



CHUNG & VANDER DOELEN
ENGINEERING LTD.

**GEOTECHNICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT**

310-316 Erb Street West
Waterloo, Ontario

SUBMITTED TO:

Urban Legend Developments Ltd.
22 King Street South, Suite 300
Waterloo, Ontario
N2J 1N8

ATTENTION:

Mr. Jason Malfara



CHUNG & VANDER DOELEN
ENGINEERING LTD.

311 VICTORIA STREET NORTH
KITCHENER / ONTARIO / N2H 5E1
519-742-8979

March 31, 2020
File No.: G19849

Urban Legend Developments Ltd.
22 King Street South, Suite 300
Waterloo, Ontario
N2J 1N8

Attention: Mr. Jason Malfara

RE: Geotechnical Investigation
Proposed Residential Development
310-316 Erb Street West, Ontario

We take pleasure in enclosing one (1) copy of our Geotechnical Investigation Report carried out at the above-referenced Site. Soil samples will be retained for a period of three (3) months and will thereafter be disposed of unless we are otherwise instructed.

If you have any questions or clarifications are required, please contact the undersigned at your convenience.

We thank you for giving us this opportunity to be of service to you.

Yours truly,
CHUNG & VANDER DOELEN ENGINEERING LTD.

Eric Y. Chung, M. Eng., P.Eng.
Principal Engineer

TABLE OF CONTENTS

	Page
Letter of Transmittal	i
Table of Contents	ii
List of Enclosures	ii
1.0 INTRODUCTION	1
2.0 FIELD WORK	1
3.0 LABORATORY TESTING	2
4.0 EXISTING SITE CONDITIONS	2
5.0 SUBSURFACE CONDITIONS	3
5.1 Pavement and Topsoil	3
5.2 Fill	3
5.3 Buried Topsoil	3
5.4 Fine Granular Deposits.....	4
5.5 Sand	4
5.6 Silt	4
5.7 Clayey Silt Till	5
5.8 Sand and Gravel	5
5.9 Groundwater.....	6
6.0 DISCUSSION AND RECOMMENDATIONS.....	7
6.1 General.....	7
6.2 One Level Basement/Underground Parking	7
6.3 Footing Foundations	8
6.4 Engineered Fill Construction.....	9
6.5 Earthquake Considerations.....	10
6.6 Open Cut Excavation and Groundwater Control	10
6.7 Shored Excavation.....	11
6.8 Floor Slab Construction.....	12
6.9 Lateral Earth Pressure.....	13
6.10 On Site Infiltration.....	14
7.0 CLOSURE.....	15

LIST OF ENCLOSURES

Appendix A	Limitations of Report
Enclosures 1 to 5	Borehole Log Sheets 1 to 5
Enclosures 6 to 10	Grain Size Distribution Charts
Drawing No. 1	Borehole Location Plan



1.0 INTRODUCTION

CHUNG & VANDER DOELEN ENGINEERING LTD. (CVD) has been retained by Urban Legend Developments Ltd. to carry out a geotechnical investigation for the proposed residential development at 310-316 Erb Street West, Waterloo, Ontario.

It is understood that the four (4) existing residential dwellings at the site are to be demolished and redeveloped with a new 6-storey residential building with one (1) level of underground parking/basement. The proposed finished floor elevation of the underground parking/basement level is to be 337.00 m according to the most recent site plan provided to CVD. Site grading plan was not available at the time of reporting.

The purpose of this investigation was to determine the subsurface conditions at the site and, based on the findings, to make geotechnical recommendations for:

- Foundation design recommendations;
- Engineered fill construction;
- Excavation condition;
- Groundwater control during and after construction;
- Slab-on-grade design;
- Backfilling recommendations;
- Foundation soil classification seismic design per OBC 2012;
- Foundation and retaining wall design; and
- Shoring design

Infiltration rates of the various soil deposits encountered during the investigation will also be provided.

2.0 FIELD WORK

In order to investigate the subsurface conditions at the site, five (5) boreholes were advanced to depths between 9.60 and 12.65 m below ground surface on December 9 and 10, 2019 and March 11, 2020 as part of the investigation. The borehole locations are indicated on the Borehole Location Plan, Drawing No. 1.

The field work was carried out under the supervision of a member of our engineering team, who logged the boreholes in the field, effected the subsurface sampling, and monitored the groundwater conditions. The boreholes were advanced using a track-mounted drilling rig, supplied and operated by a specialized contractor. The drill rig was equipped with continuous flight augers and standard soil sampling equipment. Standard penetration tests (SPTs) in accordance with ASTM Specification D1586, were carried out at frequent intervals of depth, and the results are shown on the Borehole Logs as Penetration Resistance or “N”-values.



Dynamic Cone Penetration testing (DCPT) was conducted below the sampled depth at Borehole 1 to a depth of 12.35 m below existing grade. The undrained shear strength of the cohesive soil deposits was determined on the slightly disturbed SPT samples using a field penetrometer. The compactness condition or consistency of the soil strata has been inferred from these test results.

Groundwater conditions were monitored during advancement of the borehole augering and immediately following the withdrawal of the drilling augers at each borehole location. In addition, three (3) monitoring wells were installed in Boreholes 1, 3 and 4 to enable measurement of the stabilized groundwater table.

The location and ground surface elevation of the boreholes were surveyed by CVD for the purpose of this report. The ground surface elevations were referenced to a temporary benchmark (TBM) which is shown on Drawing No. 1 and described below:

TBM: Top of manhole in centreline of Erb Street West at intersection with Mulberry Lane, as shown on Drawing No. 1
Elevation: 339.73 m (Geodetic)

3.0 LABORATORY TESTING

Soil samples obtained from the in-situ tests were examined in the field and subsequently brought to our laboratory for visual and tactile examination to confirm field classification. Moisture content determination of all retrieved samples occurred.

In addition, five (5) grain size distribution analyses were performed on the major soil deposits to confirm field identification and to provide information on the soil hydraulic conductivity for the design of infiltration galleries.

4.0 EXISTING SITE CONDITIONS

The site is bound to the north by existing residences, to the east by a church, to the south by Erb Street West and to the west by an apartment building.

The site is currently comprised of four (4) adjoining properties consisting of two (2) 1-storey residences and two (2) 2-storey residences. Asphalt paved driveways are located in front or beside all of the residences, however, the driveway at Residence No. 314 extends behind Residences No. 312 and 314 to a gravel-based parking area that is raised and supported by a block retaining wall. Mature trees are scattered throughout the site and the remainder is grass covered.

The ground surface of site generally declines in elevation from south to north with the exception of a relatively level-graded raised parking lot supported by a retaining wall behind Residences No. 312 and 314. Ground surface elevations at the borehole locations ranged between 337.84 and 339.95 m.



5.0 SUBSURFACE CONDITIONS

The detailed subsurface conditions encountered in the five (5) boreholes advanced as part of this preliminary investigation are shown on the Borehole Log Sheets, Enclosures 1 to 5. The following sections provide descriptions of the major soil deposits encountered in the boreholes.

The stratigraphic boundaries shown on the borehole logs are inferred from non-continuous sampling conducted during advancement of the borehole drilling procedures and, therefore, represent transitions between soil types rather than exact planes of geologic change. The subsurface conditions will vary between and beyond the borehole locations.

5.1 Pavement and Topsoil

Asphalt pavement was encountered at ground surface at Borehole 1 with a measured asphalt thickness of 50 mm and granular base thickness of 400 mm.

Topsoil was encountered at ground surface at Boreholes 3 to 5 with measured thicknesses between 200 and 880 mm.

5.2 Fill

A layer of fill materials was encountered underlying the pavement structure at Borehole 1, below the topsoil at Borehole 5 and at ground surface at Borehole 2. The fill layer extended to depths between 1.00 and 1.85 m below ground surface. It is noted that fill materials could be deeper adjacent to the basements of the existing structures. The fill at Boreholes 1 and 5 was comprised of fine granular soils ranging from silty sand to sandy silt with traces of gravel and clay and the fill at Borehole 2 was comprised of sand and gravel with trace to some silt. Traces of topsoil/organics were observed within the fill at Boreholes 1 and 5. Occasional silt pockets were observed within the silty sand fill at Borehole 5.

The SPT “N”-values measured within the fill materials ranged from 6 to 26 blows per 300 mm of penetration, indicating a loose to compact compactness condition. Natural moisture contents were measured between 4 and 23%, indicating a moist moisture condition. Elevated moisture contents are likely due to the presence of organics.

5.3 Buried Topsoil

A layer of buried topsoil was encountered at underlying the fill materials at Boreholes 2 and 5 with a thickness of 550± mm.



5.4 Fine Granular Deposits

Fine granular deposits were encountered at Borehole 1 below the fill materials and at Boreholes 3 and 4 below the topsoil and extended to depths ranging between 1.35 and 4.00 m below ground surface. The deposits were comprised of sand and silt to sandy silt. Occasional sand seams/layers were observed within the deposit at Borehole 1, occasional clayey seams/layers were observed at Boreholes 3 and 4 and occasional sand seams were observed at Borehole 3.

The SPT “N”-values measured within the deposits ranged from 0 to 23 blows per 300 mm of penetration, indicating a very loose to compact compactness condition. Natural moisture contents were measured between 12 and 25%, indicating a moist to saturated moisture condition.

5.5 Sand

A sand deposit was encountered at Borehole 1 below the fine granular deposit and Borehole 5 underlying the buried topsoil. The deposit at Borehole 5 extended to a depth of 3.35 m below ground surface. Borehole 1 was terminated within the deposit which extended to a depth of 9.60 m below ground surface. An intermittent silt layer was encountered within the sand deposit in Borehole 1 at depths between 6.30 and 7.75 m.

The deposit contained trace to some silt and trace gravel. Occasional silty seams were observed within the deposit at Borehole 1. Results of one (1) grain size distribution analysis from Borehole 1 are shown graphically on Enclosure 6.

The SPT “N”-values measured within the deposit ranged from 13 to 42 blows per 300 mm of penetration. A DCPT was conducted beneath the conventionally drilled and sampled Borehole 1 to a depth of 12.35 m below existing grade and yielded values between 24 and 162 blows per 300 mm. Based on the test results, the deposit exhibited a compact to dense compactness condition. Natural moisture contents were measured between 13 and 22%, indicating a moist to saturated moisture condition.

5.6 Silt

A silt deposit was encountered at Borehole 2 underlying the buried topsoil layer, underlying the fine granular deposits at Borehole 3 and below the sand deposit at Borehole 5. The deposit extended to depths between 7.15 and 8.35 m below ground surface at Boreholes 3 and 5. Borehole 2 was terminated within the deposit which extended to a depth of 12.65 m below ground surface. The silt deposit at Borehole 1 was encountered between 6.30 and 7.75 m depths.

The deposit contained trace to some sand, trace gravel and trace clay. Occasional to frequent clayey seams/layers and sand/sand seams/layers were observed throughout the deposit. Results of three (3) grain size distribution analyses from Boreholes 2, 3 and 5 are shown graphically on Enclosures 7, 8 and 10.



The SPT “N”-values measured within the deposit ranged from 10 to 66 blows per 300 mm of penetration, indicating a compact to very dense compactness condition. Natural moisture contents were measured between 13 and 23%, indicating a moist to saturated moisture condition.

5.7 Clayey Silt Till

A deposit of clayey silt till was encountered at Borehole 4 underlying the fine granular deposits and at Borehole 5 underlying the silt deposit. Both boreholes were terminated within the till deposit to a depth of 9.60 m below existing grades. The till deposit contained trace to some sand and trace gravel. Occasional silt seams were observed throughout the deposit. Results of one (1) grain size distribution analysis from Borehole 4 are shown graphically on Enclosure 9.

The SPT “N”-values measured within the deposit ranged from 12 to 26 blows per 300 mm of penetration. The undrained shear strength obtained on the retrieved samples ranged from 60 kPa to over 250 kPa. Based on the above test results and tactile examination, the till is considered to have a stiff to very stiff consistency. The measured water content of the collected samples ranged between 16 and 22%, thus indicating a moist moisture condition.

5.8 Sand and Gravel

A sand and gravel deposit was encountered at Borehole 3 underlying the silt deposit. Borehole 3 was terminated within the deposit to a depth of a 9.60 m below ground surface. The deposit contained trace silt. Occasional cobbles and silt seams were observed within the deposit.

The SPT “N”-values measured within the deposit ranged from 35 to 37 blows per 300 mm of penetration, indicating a dense compactness condition. Natural moisture contents were measured between 9 and 17%, indicating a saturated moisture condition.



5.9 Groundwater

Groundwater conditions were monitored during advancement of the borehole augering and immediately following the withdrawal of the drilling augers at each borehole location.

In addition, three (3) monitoring wells were installed in Boreholes 1, 3 and 4. The table below summarizes the water level readings in the monitoring wells taken on March 17, 2020:

Borehole No.	Existing Ground Elevation (m)	Measured Water Level Below Existing Ground Surface (m)	Water Level Elevation (m)
1	339.95	2.70	337.25
3	338.29	0.00	338.29
4	337.84	1.24	336.60

Groundwater levels in monitoring wells at Boreholes 1, 3 and 4 were measured to depths between 0.00 (at ground surface) and 2.70 m below existing grades, corresponding to elevations between 336.60 and 338.29 m. The elevated groundwater level at Borehole 3 is likely due to being located in a “catchment” or “lower” topographical area and a “perched” groundwater condition in which the groundwater is sitting above the silt deposit containing clayey seams/layers.

Groundwater was observed at Borehole 5 at a depth of 5.35± m below ground surface upon withdrawal of the drilling augers and Borehole 2 experienced a wet cave-in to 5.2± m depth. However, elevated natural moisture contents were measured as high as 2.5± m below existing grades at both borehole locations.

Based on the observed/measured groundwater levels in the monitoring wells and boreholes during sampling and measured moisture contents, the groundwater table at the site exists at elevations between 337.25± and 336.60± m. It is anticipated that the groundwater table drops in both northerly and easterly directions.

It is noted that the observed groundwater table will fluctuate seasonally and in response to major weather events.



6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is understood that the four (4) existing residential dwellings at the site are to be demolished and redeveloped with a new 6-storey residential building with one (1) level of underground parking/basement. The proposed finished floor elevation of the underground parking/basement level is to be 337.00 m according to the most recent site plan provided to CVD. Site grading plan was not available at the time of reporting.

In general, the surficial topsoil and pavement, fill materials and buried topsoil were underlain, in turn, by very loose to compact sands and silts, compact to dense sand, compact to very dense silt, stiff to very stiff clayey silt till and dense sand and gravel deposits to the maximum explored depths of the boreholes.

Based on the observed/measured groundwater levels in the monitoring wells and boreholes during sampling and measured moisture contents, the groundwater table at the site exists at elevations between 337.25± and 336.60± m. It is anticipated that the groundwater table drops in both northerly and easterly directions. The elevated groundwater level at Borehole 3 is likely due to being located in a “catchment” or “lower” topographical area and a “perched” groundwater condition sitting above the silt deposit containing clayey seams/layers. It is noted that the observed groundwater table will fluctuate seasonally and in response to major weather events.

6.2 One Level Basement/Underground Parking

The finished floor elevation of the basement/underground parking level is proposed at 337.00 m according to the most recent site plan provided to CVD. Based on the groundwater elevations measured on March 17, 2020, it is recommended to establish the basement floor at elevation 337.50 m or higher. In addition to the perimeter weeping tile, a system of under-floor drains is recommended to guard against future seasonal fluctuation of the groundwater table.

If the basement is located below the water table, the entire basement will need to be water-proofed (including the basement floor slab and foundation walls). The basement floor slab will need to be structurally reinforced to withstand the hydrostatic pressure and may require to be anchored down dependent on the final structural design and analysis.

Further, dewatering may be required during construction to enable working in a “dry condition” and to maintain the integrity of the foundation sand and silt soils. Since the amount of groundwater to be pumped could be over 400,000 litres per day, the dewatering would require a “Permit to Take Water” (PTTW) as well as the approval by the City and Region to empty the water into the storm sewer. The “PTTW” from the MECP will require a detailed hydrogeological study to support the application and may take at least 90 days for the MECP to review and grant the permit.

CVD can provide further guidance on the dewatering requirement once the basement floor elevation is established.



In addition, a shoring system may be required to support the exaction side walls and the adjacent structures, driveway and roadways depending on the final locations of the residential development (if open cut excavation cannot be carried out due to special constraints).

As dewatering and shoring may be implemented for the proposed redevelopment, a pre-construction condition survey of the structures on the neighbouring properties is recommended to document the existing condition of these structures.

6.3 Footing Foundations

Conventional strip and spread footing foundations can be used to support the proposed 6-storey residential development. Footings cast on competent native sand and silt deposits can be designed using a Geotechnical Reaction at SLS of 150 kPa. The SLS value given above is based on a maximum settlement of 25 mm under the footing foundations. The Factored Geotechnical Resistance at ULS is 250 kPa.

The following table summarizes the highest founding level and elevation for the footing at each borehole location:

Borehole No.	Existing Ground Elevation (m)	Highest Founding Depth (m)	Highest Founding Elevation (m)
1	339.95	1.55	338.40
2	339.78	2.58	337.20
3	338.29	1.59	336.70
4	337.84	2.24	335.60
5	339.27	2.47	336.80

These soil bearing pressures can be achieved provided that the founding subgrade is undisturbed during construction. The majority of the settlements will take place during construction and the first loading cycle of the building.

In addition, the footings should be founded below any existing fill materials, buried topsoil and former basements/foundations, on competent native undisturbed soils. Spacing between adjacent footing steps should not be steeper than 10H to 7V.

The maximum total and differential settlements of footings designed to the above recommended soil bearing pressure are expected to be less than 25 and 20 mm, respectively, and these are considered tolerable for the structure being contemplated.



It is recommended that a lean concrete mat be placed over approved footing subgrade in wet or saturated areas to prevent further disturbance to the bearing soils resulting from construction activities.

Exterior footings and footings in unheated portions of the building should be provided with a soil cover of not less than 1.2 m or equivalent synthetic thermal insulation for adequate frost protection. The founding subgrade soils must be protected from frost penetration during winter construction.

It is recommended that the footing excavations be inspected by the geotechnical engineer to ensure adequate soil bearing and proper subgrade preparation.

6.4 Engineered Fill Construction

The existing fill materials, buried topsoil and upper very loose to loose soils are not considered suitable for the floor slab and foundation of the proposed 6-storey residential development in its present condition. Removal of these soils and constructing engineered fill could prove to be an effective and economical method to repair poor bearing soil areas to provide suitable bearing at more desirable elevations.

Imported sand and gravel containing less than 8% silt sized particles can be used to construct the engineered fill under controlled and supervised conditions. The moisture content of the soil requires to be within 3% dry of its optimum moisture condition to achieve the specified degree of compaction.

Engineered fill is to be constructed in accordance with the following procedures in order to support the future foundations and floor slabs, if adopted:

1. All existing footings/foundations, fill materials, pavement, surficial/buried topsoil, very loose to loose native soils and otherwise deleterious materials are to be excavated/removed to expose the underlying competent native subgrade;
2. The exposed subgrade surface is to be thoroughly recompacted by large heavy compaction equipment (10 tonne recommended) and inspected by qualified geotechnical personnel. Any loose or soft areas identified should be excavated to the level of competent soil;
3. In areas where wet/saturated unstable subgrade conditions are exposed, the initial lift to raise the grade should consist of coarse imported sand and gravel fill (500 mm thick) which should be statically compacted (without vibration) in order to stabilize and “bridge” the prepared subgrade;
4. The required grades can then be achieved by placing approved sand and gravel in maximum 300 mm thick lifts and compacted to no less than 100% Standard Proctor maximum dry density (SPMDD). The moisture content of the soil requires to be within 3% dry of its optimum moisture condition to achieve the specified degree of compaction;



5. Engineered fill must be placed such that the fill pad extends horizontally outwards from all footings/foundation at least the same distance as how thick the engineered fill pad will exist between the underside of future footings and the approved native subgrade;
6. All fill placement and compaction operations must be supervised on a full-time basis by qualified geotechnical personnel to approve fill material and ensure the specified degree of compaction has been achieved.

Foundations supported on approved engineered fill constructed in accordance with the procedures given above can be designed to 150 kPa at SLS and 250 kPa at ULS.

Vibration could be generated from various construction equipment, such as compactors and rollers which could be harmful to potential surrounding structures and buildings during construction. Peak particle velocity (PPV) of ground motion is widely accepted as the best descriptor of potential for vibration damage to structures. The safe vibration limit can be set to 10 to 20 mm/s PPV, depending on the sensitivity of any potential surrounding structures to vibration.

Vibration monitoring can be carried out to measure the PPV of ground motion from vibration generated from typical compaction equipment at the beginning of the project in the potentially critical areas. This will set criteria and establish the type of equipment to be used for this project.

6.5 Earthquake Considerations

In accordance with The Ontario Building Code 2012 (OBC), the proposed structure should be designed to resist earthquake load and effects as per OBC Subsection 4.1.8. Based on the anticipated condition of the engineered fill materials and the underlying soil condition encountered at the boreholes, the site can be classified as a Site Class C as per OBC Table 4.1.8.4.A (Page B4-24).

6.6 Open Cut Excavation and Groundwater Control

Excavations are expected to be in the order of 1.5 to 3.5 m for basement, footing foundations and site servicing. The excavations will penetrate compact fill and native very loose to compact variable sand and silt deposits.

Above the groundwater table, these materials are considered to be Type 3 Soils in accordance with the latest Occupational Health and Safety Act. Excavations in the Type 3 Soils are expected to remain stable during the construction period provided that side slopes are cut to 1H : 1V from the bottom of the excavation. Where seepage or groundwater is encountered, side slopes should be cut to more stable angles of 3H : 1V. The side slopes should be suitably protected from erosion processes.

Above the groundwater table, rainwater or local seepage can be controlled by pumping from filtered sump pits as and where required. It is recommended that excavation for the future development be done during the typically drier summer months when ground water conditions would be expected to lie at lower elevations.



If it is planned to mass excavate the entire basement area and the basement is to lie below the groundwater table, dewatering and pre-draining the site will be required. Without pre-draining, the fine granular soils will become “quick” and lose its integrity to support loads. The groundwater table must be lowered and controlled to at least 600 mm below the excavation level to facilitate the excavation and construction of footings and foundation walls to be carried out in the dry condition.

In wet to saturated subgrade condition, it will be necessary to excavate below founding level and pour a 75 mm thick mud slab of lean concrete to protect the founding soil from disturbance during the installation of reinforcing steel bars and form work.

6.7 Shored Excavation

As excavations are expected to be in the order of 1.5 to 3.5 m deep for the proposed footing foundations, a shoring system will be required for temporary excavation support during construction where sufficient space is not available for open cut excavations and to support the adjacent structures. Possible shoring supports include soldier pile and timber lagging system, caisson wall or soil nail retaining system with shotcrete facing.

The shoring system is generally designed and built by a specialized shoring contractor. The shoring system should be designed in accordance with the guidelines provided in the Canadian foundation Engineering Manual (CFEM) 4th Edition.

The shoring system will have to withstand the lateral earth pressure, the adjacent roadway, buried services and the traffic loads as well as the adjacent building structures. Frost pressures on the shoring system should be considered if the system is exposed to winter freezing condition. The shoring system should be monitored to ensure deflection and lateral movements are acceptable, and modifications made to the shoring system if deflection and lateral movements become a problem.

The following soil parameters may be used in the design of shoring. K_o (at rest condition) should be used where the shoring will need to support any existing building/structure.

Soil	Unit Weight (kN/m ³)	Friction Angle (ϕ^0)	K_o	K_a	K_p
Fill Materials & Loose Native Fine Granular Deposits	19	28	0.53	0.36	2.77
Compact Fine Granular Deposits	20	30	0.50	0.33	3.00
Compact to Dense Sand	20	30	0.50	0.33	3.00
Compact to Dense Silt	21	30	0.50	0.33	3.00
Stiff to Very Stiff Clayey Silt Till	20	29	0.52	0.35	2.85



The shoring system can be supported by soil anchor tie-backs and/or raker footings. Soil anchors will provide an unobstructed open space for construction whereas raker supports will obstruct the forming and construction of footings and foundation walls.

If a soldier pile and timber lagging system is adopted, the augering/installation of the soldier piles and timber laggings, especially where they are located adjacent existing structures, should be carried out with caution such that the installation process will not cause future settlements to the adjacent existing structures. The geotechnical engineer should be retained to perform inspection during the installation.

6.8 Floor Slab Construction

At the time of floor slab construction, the exposed subgrade should be proof-rolled with a heavy roller in conjunction with an inspection by the geotechnical engineer. Any soft and/or unstable areas detected should be replaced with granular fill which should be compacted to at least 95% SPMDD. On-site excavated granular soils or imported sand and gravel may be reused to raise grades where necessary provided the natural moisture content is near to the optimum moisture content. The backfill should be thoroughly compacted in thin lifts to at least 95% SPMDD.

Care should be taken to ensure that the backfill against the foundation wall and around the interior columns are placed in thin layers and each layer compacted to at least 95% SPMDD. Backfilling these types of confined areas with granular soils is recommended if the weather is not favourable and the work is being carried out in the winter months. The Granular "B" Type II drainage layer should also be compacted to at least 95% SPMDD.

In addition to the perimeter weeping tile, a system of under-floor drains is recommended to guard against future seasonal fluctuation of the groundwater table. For preliminary design purpose, the under-floor drainage system will require the installation of a drainage course underneath the floor slab and adjacent to the foundation wall for the collection of the groundwater migrating towards the basement. The drainage layer should consist of 300 mm thick OPSS Granular "B" Type II (and with less than 5% silt), in which filter cloth wrapped perforated tiles (150 mm diameter) should be installed at typical spacing of 6 m at a 0.5% gradient. The soil subgrade below the 300 mm thick drainage layer should be covered with a non-woven geotextile (filter cloth, such as Terrafix 270R or equivalent) to prevent "silt" from migrating into the drainage layer.

Following the proof-rolling of the subgrade, it is recommended that a minimum 150 mm thick layer of OPSS Granular "A" be placed and compacted to at least 100% SPMDD beneath the concrete floor slabs to provide uniform support.

A modulus of subgrade reaction (k_s) of 30 MN/m³ may be used for the design of the floor slab, assuming a sand and/or silt subgrade.

The floor slabs should be separated structurally from the columns and foundation walls. Sawcut control joints should be provided at regular spacing (less than 30 times the concrete slab thickness) and to depths between one-third to one-quarter of the slab thickness.



Moisture migration from the underlying soils through the concrete slab-on-grade will take place via “capillary action” and “diffusion” (due to vapour pressure differential). Although, the Granular “A” layer and Granular “B” drainage course will provide a capillary break, the low permeance of the concrete slab and floor coverings will result in 100% humidity under the concrete slab and, consequently, the moisture in the concrete will increase over time. The potential effect of the soil moisture should be considered in selecting the floor coverings. A vapour retarder material (such as a 15-mil poly, ASTM E-1745) can be placed to reduce soil moisture migration. Reference is made to ACI 302. The vapour retarder should be considered in the enclosed rooms/areas such as the lobby and mechanical/electrical rooms.

6.9 Lateral Earth Pressure

The unbalanced foundation walls and any other soil retaining structures should be designed to resist the lateral earth pressure acting against these walls. The following formula may be used to calculate the unfactored earth pressure distribution. The factored resistance can be calculated by using a factor of 0.8.

$$P = K(\gamma H + q)$$

where:

P =	lateral earth pressure	kPa
K =	earth pressure coefficient, 0.5 for non-yielding foundation wall earth pressure coefficient, 0.3 for yielding retaining wall	
γ =	unit weight of granular backfill, compacted to 95% SPMDD	21 kN/m ³
H =	unbalanced height of wall	m
q =	surcharge load at ground surface	kPa

The backfill for the foundation walls and retaining walls should be free-draining granular materials which should have less than 8% silt particles (OPSS Granular “B” Type I). The backfill should be placed in thin layers and compacted to 95% SPMDD. Over-compaction adjacent to the foundation/retaining walls should be avoided. Weeping tiles leading to a frost-free outlet or weep holes should be installed to effect drainage behind the retaining wall.

If the basement floor is located below the groundwater table, the basement/foundation walls will need to be designed against hydrostatic pressure.



The sliding resistance of the retaining wall footings should be checked. The unfactored horizontal resistance against sliding between cast-in-place concrete and the various soils can be calculated using a friction coefficient as follows:

- Very loose to compact fine granular deposits: 0.30
- Compact to dense sand: 0.40
- Compact to very dense silt: 0.30
- Stiff to very stiff clayey silt till: 0.40

The unit weight of the fine granular, sand, silt, and clayey silt till deposits is 20 kN/m^3 , and a unit weight of the granular backfill compacted to 95% SPMDD is 21 kN/m^3 .

6.10 On Site Infiltration

Grain size distribution analyses were conducted on samples of the native sand and silt deposits and the results are graphically presented on in the Enclosures 6 to 10.

Based on the results of grain size analyses and our past experience, the hydraulic conductivity and infiltration rate of the native inorganic soil types encountered at the boreholes are estimated and provided in the following table:

MATERIAL	PERMEABILITY (K) (cm/sec)	INFILTRATION RATE (mm/hr)
Sand and Silt to Sandy silt	5×10^{-4}	20
Sand (Enclosures 6)	3×10^{-3}	50
Silt (Enclosures 7, 8 & 10)	2×10^{-5} to 2×10^{-4}	7 to 12
Clayey Silt Till (Enclosure 9)	9×10^{-6}	3
Sand and Gravel	1×10^{-2}	100

However, due to the high groundwater table at the site, infiltration of storm water is not considered viable.



7.0 CLOSURE

The Limitations of Report, as quoted in Appendix A, is an integral part of this report.

We trust that the information presented in this report is complete within our terms of reference. If there are any further questions concerning this report, please do not hesitate to contact our office.

Yours truly,

CHUNG & VANDER DOELEN ENGINEERING LTD.



Joseph van der Zalm
Geotechnical Engineering Intern



Eric Y. Chung, M. Eng., P.Eng.
Principal Engineer



APPENDIX A

LIMITATIONS OF REPORT



APPENDIX “A”

LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the testhole locations. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction which could not be detected or anticipated at the time of the site investigation. It is recommended practice that the Soils Engineer be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes and their respective depths may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

The benchmark and elevations mentioned in this report were obtained strictly for use in the geotechnical design of the project and by this office only, and should not be used by any other parties for any other purposes.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. CHUNG & VANDER DOELEN ENGINEERING LIMITED accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

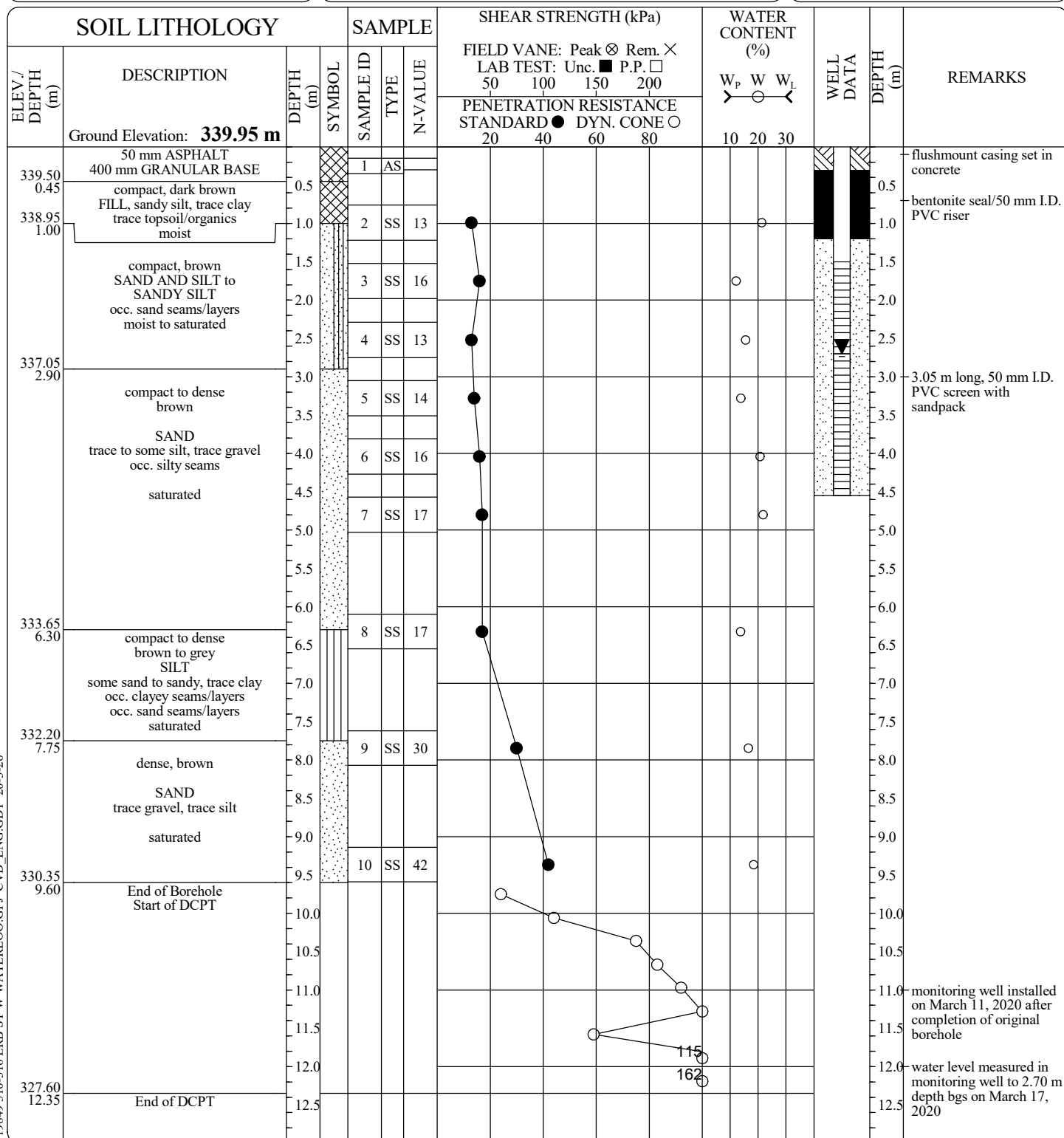
The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final design stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

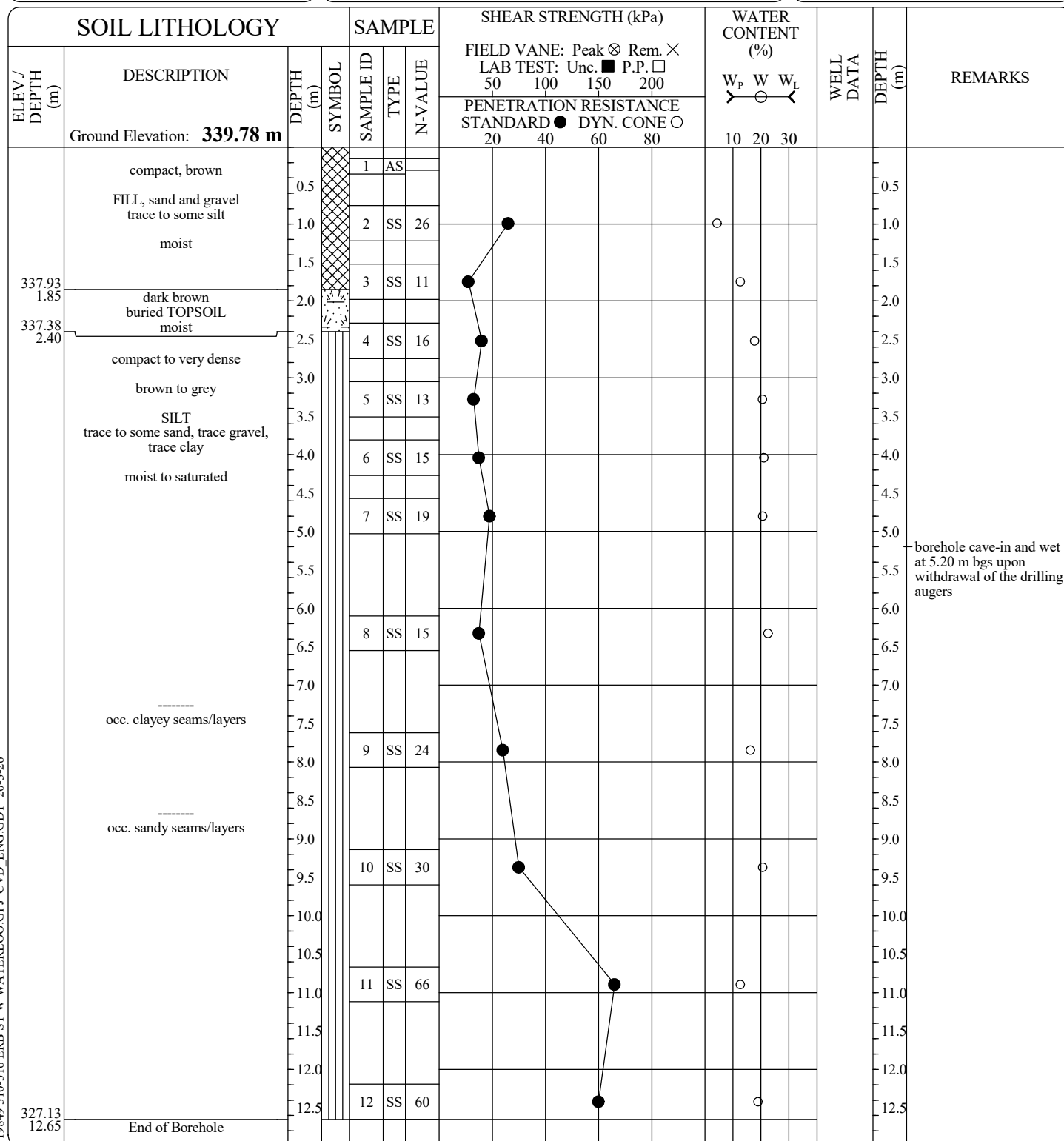
This report does not reflect the environmental issues or concerns unless otherwise stated in the report.

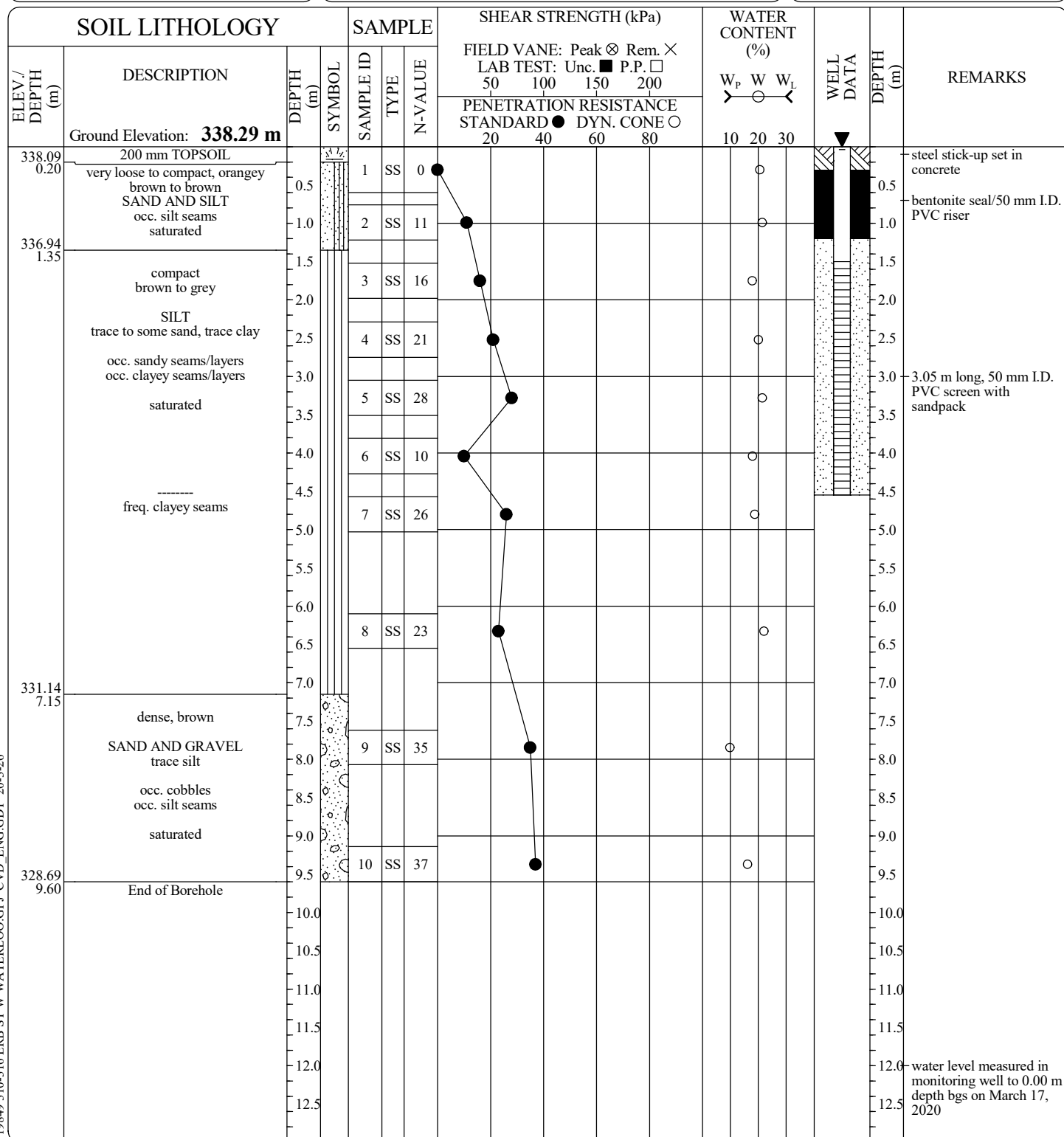


ENCLOSURES



FILE No: G19849**BOREHOLE No. 1**Client: **Urban Legend Development Ltd.**Project: **Proposed Residential Development**Location: **310-316 Erb Street West, Waterloo, Ontario****EQUIPMENT DATA**Machine: **Diedrich D50T**Method: **Hollow Stem Auger**Size: **107 mm I.D.**Date: **Dec 09 - 19 TO Dec 09 - 19**PROJECT MANAGER: **EYC****CHUNG & VANDER DOELEN
ENGINEERING LTD.**311 Victoria Street North
Kitchener, Ontario N2H 5E1
ph. (519) 742-8979, fx. (519) 742-7739

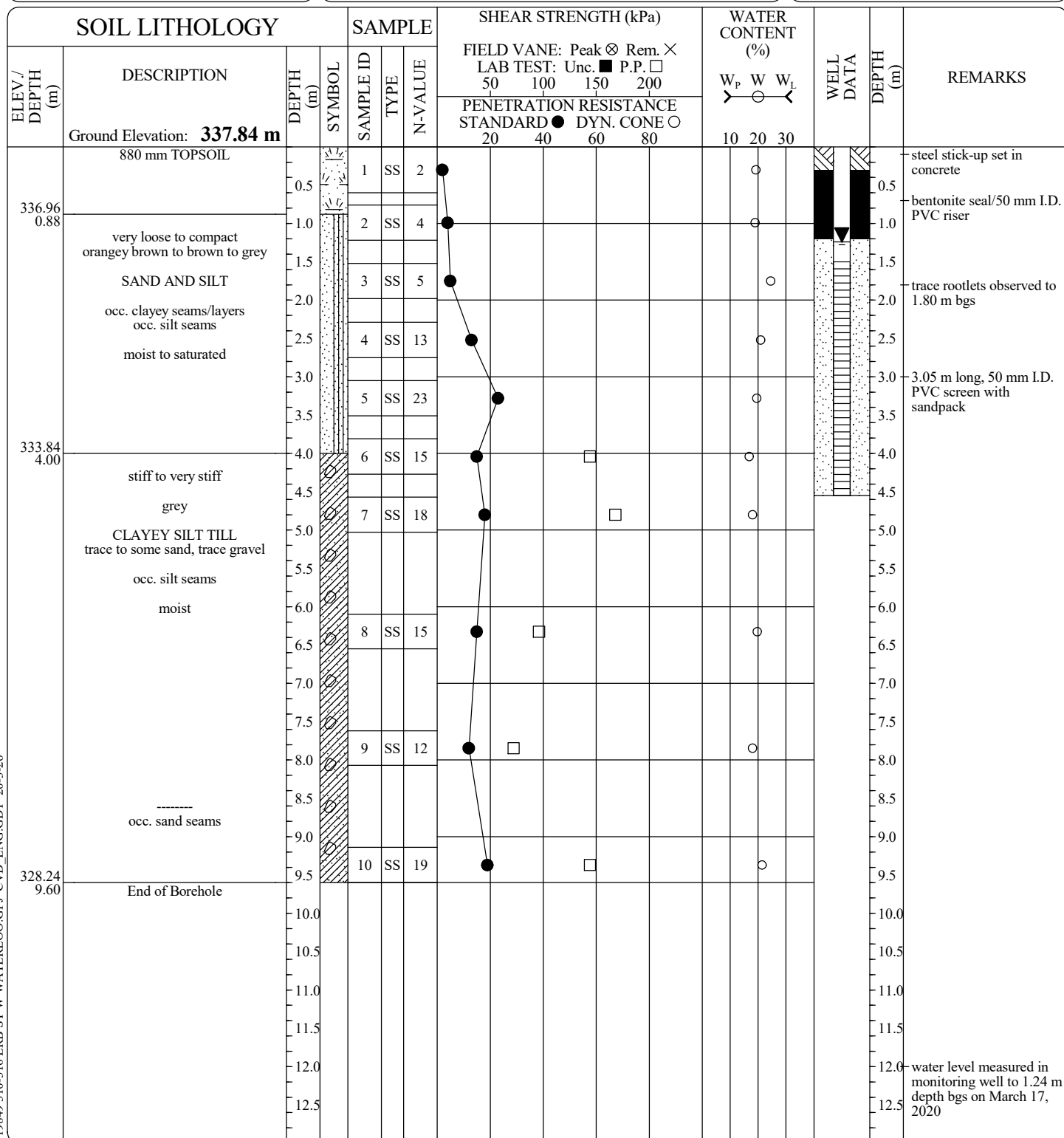
FILE No: G19849**BOREHOLE No. 2**Client: **Urban Legend Development Ltd.**Project: **Proposed Residential Development**Location: **310-316 Erb Street West, Waterloo, Ontario****EQUIPMENT DATA**Machine: **Diedrich D50T**Method: **Hollow Stem Auger**Size: **107 mm I.D.**Date: **Dec 10 - 19 TO Dec 10 - 19**PROJECT MANAGER: **EYC****CHUNG & VANDER DOELEN
ENGINEERING LTD.**311 Victoria Street North
Kitchener, Ontario N2H 5E1
ph. (519) 742-8979, fx. (519) 742-7739

FILE No: G19849**BOREHOLE No. 3**Client: **Urban Legend Development Ltd.**Project: **Proposed Residential Development**Location: **310-316 Erb Street West, Waterloo, Ontario****EQUIPMENT DATA**Machine: **Mobile B57**Method: **Hollow Stem Auger**Size: **107 mm I.D.**Date: **Mar 11 - 20 TO Mar 11 - 20**

water level measured in monitoring well to 0.00 m depth bgs on March 17, 2020

PROJECT MANAGER: **EYC**
**CHUNG & VANDER DOELEN
ENGINEERING LTD.**

311 Victoria Street North
Kitchener, Ontario N2H 5E1
ph. (519) 742-8979, fx. (519) 742-7739

FILE No: G19849**BOREHOLE No. 4**Client: **Urban Legend Development Ltd.**Project: **Proposed Residential Development**Location: **310-316 Erb Street West, Waterloo, Ontario****EQUIPMENT DATA**Machine: **Mobile B57**Method: **Hollow Stem Auger**Size: **107 mm I.D.**Date: **Mar 11 - 20 TO Mar 11 - 20**PROJECT MANAGER: **EYC****CHUNG & VANDER DOELEN
ENGINEERING LTD.**311 Victoria Street North
Kitchener, Ontario N2H 5E1
ph. (519) 742-8979, fx. (519) 742-7739

FILE No: G19849**BOREHOLE No. 5**Client: **Urban Legend Development Ltd.**Project: **Proposed Residential Development**Location: **310-316 Erb Street West, Waterloo, Ontario****EQUIPMENT DATA**Machine: **Mobile B57**Method: **Hollow Stem Auger**Size: **107 mm I.D.**Date: **Mar 11 - 20 TO Mar 11 - 20**

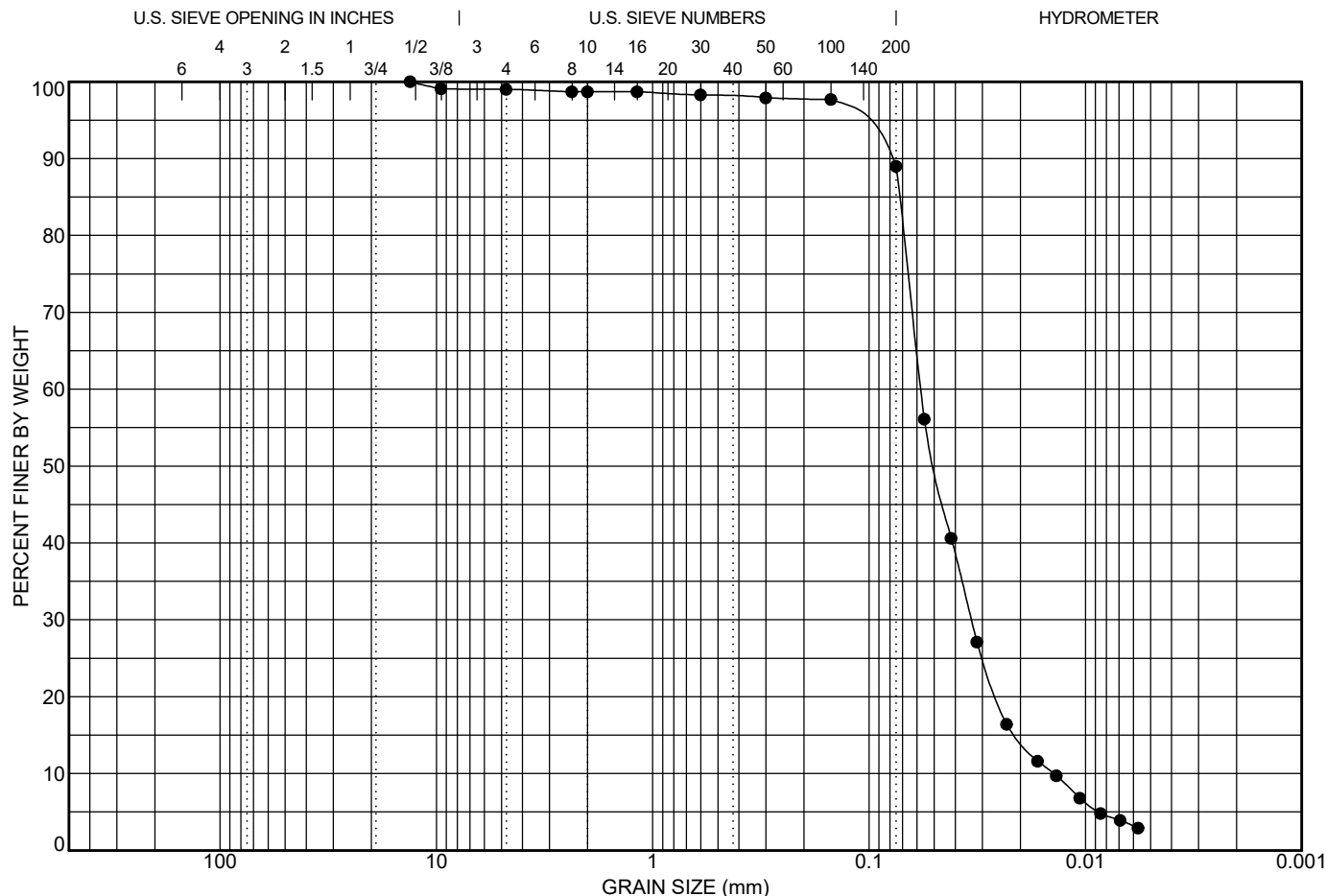
SOIL LITHOLOGY				SAMPLE			SHEAR STRENGTH (kPa)				WATER CONTENT (%)			WELL DATA	DEPTH (m)	REMARKS
ELEV./ DEPTH (m)	DESCRIPTION	DEPTH (m)	SYMBOL	SAMPLE ID	TYPE	N-VALUE	FIELD VANE: Peak ⊗ Rem. × LAB TEST: Unc. ■ P.P. □ 50 100 150 200				W _P W W _L ↔—○—↔					
							PENETRATION RESISTANCE STANDARD ● DYN. CONE ○									
Ground Elevation: 339.27 m							20	40	60	80	10	20	30			
339.07 0.20	200 mm TOPSOIL			1	SS	6	●					○				
	loose to compact dark brown to brown FILL, silty sand trace gravel, trace clay trace topsoil/organics occ. silt pockets moist	0.5														
		1.0		2	SS	10	●					○				
		1.5														
337.47 1.80	dark brown buried TOPSOIL	2.0		3	SS	6	●					○				
336.92 2.35	moist															
	compact, brown SAND	2.5		4	SS	16	●					○				
	some silt moist to saturated	3.0														
335.92 3.35		3.5		5	SS	26						○				
	compact brown to grey	4.0		6	SS	21						○				
	SILT trace to some, trace clay	4.5														
	occ. sandy seams/layers occ. clayey seams/layers	5.0		7	SS	24						○				
	saturated	5.5														
		6.0														
		6.5		8	SS	24						○				
		7.0														
	----- freq. clayey seams	7.5														
		8.0		9	SS	26						○				
330.92 8.35		8.5														
	very stiff, grey CLAYEY SILT TILL trace gravel, trace sand occ. silt seams moist	9.0														
329.67 9.60	End of Borehole	9.5		10	SS	26						□	○			
		10.0														
		10.5														
		11.0														
		11.5														
		12.0														
		12.5														

water level at 5.35 m bgs upon withdrawal of the drilling augers
borehole cave-in to 5.50 m bgs upon withdrawal of the drilling augers

water level at 5.35 m bgs upon withdrawal of the drilling augers
borehole cave-in to 5.50 m bgs upon withdrawal of the drilling augers

PROJECT MANAGER: **EYC**
**CHUNG & VANDER DOELEN
ENGINEERING LTD.**

 311 Victoria Street North
 Kitchener, Ontario N2H 5E1
 ph. (519) 742-8979, fx. (519) 742-7739



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

LL	PL	PI	Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
			1.40	4.10	13.2	0.058	0.034	0.014	1.0	10.0	89.0	

Date: Dec. 17 - 2019
Client: Urban Legend Development Ltd.
Contractor:
Source:
Sampled From: BH 2 - SA 6, 3.80 to 4.25 m depth
Sample No.: 2-6
Date Sampled: Dec. 09 - 2019
Sampled By: JV
Lab No.: 1403
Date Tested: Dec. 16 - 2019
Type of Material: Silt, trace to some sand, trace gravel

Sieve Size (mm)	Percent Passing	No Specifications



**CHUNG & VANDER DOELEN
ENGINEERING LTD.**
 311 Victoria Street North
 Kitchener, Ontario N2H 5E1
 Telephone: 519-742-8979
 Fax: 519-742-7739
 e-mail: info@cvdengineering.com

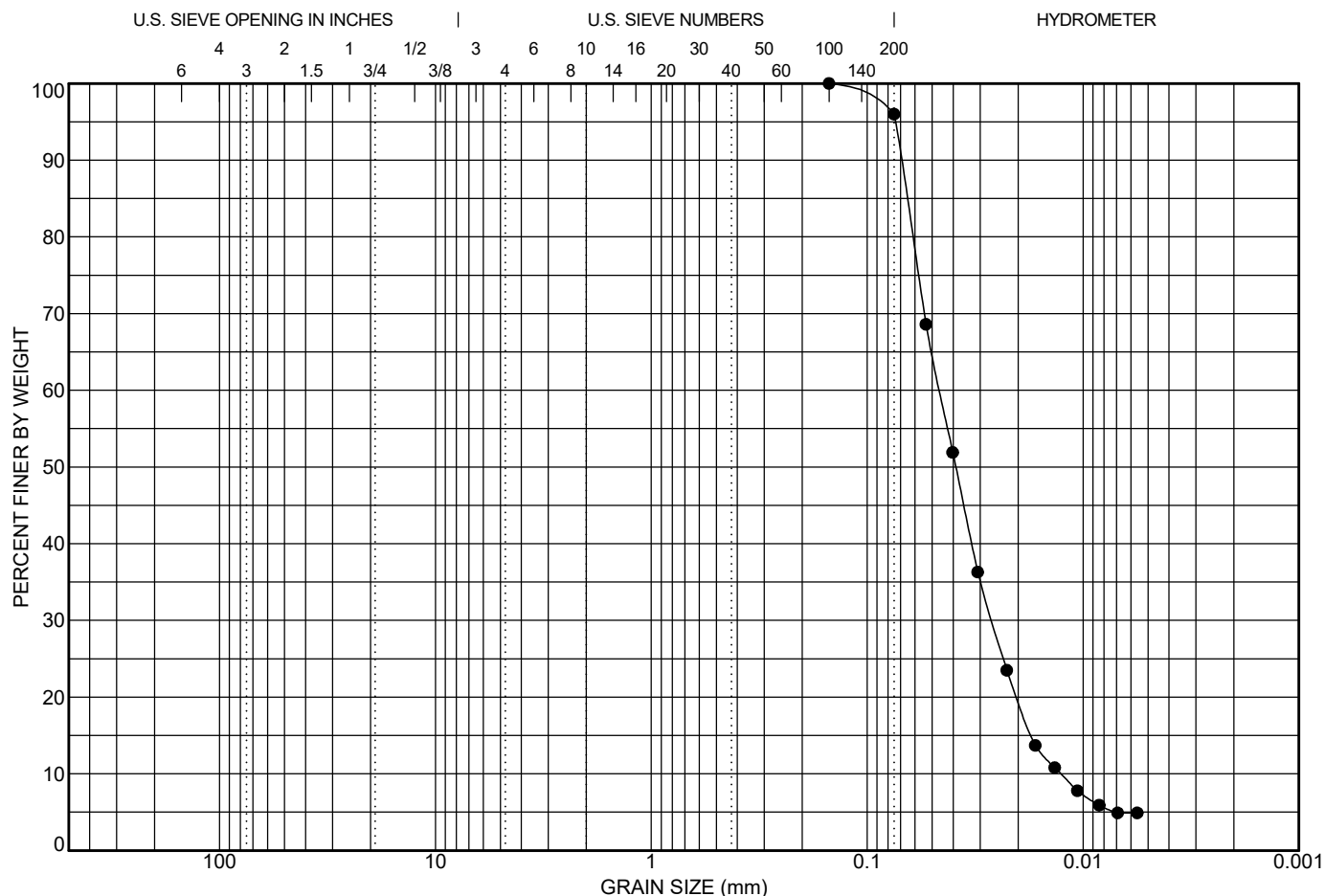
GRAIN SIZE DISTRIBUTION

Project: Proposed Residential Development

Location: 310-316 Erb Street West, Waterloo, Ontario

File No.: G19849

Enclosure No.: 7



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

LL	PL	PI	Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
			1.19	3.64	0.15	0.046	0.026	0.013	0.0	4.0	96.0	

Date: Mar. 24 - 2020
Client: Urban Legend Development Ltd.
Contractor:
Source:
Sampled From: BH 3 - SA 5, 3.05 to 3.50 m depth
Sample No.: 3-5
Date Sampled: Mar. 11 - 2020
Sampled By: JV
Lab No.: 0179
Date Tested: Mar. 16 - 2020
Type of Material: Silt, trace sand

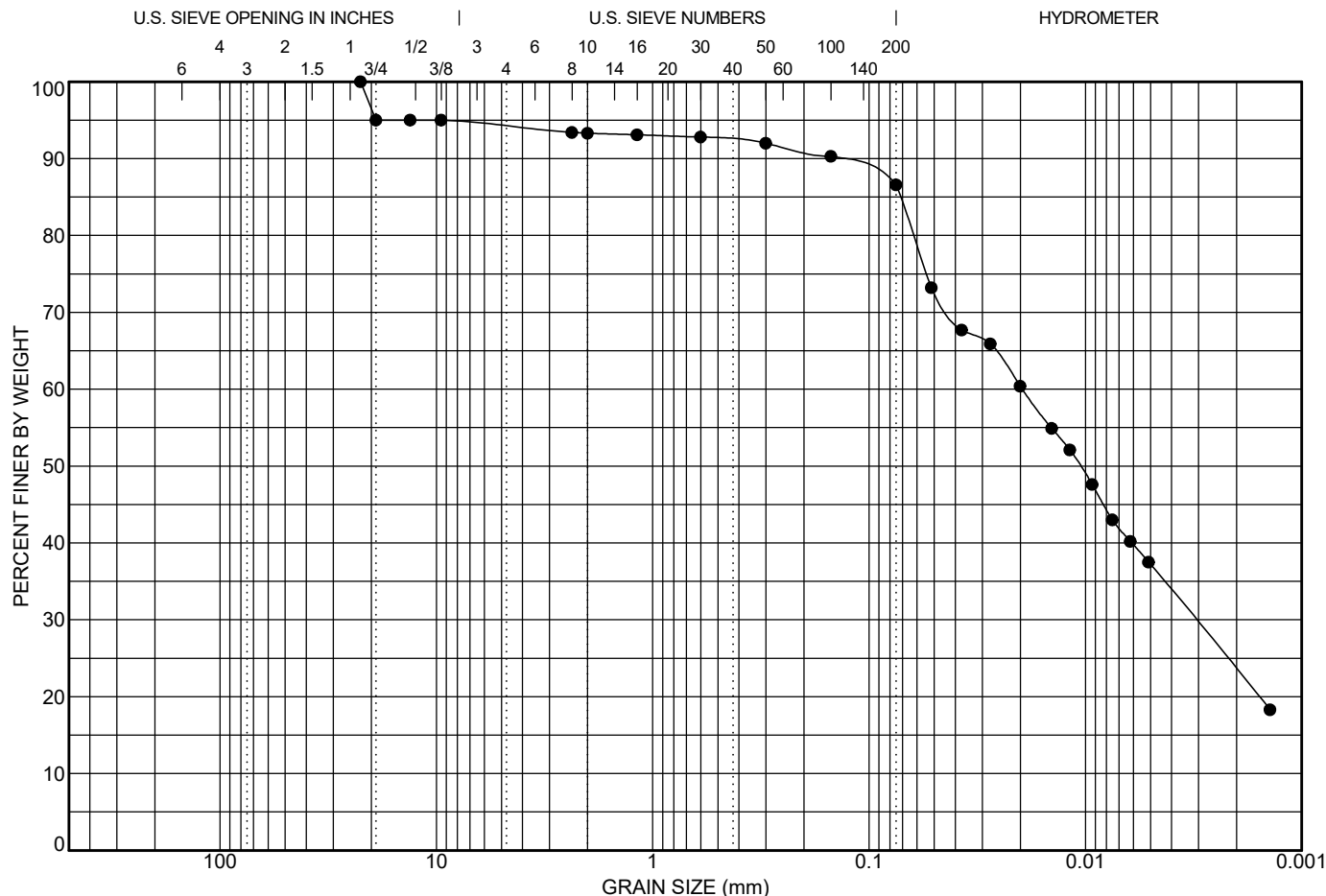
Sieve Size (mm)	Percent Passing	No Specifications



**CHUNG & VANDER DOELEN
ENGINEERING LTD.**
 311 Victoria Street North
 Kitchener, Ontario N2H 5E1
 Telephone: 519-742-8979
 Fax: 519-742-7739
 e-mail: info@cvdengineering.com

GRAIN SIZE DISTRIBUTION

Project: Proposed Residential Development
Location: 310-316 Erb Street West, Waterloo, Ontario
File No.: G19849
Enclosure No.: 8



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

LL	PL	PI	Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
					22.4	0.02	0.003		5.8	7.6	86.6	

Date: Mar. 24 - 2020
Client: Urban Legend Development Ltd.
Contractor:
Source:
Sampled From: BH 4 - SA 7, 4.55 to 5.00 m depth
Sample No.: 4-7
Date Sampled: Mar. 11 - 2020
Sampled By: JV
Lab No.: 0180
Date Tested: Mar. 16 - 2020
Type of Material: Clayey Silt Till, trace gravel, trace sand

Sieve Size (mm)	Percent Passing	No Specifications



**CHUNG & VANDER DOELEN
ENGINEERING LTD.**
 311 Victoria Street North
 Kitchener, Ontario N2H 5E1
 Telephone: 519-742-8979
 Fax: 519-742-7739
 e-mail: info@cvdengineering.com

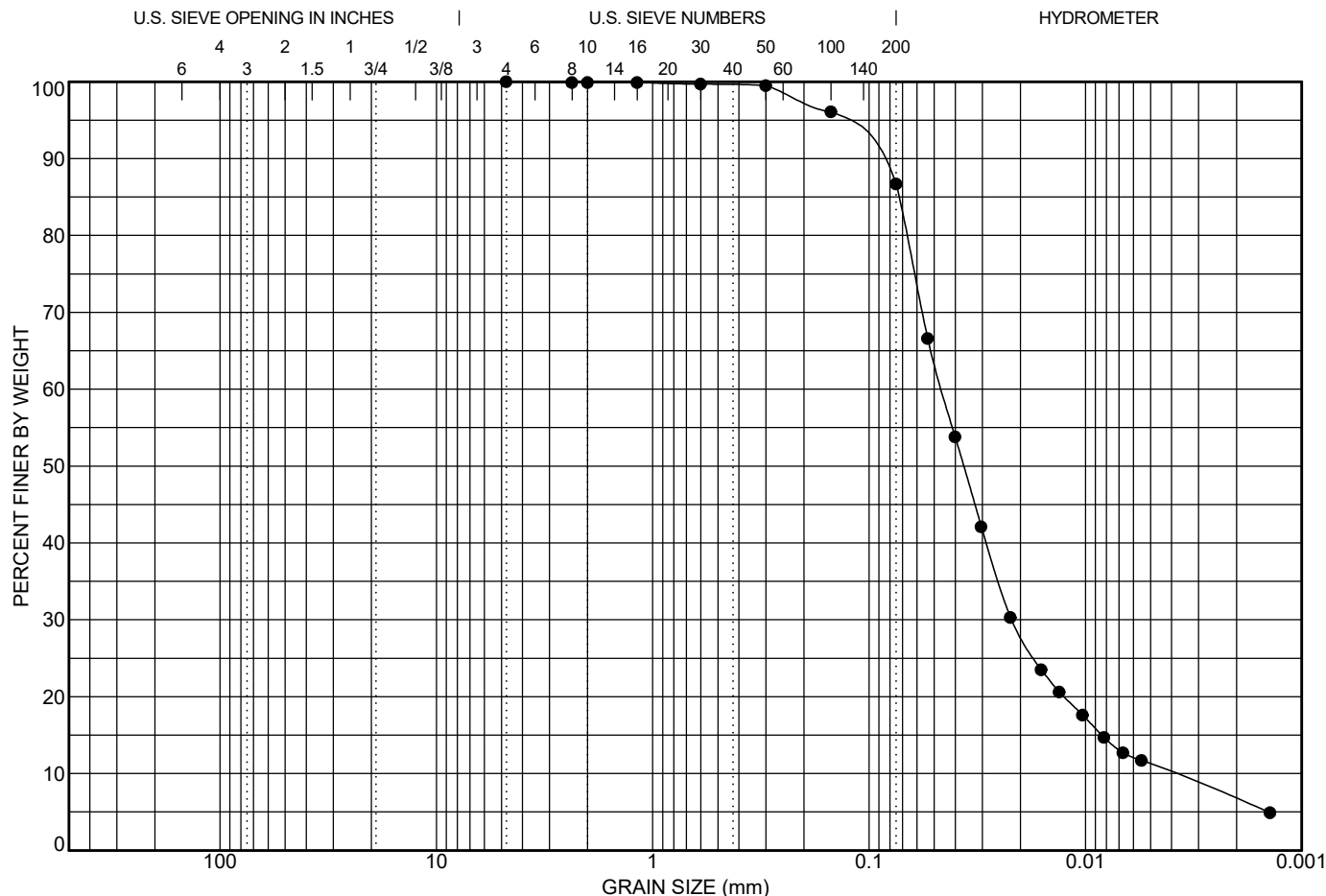
GRAIN SIZE DISTRIBUTION

Project: Proposed Residential Development

Location: 310-316 Erb Street West, Waterloo, Ontario

File No.: G19849

Enclosure No.: 9



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

LL	PL	PI	Cc	Cu	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
			2.66	11.80	4.75	0.046	0.022	0.004	0.0	13.3	86.7	

Date: Mar. 24 - 2020
Client: Urban Legend Development Ltd.
Contractor:
Source:
Sampled From: BH 5 - SA 6, 3.80 to 4.25 m depth
Sample No.: 5-6
Date Sampled: Mar. 11 - 2020
Sampled By: JV
Lab No.: 0181
Date Tested: Mar. 16 - 2020
Type of Material: Silt, some sand, trace clay

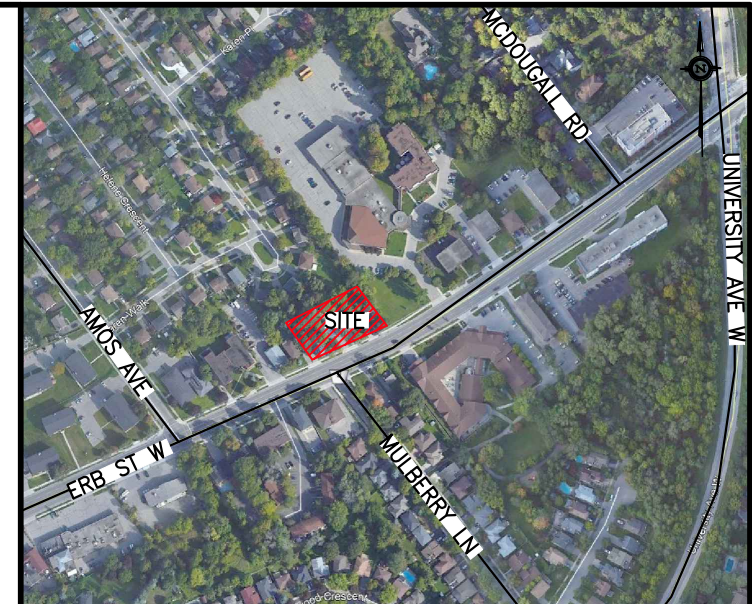
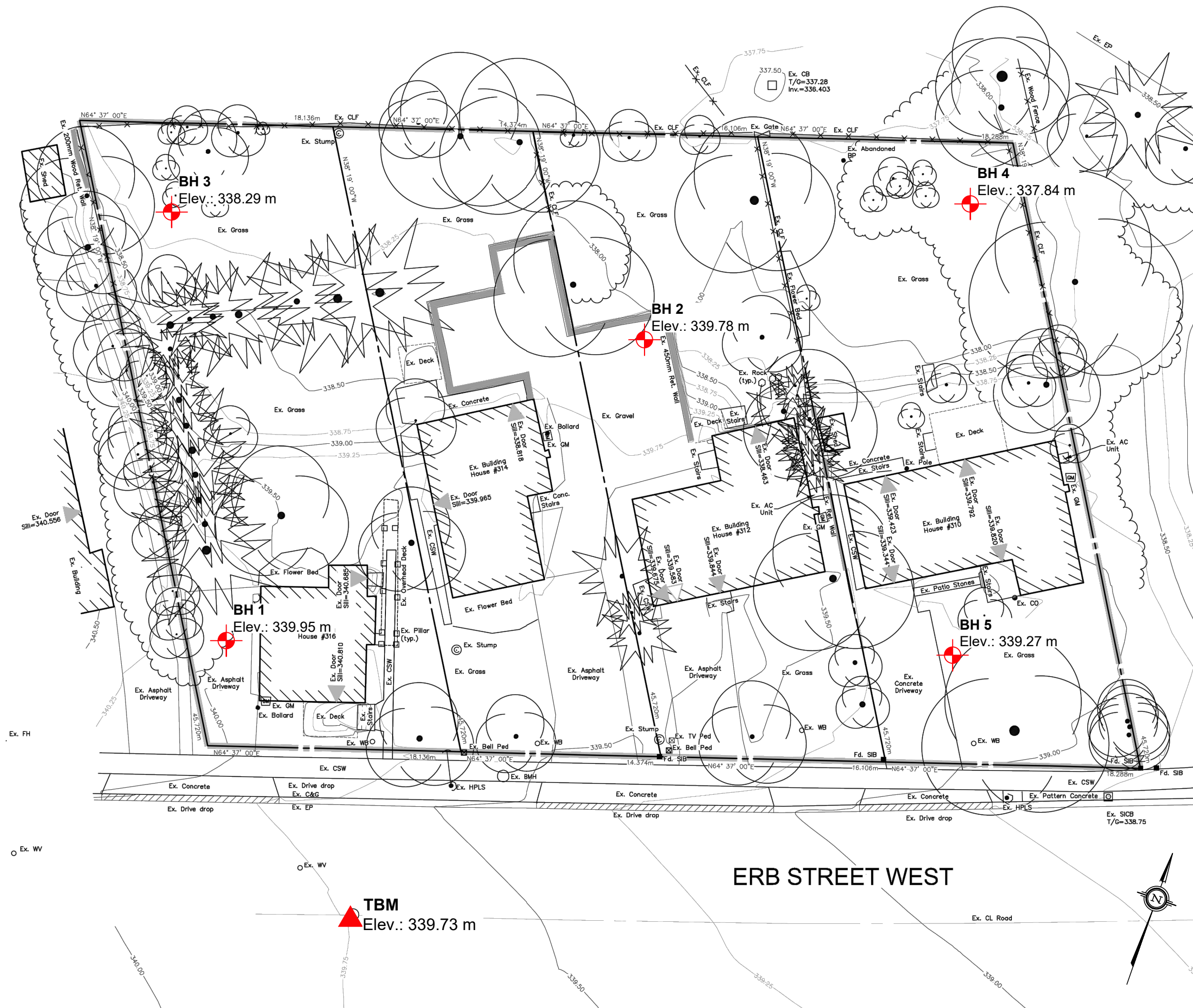
Sieve Size (mm)	Percent Passing	No Specifications



**CHUNG & VANDER DOELEN
ENGINEERING LTD.**
 311 Victoria Street North
 Kitchener, Ontario N2H 5E1
 Telephone: 519-742-8979
 Fax: 519-742-7739
 e-mail: info@cvdengineering.com

GRAIN SIZE DISTRIBUTION

Project: Proposed Residential Development
Location: 310-316 Erb Street West, Waterloo, Ontario
File No.: G19849
Enclosure No.: 10



KEY PLAN SOURCE: Google Earth

LEGEND

- TBM: Top of manhole in centrline of Erb Street West at intersection with Mulberry Lane Elev.: 339.73 m (Geodetic)
- Borehole Location

Dwg/Elev. Ref.: MTE; Urban Legend Developments Ltd.; "Exisiting Conditions Plan"; 310-316 Erb Street West, Proj. No. 46981-100; Dwg No.: C1.1; November 29, 2019

BOREHOLE LOCATION PLAN

Geotechnical Investigation
Proposed Residential Development

310-316 Erb Street West
Waterloo, Ontario

CHUNG & VANDER DOELEN
ENGINEERING LTD.

311 VICTORIA STREET NORTH
KITCHENER / ONTARIO / N2H 5E1 / 519-742-8979

Drawn By: JV	Date: March, 2020	File No.: G19849
Checked By: EYC	Scale: N.T.S.	Drawing No.: 1