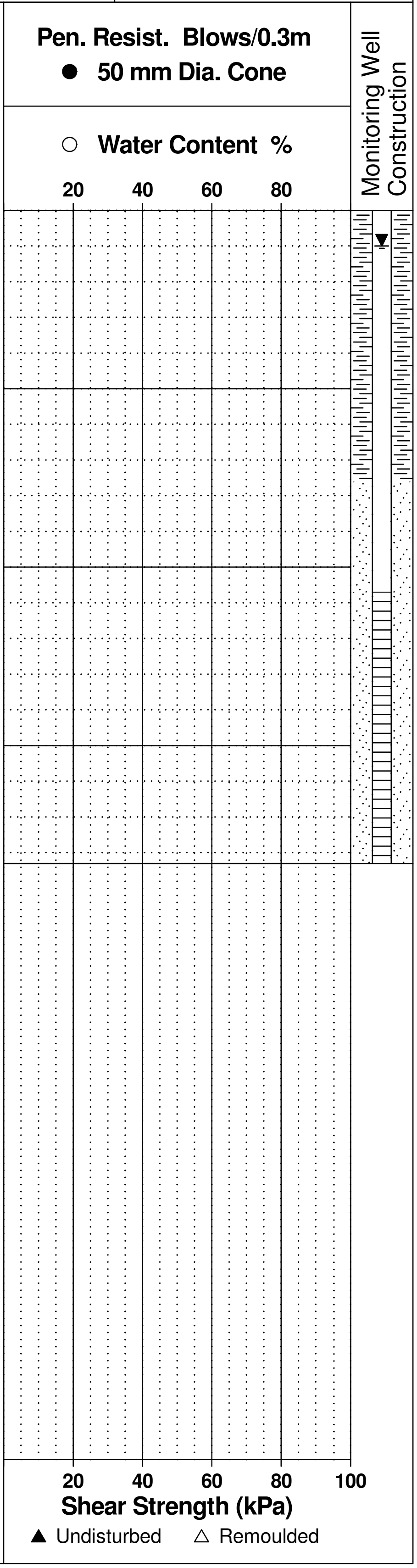
BORINGS BY CME 55 Power Auger

DATE February 27, 2017

FILE NO. PG4049

HOLE NO. MW 1B

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						0	86.76
TOPSOIL ... 0.28	■						
Very stiff to stiff, brown **SILTY CLAY,** trace sand ... 1.80	▨					1	85.76
						2	84.76
Firm, grey **SILTY CLAY,** trace sand ... 3.66	▨					3	83.76
End of Monitoring Well (GWL @ 0.20m - May 2, 2017)							



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
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Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

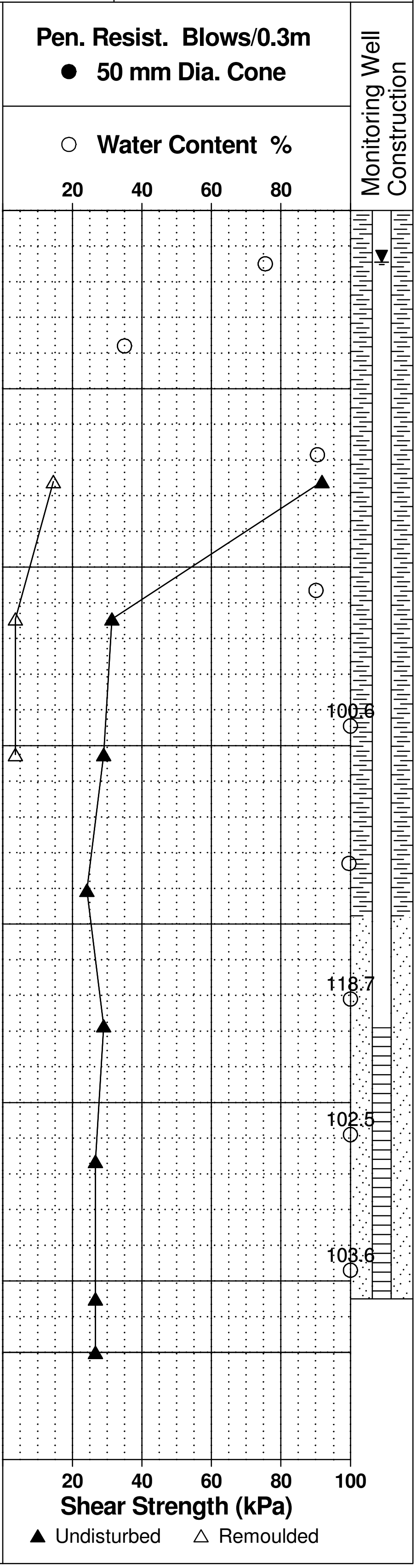
BORINGS BY CME 55 Power Auger

DATE February 27, 2017

FILE NO. PG4049

HOLE NO. MW 2A

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						0	86.40
TOPSOIL 0.25		AU	1				
Very stiff to stiff, brown **SILTY CLAY,** trace sand 2.70		SS	2	83	4	1	85.40
						2	84.40
Firm, grey **SILTY CLAY,** trace sand 6.40						3	83.40
						4	82.40
						5	81.40
						6	80.40
End of Monitoring Well (GWL @ 0.29m - May 2, 2017)							



SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

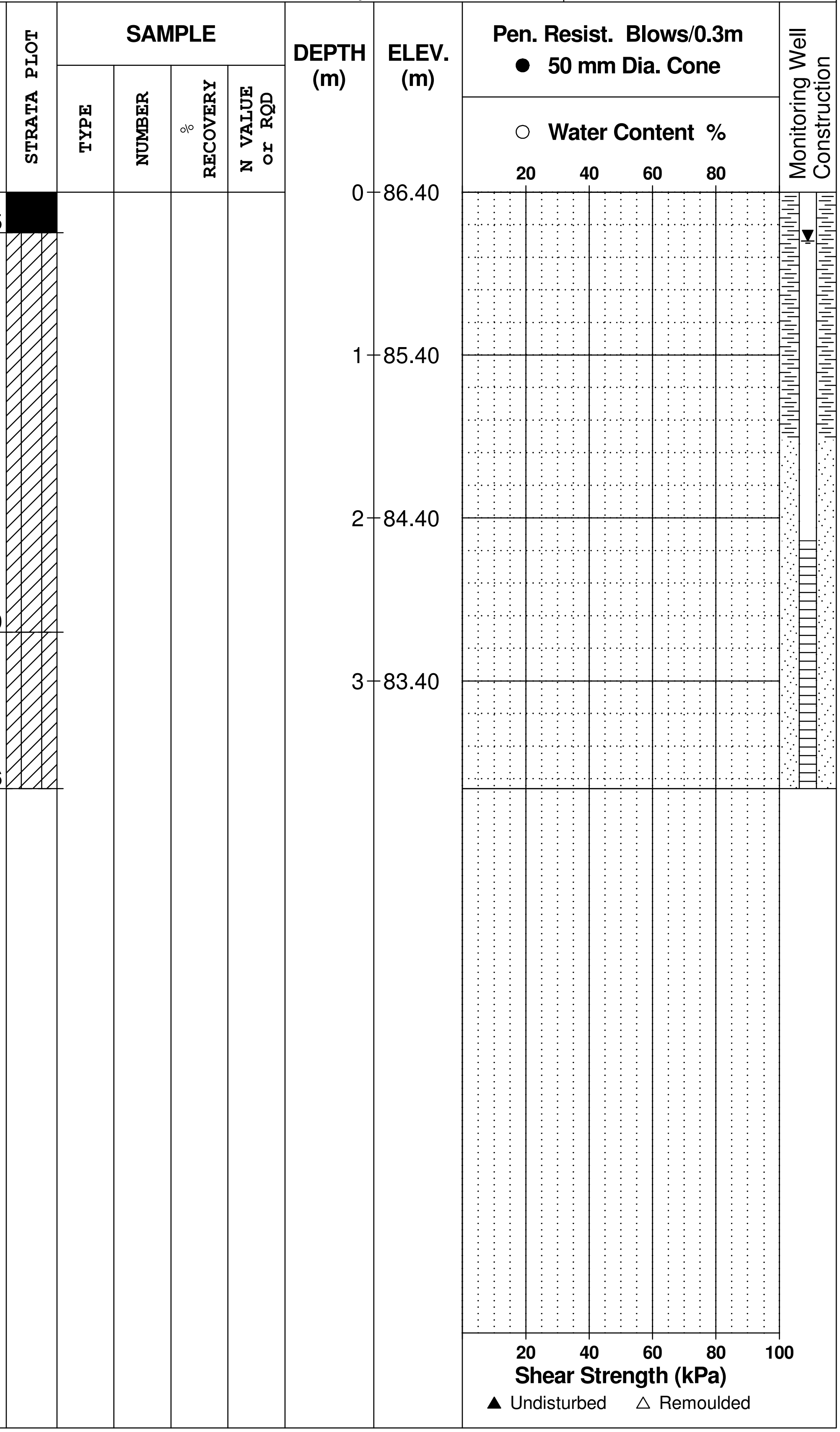
FILE NO. PG4049

REMARKS

HOLE NO. MW 2B

BORINGS BY CME 55 Power Auger **DATE** February 27, 2017

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						0	86.40
TOPSOIL — 0.25							
Very stiff to stiff, brown **SILTY CLAY,** trace sand — 2.70						1	85.40
						2	84.40
Firm, grey **SILTY CLAY,** trace sand — 3.66						3	83.40
End of Monitoring Well (GWL @ 0.30m - May 2, 2017)							



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. **PG4049**

REMARKS

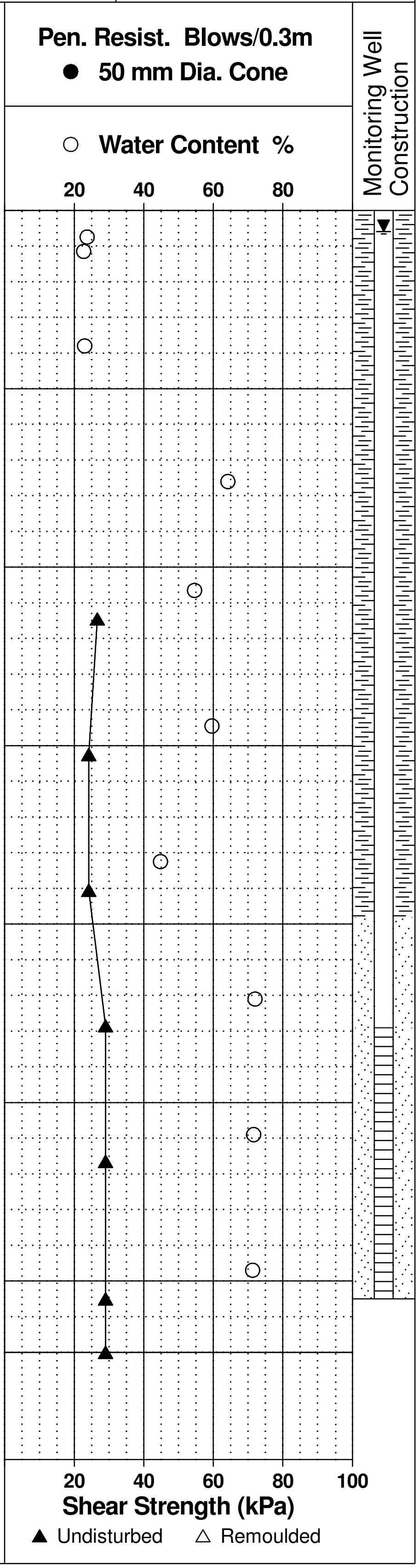
HOLE NO. **MW 3A**

BORINGS BY CME 55 Power Auger

DATE February 28, 2017

SOIL DESCRIPTION	Bottom depth (m)	SAMPLE TYPE	NUMBER	% RECOVERY	N VALUE or RQD
GROUND SURFACE					
TOPSOIL	0.20	AU	1		
Compact, brown **SILTY SAND**	1.22	SS	2	38	11
Firm, brown **SILTY CLAY,** some sand - grey by 2.0m depth	6.40	SS	3	92	2
End of Monitoring Well (GWL @ 0.12m - May 2, 2017)					

DEPTH (m)	ELEV. (m)
0	86.82
1	85.82
2	84.82
3	83.82
4	82.82
5	81.82
6	80.82



SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. **PG4049**

REMARKS

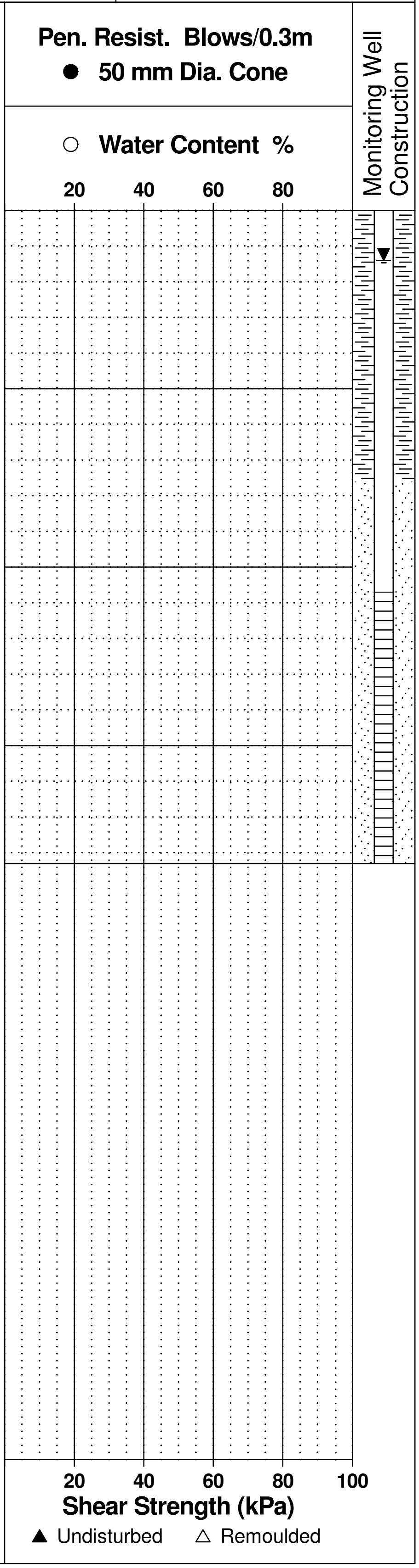
HOLE NO. **MW 3B**

BORINGS BY CME 55 Power Auger

DATE February 28, 2017

SOIL DESCRIPTION	Bottom depth (m)
GROUND SURFACE	
TOPSOIL	0.20
Compact, brown **SILTY SAND**	1.22
Firm, brown **SILTY CLAY,** some sand - grey by 2.0m depth	3.66
Dynamic Cone Penetration Test (DCPT) commenced at 3.66m depth. Cone pushed to 30.48m depth. No refusal encountered. (GWL @ 0.28m - May 2, 2017)	

STRATA PLOT	SAMPLE TYPE	NUMBER	% RECOVERY	N VALUE or RQD	DEPTH (m)	ELEV. (m)
					0	86.82
					1	85.82
					2	84.82
					3	83.82



SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. PG4049

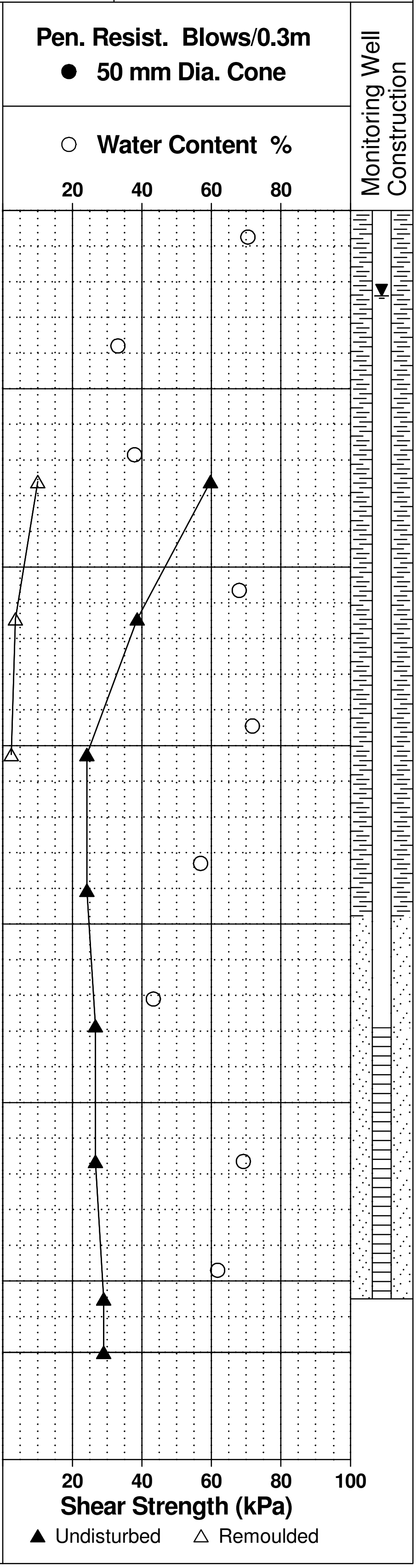
REMARKS

HOLE NO. MW 4A

BORINGS BY CME 55 Power Auger **DATE** February 28, 2017

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD
GROUND SURFACE				
TOPSOIL (to 0.30)	AU	1		
Very stiff to stiff, brown **SILTY CLAY,** trace sand (0.30 to 2.00)	SS	2	42	6
Firm, grey **SILTY CLAY,** trace sand (2.00 to 6.40)				
End of Monitoring Well (GWL @ 0.48m - May 2, 2017)				

DEPTH (m)	ELEV. (m)
0	86.41
1	85.41
2	84.41
3	83.41
4	82.41
5	81.41
6	80.41



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

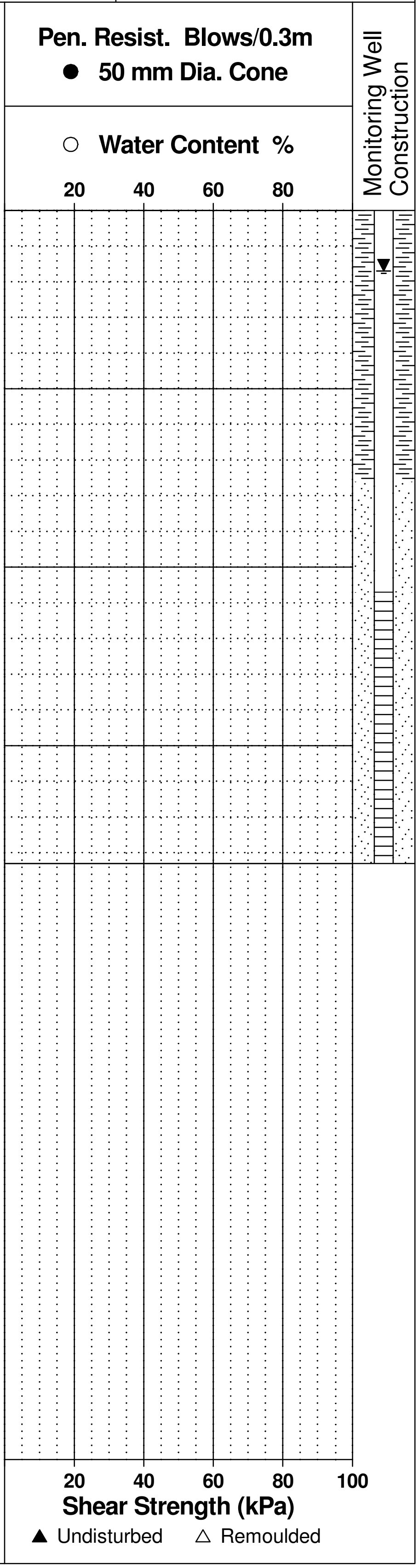
BORINGS BY CME 55 Power Auger

DATE February 28, 2017

FILE NO. PG4049

HOLE NO. MW 4B

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						0	86.41
TOPSOIL 0.30							
Very stiff to stiff, brown **SILTY CLAY,** trace sand						1	85.41
2.00						2	84.41
Firm, grey **SILTY CLAY,** trace sand						3	83.41
3.66							
End of Monitoring Well (GWL @ 0.34m - May 2, 2017)							



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

BORINGS BY CME 55 Power Auger

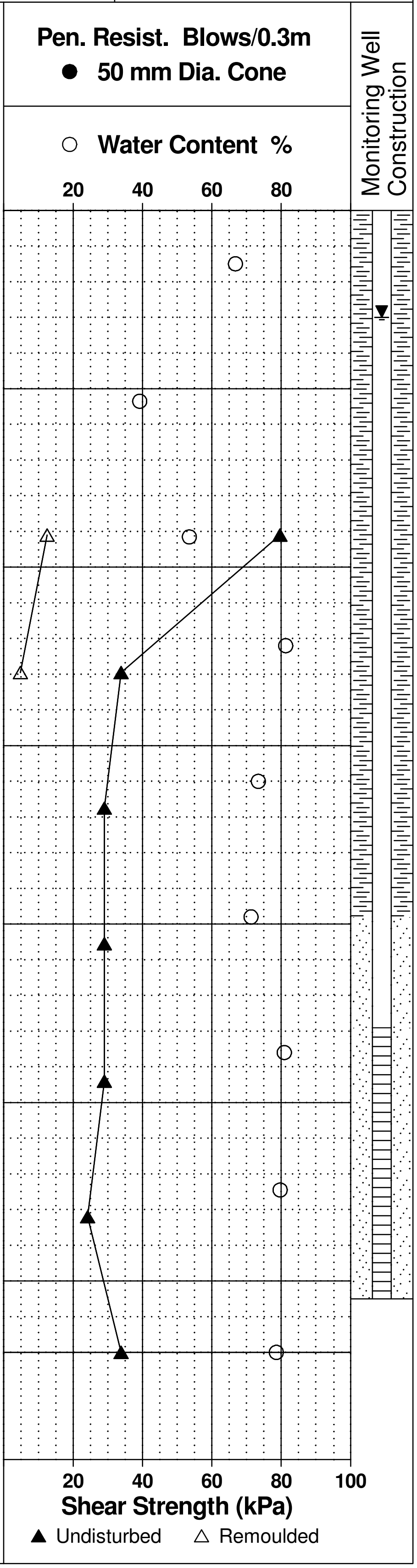
DATE February 28, 2017

FILE NO. PG4049

HOLE NO. MW 5A

SOIL DESCRIPTION		SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD
GROUND SURFACE					
TOPSOIL	0.28	AU	1		
Stiff to firm, brown **SILTY CLAY,** trace sand	3.00	SS	2	83	4
		SS	3	100	P
Firm, grey **SILTY CLAY,** trace sand	6.40				
End of Monitoring Well (GWL @ 0.60m - May 2, 2017)					

DEPTH (m)	ELEV. (m)
0	86.55
1	85.55
2	84.55
3	83.55
4	82.55
5	81.55
6	80.55



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SOIL PROFILE AND TEST DATA

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Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

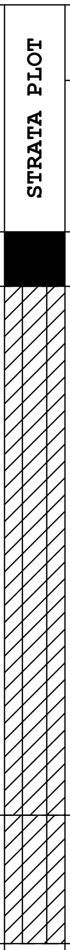
BORINGS BY CME 55 Power Auger

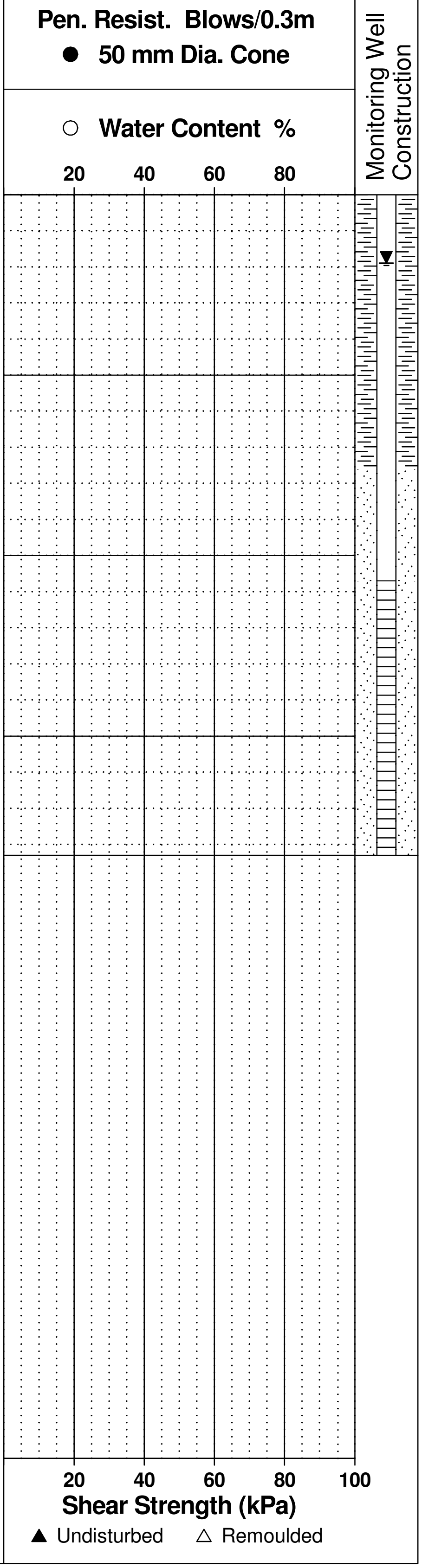
DATE February 28, 2017

FILE NO. PG4049

HOLE NO. MW 5B

SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	% RECOVERY	N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						
TOPSOIL 0.28					0	86.55
Stiff to firm, brown **SILTY CLAY,** trace sand 3.00					1	85.55
					2	84.55
Firm, grey **SILTY CLAY,** trace sand 3.66					3	83.55
End of Monitoring Well (GWL @ 0.38m - May 2, 2017)						





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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

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REMARKS

BORINGS BY CME 55 Power Auger

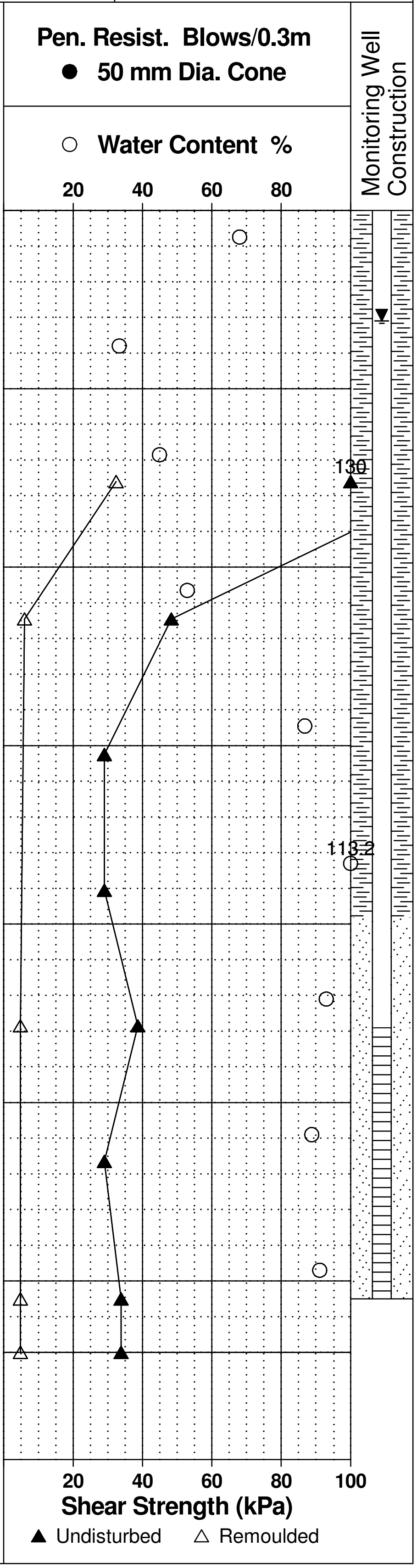
DATE February 28, 2017

FILE NO. PG4049

HOLE NO. MW 6A

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD
GROUND SURFACE					
TOPSOIL — 0.33		AU	1		
Very stiff to firm, brown **SILTY CLAY,** trace sand — 2.40		SS	2	75	7
Firm, grey **SILTY CLAY,** trace sand — 6.40					
End of Monitoring Well (GWL @ 0.62m - May 2, 2017)					

DEPTH (m)	ELEV. (m)
0	86.17
1	85.17
2	84.17
3	83.17
4	82.17
5	81.17
6	80.17



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. **PG4049**

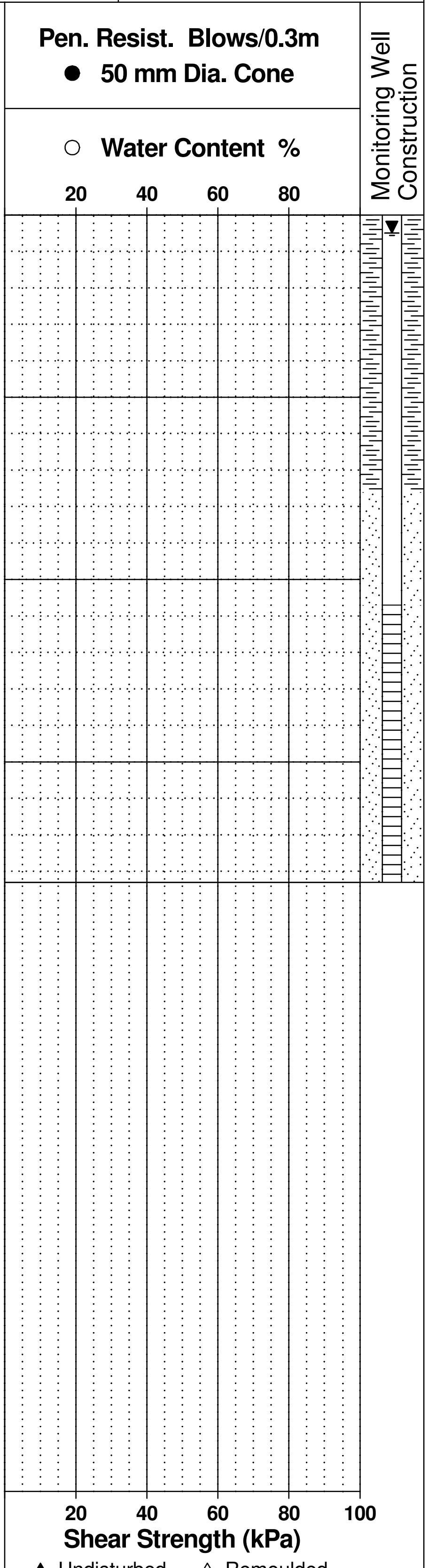
REMARKS

HOLE NO. **MW 6B**

BORINGS BY CME 55 Power Auger

DATE February 28, 2017

SOIL DESCRIPTION	STRATA PLOT	SAMPLE				DEPTH (m)	ELEV. (m)
		TYPE	NUMBER	% RECOVERY	N VALUE or RQD		
GROUND SURFACE						0	86.17
TOPSOIL 0.33	■						
Very stiff to firm, brown **SILTY CLAY,** trace sand 2.40	▨					1	85.17
						2	84.17
Firm, grey **SILTY CLAY,** trace sand 3.66	▨					3	83.17
End of Monitoring Well (GWL @ 0.10m - May 2, 2017)							



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

REMARKS

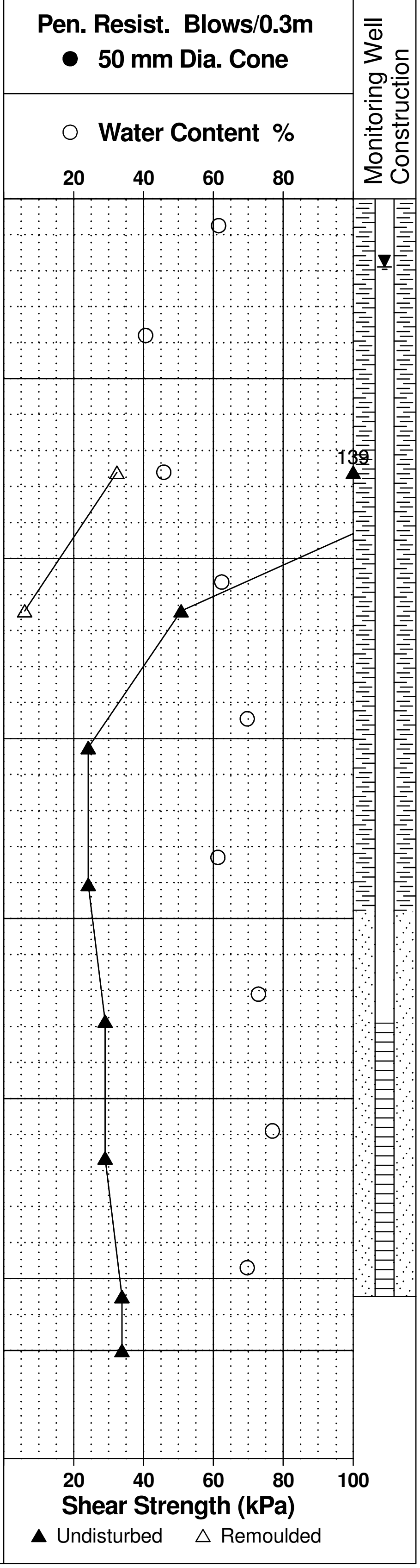
BORINGS BY CME 55 Power Auger

DATE February 28, 2017

FILE NO. PG4049

HOLE NO. MW 7A

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE					0	86.60
TOPSOIL 0.36	AU	1				
	SS	2	75	5		
					1	85.60
Very stiff to stiff, brown **SILTY CLAY,** trace sand	SS	3	92	P		
2.60					2	84.60
					3	83.60
					4	82.60
Soft to firm, grey **SILTY CLAY,** trace sand					5	81.60
6.40					6	80.60
End of Monitoring Well (GWL @ 0.38m - May 2, 2017)						



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SOIL PROFILE AND TEST DATA

Geotechnical Residential
Residential Development - Summerside West Phase 4 & 5
Tenth Line Road, Ottawa, Ontario

DATUM Ground surface elevations provided by J.D. Barnes Limited.

FILE NO. **PG4049**

REMARKS

HOLE NO. **MW 7B**

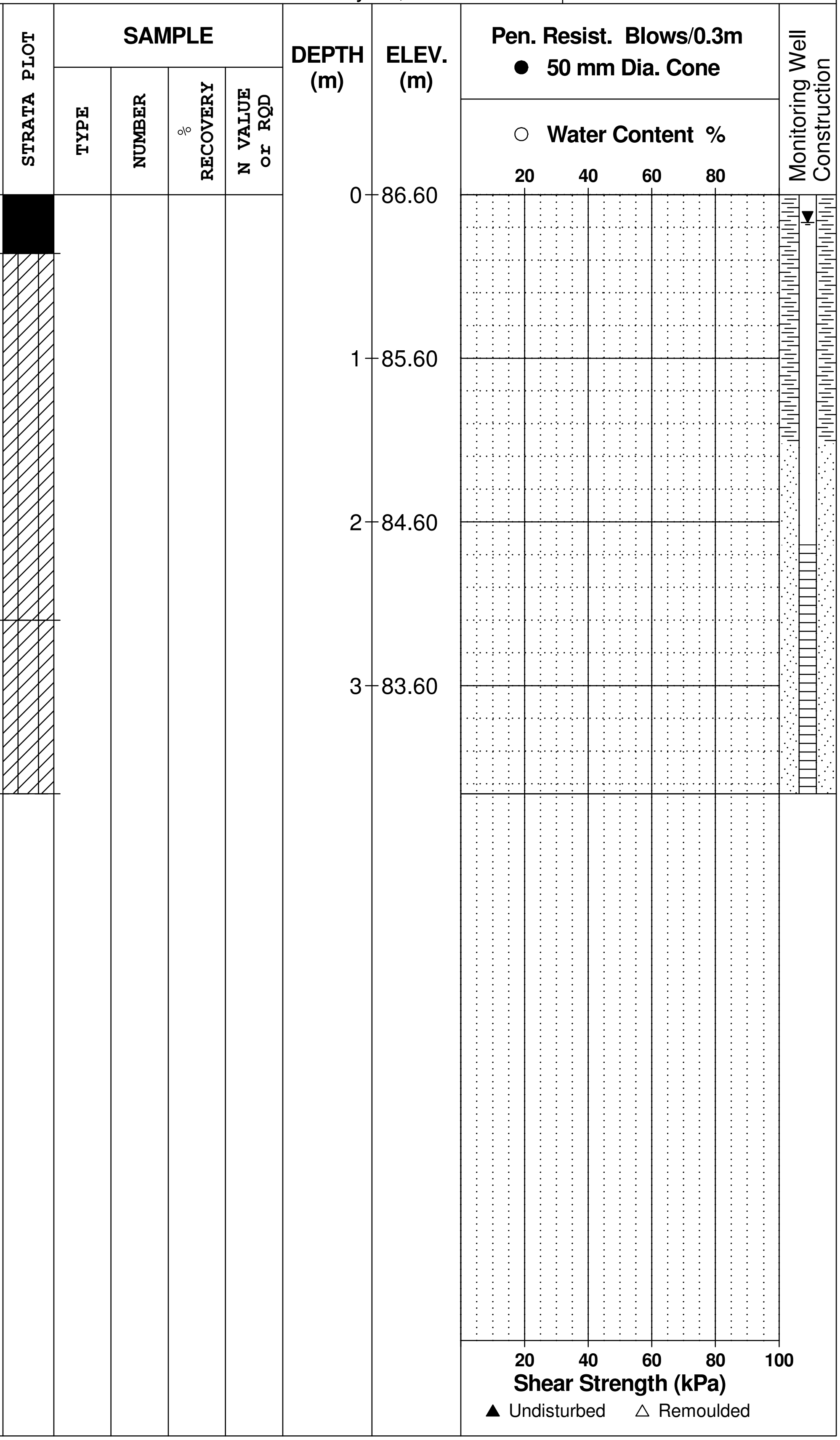
BORINGS BY CME 55 Power Auger

DATE February 28, 2017

SOIL DESCRIPTION	Depth to base (m)
GROUND SURFACE	
TOPSOIL	0.36
Very stiff to stiff, brown **SILTY CLAY,** trace sand	2.60
Soft to firm, grey **SILTY CLAY,** trace sand	3.66

End of Monitoring Well

(GWL @ 0.17m - May 2, 2017)



SYMBOLS AND TERMS

SOIL DESCRIPTION

Behavioural properties, such as structure and strength, take precedence over particle gradation in describing soils. Terminology describing soil structure are as follows:

Desiccated	-	having visible signs of weathering by oxidation of clay minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure.
Varved	-	composed of regular alternating layers of silt and clay.
Stratified	-	composed of alternating layers of different soil types, e.g. silt and sand or silt and clay.
Well-Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes (see Grain Size Distribution).
Uniformly-Graded	-	Predominantly of one grain size (see Grain Size Distribution).

The standard terminology to describe the strength of cohesionless soils is the relative density, usually inferred from the results of the Standard Penetration Test (SPT) ‘N’ value. The SPT N value is the number of blows of a 63.5 kg hammer, falling 760 mm, required to drive a 51 mm O.D. split spoon sampler 300 mm into the soil after an initial penetration of 150 mm.

Relative Density	‘N’ Value	Relative Density %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe the strength of cohesive soils is the consistency, which is based on the undisturbed undrained shear strength as measured by the in situ or laboratory vane tests, penetrometer tests, unconfined compression tests, or occasionally by Standard Penetration Tests.

Consistency	Undrained Shear Strength (kPa)	‘N’ Value
Very Soft	<12	<2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

SYMBOLS AND TERMS (continued)

SOIL DESCRIPTION (continued)

Cohesive soils can also be classified according to their “sensitivity”. The sensitivity is the ratio between the undisturbed undrained shear strength and the remoulded undrained shear strength of the soil.

Terminology used for describing soil strata based upon texture, or the proportion of individual particle sizes present is provided on the Textural Soil Classification Chart at the end of this information package.

ROCK DESCRIPTION

The structural description of the bedrock mass is based on the Rock Quality Designation (RQD).

The RQD classification is based on a modified core recovery percentage in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be a result of closely-spaced discontinuities (resulting from shearing, jointing, faulting, or weathering) in the rock mass and are not counted. RQD is ideally determined from NXL size core. However, it can be used on smaller core sizes, such as BX, if the bulk of the fractures caused by drilling stresses (called “mechanical breaks”) are easily distinguishable from the normal in situ fractures.

RQD %	**ROCK QUALITY**
90-100	Excellent, intact, very sound
75-90	Good, massive, moderately jointed or sound
50-75	Fair, blocky and seamy, fractured
25-50	Poor, shattered and very seamy or blocky, severely fractured
0-25	Very poor, crushed, very severely fractured

SAMPLE TYPES

SS	-	Split spoon sample (obtained in conjunction with the performing of the Standard Penetration Test (SPT))
TW	-	Thin wall tube or Shelby tube
PS	-	Piston sample
AU	-	Auger sample or bulk sample
WS	-	Wash sample
RC	-	Rock core sample (Core bit size AXT, BXL, etc.). Rock core samples are obtained with the use of standard diamond drilling bits.

SYMBOLS AND TERMS (continued)

GRAIN SIZE DISTRIBUTION

MC% - Natural moisture content or water content of sample, %

LL - Liquid Limit, % (water content above which soil behaves as a liquid)

PL - Plastic limit, % (water content above which soil behaves plastically)

PI - Plasticity index, % (difference between LL and PL)

Dxx - Grain size which xx% of the soil, by weight, is of finer grain sizes
These grain size descriptions are not used below 0.075 mm grain size

D10 - Grain size at which 10% of the soil is finer (effective grain size)

D60 - Grain size at which 60% of the soil is finer

Cc - Concavity coefficient = $(D30)^2$ / (D10 x D60)

Cu - Uniformity coefficient = D60 / D10

Cc and Cu are used to assess the grading of sands and gravels:
Well-graded gravels have: $1 < Cc < 3$ and $Cu > 4$
Well-graded sands have: $1 < Cc < 3$ and $Cu > 6$
Sands and gravels not meeting the above requirements are poorly-graded or uniformly-graded.
Cc and Cu are not applicable for the description of soils with more than 10% silt and clay
(more than 10% finer than 0.075 mm or the #200 sieve)

CONSOLIDATION TEST

p'_o - Present effective overburden pressure at sample depth

p'_c - Preconsolidation pressure of (maximum past pressure on) sample

Ccr - Recompression index (in effect at pressures below p'_c)

Cc - Compression index (in effect at pressures above p'_c)

OC Ratio Overconsolidaton ratio = p'_c / p'_o

Void Ratio Initial sample void ratio = volume of voids / volume of solids

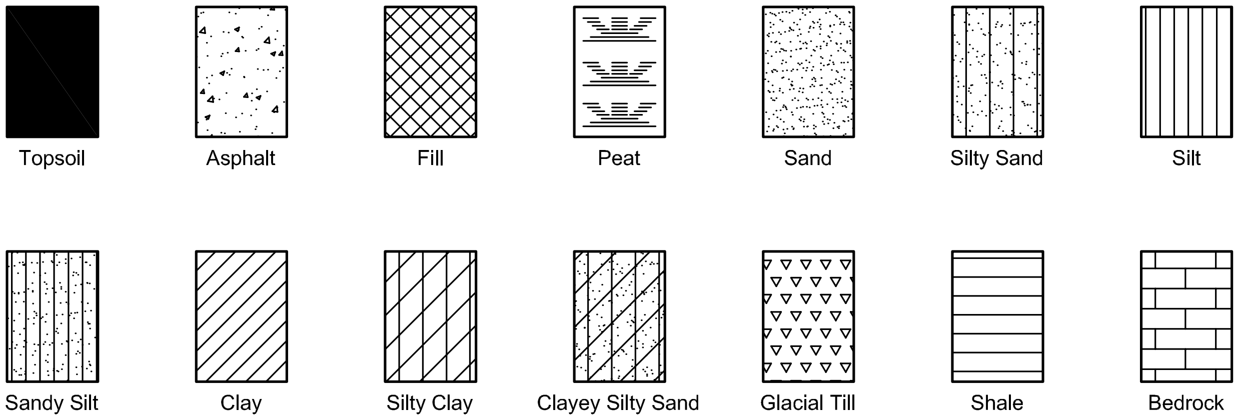
Wo - Initial water content (at start of consolidation test)

PERMEABILITY TEST

k - Coefficient of permeability or hydraulic conductivity is a measure of the ability of water to flow through the sample. The value of k is measured at a specified unit weight for (remoulded) cohesionless soil samples, because its value will vary with the unit weight or density of the sample during the test.

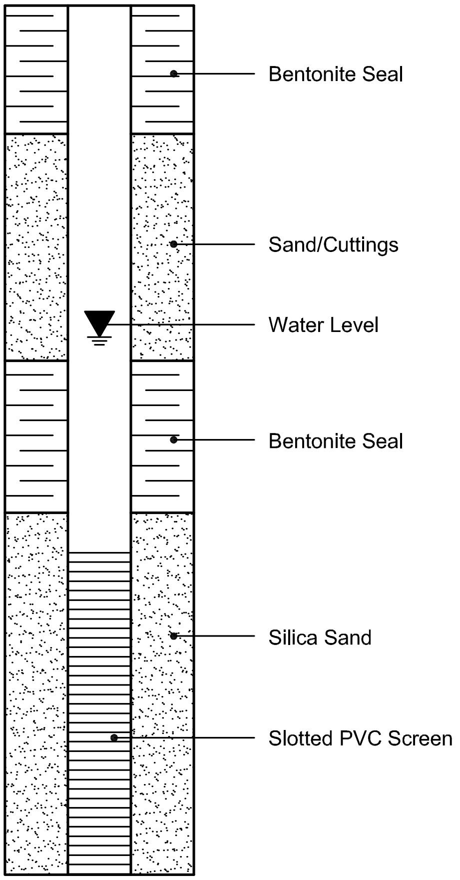
SYMBOLS AND TERMS (continued)

STRATA PLOT

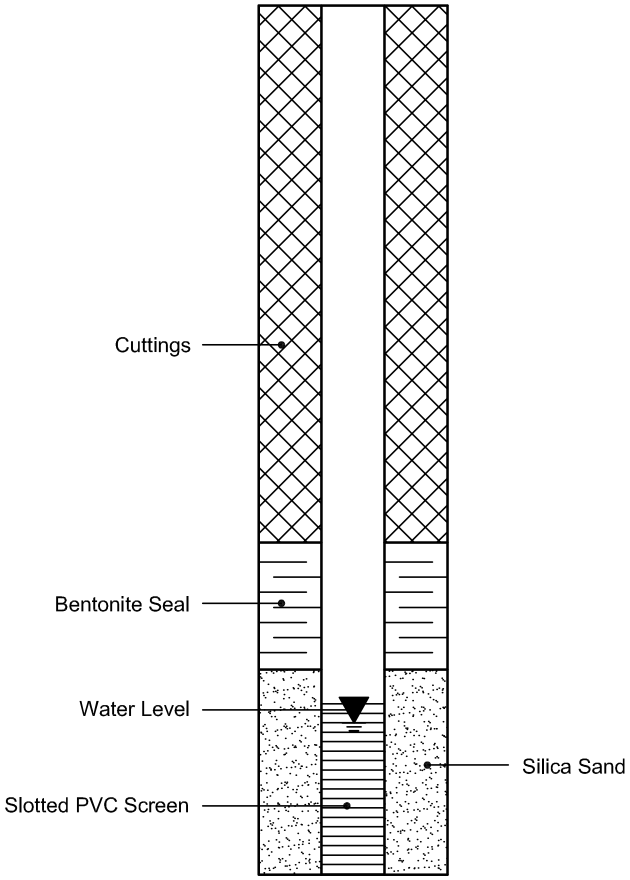


MONITORING WELL AND PIEZOMETER CONSTRUCTION

MONITORING WELL CONSTRUCTION



PIEZOMETER CONSTRUCTION



Certificate of Analysis

Client: Paterson Group Consulting Engineers

Client PO: 21693

Report Date: 07-Mar-2017

Order Date: 3-Mar-2017

Project Description: PG4049

	Client ID:	MW1-SS3	-	-	-
	Sample Date:	27-Feb-17	-	-	-
	Sample ID:	1709440-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	69.4	-	-	-
General Inorganics					
pH	0.05 pH Units	7.62	-	-	-
Resistivity	0.10 Ohm.m	8.69	-	-	-
Anions					
Chloride	5 ug/g dry	496	-	-	-
Sulphate	5 ug/g dry	177	-	-	-

APPENDIX 2

FIGURE 1 - KEY PLAN

DRAWING PG4049-1 - TEST HOLE LOCATION PLAN

FIGURE 1

KEY PLAN

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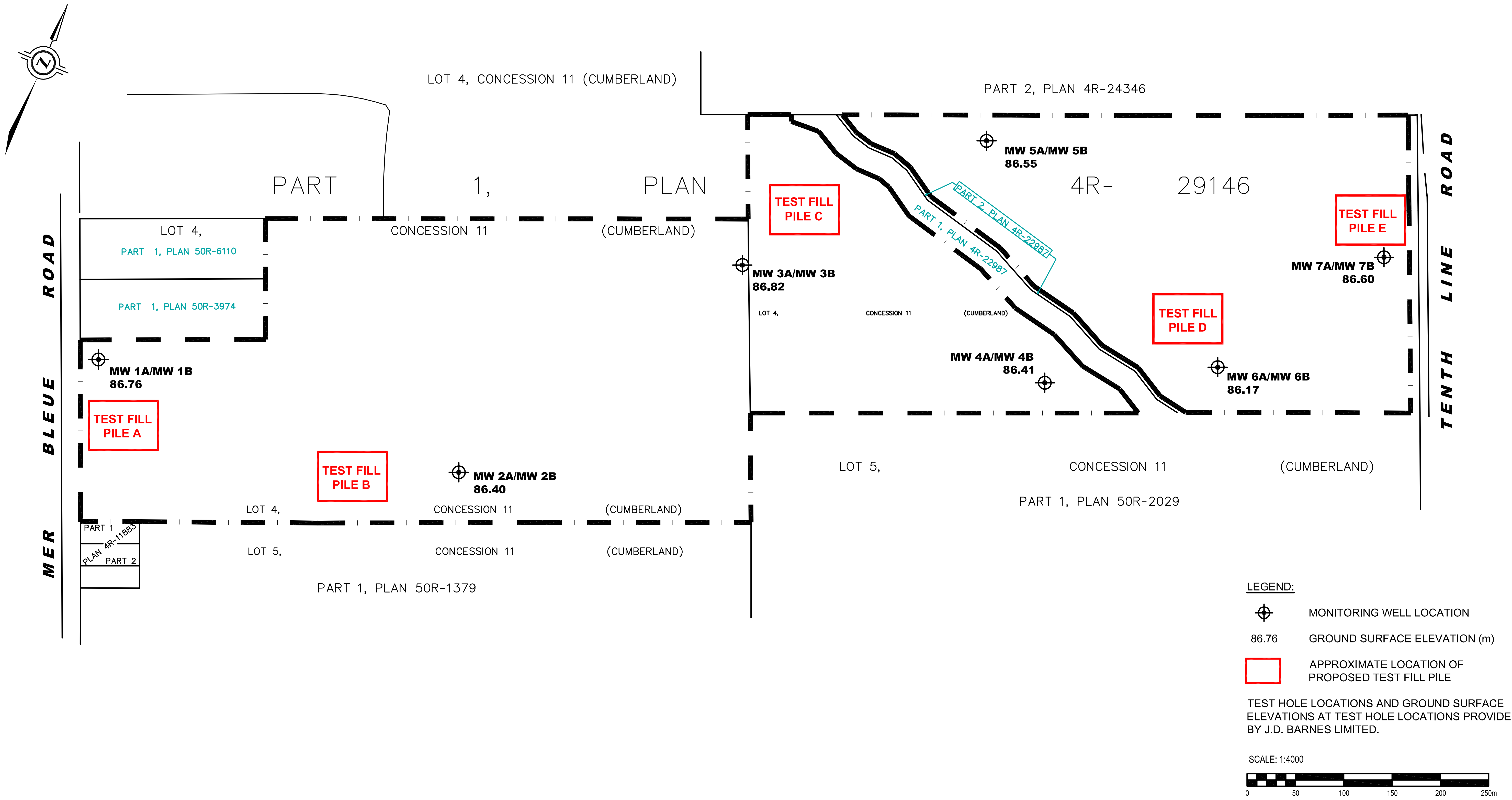

patersongroup
consulting engineers

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Tel: (613) 226-7381 Fax: (613) 226-6344

NO.	REVISIONS	DATE	INITIAL
0			

2447591 ONTARIO INC.
GEOTECHNICAL INVESTIGATION
RESIDENTIAL DEVELOPMENT - SUMMERSIDE WEST PHASES 4 & 5
OTTAWA, ONTARIO

Title:
TEST HOLE LOCATION PLAN

Scale: 1:4000	Date: 05/2017
Drawn by: MPG	Report No.: PG4049-1
Checked by: CB	Dwg. No.: PG4049-1
Approved by: DJG	Revision No.: 0

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