Hydrogeological Study in Support of Draft Plan

Ballymore Building (Barrie) Corp.
Barrie, Ontario

R.J. Burnside & Associates Limited
292 Speedvale Avenue West Unit 20
Guelph ON   N1H 1C4 CANADA

January 2019
300041171.0000

Distribution List

No. of Hard Copies	PDF	Email	Organization Name
0	Yes	Yes	Sharon Dionne, Ballymore Homes
0	Yes	Yes	Keith MacKinnon, KLM Planning

Record of Revisions

Revision	Date	Description
-	February 25, 2019	Submission to Ballymore Building (Barrie) Corp.

R.J. Burnside & Associates Limited

Report Prepared By: Stephanie Charity

PROFESSIONAL GEOSCIENTISTS
STEPHANIE L. CHARITY
PRACTISING MEMBER
1796
ONTARIO

Stephanie Charity, P.Geo.
Hydrogeologist
SC:cl

Report Reviewed By:

PROFESSIONAL GEOSCIENTISTS
DWIGHT J. SMIKLE
PRACTISING MEMBER
1293
ONTARIO

Dwight Smikle, P.Geo.
Senior Hydrogeologist
DS:cl

Table of Contents

Tables

Figures

Appendices

Disclaimer

Other than by the addressee, copying or distribution of this document, in whole or in part, is not permitted without the express written consent of R.J. Burnside & Associates Limited.

In the preparation of the various instruments of service contained herein, R.J. Burnside & Associates Limited was required to use and rely upon various sources of information (including but not limited to: reports, data, drawings, observations) produced by parties other than R.J. Burnside & Associates Limited. For its part R.J. Burnside & Associates Limited has proceeded based on the belief that the third party/parties in question produced this documentation using accepted industry standards and best practices and that all information was therefore accurate, correct and free of errors at the time of consultation. As such, the comments, recommendations and materials presented in this instrument of service reflect our best judgment in light of the information available at the time of preparation. R.J. Burnside & Associates Limited, its employees, affiliates and subcontractors accept no liability for inaccuracies or errors in the instruments of service provided to the client, arising from deficiencies in the aforementioned third party materials and documents.

R.J. Burnside & Associates Limited makes no warranties, either express or implied, of merchantability and fitness of the documents and other instruments of service for any purpose other than that specified by the contract.

1.0 Introduction

R.J. Burnside & Associates Limited (Burnside) has been retained by Ballymore Building (Barrie) Corp. to complete a hydrogeological assessment of lands at 750 Lockhart Road, Barrie in support of a draft plan of subdivision. The Ballymore lands, herein referred to as the subject lands are located north of Lockhart Road and east of Yonge Street in the City of Barrie, Ontario (Figure 1). The subject lands are located within the Barrie Annexed Lands and the OPA 39 Hewitt's Secondary Plan Area (SPA) located on the southern boundary of the City of Barrie. In 2016, a Subwatershed Impact Study (SIS) for the Hewitt's SPA was completed for the Hewitt's Creek Landowners Group (Burnside, 2016). The Hewitt's Creek SPA includes lands bounded by Lockhart Road to the south, Sideroad 20 to the east, Mapleview Drive and Big Bay Point Road to the north (Figure 1).

1.1 Scope of Work

The scope of work completed for the hydrogeological assessment was developed to build upon the more regional work completed for the Hewitt's SIS (Burnside, 2016) and to address requirements for hydrogeological studies in support of draft plan approval.

The scope of the hydrogeological assessment involved a review of available regional information as well as the completion of site-specific investigations as described below:

1. Review of published geological and hydrogeological information: A review of background material for the area, including topography, surficial geology and bedrock geology mapping and existing geotechnical and hydrogeological reports was completed to assess the regional hydrogeological setting.

2. Review of the Ministry of the Environment, Conservation and Parks (MECP) water well records: The MECP maintains a database that provides geological records of water supply wells drilled in the province. A list of the available MECP water well records for local wells is provided in Appendix A and the well locations are plotted on Figure 5. It is noted that the well locations listed in the MECP records are approximations only and may not be representative of the precise well locations in the field. These well data were compiled and mapped to characterize the local groundwater resources and assess potential impacts to the local private wells from development of the subject lands.

3. Install groundwater monitoring network: Groundwater monitoring locations were established to characterize seasonal variations in the water table in both the shallow and deep aquifers. A total of six locations had monitoring wells installed (5 cm diameter) to determine the local stratigraphy and site-specific soil and groundwater conditions of the subject lands. Two of the locations had monitoring

well nests (two wells of different depths at the same location) installed to assess vertical gradients. Two nests of piezometers (one shallow, one deep) were installed in wetland features to determine the nature of potential groundwater/surface water interactions with these features. The locations of the monitoring wells/piezometers are shown on Figure 2 and monitoring well construction details are provided on the borehole logs in Appendix B.

4. Hydraulic conductivity testing: Burnside conducted single well response tests in order to determine hydraulic conductivity. Single well response tests were completed at four groundwater monitoring wells (BM-1, BM-5d, BM-7 and BM-9) in 2018. The hydraulic conductivity field testing results are provided in Appendix C.

5. Monitoring of groundwater levels: Monitoring has been completed to measure the depth to the water table and assess the horizontal and vertical groundwater flow conditions. Groundwater level monitoring was completed from August 2017 to December 2018. Automatic water level recorders (dataloggers) were installed in three monitoring wells to document the range of groundwater fluctuations and the response of aquifers to precipitation events (BM-5s, BM-5d and BM-9). Barometric data from a barologger installed in the vicinity of the subject lands was used for calibration of the datalogger results. The groundwater monitoring data and hydrographs are provided in Appendix D.

6. Water quality review and testing: Water quality data was collected from selected monitoring wells to typify the groundwater quality in the vicinity of the subject lands. Groundwater samples were collected in 2017 from BM-1, BM-5d and BM-9. The water samples were submitted to a qualified laboratory for analyses of general water quality indicators (e.g., pH, hardness, and conductivity), basic ions (including chloride and nitrate) and selected metals to characterize the background water quality at the property. The laboratory water quality data are provided in Appendix E.

7. Water balance calculations: Pre and post-development water balance calculations have been completed to assess the groundwater infiltration volumes across the study area. The local climate data and detailed water balance calculations are provided in Appendix F.

8. Data compilation, assessment of site conditions and reporting.

2.0 Physical Setting

2.1 Topography and Drainage

The subject lands are located within the Lake Simcoe watershed and Hewitt's Creek subwatershed. The topography of the subject lands is generally flat to gently rolling with a gradual east/northeastern slope towards St. Paul's Swamp (Figure 3). The topography ranges from a high of 268 masl along the western boundary to 251 masl within the low-lying swamp in the central and eastern portions of the subject lands. Hewitt's Creek flows through St. Paul's Swamp east of the subject lands.

2.2 Geology

The subject lands are located in the physiographic region known as the Peterborough Drumlin Field. The region is characterized as a rolling drumlinized till plain. The drumlins through the region are comprised of highly calcareous till (Chapman & Putnam, 1984).

The overburden was deposited as a series of advances and retreats of the Simcoe glacial ice lobe. This has resulted in drumlinized sheets of glacial till (Newmarket till), stratified glaciolacustrine deposits of sand and gravel, littoral-foreshore deposits and massive-well laminated deposits of sand and gravel. A review of the quaternary geology mapping for the area (OGS, 2003) indicates that the overburden sediments of the subject lands consist primarily of silty to sandy glacial till. Some organic deposits are mapped in the northeast corner of the subject lands (Figure 4).

The bedrock underlying the subject lands is mapped as the Lindsay Formation of the Simcoe Group, which consists of limestone and shale (OGS, 2007).

2.3 Regional Hydrostratigraphy

The overburden deposits of the subject lands influence groundwater occurrence and flow. The overburden has been interpreted by regional studies such as the Tier 3 Water Quantity Assessment (AquaResource, 2011) and Source Water Protection Assessment Report (LSRCA, 2012) to consist of alternating sequences of coarser-grained permeable layers (aquifers) and finer-grained less permeable layers (aquitards) of varying thicknesses. The basic hydrostratigraphic sequence that was modelled in the regional studies (AquaResource, 2011) consists of four main aquifer layers (A1-A4) and four main aquitards (C1 to C4) with a confining layer (UC) over the uppermost aquifer (A1).

A description of the interpreted regional hydrostratigraphic framework is provided below (LSRCA, 2012):

- Surficial Geology Layer – This layer represents coarse grained sediments in stream beds and at surface surficial geology areas that overly the UC. The thickness ranges from 0.1 m to 3 m.
- UC – Upper Confining Layer – Represents smaller areas of less permeable surficial material. The upper confining layer has been mapped as coarse-grained lacustrine deposits which are part of a regionally extensive sand plain (LSRCA, 2012). Regional studies such as the AquaResource (2011) report indicate that the confining layer (UC) is patchy in the area of the subject lands.
- A1 – Represents the uppermost aquifer. Frequently exists as a surficial unconfined aquifer and is stratigraphically equivalent to the Oak Ridges Moraine. It is generally associated with coarse grained glacial and interglacial sediments mapped as ice contact stratified drift. The majority of the local domestic wells are completed within this layer. The upper aquifer A1 is reported to be present throughout the larger Barrie area, and has been interpreted to occur extensively in the area of the subject lands.
- C1 – Upper aquitard; Described as varved clay and silt (LRSCA, 2012).
- A2 – Intermediate aquifer which is stratigraphically equivalent to areas within the Northern Till. The aquifer is generally described as being composed of sand with some clast rich portions (LRSCA, 2012). This layer is used for the Innisfil Heights water supply.
- C2 – Intermediate aquitard.
- A3 – This layer constitutes the main Barrie municipal aquifer and is the source of the Stroud water supply; it is stratigraphically equivalent to the Thorncliffe deposits in the Upland regions.
- C3 – Lower aquitard.
- A4 – Lower aquifer, thin and sometimes combined with A3 where C3 is thin or absent.
- C4 – Lower aquitard but may also represent weathered bedrock.

2.4 Local Stratigraphy

Eleven geotechnical boreholes were completed on the subject lands in 2017 by Soil Engineers Ltd. (logs provided in Appendix B and locations shown on Figure 5). Six of the boreholes were completed as groundwater monitoring wells (Figure 5).

The boreholes indicated that the overburden stratigraphy is generally composed of layers of glacial till and sand. Topsoil and ploughed soil was encountered at surface with a thickness of 0.8 m to 1.4 m. Fill was encountered at surface at BH2, BH3, BH5 and BH6 with a thickness of 0.8 m to 3.1 m. Underlying the surficial topsoil and fill were sandy silt till deposits. The till deposits extended to depths from 2.3 m up to 9.3 m below ground surface (mbgs). Underlying the till deposits, sand and silt deposits were encountered extending to depths of 11.2 m.

To illustrate the shallow hydrostratigraphic sequence of the subject lands, schematic geologic cross-sections have been prepared by Burnside (Figures 6 and 7) using the MECP well records (Appendix A) and the soils information collected during drilling of boreholes and monitoring wells (Appendix B). The locations of the cross-sections are illustrated on Figure 5 along with the locations of water wells and boreholes used in the construction of the cross-sections.

The cross-sections illustrate that the subject lands are underlain by a confining layer of sandy silt till (approximately 5 meters) overlying a layer of sand with a thickness of up to approximately 20 to 30 m. The sand layer is interpreted to form the local aquifer where supply wells are completed to depths that are generally less than 20 m to 30 m below ground surface. The sand layer is underlain by a low permeability clay silt till (Figures 6 and 7).

2.5 Hydraulic Conductivity

There are various methods that can be used to assess soil hydraulic conductivity, i.e., the ability of the soil to transmit groundwater. Grainsize data and soil characteristics can be used to provide a general estimate of hydraulic conductivity. In situ bail-down or slug-testing methods are used in groundwater monitoring wells to assess site-specific hydraulic conductivity. These methods have been used to estimate the hydraulic conductivity of the soils encountered in the area of the subject lands as discussed below.

2.5.1 Grainsize Analysis

Grainsize analysis of soil samples was completed as part of the geotechnical study (Soil Eng., 2016). A summary of the grainsize analyses and estimated permeability is provided in Table 1 (data provided in Appendix C).

Table 1: Summary of Grainsize Analyses

Sample ID	Depth of Sample (mbgs)	Soil Classification	Hydraulic Conductivity (cm/s)
BH5-SS8	6.3	Sandy Silt Till, some clay, a trace of gravel	1 x 10^{-6}
BH8-SS3	1.8	Sandy Silt Till, some clay, a trace of gravel	1 x 10^{-7}
BH2-SS5	3.3	Fine to Medium Sand, trace to some silt and gravel	1 x 10^{-3}
BH4-SS6	4.0	Fine to Medium Sand, trace to some silt and gravel	1 x 10^{-2}
BH9-SS6	4.8	Fine Sand, some silt and trace clay	1 x 10^{-3}
BH5-SS11	11	Silt, some fine sand, trace clay	1 x 10^{-4}
BH8-SS9	9.3	Sandy Silt, trace clay	1 x 10^{-4}

2.5.2 Single Well Response Tests

To assess the in situ hydraulic conductivity of the sediments, single well response tests (bail-down tests) were conducted at monitoring wells BM-1, BM-5d, BM-7 and BM-9. The results from the tests were plotted (Appendix C) and analyzed to calculate hydraulic conductivity of the sediments screened. A summary the calculated hydraulic conductivities is provided below in Table 2.

Table 2: Single Well Response Testing Results

Monitoring Well	Screen Interval (mbgs)*	Formation Screened	Hydraulic Conductivity (cm/sec)
BM-1	1.7 - 5.3	Sandy Silt, Sand and Silt	4.3 x 10^{-4}
BM-5d	7.1 - 10.6	Sandy Silt Till, Silt	2.3 x 10^{-4}
BM-7	0.4 - 3.6	Sandy Silt Till and Sand	1.5 x 10^{-3}
BM-9	2.4 - 5.9	Sandy Silt Till and Sand	1.1 x 10^{-3}

*metres below ground surface

2.5.3 Hydraulic Conductivity Discussion

Grainsize analyses results indicate that the sediments within the overburden range in composition from fine to medium sand with trace silt and trace gravel to sandy silt till. The greater amount of fines within a deposit impacts the ability of the material to transmit water and generally lowers the overall hydraulic conductivity. Groundwater flow is generally limited by fine grained sediments with lower hydraulic conductivity.

Grainsize analysis completed on a range of sediment types indicate that there are some sediments with lower hydraulic conductivity but the majority of the sediments found on the subject lands are sand and silty sand. The hydraulic conductivities based on grainsize analyses for the majority of the sediments is estimated in the range of 10^{-2} to 10^{-7} cm/sec.

The single well response test analyses resulted in moderate hydraulic conductivities ranging from 10^{-3} to 10^{-4} cm/sec. The wells tested were all screened across Sandy Silt Till and sand in the surficial sand layer which forms the local surficial aquifer.

Overall, the hydraulic conductivity of the overburden sediments on the subject lands consisting of sand and silty sand till is interpreted to be 10^{-3} cm/sec to 10^{-4} cm/sec.

3.0 Hydrogeology

3.1 Local Groundwater Use

The City of Barrie obtains its water from a combination of groundwater and surface water based supplies. Municipal servicing is assumed to be available for lands within the municipal boundary which includes lands north of Mapleview Drive (Figure 2) and outside of the SPA. Areas outside of municipal servicing and within the SPA are assumed to have individual private water supply wells. A review of the MECP water well records indicated that there are approximately 23 water supply well records within 500 m of the subject lands. Based on the well records and interpreted hydrostratigraphy, most of these wells are completed in the surficial (local) aquifer with depths ranging from 6 m to 50 m. The locations of the MECP water well records are shown on Figure 5.

The City of Barrie groundwater supply wells are located in deep aquifers (A3 and A4 in the regional hydrostratigraphy). There are no municipal water supply wells located close to the subject lands; the municipal water supply wells are located on the west and northern sides of the City. The subject lands do not fall within any wellhead protection areas or intake protection zones associated with the City of Barrie water supply systems (LSRCA, 2012).

3.2 Water Level Monitoring Results

Groundwater levels were monitored at the on-site monitoring wells on a monthly basis between August 2017 and August 2018 and bimonthly to December 2018. Groundwater level data is provided in tables and hydrographs in Appendix D. Groundwater elevations are plotted with daily precipitation data obtained from a nearby climate station – Barrie-Oro (Climate Station ID# 6117700) – which is the closest station with daily precipitation values for 2017. In addition to the manual water level measurements recorded at each location, automatic water level recorders were installed in BM-5s, BM-5d and BM-9 to record continuous water levels. The datalogger data collected are included on the hydrographs provided in Appendix D.

The groundwater monitoring data show the following (refer to Figure 2 for the monitoring locations and the data tables and hydrographs in Appendix D):

- Typically, in shallow wells in southern Ontario, a seasonal groundwater level fluctuation pattern is apparent with highest levels occurring in the spring, declining throughout the summer and early fall and then rising again in the late fall/early winter. This seasonal pattern is observed at the wells on the subject lands with season variations ranging from 0.8 m to 1.2 m (Figures D-1 to D-6, Appendix D).

- Continuous water level data are plotted against precipitation to determine if there is a correlation between changes in water level and the occurrence of precipitation events (Figures D-2 and D-5). At BM-9, water levels increase 0.8 m in response to a large rain and melt event in February 2018. Responses to precipitation events are also observed at BM-5s/d with a typical response to a greater than 20 mm rain event of around 0.4 m.
- The groundwater table is interpreted to generally reflect the topography of the area. From August 2017 to December 2018, groundwater elevations in the monitoring wells ranged from 254.20 masl to 263.89 masl. Groundwater was shallowest at BM-7 and BM-8s with levels less than 0.5 m below ground surface (Figures D-3 and D-4, Appendix D) and deepest at BM-1 with levels around 3 to 4 m below ground surface (Figure D-1).

3.3 Interpreted Groundwater Flow Pattern

Groundwater flow within the shallow overburden (water table) is interpreted to be influenced by the surface topography with groundwater flow from the topographically higher areas towards topographically lower areas and surface water features. Groundwater elevation data (April 2018) obtained from the monitoring wells are shown on Figure 8, along with the interpreted groundwater elevation contours for the subject lands. Arrows perpendicular to the groundwater elevation contours shown on Figure 8 illustrate the interpreted direction of the groundwater movement. Groundwater flow is interpreted to be in an east, northeast direction towards St. Paul’s Swamp and Hewitt’s Creek with an interpreted convergence towards these watercourses.

3.4 Recharge and Discharge Conditions

Areas where water from precipitation infiltrates into the ground and moves downward (i.e., areas of downward hydraulic gradients) are known as recharge areas. These areas are generally in areas of relatively higher topographic elevation. Areas where groundwater moves upward (i.e., areas of upward hydraulic gradients) to be discharged at surface are known as discharge areas and these generally occur in areas of relatively lower topographic elevation, such as along watercourses.

The monitoring of groundwater levels in nested wells BH5s/d and BH8s/d was intended to assist with the determination of vertical hydraulic gradients and thereby to assist with the evaluation of groundwater recharge or discharge conditions in the subject lands. Upward gradients are observed at both BM-5s/d and BM-8s/d (Figures D-2 and D-4, Appendix D). Both these well nests are located in close proximity to St Paul's Swamp and the occurrence of upwards gradients is interpreted to indicate groundwater discharge conditions in the swamp.

To assess shallow groundwater conditions and gradients within the swamp, two drive-point piezometer nests were monitored (PZ1s/d-BM and PZ2s/d-BM). PZ1s/d-BM is located on the southeast edge of the wetland on the subject lands (see Figure 2 for location). The hydrograph for PZ1s/d-BM (Figure D-7, Appendix D) shows that the groundwater level is generally close to or above ground surface. A small upward gradient (shallow water level lower than deep water level) is observed at PZ1s/d and this confirms that groundwater discharge conditions exist in this area. PZ2s/d-BM is located near the northern edge of the wetland (see Figure 2 for location). The hydrograph for PZ2s/d-BM (Figure D-8, Appendix D) indicates an upward gradient from May to December 2018. From November 2017 to April 2018, the water levels at PZ2d-BM are interpreted to be recovering from installation, indicating very tight low hydraulic conductivity soils which did not allow for the existing gradient to re-establish for an extended period after piezometer installation.

3.5 Significant Groundwater Recharge Areas and Ecologically Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) can be described as areas that can effectively move water from the surface through the unsaturated soil zone to replenish available groundwater resources (LSRCA, 2012). SGRAs were mapped by the Source Water Protection Assessment Report (LSRCA, 2012) as a requirement of the Clean Water Act, 2006 and based on guidance provided by the MECP. The delineation of these areas was completed using numerical models and analyses that included the evaluations of numerous factors including precipitation, temperature and other climate data along with land use, soil type, topography and vegetation to predict groundwater recharge, runoff and evapotranspiration. SGRAs represent areas where the annual recharge rate is greater than 115% of the average recharge of 164 mm/year across the Lake Simcoe watershed (or greater than the threshold recharge rate of 189 mm/year) (LSRCA, 2012). There are no SGRAs mapped within the subject lands (Figure 9).

Ecologically Significant Groundwater Recharge Areas (ESGRAs) were delineated for the Barrie Creek, Lovers Creek and Hewitt's Creek subwatersheds by Earthfx (2012) using the model developed by AquaResources for the Source Protection studies. ESGRAs were identified as areas of land that are assumed to support groundwater systems or environmentally sensitive features like lakes, cold water streams and wetlands

(Earthfx, 2012). ESGRAs were delineated by identifying pathways in which recharge, if it occurred, would reach an ecologically significant feature. Ecologically significant features used for the delineation of the ESGRAs included headwater streams, cold water fisheries, wetlands, and brook trout and sculpin capture sites.

ESGRAs and SGRAs are not mutually exclusive. ESGRAs are determined based on the linkage between a recharge area and an ecologically sensitive feature while SGRAs are located where high volumes of recharge are assumed to occur. The locations of mapped SGRAs and ESGRAs in the vicinity of the subject lands are shown in Figure 9. The mapping shows that there are no SGRAs mapped on the subject lands. There are however areas of ESGRA located to the west of the subject lands. The ESGRAs mapped within uplands area of the subject lands are assumed to be supporting the St. Paul's Swamp. The interpreted groundwater contours for the subject lands (Figure 8) support this interpretation as the upland areas are the areas mapped as ESGRA. The mapping however indicates areas of ESGRA within the wetland and low lying areas on the subject lands. Based on the observed gradients and the interpreted groundwater contours for the subject lands it has been concluded that groundwater discharge conditions exist within the wetland and low lying areas. Groundwater conditions at BM-8s/d indicate discharge conditions with BM-8d being a flowing well. With groundwater discharge being evident in these areas it is not likely that they will support groundwater recharge.

4.0 Water Quality

4.1 Groundwater Quality

Water quality data was collected from selected monitoring wells to typify the groundwater quality in the vicinity of the subject lands. Groundwater sampling was completed on April 24, 2018 at three groundwater monitoring wells (BH1, BH5d and BH9). The water samples were submitted to a certified laboratory for analyses of general water quality indicators (e.g., pH, hardness, and conductivity), basic ions (including chloride and nitrate) and selected metals to characterize the background water quality. The groundwater testing results from the analytical laboratory are provided in Table E-1, Appendix E and discussed below.

- The results showed that the water generally met the Ontario Drinking Water Quality Standards (ODWQS).
- All samples exceeded the ODWQS for total hardness (100 mg/L) with values ranging from 214 mg/L (BH1) to 403 mg/L (BH5d). Hardness in groundwater is caused by dissolved calcium and magnesium and is typically related to the geologic material of the aquifer.

- All samples exceeded the ODWQS for turbidity (5 NTU) with values ranging from 472 NTU (BM-9) to 10,400 NTU (BM-5s). This is likely a result of high silt content in the samples and may be due to lack of development of the monitoring wells after completion. It is noted that the monitoring wells were completed as part of the site geotechnical assessment and hence well development would not have been a requirement of construction. Due to the fact that no groundwater use is proposed on the subject lands, the lack of development is not regarded as an issue.

- Nitrate was detected in all samples with values ranging from 6.37 mg/L at BM-1 to 8.92 mg/L at BM-5d. Nitrate in shallow groundwater is typical of areas where agricultural activities are present. The sample from the deeper well BM-5d was greater than from the shallow wells BM-1 and BM-9. This suggests that the source of the nitrate may be off-site.

- Total phosphorus was reported in the samples at values ranging from 0.08 mg/L to 1.55 mg/L. Total phosphorus is a measure of all forms of phosphorus (dissolved or particulate) that are found in the water sample. There was no dissolved phosphorus (ortho-phosphate) reported in the groundwater samples suggesting the reported concentrations are particulate.

- Elevated sodium concentrations at BM-1 (68.9 mg/L) and BM-5d (54 mg/L) may be a result of impacts from road salt. Sodium at BM-9 was 8.1 mg/L.

5.0 Water Balance

In order to assess potential land development impacts on the local groundwater conditions, a detailed water balance analysis has been completed to determine the pre-development recharge volumes (based on existing land use conditions) and the post-development recharge volumes that would be expected based on the proposed land use plan. The detailed water balance calculations are provided in Appendix F. The water balance was completed based on interpreted groundwater flow to specific groundwater supported features that were delineated during the SIS process. The locations of groundwater supported features is provided on Figure 10.

5.1 Water Balance Components

A water balance is an accounting of the water resources within a given area. As a concept, the water balance is relatively simple and may be estimated from the following equation:

$$P = S + ET + R + I$$

Where:
P = precipitation
S = change in groundwater storage

ET = evapotranspiration/evaporation
R = surface water runoff
I = infiltration

The components of the water balance vary in space and time and depend on climatic conditions as well as the soil and land cover conditions (i.e., rainfall intensity, land slope, soil hydraulic conductivity and vegetation). Runoff, for example, occurs particularly during periods of snowmelt when the ground is frozen, or during intense rainfall events. Precise measurement of the water balance components is difficult and as such, approximations and simplifications are made to characterize the water balance of a property. Field observations of the drainage conditions, land cover and soil types, groundwater levels and local climatic records are important input considerations for the water balance calculations.

The groundwater balance components for the subject lands are discussed below:

Precipitation (P)

The long-term average annual precipitation for the area is 933 mm based on data from the Environment Canada Barrie WPCC (Station 6110557, 44°22'33.012" N, 79°41'23.010" W, elevation 221.0 masl) for the period between 1981 and 2010. The climate station is located 6 km northeast of the subject lands. Average monthly records of precipitation and temperature from this station have been used for the water balance calculations in this study (Appendix F).

Storage (S)

Although there are groundwater storage gains and losses on a short-term basis, the net change in groundwater storage on a long-term basis is assumed to be zero so this term is dropped from the equation.

Evapotranspiration (ET)

Evapotranspiration and evaporation components vary based on the characteristics of the land surface cover (i.e., type of vegetation, soil moisture conditions, perviousness of surfaces, etc.). Potential evapotranspiration (PET) refers to the water loss from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of evapotranspiration (AET) is generally less than the PET under dry conditions (i.e., during the summer when there is a soil moisture deficit). In this report, the PET and AET have been calculated using a soil-moisture balance approach.

Water Surplus (R + I)

The difference between the mean annual P and the mean annual ET is referred to as the water surplus. This water surplus is the component that becomes available for runoff and infiltration. Within the water balance computation it is assumed that a part of the water surplus travels across the surface of the soil as surface or overland runoff (R) and the remainder infiltrates the surficial soil (I). The infiltration is comprised of two end member components: one component that moves vertically downward to the groundwater table (referred to as recharge) and a second component that moves laterally through the topsoil profile or shallow soils as interflow that re-emerges locally to surface (i.e., as delayed runoff) at some short time following cessation of precipitation. As opposed to the “direct” component of surface runoff that occurs during precipitation or snowmelt events, interflow becomes an “indirect” component of runoff. The interflow component of surface runoff is not accounted for in the water balance equation cited above since it is often difficult to distinguish between interflow and direct (overland) runoff, however both interflow and direct runoff together form the total surface water runoff component.

5.2 Approach and Methodology

The analytical approach to calculate the water balance involves monthly soil-moisture balance calculations to determine the pre-development (based on existing land use) infiltration volumes. A soil-moisture balance approach assumes that soils do not release water as potential recharge while a soil moisture deficit exists. During wetter periods, any excess of precipitation over evapotranspiration first goes to restore soil moisture. Once the soil moisture deficit is overcome, any further excess water can then pass through the soil as infiltration and either become interflow (indirect runoff) or recharge (deep infiltration).

A soil moisture storage capacity of 150 mm was used for the areas where the land cover was predominantly short to moderate-rooted vegetation in the fields and agricultural areas (Table F-1, Appendix F). A soil moisture storage capacity of 300 mm was used for wooded areas within the subject lands (Table F-2, Appendix F). Tables F-1 and F-2 in Appendix F detail the monthly potential evapotranspiration calculations accounting for latitude and climate, and then calculate the actual evapotranspiration and water surplus components of the water balance based on the monthly precipitation and soil moisture conditions.

The MECP SWM Planning and Design Manual (2003) methodology for calculating total infiltration based on topography, soil type and land cover was used and a corresponding runoff component was calculated for the soil moisture storage conditions. The calculated water balance components from this table are then used to assess the pre-development and post development volumes for runoff and infiltration as presented on Tables F-3, F-4 and F-5 in Appendix F. The water balance was computed based on contributing areas to groundwater supported features as delineated during the SIS.

5.3 Water Balance Component Values

The detailed monthly calculations of the water balance components are provided in Tables F-1 and F-2 in Appendix F. For these calculations, it has been assumed that sandy loam soils are representative for the subject lands for estimating the soil infiltration factor. The calculations show that a water surplus is generally available from November to May (see Figure F-1). The monthly water balance calculations illustrate how infiltration occurs during periods when there is sufficient water available to overcome the soil moisture storage requirements. The monthly calculations are summed to provide estimates of the annual water balance component values (Tables F-1 and F-2, Appendix F). A summary of these values is provided in Table 3.

Table 3: Water Balance Component Values

Water Balance Component	Agricultural Lands	Wooded Areas
Average Precipitation	933 mm/year	933 mm/year
Actual Evapotranspiration	593 mm/year	593 mm/year
Water Surplus	340 mm/year	340 mm/year
Infiltration	283 mm/year	272 mm/year
Runoff	102 mm/year	68 mm/year

5.4 Pre-Development Water Balance (Existing Conditions)

There are three wetland areas that are interpreted to receive groundwater contributions from the subject lands, Wetland #3, Wetland #4 and Wetland #6 (Figure 10). The wetland feature areas in the Hewitt’s SPA SIS were originally delineated by Azimuth in 2014. As part of the Hewitt’s SPA SIS (Burnside, 2016), the associated catchments for each wetland were delineated. Wetland mapping was updated by Savanta in 2018 and the updated areas are used for the water balance calculations performed as part of the current assessment.

Based on the water balance component values calculated in Tables F-1 and F-2 (Appendix F), an estimate of the total pre-development groundwater infiltration volume for each catchment within the subject lands was calculated (Tables F-3 to F-5, Appendix F). Similar to the Hewitt’s SPA SIS water balance calculations, wetland areas were assigned an impervious factor of 100%, since upward gradients and shallow water table prevent infiltration from occurring. A summary of the pre-development groundwater infiltration values is provided in Table 4.

Table 4: Summary of Pre-Development Infiltration Values

Wetland Catchment	Approximate Land Area (ha)	Average Annual Infiltration (m^3/year)
3	6.3	5,400
4	18.5	22,900
6	1.6	3,100
TOTALS	**26.4**	**31,400**

5.5 Potential Urban Development Impacts to Water Balance

Development of an area affects the natural water balance. The most significant difference between pre and post development conditions is the addition of impervious surfaces as a type of surface cover (i.e., roads, parking lots, driveways, and rooftops). Impervious surfaces prevent infiltration of water into the soils and the removal of the vegetation removes the evapotranspiration component of the natural water balance resulting in evaporation as the only remaining loss mechanism (beside runoff). The evaporation component from impervious surfaces is relatively minor (estimated to be 10% to 20% of precipitation) compared to the evapotranspiration component that occurs with vegetation in this area (about 64% of precipitation in the subject lands). So the net effect of the construction of impervious surfaces is that most of the precipitation that falls onto impervious surfaces becomes surplus water and direct runoff. The natural infiltration components (interflow and deep recharge) are reduced.

A water balance calculation of the potential water surplus for impervious areas is shown at the bottom of Table F-1 in Appendix F. The evaporation component for the impervious surfaces has been estimated at 15% of precipitation for the purposes of this study. The remaining 85% of the precipitation that falls on impervious surfaces is assumed to become runoff. Therefore, assuming an evaporation/loss from impervious surfaces of 15% of the precipitation, there is a potential water surplus from impervious areas of 793 mm/year.

It is noted that the proposed development will be serviced by municipal water supply and waste water services. Therefore, there will be no impact on the water balance and local groundwater or surface water quantity and quality conditions related to any on-site groundwater supply pumping or disposal of septic effluent.

5.6 Post-Development Water Balance with No Mitigation

To assess potential development impacts on infiltration, the post-development infiltration volumes have been calculated for each of the wetland catchment areas on the subject lands on Tables F-3, F-4 and F-5 in Appendix F. These calculations assume no low impact development (LID) measures for stormwater management are in place. The total areas for the proposed land uses and the associated percentage impervious factors were provided by SCS Consulting Group.

The infiltration and runoff components for the post-development land uses have been calculated using the MECP SWM Planning and Design Manual (2003) methodology based on topography, soil type and land cover as shown on Tables F-1 and F-2 in Appendix F.

From these tables, the total calculated post-development infiltration volume (without LID measures) for each wetland catchment area is provided in Table 5 below.

Table 5: Summary of Post-Development Infiltration Values (without LID measures)

Wetland Catchment	Post-Development Infiltration (m^3/year)	Post-Development Infiltration Deficit (m^3/year)	Percentage Change
3	2,000	3,500	-64%
4	9,750	13,100	-57%
6	900	2,200	-71%
TOTAL	**12,650**	**18,800**	-64%

5.7 Recommended Mitigation Strategies for Infiltration

The water balance calculations suggest that, without mitigation, the subject lands will receive about 36% of the current amount of average annual groundwater infiltration after development. The overall deficit in groundwater infiltration has been estimated to be 18,800 m^3/year (see Table 5 and Tables F-3, F-4 and F-5 in Appendix F). It is recommended to minimize the potential development impacts to infiltration through the use of 'low impact development' (LID) measures for stormwater management to ensure the post-development groundwater infiltration volume is maintained as close to the pre-development infiltration volume as possible.

In order to maintain existing groundwater inputs to each of the wetland catchments, the target infiltration through the use of LIDs for each catchment is provided above in Table 5. There, as outlined in the MECP SWM Design Manual (2003), a number of mitigation techniques that can be used to increase the potential for post-development infiltration and mitigate the reductions in infiltration that may occur with land development. Techniques to maximize the water availability in pervious areas such as designing grades to direct roof runoff towards lawns, side and rear yard swales, boulevards, parks, and other open space areas throughout the development where possible and increasing the topsoil thickness (i.e., from typical thicknesses of about 15 cm up to 20 cm or 30 cm) can increase the potential for infiltration in developed areas. These types of surface LID techniques promote natural infiltration by providing additional water volumes in the pervious areas. This may be particularly effective in the summer months, when natural infiltration would not generally occur because the additional water overcomes the natural soil moisture deficit. Other LID measures that may be considered to reduce runoff volumes include bioswales, rain gardens, perforated pipe systems, infiltration trenches and facilities, permeable pavements, tree boxes, and rainwater harvesting techniques, such as cisterns and rain barrels.

6.0 Development Considerations

6.1 Construction Below the Water Table

Based on groundwater level data collected as part of this study water table on the subject lands ranges from 0 m to 4 m below ground surface. Should excavations during construction of servicing extend below the water table the local soils may need to be dewatered. Significant groundwater flows may be encountered in areas where high permeability sand and gravel layers are encountered. The construction of buried services below the water table has the potential to capture and redirect groundwater flow through more permeable fill materials typically placed in the base of excavations. Groundwater may also infiltrate into joints in storm sewers and manholes. Over the long-term, these impacts can lower the groundwater table across the development area. To mitigate this effect, services to be installed below the water table should be constructed to prevent redirection of groundwater flow. This will involve the use of anti-seepage collars or clay plugs surrounding the pipes to provide barriers to flow and prevent groundwater flow along granular bedding material and erosion of the backfill materials.

Due to shallow water table conditions on some areas of the subject lands there is the potential for encountering the water table during construction. The dewatering of local aquifers may be required in order for services to be installed below the water table. The undertaking of dewatering according to industry standards and in accordance with a MECP processes will ensure that adequate attention is paid to potential adverse impacts to the environment. Currently the MECP allows for construction dewatering of less than 400,000 L/d to proceed under the Environmental Activity Sector Registry (EASR) process. If dewatering is to be above this threshold, then the standard Permit to Take Water (PTTW) process applies. In both cases, a scientific study is required in support of EASR registration or PTTW application. This scientific study must review the potential for environmental impacts and provide mitigation and monitoring measures to the satisfaction of the MECP or other review agency. The requirements for construction dewatering should be confirmed by geotechnical/hydrogeological investigations completed in support of detailed design.

6.2 Local Groundwater Supply Wells

The area surrounding the subject lands is not currently serviced and residences are supplied by private wells. A water well survey study was completed on behalf of the Hewitt’s SPA Landowner’s Group for residences within 300 m of the Hewitt’s SPA lands to assess the potential for impacts to private supply wells (Burnside, 2018). The report, which included the subject lands identified potentially vulnerable wells in the vicinity of the subject lands and outlined a monitoring and mitigation plan. This report will be submitted as a separate document in the Draft Plan approval submission.

It is expected that the monitoring outlined in this report will be implemented during construction and the interference protocol identified will be implemented should any episode of interference occur.

6.3 Well Decommissioning

Prior to or during construction, it is necessary to ensure that all inactive wells within the development footprint have been located and properly decommissioned by a licensed water well contractor according to Ontario Regulation 903. This regulation applies private domestic wells and to the groundwater observation wells installed for this study unless they are maintained throughout the construction for monitoring purposes.

7.0 References

AquaResource et al. 2011. City of Barrie Tier Three Water Balance and Local Area Risk Assessment Groundwater Flow Model, AquaResource, Golder and IWC, 2011.

Burnside, 2016. Hewitt's Secondary Plan Area Hydrogeological Assessment, Hewitt's Landowners Group, R.J. Burnside & Associates Limited, June 2016.

Burnside, 2018. Hewitt's SPA Lands Well Survey Report, Hewitt's Creek Landowners Group, Barrie, Ontario. R.J. Burnside & Associates Limited, October 2018.

Chapman, L.J. and D.F. Putnam, 1984. The Physiography of Southern Ontario, Third Edition; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map 2715.

Earthfx, 2012. Barrie, Lovers, and Hewitt Creeks – Ecologically Significant Groundwater Recharge Area Assessment and Sensitivity Analysis, Earthfx Incorporated, June 2012.

LSRCA, 2012. The Barrie Creeks, Lovers Creek and Hewitt's Creek Subwatershed Plans, Lake Simcoe Region Conservation Authority, 2012.

LSRCA, 2015. Lake Simcoe Region Conservation Authority – Approved Assessment Report; Lake Simcoe and Couchiching- Black River Source Protection Area, Part 1 Lake Simcoe Watershed, January 2015.

Ontario Geological Survey. 2003. Surficial Geology of Southern Ontario, Open File 3300, Scale 1:50,000.

OGS, 2007. Paleozoic Geology of Southern Ontario; Ontario Geological Society, Miscellaneous Release – Data 219, 2007.

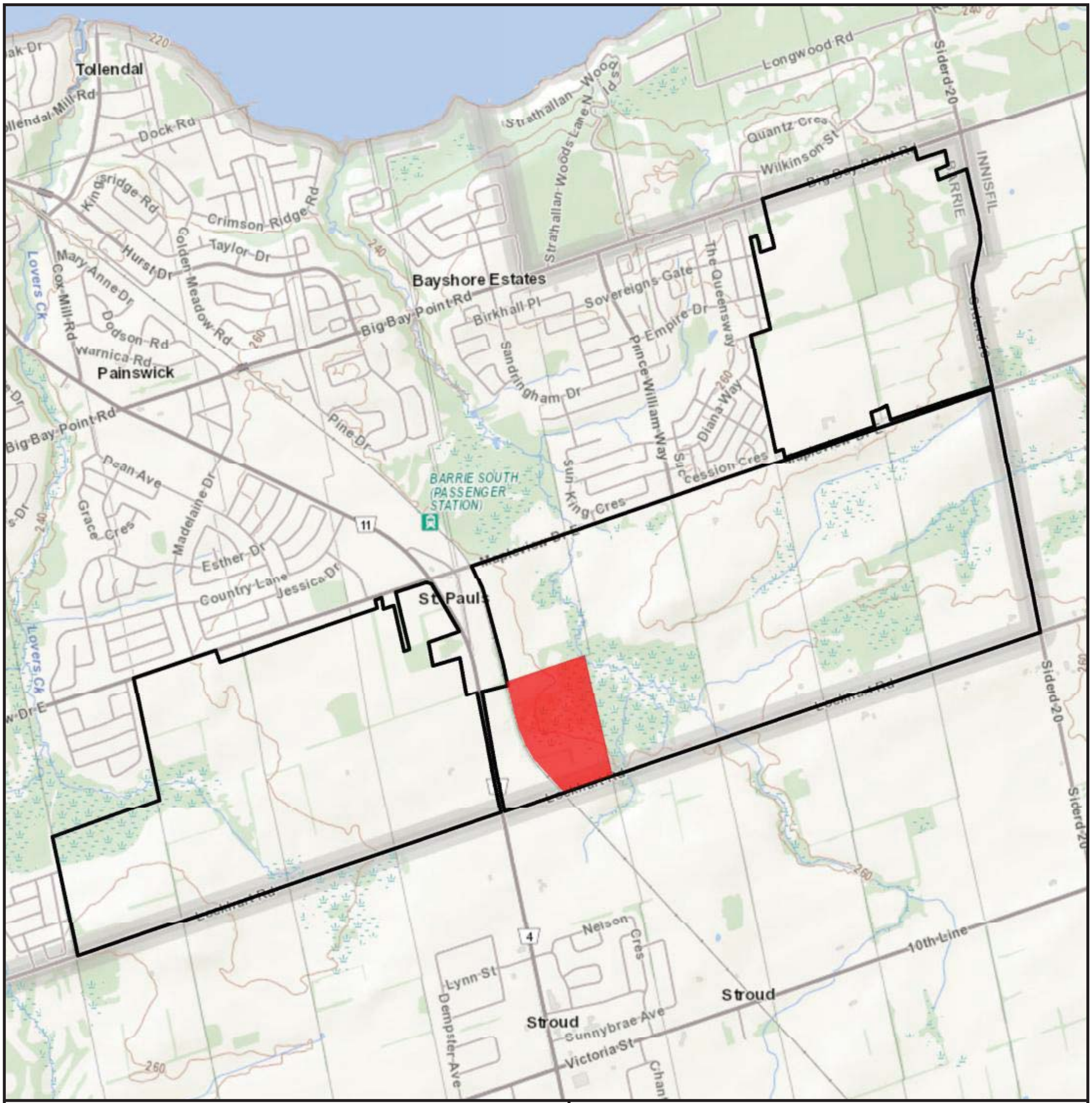
Ontario Ministry of the Environment and Climate Change, Water Well Records.

Soil Eng., 2017. Preliminary Geotechnical Investigation Due Diligence for Land Acquisition, 750 Lockhart Road, Barrie, Ontario. Soil Engineers Ltd., September 5, 2017.

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Figures



LEGEND

🟥 SUBJECT LANDS

▭ HEWITT'S SECONDARY PLAN AREA (STUDY

N

0 250 500 1,000 1,500 2,000

Meters

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	1
Scale		Project No.	
1:31,350		300041171	

File Path: Nigel\ Shared Work Areas\A:\041171 Ballymore\041171 Site Location.mxd Print Date: 2019/02/14 Time: 01:13 PM

LEGEND

🟥 SUBJECT LANDS

▬ RAILWAY

— WATERCOURSE

⊕ MONITORING WELL (SOIL ENG., 2017)

● DRIVE POINT PIEZOMETER (RJB, 2017)

Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.

Satellite Imagery:
ESRI Service Layers (if present): Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User

N

0 50 100 150 200 250 300
Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

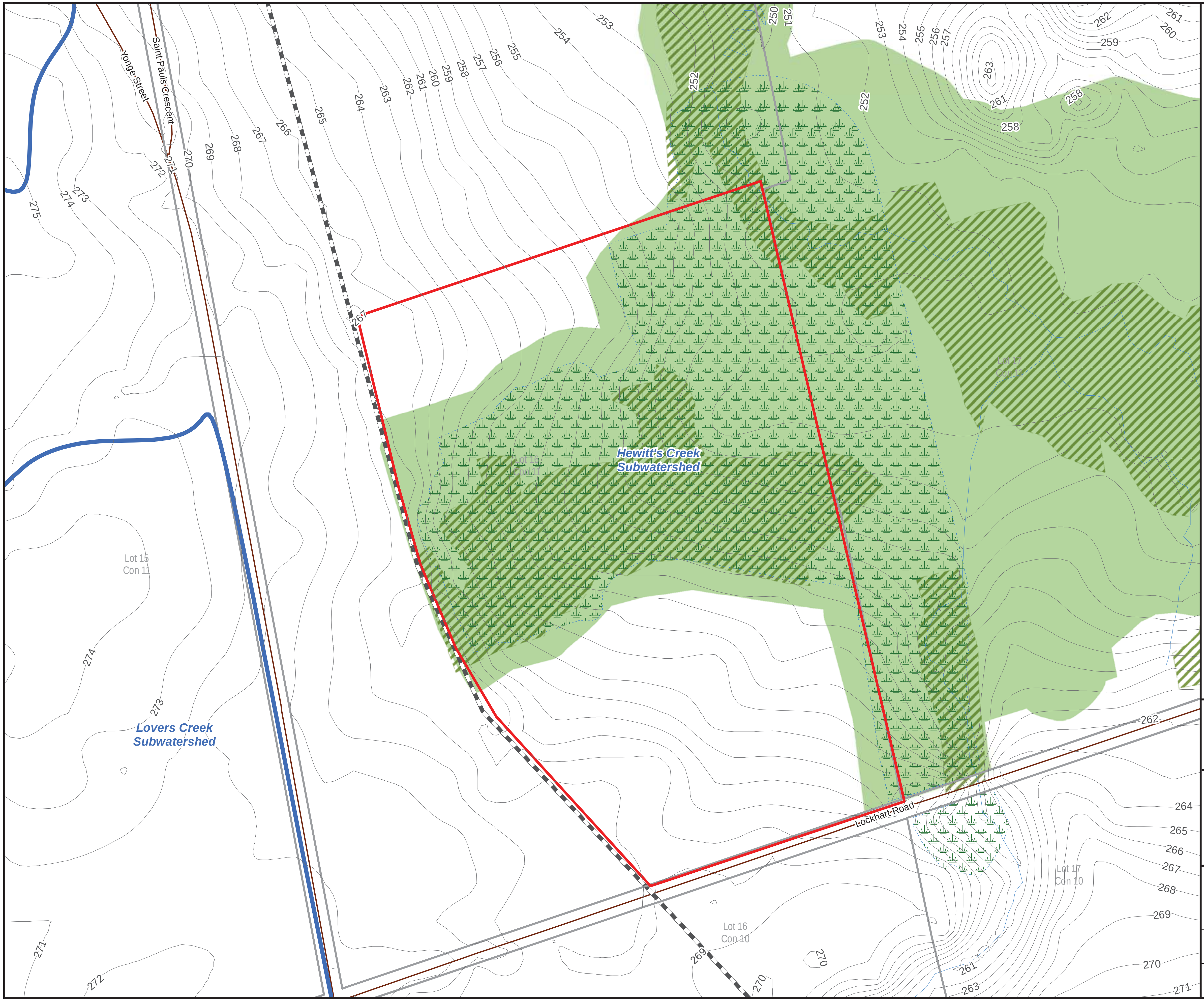
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

SITE PLAN

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	2
Scale		Project No.	
1:4,000		300041171	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Site Plan.mxd Print Date: 2019/02/14 Time: 01:31 PM

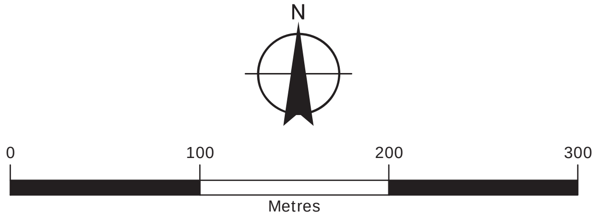


LEGEND

🟥 SUBJECT LANDS
SUBWATERSHED BOUNDARY
▨ WETLAND (AZIMUTH, 2014)
WETLAND (Savanta, 2018)
🟩 NHS CORE AND BUFFER
RAILWAY
WATERCOURSE: PERMANENT
WATERCOURSE: INTERMITTENT
ROADWAY
CONTOUR (1m intervals - masl)

Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. Regional Contours derived from Ontario Ministry of Natural Resources and Forestry, Provincial Digital Elevation Model Version 3.0, 2013.
4. Site contours provided by RUDY MAK SURVEYING LTD., 2018.



BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

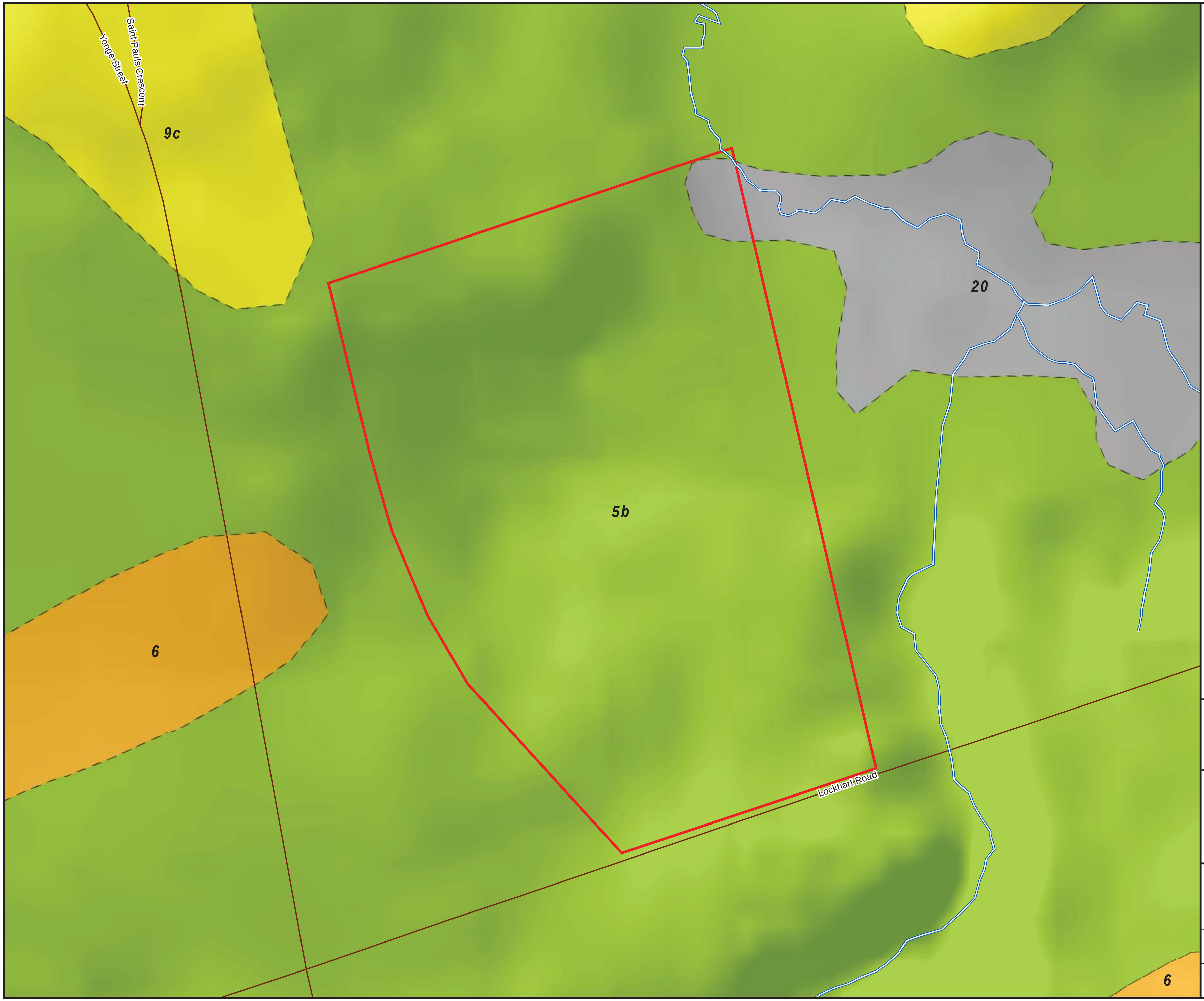
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

TOPOGRAPHY AND DRAINAGE

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	3
Scale		Project No.	
1:4,000		300040647	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Topography and Drainage.mxd   Print Date: 2019/02/14 Time: 02:00 PM



LEGEND

- 🟥 SUBJECT LANDS
- ═ WATERCOURSE
- — ROADWAY
- 🟩 5b: Stone-poor, carbonate-derived silty to sandy till
- 🟧 6: Ice-contact stratified deposits
- 🟨 9b: Coarse-textured glaciolacustrine deposits: Littoral-foreshore deposits
- 🟨 9c: Coarse-textured glaciolacustrine deposits: Foreshore-basinal deposits
- ⬜ 20: Organic deposits

Sources:

1. Ministry of Natural Resources, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. Ontario Geological Survey 2003. Surficial Geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128.

N

0 50 100 150 200 250 300
Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

SURFICIAL GEOLOGY

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	4
Scale		Project No.	
1:4,000		300041171	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Surficial Geology.mxd Print Date: 2019/02/14 Time: 01:33 PM

LEGEND

— SUBJECT LANDS
— WATERCOURSE
⊕ MONITORING WELL (RJB, 2014)
⊕ MONITORING WELL (RJB, 2017)
⊕ MONITORING WELL (SOIL ENG., 2017)
⊕ MONITORING WELL (SOIL ENG., 2018)
⊕ BOREHOLE (SOIL ENG., 2017)
⊕ BOREHOLE (GOLDER, 2006)
⊕ BOREHOLE (SOIL ENG., 2018)
⊕ MOECC WELL RECORD LOCATION
A A' CROSS-SECTION LOCATION KEY

N

0 100 200 400 600
Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

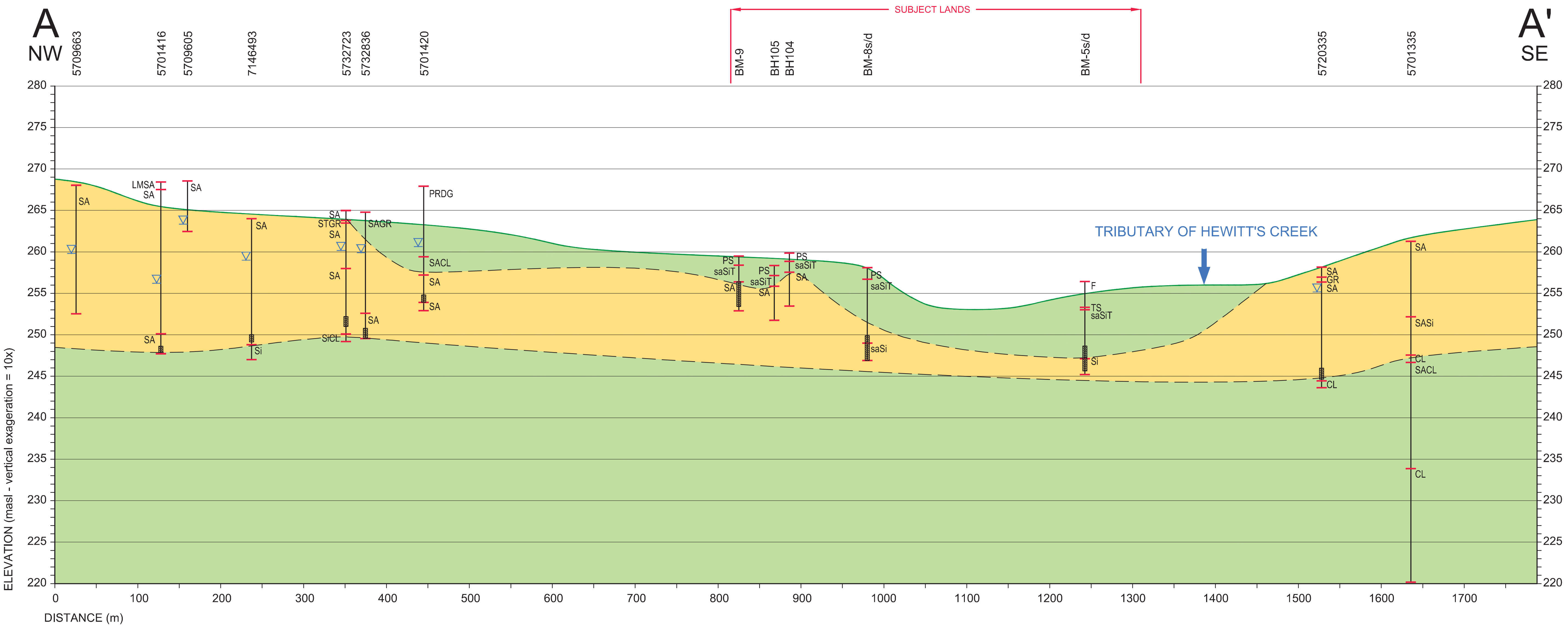
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

WELL LOCATION PLAN

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	5
Scale		Project No.	
1:7,500		300041171	

File Name: 041171 Cross-Sections.dwg Date Plotted: February 14, 2019 - 1:42 PM



LEGEND

BH1 WELL NUMBER / ID

EXISTING GROUND PROFILE

GEOLOGICAL CONTACT

▽ STATIC WATER LEVEL
(MOECC WELL RECORD)

▨ WELL SCREEN

si	SILTY
sa	SANDY
cl	CLAYEY
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
T	TILL
PRDG	PREDUG

----- INTERPRETED STRATIGRAPHY

🟨 SAND / GRAVEL

🟩 SILT / CLAY

BURNSIDE

Client / Report

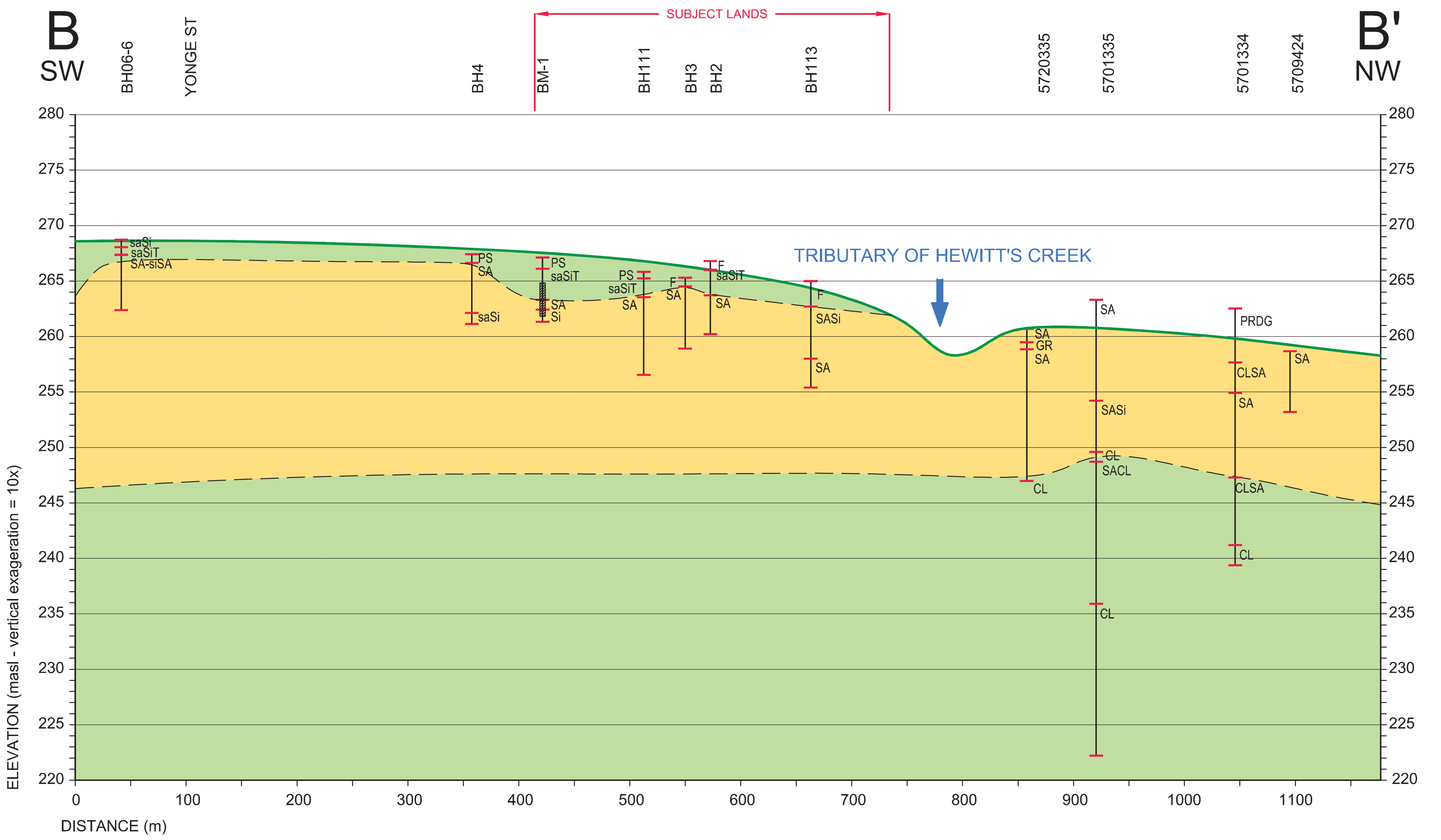
BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION A-A'

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	6
Scale		Project No.	
1:5,000		300041171	

File: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Cross-Sections.dwg Date Plotted: February 14, 2019 - 1:42 PM



LEGEND

BH1 WELL NUMBER / ID

EXISTING GROUND PROFILE

GEOLOGICAL CONTACT

▽ STATIC WATER LEVEL
(MOECC WELL RECORD)

▨ WELL SCREEN

si	SILTY
sa	SANDY
cl	CLAYEY
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
T	TILL
PRDG	PREDUG

----- INTERPRETED STRATIGRAPHY

🟨 SAND / GRAVEL

🟩 SILT / CLAY

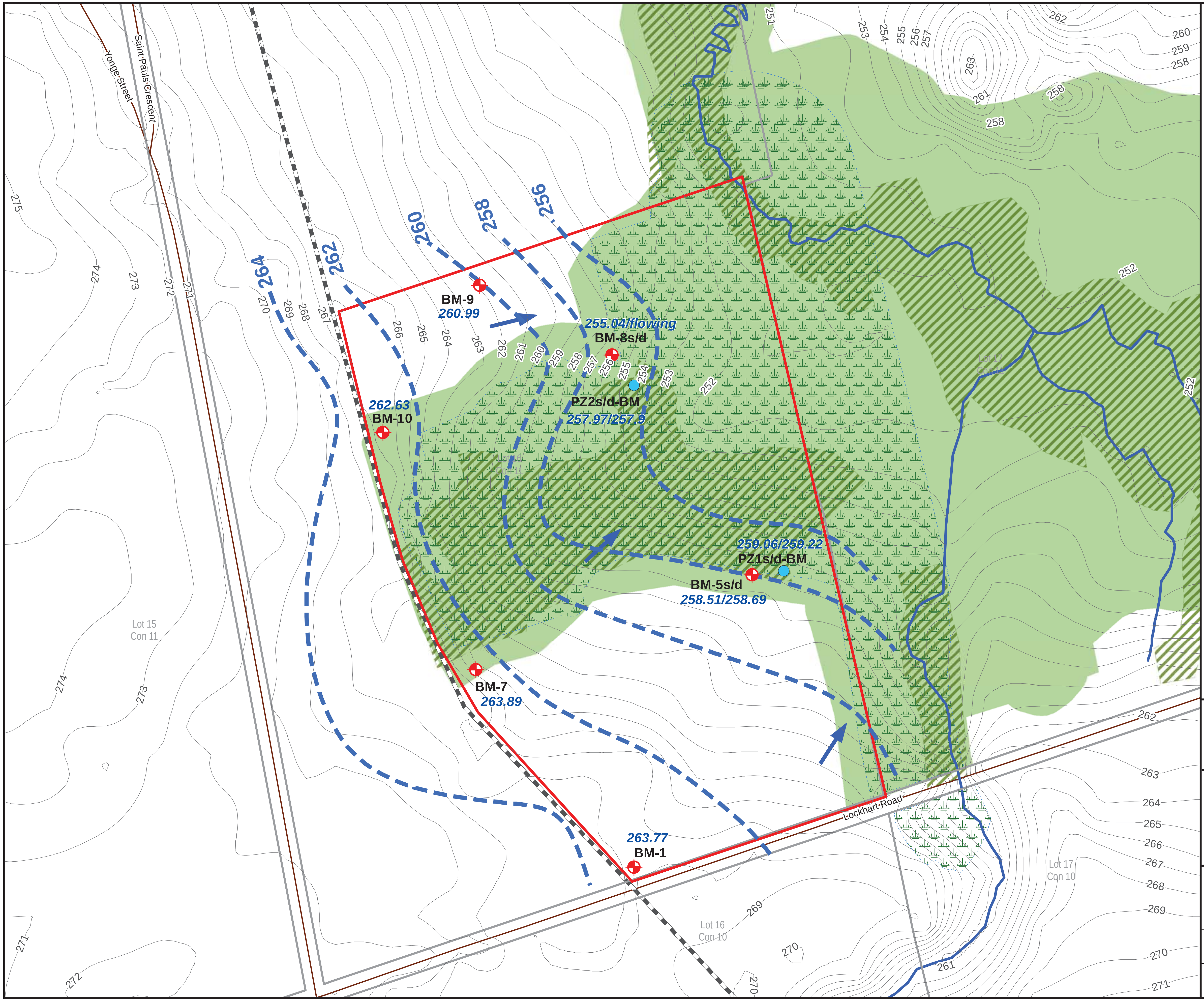
BURNSIDE

Client / Report
BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title
INTERPRETED GEOLOGICAL CROSS-SECTION B-B'

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	7
Scale		Project No.	
1:5,000		300041171	

File: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Cross-Sections.dwg Date Plotted: February 14, 2019 - 1:42 PM



LEGEND

🟥 SUBJECT LANDS
WETLAND (Savanta, 2018)
▨ WETLAND (AZIMUTH, 2014)
🟩 NHS CORE AND BUFFER
RAILWAY
WATERCOURSE
ROADWAY
CONTOUR (1m intervals - masl)
MONITORING WELL (SOIL ENG., 2017)
● DRIVE POINT PIEZOMETER (RJB, 2017)
INTERPRETED GROUNDWATER CONTOUR (masl)
263.89 MEASURED WATER LEVEL (April 24, 2018)
➡ INTERPRETED GROUNDWATER FLOW DIRECTION

Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. Regional Contours derived from Ontario Ministry of Natural Resources and Forestry, Provincial Digital Elevation Model Version 3.0, 2013.
4. Site contours provided by RUDY MAK SURVEYING LTD., 2018.

N

0 50 100 150 200 250 300
Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

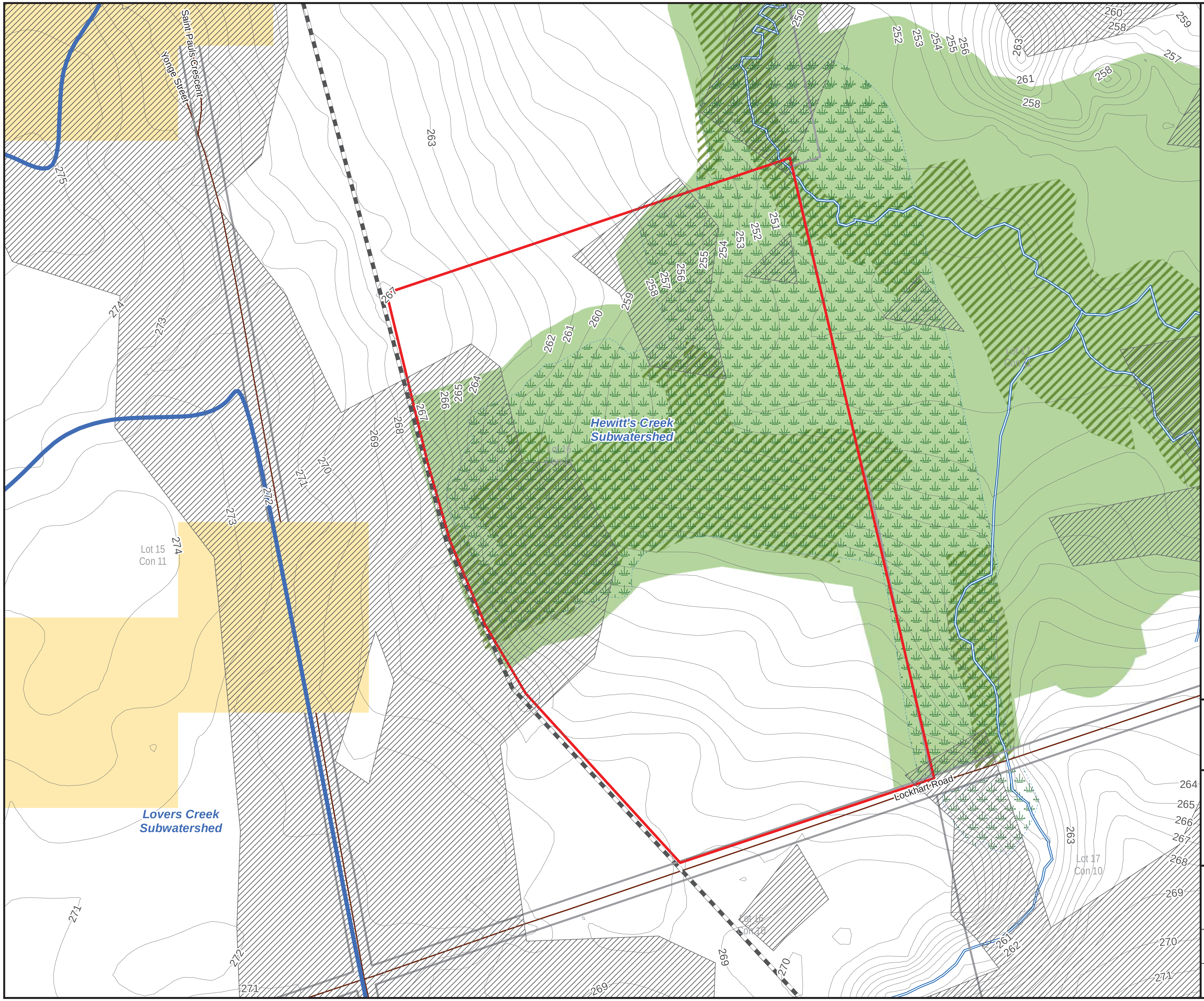
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

INTERPRETED GROUNDWATER FLOW

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	8
Scale		Project No.	
1:4,000		300040647	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Groundwater Flow.mxd Print Date: 2019/02/14 Time: 01:57 PM



LEGEND

- 🟥 SUBJECT LANDS
- ━ SUBWATERSHED BOUNDARY
- ▨ ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (ESGRA, LSRCA)
- 🟨 SIGNIFICANT GROUNDWATER RECHARGE AREAS (SGRA, LSRCA)
- ▨ WETLAND (Savanta, 2018)
- ▨ WETLAND (AZIMUTH, 2014)
- 🟩 NHS CORE AND BUFFER *NHS CORE AND BUFFER*
- ▬ RAILWAY
- ═ Watercourse (OHN)
- ― ROADWAY
- ― CONTOUR (1m intervals - masl)

Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. Regional Contours derived from Ontario Ministry of Natural Resources and Forestry, Provincial Digital Elevation Model Version 3.0, 2013.
4. Recharge Area mapping provided by Lake Simcoe Region

N

0 100 200 300
Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

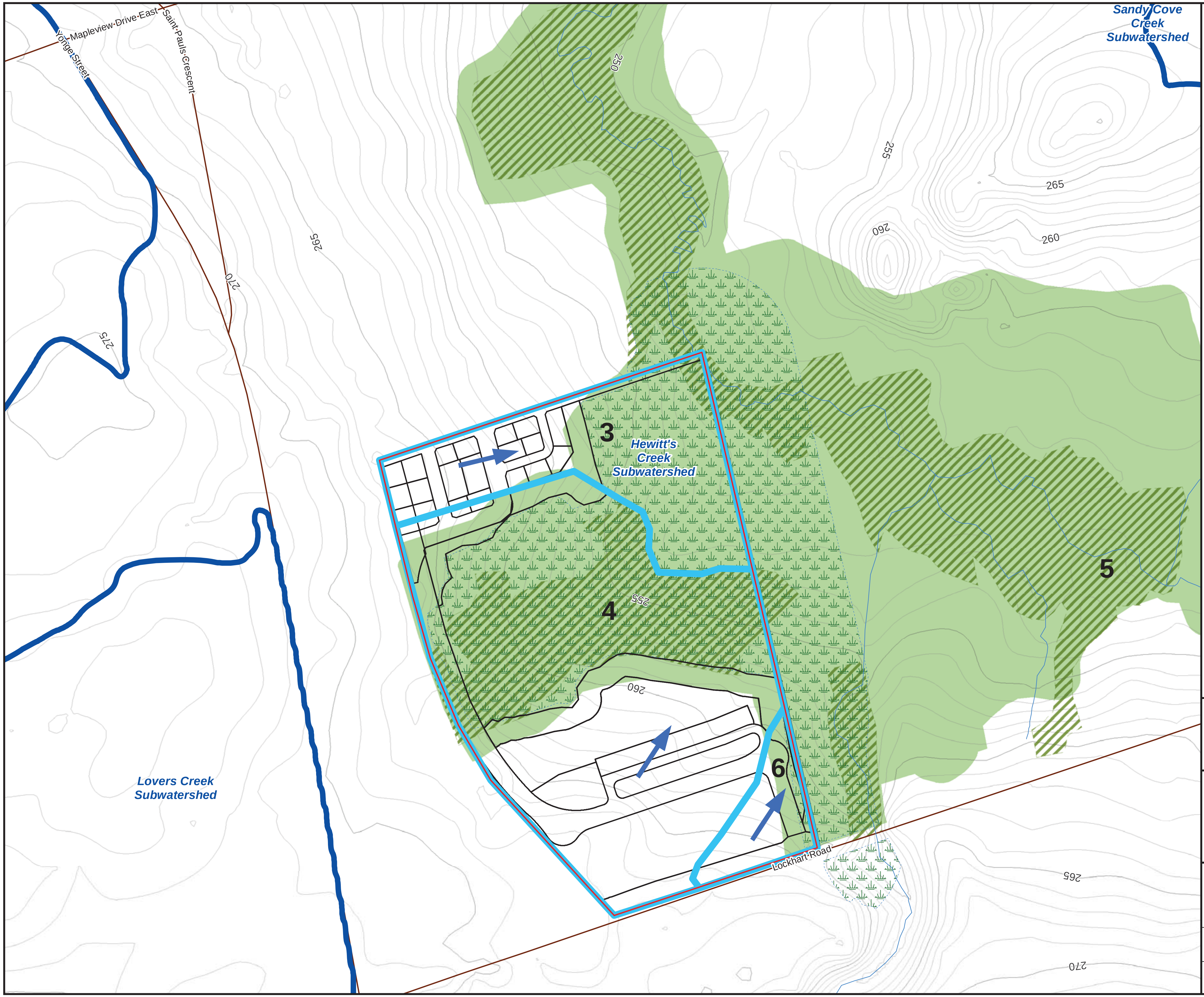
HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

RECHARGE AREAS

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	9
Scale		Project No.	
1:4,000		300041171	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Recharge Areas.mxd Print Date: 2019/02/14 Time: 02:07 PM



LEGEND

- 🟥 SUBJECT LANDS
- ━ SUBWATERSHED BOUNDARY
- ─ WATERCOURSE
- ─ CONTOUR (5m intervals - masl)
- ─ CONTOUR (1m intervals)
- ─ ROADWAY
- ▨ WETLAND (Savanta, 2018)
- ▨ WETLAND (AZIMUTH, 2014)
- 🟩 NHS CORE AND BUFFER
- ━ AREAS CONTRIBUTING TO WETLANDS
- ─ PROPOSED DEVELOPMENT PLAN
- **1** WETLAND REFERENCE NUMBER (AZIMUTH, 2016)
- ➡ GROUNDWATER FLOW DIRECTION

Sources:

1. Ministry of Natural Resources, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.

N

0 100 200 300 400

Metres

BURNSIDE

Client / Report

BALLYMORE BUILDING (BARRIE) CORP.
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

WETLAND CONTRIBUTING AREAS

Drawn	Checked	Date	Figure No.
SK	SC	February 2019	10
Scale		Project No.	
1:5,000		300041171	

File Path: Nigel/Shared Work Areas/A:\041171 Ballymore\041171 Wetland Contributing Areas.mxd Print Date: 2019/02/14 Time: 01:29 PM

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix A

MECP Water Well Records

Water Well Records

Monday, September 17, 2018

2:57:17 PM

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP	17 609712 4910766 W	2014/04 6809	2			TH	0022 5	7239318 (Z175927) A152307	BRWN CLAY SILT 0015 BRWN CSND 0028
INNISFIL TOWNSHIP	17 610469 4910446 W	2016/06 6946	2			MO	0010 10	7266354 (Z232470) A203374	BRWN SAND STNS WBRG 0020
INNISFIL TOWNSHIP CON 10 017	17 610599 4910458 W	1967/07 2514	6					5701335 () A	LOAM 0001 MSND 0030 GREY FSND SILT 0045 BLUE CLAY 0048 GREY FSND CLAY 0090 BLUE CLAY 0135
INNISFIL TOWNSHIP CON 10 017	17 610725 4910471 W	1965/10 2514	6					5701334 () A	PRDG 0016 BRWN CLAY MSND 0025 GREY FSND 0050 BLUE CLAY MSND STNS 0070 BLUE CLAY 0076
INNISFIL TOWNSHIP CON 11 015	17 609376 4910783 L	2004/04 2513	6.28	FR 0085	36/55/2/1:0	DO	0086 6	5738721 (Z00199) A000103	BRWN SAND SILT STNS 0014 YLLW SAND 0062 BLUE SAND SILT CLAY 0085 GREY SAND SILT CMTD 0092
INNISFIL TOWNSHIP CON 11 015	17 609614 4910663 W	1968/09 4608	30	FR 0025	26///:	DO		5705828 ()	BRWN CLAY STNS 0020 MSND 0036
INNISFIL TOWNSHIP CON 11 015	17 609571 4911277 W	1963/01 4102	30	FR 0018	18//2/:	DO		5701477 ()	CSND 0025
INNISFIL TOWNSHIP CON 11 015	17 609575 4910893 W	1967/01 4608	30	FR 0035	35//2/:	DO		5701419 ()	BRWN CLAY 0035 MSND 0050
INNISFIL TOWNSHIP CON 11 015	17 609572 4910457 W	1965/08 2514	6	FR 0043	30/52/3/2:30	ST DO	0052 3	5701415 ()	PRDG 0033 MSND CLAY 0043 MSND 0055 FSND 0058
INNISFIL TOWNSHIP CON 11 015	17 609564 4910423 W	1979/04 3203	6 5	FR 0060	30/75/2/6:10	DO	0080 3	5716067 ()	PRDG 0030 PRDR 0060 BRWN SAND CLAY 0064 GREY SAND CLAY LYRD 0083 GREY CLAY 0092
INNISFIL TOWNSHIP CON 11 015	17 609488 4911138 W	1959/10 1510	2	FR 0045	35/40/5/1:30	DO	0040 5	5701413 ()	CSND 0050
INNISFIL TOWNSHIP CON 11 015	17 609376 4910783 L	2004/04 2513				NU		5738722 (Z00200) A000104 A	
INNISFIL TOWNSHIP CON 11 015	17 609665 4911082 W	2008/01 2514	6.25	FR 0055	25/51/4/1:0	DO	0051 8	7102395 (Z54565) A048085	BLCK SAND GRVL LOAM 0001 GREY CLAY SAND LOOS 0049 GREY SAND PORS 0059
INNISFIL TOWNSHIP CON 11 015	17 609690 4911113 W	2008/01 2514	36					7102396 (Z54564) A048086 A	0030
INNISFIL TOWNSHIP CON 11 015	17 609801 4911416 W	2008/06 2513						7111723 (Z77611) A045658 A	

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 11 015	17 609400 4911050 W	2011/02 2513				NU		7168649 (Z103439) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 015	17 609486 4911210 W	2011/02 2513				NU		7168650 (Z103440) A000103 A	
INNISFIL TOWNSHIP CON 11 015	17 609486 4911208 W	2011/02 2513				NU		7168651 (Z103441) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 015	17 609379 4910783 L	1999/03 2513	6	FR 0064	26/58/9/1:0	DO	0060 6	5734439 (195331)	LOAM 0001 YLLW SAND 0004 YLLW SILT 0018 YLLW SAND 0027 YLLW SAND SILT CLAY 0052 YLLW SAND 0064 YLLW CLAY 0064
INNISFIL TOWNSHIP CON 11 016	17 609626 4911235 W	1997/05 5528				DO		5732724 (155259) A	PRDG 0036
INNISFIL TOWNSHIP CON 11 016	17 609623 4911154 W	1965/11 2514	6	FR 0043	24/43/4/2:0	DO	0043 3	5701420 ()	PRDG 0028 MSND CLAY 0035 BRWN MSND 0046 FSND 0049
INNISFIL TOWNSHIP CON 11 016	17 609694 4911024 W	1965/10 4102	30	FR 0026	26//6/:	DO		5701421 ()	BRWN CLAY 0012 CSND 0040
INNISFIL TOWNSHIP CON 11 016	17 609714 4910923 W	1974/10 3203	5	FR 0023	23/44/7/1:0	DO		5711629 ()	LOAM 0002 BRWN CLAY 0016 BRWN SAND CLAY 0023 GREY SAND 0058
INNISFIL TOWNSHIP CON 11 016	17 609714 4910823 W	1982/11 3660	5	FR 0058	21/45/6/2:0	DO	0062 3	5718243 ()	PRDG 0023 BRWN SILT 0058 GREY MSND 0065
INNISFIL TOWNSHIP CON 11 016	17 609714 4910823 W	1983/08 2514	6 5	FR 0060	27/70/6/1:30	DO	0071 4	5718813 ()	FILL 0003 BRWN CLAY SAND 0040 YLLW SAND CLAY GRVL 0060 GREY FSND VERY 0075
INNISFIL TOWNSHIP CON 11 016	17 609611 4911278 W	1997/05 5528	5 5	FR 0042	16/32/4/2:0	DO	0042 4	5732723 (155258)	LOAM 0001 BRWN SAND 0004 STNS GRVL 0005 BRWN SAND MGRD 0023 BRWN FSND 0049 BRWN SILT CLAY 0052
INNISFIL TOWNSHIP CON 11 016	17 609621 4911258 W	1997/06 5528	6 5	FR 0046	16/38/6/1:0	DO	0046 4	5732836 (155265)	BRWN SAND GRVL 0040 BRWN SAND 0050
INNISFIL TOWNSHIP CON 11 016	17 609620 4911251 W	1997/06 5528				DO		5732837 (155266) A	UNKN 0030
INNISFIL TOWNSHIP CON 11 016	17 609971 4910979 L	1997/10 1851	6	FR 0044	17/48/4/1:0	DO	0044 6	5733085 (187561)	BLCK LOAM 0001 BRWN SAND 0004 GREY SAND 0010 BRWN SAND WBRG 0015 BRWN CLAY SLTY 0044 BRWN SAND WBRG 0050
INNISFIL TOWNSHIP CON 11 016	17 609686 4910964 W	2002/06 2513	7	FR 0067	23/59/8/1:0	DO	0062 5	5736948 (246396)	BLCK LOAM 0001 BRWN SILT SAND 0017 YLLW SAND 0060 GREY SAND VERY 0067
INNISFIL TOWNSHIP CON 11 016	17 609682 4911066 W	2016/04 1851	6.25	FR 0063	29/56/4/1:30	DO	0063 5	7261373 (Z164616) A063855	BRWN CLAY 0018 GREY CLAY SAND 0053 GREY SAND DRTY 0063 BRWN SAND 0068
INNISFIL TOWNSHIP CON 11 017	17 610736 4910591 W	1972/09 4608	30	FR 0010	8/11/3/0:30	DO		5709424 ()	GREY SAND 0018

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 11 017	17 610514 4910523 W	1985/11 4816	6		10/20/5/2:0	DO	0040 4	5720335 ()	SAND 0004 GRVL 0006 BRWN SAND 0045 GREY CLAY 0045
INNISFIL TOWNSHIP CON 11 017	17 610550 4911182 L	1989/08 1467	5	SU 0142	37/98/5/2:30	DO	0158 7	5725449 (65157)	BRWN SAND 0006 BRWN CLAY SAND 0014 GREY CLAY SAND 0037 GREY SILT 0049 GREY CLAY 0142 GREY SAND CLAY LYRD 0165 GREY CLAY 0165

Notes:
UTM: UTM in Zone, Easting, Northing and Datum is NAD83; L: UTM estimated from Centroid of Lot; W: UTM not from Lot Centroid
DATE CNTR: Date Work Completedand Well Contractor Licence Number
CASING DIA: .Casing diameter in inches
WATER: Unit of Depth in Fee. See Table 4 for Meaning of Code
PUMP TEST: Static Water Level in Feet / Water Level After Pumping in Feet / Pump Test Rate in GPM / Pump Test Duration in Hour : Minutes
WELL USE: See Table 3 for Meaning of Code
SCREEN: Screen Depth and Length in feet
WELL: WEL (AUDIT #) Well Tag . A: Abandonment; P: Partial Data Entry Only
FORMATION: See Table 1 and 2 for Meaning of Code

1. Core Material and Descriptive terms

Code	Description	Code	Description	Code	Description	Code	Description	Code	Description
BLDR	BOULDERS	FCRD	FRACTURED	IRFM	IRON FORMATION	PORS	POROUS	SOFT	SOFT
BSLT	BASALT	FGRD	FINE-GRAINED	LIMY	LIMY	PRDG	PREVIOUSLY DUG	SPST	SOAPSTONE
CGRD	COARSE-GRAINED	FGVL	FINE GRAVEL	LMSN	LIMESTONE	PRDR	PREV. DRILLED	STKY	STICKY
CGVL	COARSE GRAVEL	FILL	FILL	LOAM	TOPSOIL	QRTZ	QUARTZITE	STNS	STONES
CHRT	CHERT	FLDS	FELDSPAR	LOOS	LOOSE	QSND	QUICKSAND	STNY	STONEY
CLAY	CLAY	FLNT	FLINT	LTCL	LIGHT-COLOURED	QTZ	QUARTZ	THIK	THICK
CLN	CLEAN	FOSS	FOSILIFEROUS	LYRD	LAYERED	ROCK	ROCK	THIN	THIN
CLYY	CLAYEY	FSND	FINE SAND	MARL	MARL	SAND	SAND	TILL	TILL
CMTD	CEMENTED	GNIS	GNEISS	MGRD	MEDIUM-GRAINED	SHLE	SHALE	UNKN	UNKNOWN TYPE
CONG	CONGLOMERATE	GRNT	GRANITE	MGVL	MEDIUM GRAVEL	SHLY	SHALY	VERY	VERY
CRYS	CRYSTALLINE	GRSN	GREENSTONE	MRBL	MARBLE	SHRP	SHARP	WBRG	WATER-BEARING
CSND	COARSE SAND	GRVL	GRAVEL	MSND	MEDIUM SAND	SHST	SCHIST	WDFR	WOOD FRAGMENTS
DKCL	DARK-COLOURED	GRWK	GREYWACKE	MUCK	MUCK	SILT	SILT	WTHD	WEATHERED
DLMT	DOLOMITE	GVLY	GRAVELLY	OBDN	OVERBURDEN	SLTE	SLATE		
DNSE	DENSE	GYPS	GYPSUM	PCKD	PACKED	SLTY	SILTY		
DRTY	DIRTY	HARD	HARD	PEAT	PEAT	SNDS	SANDSTONE		
DRY	DRY	HPAN	HARDPAN	PGVL	PEA GRAVEL	SNDY	SANDYOAPSTONE		

2. Core Color

Code	Description
WHIT	WHITE
GREY	GREY
BLUE	BLUE
GREN	GREEN
YLLW	YELLOW
BRWN	BROWN
RED	RED
BLCK	BLACK
BLGY	BLUE-GREY

3. Well Use

Code	Description	Code	Description
DO	Domestic	OT	Other
ST	Livestock	TH	Test Hole
IR	Irrigation	DE	Dewatering
IN	Industrial	MO	Monitoring
CO	Commercial	MT	Monitoring TestHole
MN	Municipal		
PS	Public		
AC	Cooling And A/C		
NU	Not Used		

4. Water Detail

Code	Description	Code	Description
FR	Fresh	GS	Gas
SA	Salty	IR	Iron
SU	Sulphur		
MN	Mineral		
UK	Unknown		

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix B

Borehole Logs

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

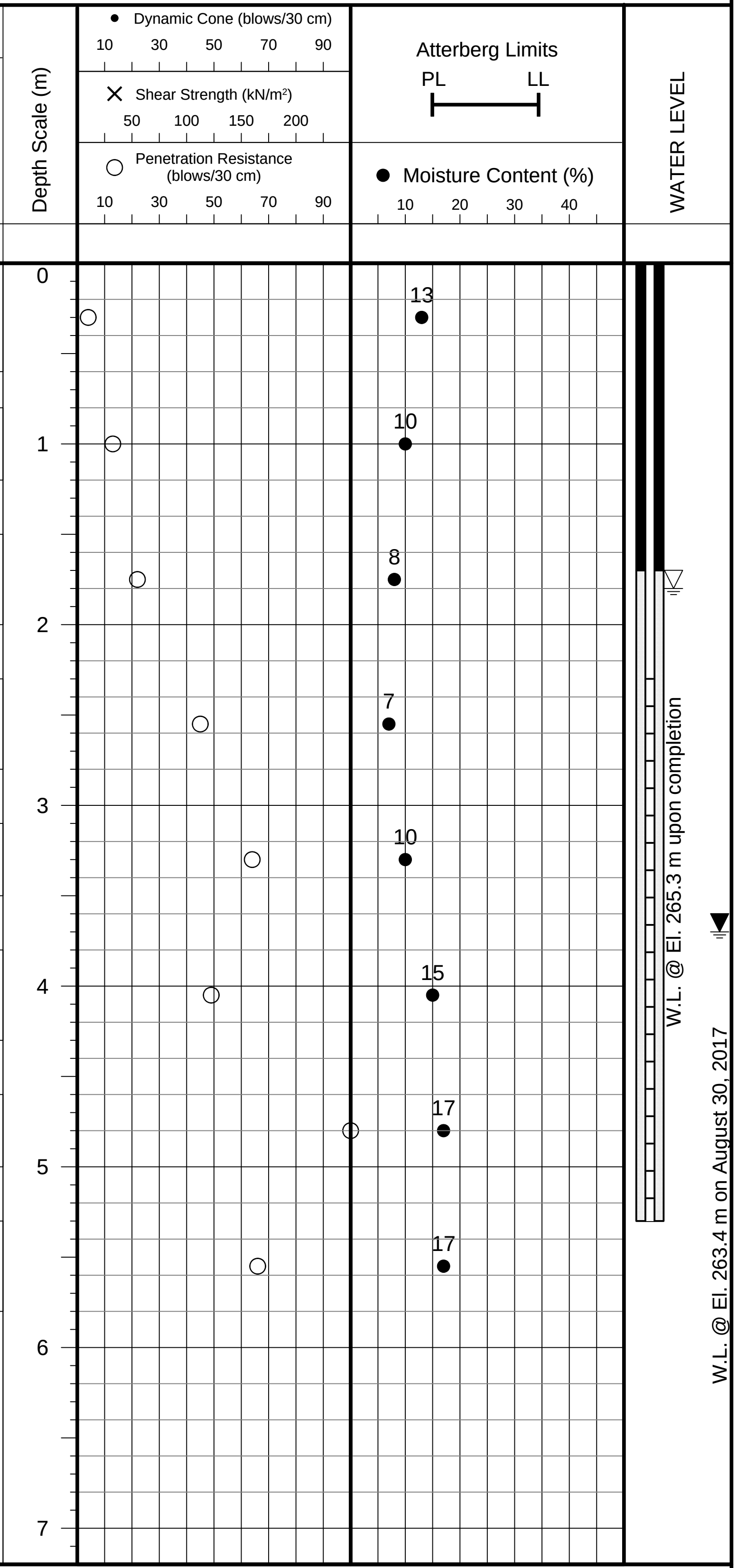
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 27, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
267.1	Ground Surface			
0.0	**33 cm TOPSOIL**			
	PLOUGHED SOIL brown sandy silt mixed with topsoil	1	DO	4
266.1 1.0	Brown, compact to very dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders	2	DO	13
		3	DO	22
		4	DO	45
		5	DO	64
263.3 3.8	Brown, dense, wet **SAND** well graded traces of silt and fine gravel	6	DO	49
262.4 4.7	Brown, very dense, wet **SILT** some sand to sandy	7	DO	85/23
		8	DO	66
261.3 5.8	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

PROJECT DESCRIPTION: Due Diligence for Land Acquisition

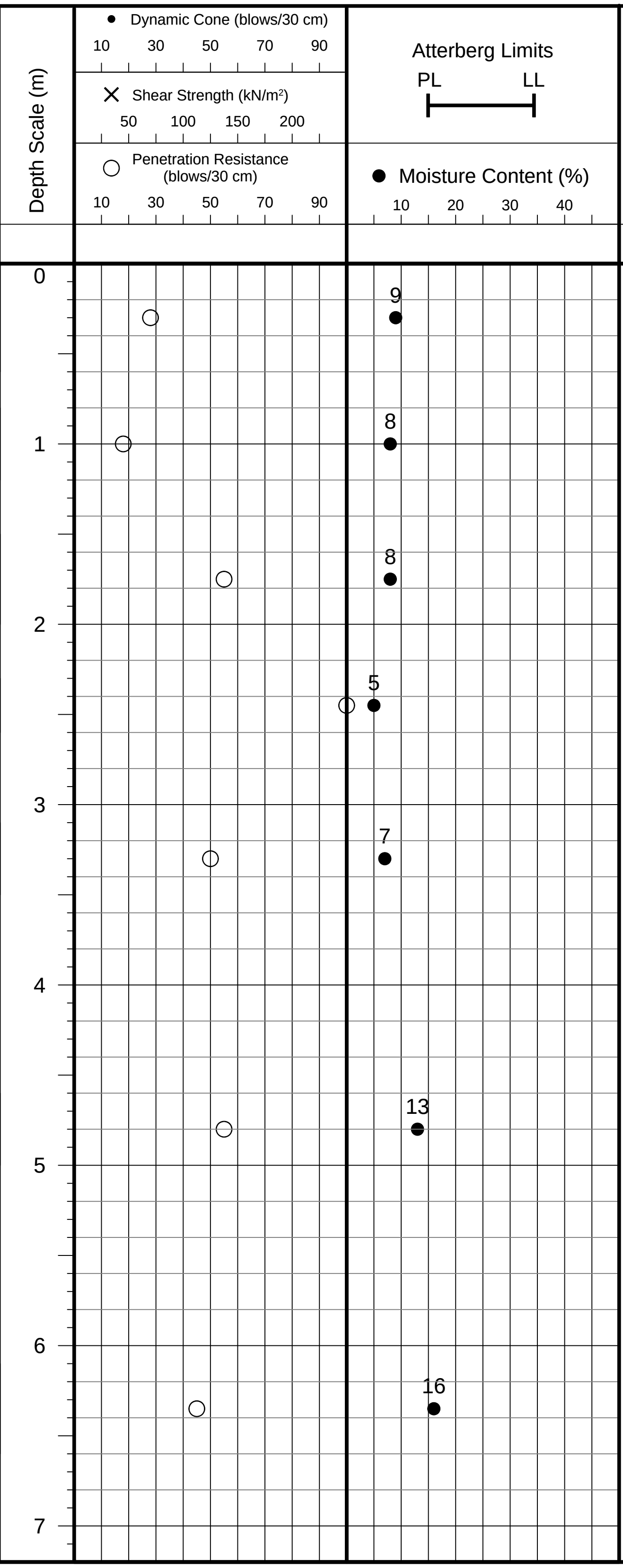
METHOD OF BORING: Flight Auger

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 21, 2017

El. (m) Depth (m)	SOIL DESCRIPTION
266.8	Ground Surface
0.0	**23 cm TOPSOIL**
	EARTH FILL brown sand occ. gravel and rock fragments
266.0 0.8	Brown, compact to very dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders
263.7 3.1	Brown, very dense **SAND** fine to medium grained some silt a trace of fine gravel wet below 4.6 m
260.2 6.6	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1	DO	28
2	DO	18
3	DO	55
4	DO	50/15
5	DO	50
6	DO	55
7	DO	45



WATER LEVEL

Cave-In @ El. 262.9 m upon completion

Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

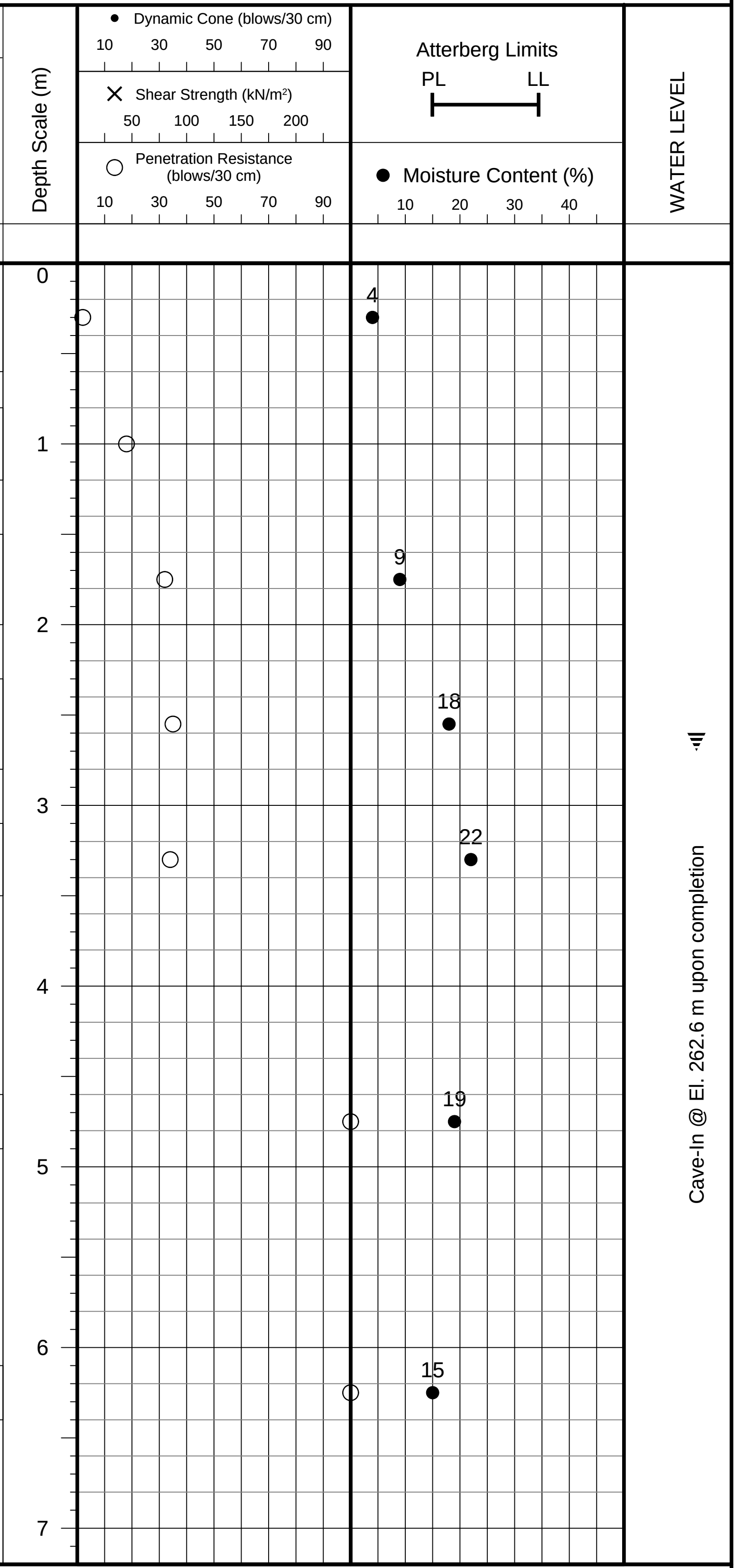
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 21, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
265.3	Ground Surface			
0.0	**EARTH FILL** dark brown silty sand occ. topsoil inclusions and rock fragments	1	DO	2
264.5 0.8	Brown, compact to very dense **SAND** well graded some silt a trace of gravel wet below 2.3 m	2	DO	18
		3	DO	32
		4	DO	35
		5	DO	34
		6	DO	50/15
		7	DO	50/15
258.9 6.4	**END OF BOREHOLE**			



JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

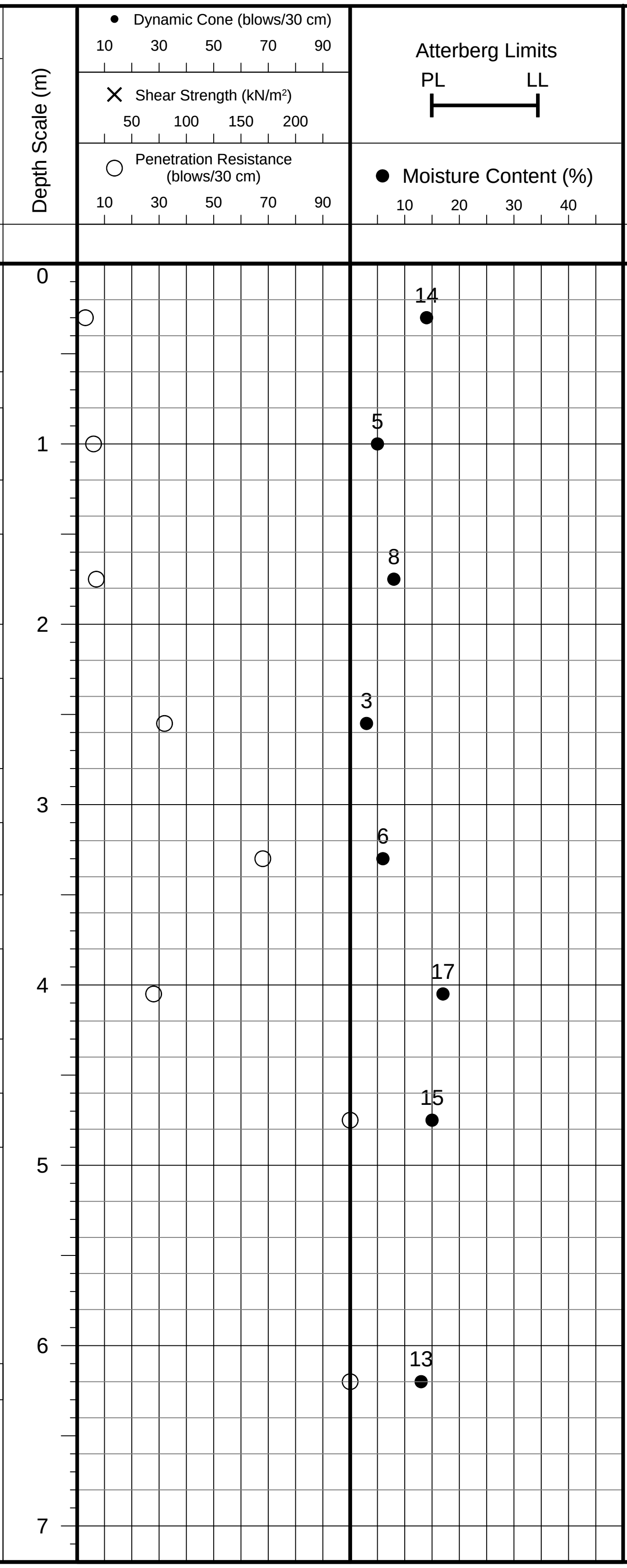
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 27, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
267.4	Ground Surface			
0.0	**35 cm TOPSOIL**	1	DO	3
	PLOUGHED SOIL brown sandy silt mixed with topsoil			
266.6 0.8	Brown, loose to very dense **SAND** weathered fine to medium grained traces of silt and fine gravel wet below 3.8 m	2	DO	6
		3	DO	7
		4	DO	32
		5	DO	68
		6	DO	28
		7	DO	50/15
262.1 5.3	Brown, very dense, wet **SANDY SILT**	8	DO	50/15
261.1 6.3	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 263.6 m upon completion

Cave-In @ El. 263.5 m upon completion

Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

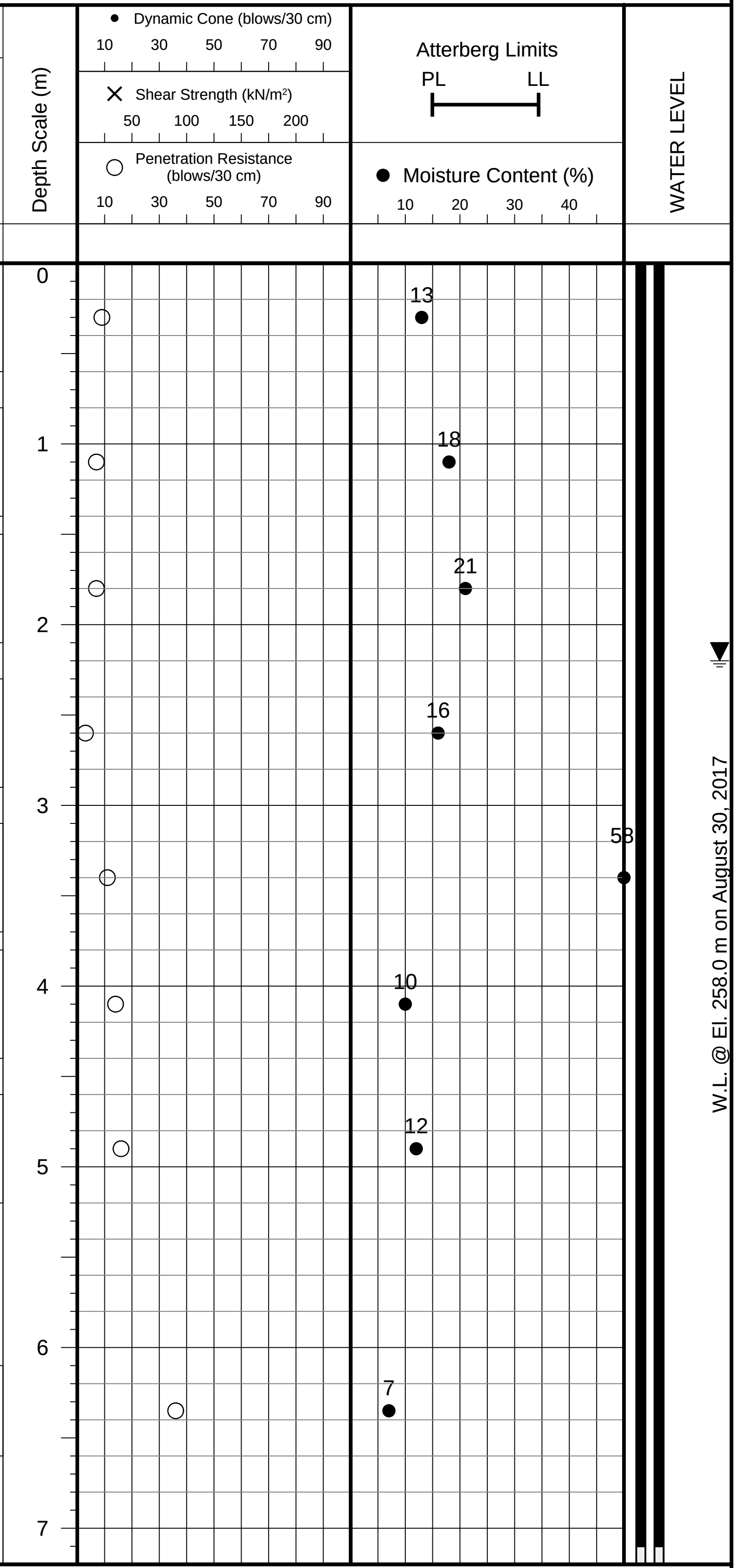
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 24, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
260.2	Ground Surface			
0.0	**30 cm TOPSOIL**	1	DO	9
	EARTH FILL brown to grey sand and clay mixed with topsoil	2	DO	7
		3	DO	7
		4	DO	3
257.1 3.1	**TOPSOIL AND ORGANIC PEAT**	5	DO	11
256.8 3.4	Brown, compact to dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders	6	DO	14
		7	DO	16
	grey	8	DO	36
253.0				



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

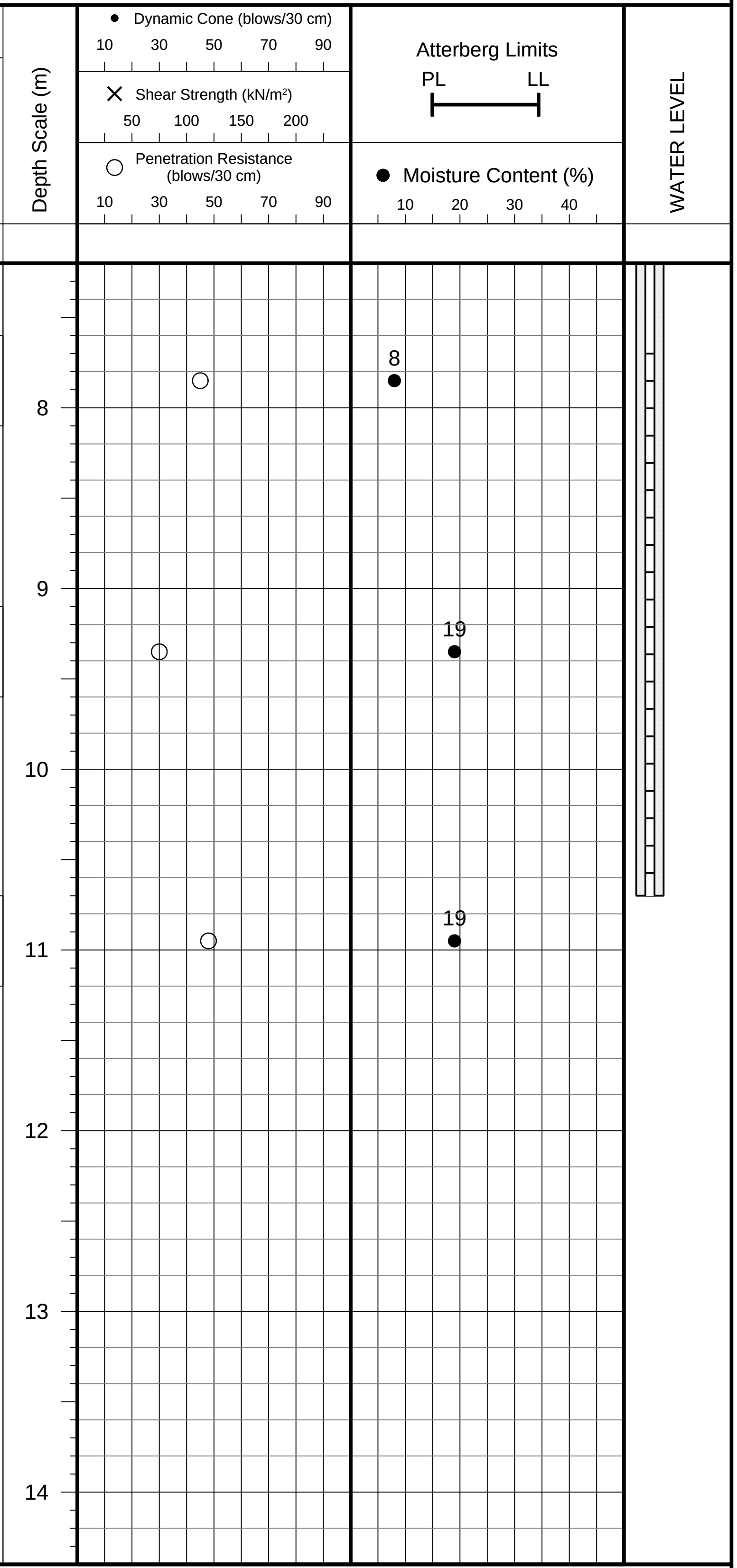
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 24, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
7.2	Brown, compact to dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders	9	DO	45
250.9 9.3	Dense, wet **SILT** occ. sand seams	10	DO	30
	brown grey	11	DO	48
249.0 11.2	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

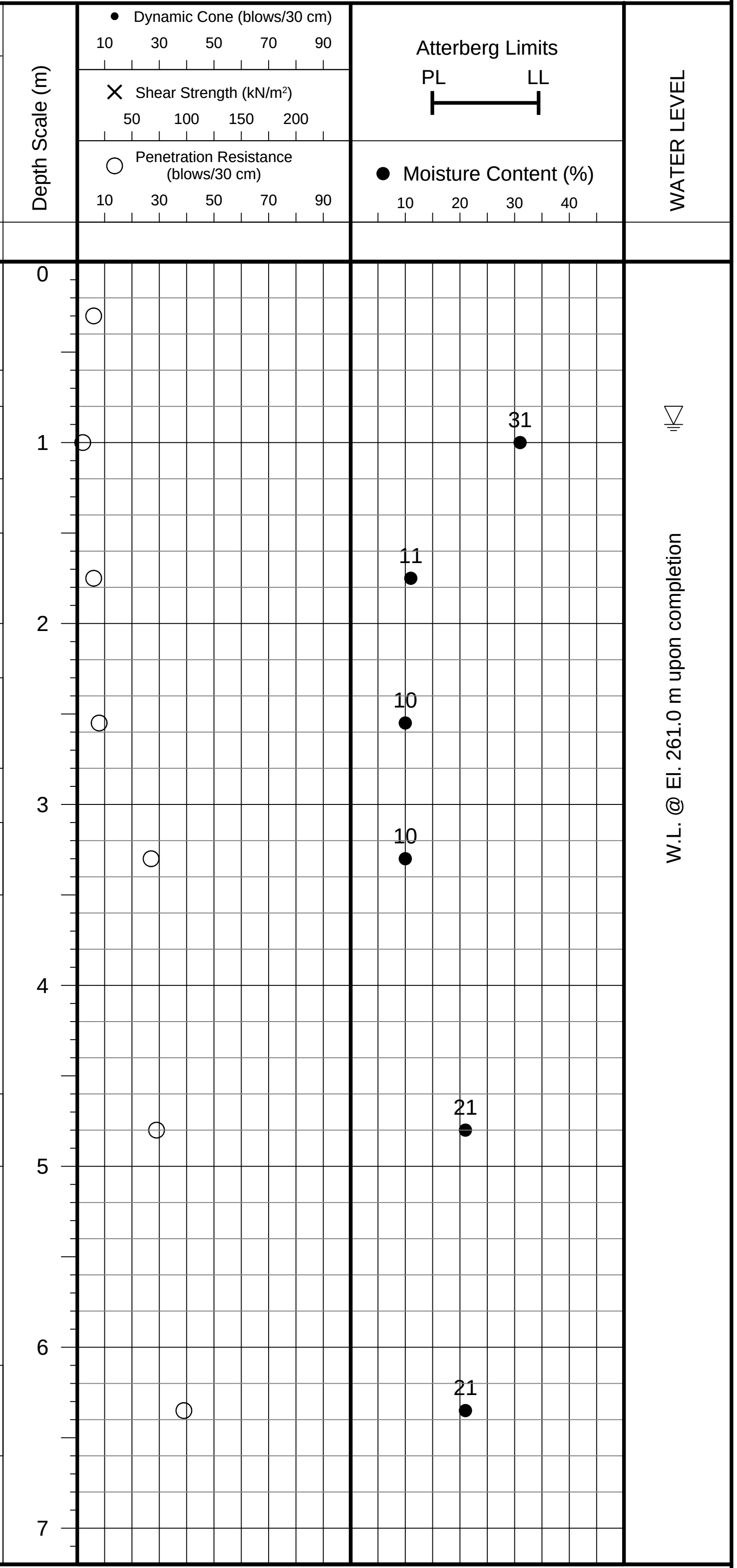
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 21, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
261.9	Ground Surface			
0.0	**30 cm TOPSOIL**			
	EARTH FILL brown to grey sand and clay mixed with topsoil	1	DO	6
		2	DO	2
260.4 1.5	Brown, loose to compact **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders	3	DO	6
		4	DO	8
		5	DO	27
257.9 4.0	Brown, compact to dense, wet **SAND** fine grained a trace of silt	6	DO	29
		7	DO	39
255.3 6.6	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

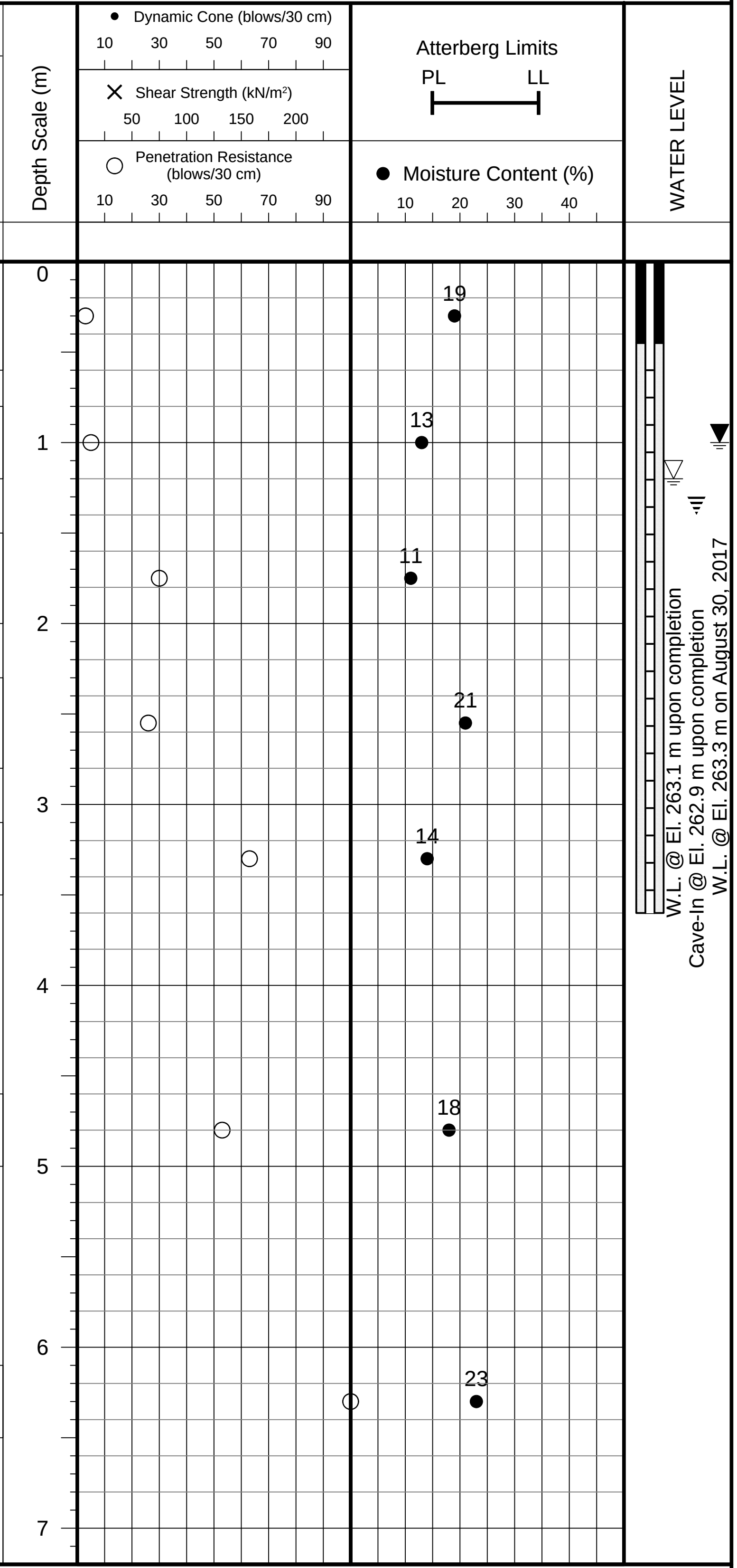
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 27, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
264.3	Ground Surface			
0.0	**13 cm TOPSOIL** **PLOUGHED SOIL** brown sandy silt mixed with topsoil	1	DO	3
263.3 1.0	Brown, very loose to compact **SANDY SILT TILL**	2	DO	5
	weathered some clay a trace of gravel wet below 1.0 m	3	DO	30
262.0 2.3	Brown, compact to very dense, wet **SAND** well graded a trace of silt	4	DO	26
	silt layers	5	DO	63
		6	DO	53
		7	DO	84/25
257.8 6.5	**END OF BOREHOLE**			



W.L. @ El. 263.1 m upon completion

Cave-In @ El. 262.9 m upon completion

W.L. @ El. 263.3 m on August 30, 2017

Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

PROJECT DESCRIPTION: Due Diligence for Land Acquisition

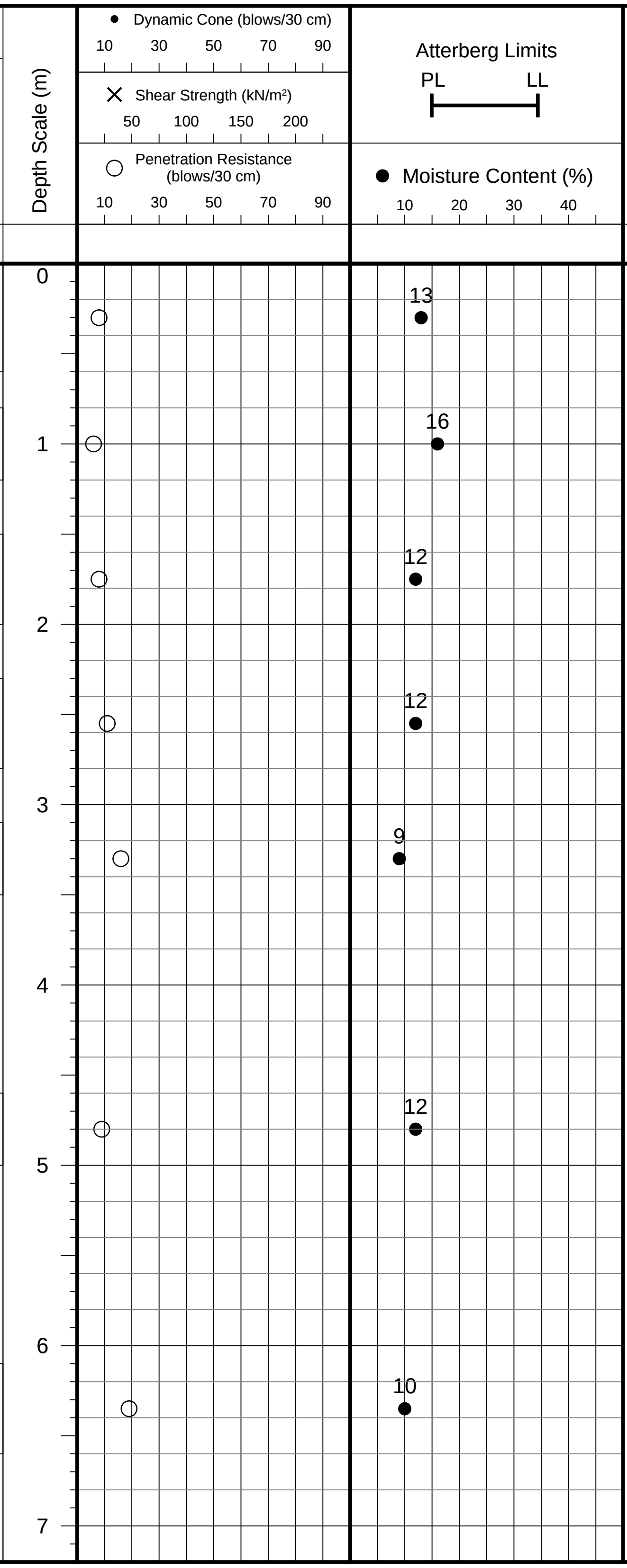
METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 25, 2017

El. (m) Depth (m)	SOIL DESCRIPTION
255.7	Ground Surface
0.0	**60 cm TOPSOIL**
	PLOUGHED SOIL brown sandy silt mixed with topsoil
254.3 1.4	Loose to dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders brown grey
248.5	

SAMPLES		
Number	Type	N-Value
1	DO	8
2	DO	6
3	DO	8
4	DO	11
5	DO	16
6	DO	9
7	DO	19



WATER LEVEL

W.L. @ El. 254.3 m on August 30, 2017

Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

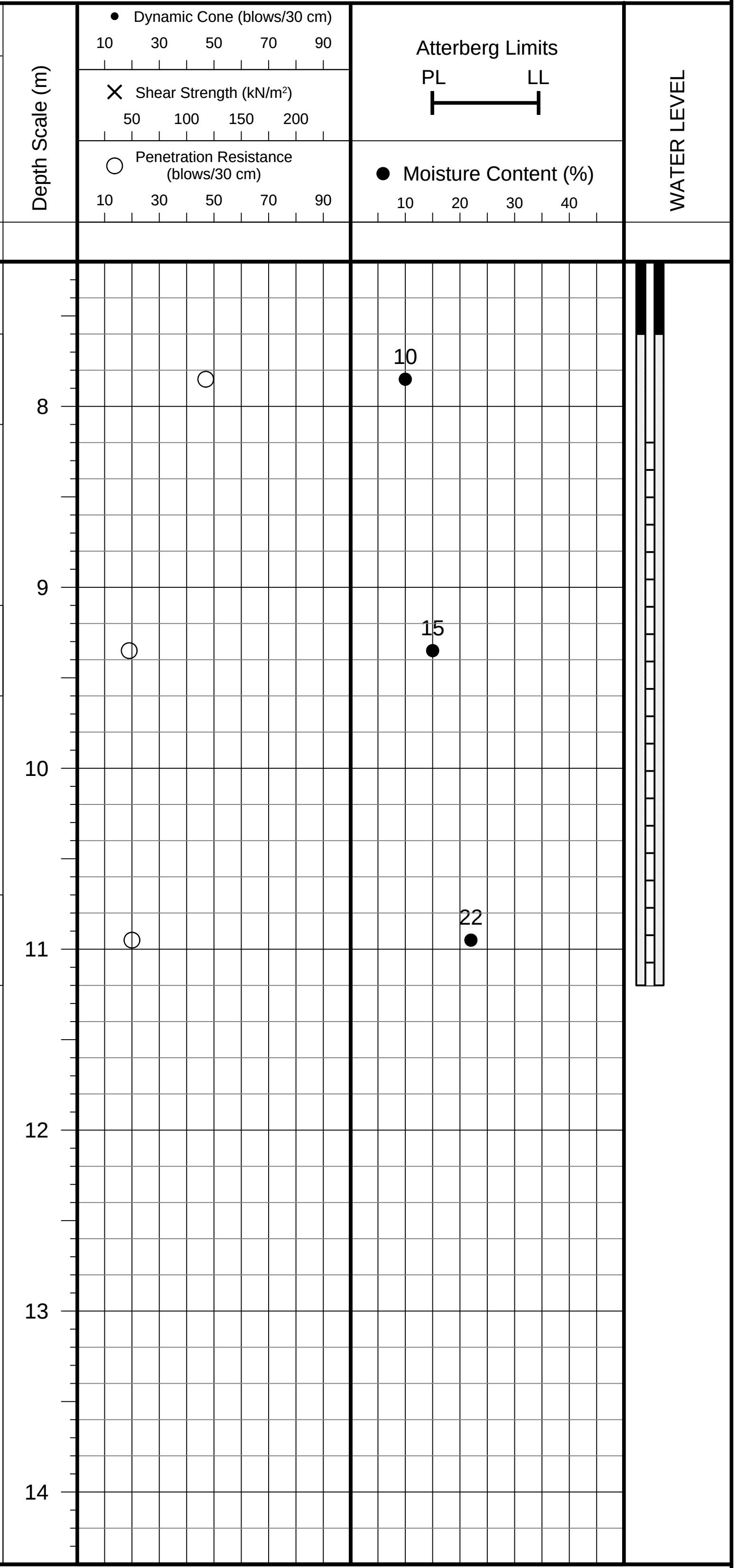
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger
(Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 25, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
7.2	Loose to dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders	8	DO	47
246.6 9.1	Brown, compact, wet **SANDY SILT** fine grained occ. sand seams	9	DO	19
		10	DO	20
244.5 11.2	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

PROJECT DESCRIPTION: Due Diligence for Land Acquisition

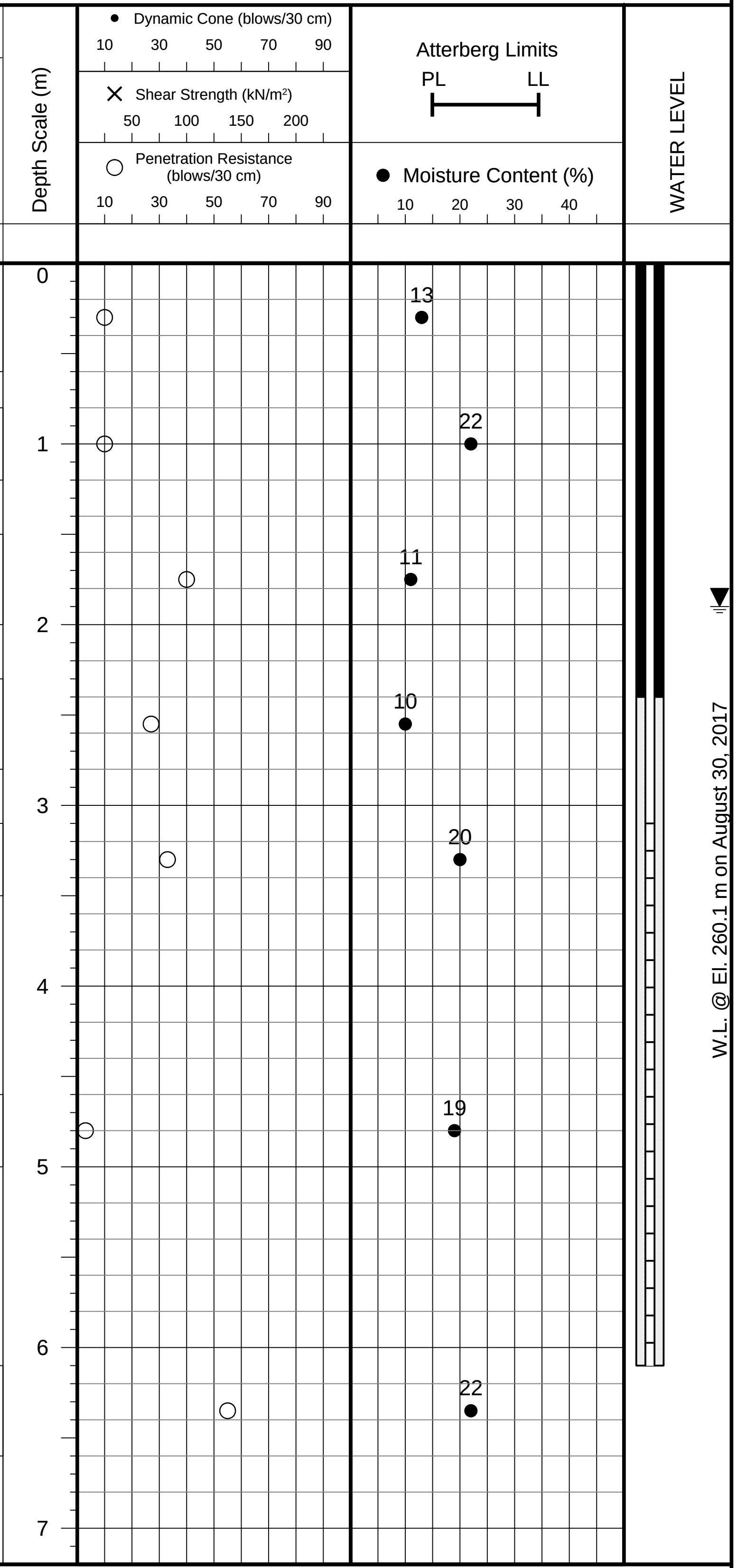
METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 26, 2017

El. (m) Depth (m)	SOIL DESCRIPTION
262.0	Ground Surface
0.0	**35 cm TOPSOIL**
	PLOUGHED SOIL brown sandy silt mixed with topsoil and clay
260.9 1.1	Brown, compact to dense **SANDY SILT TILL** some clay a trace of gravel occ. sand seams and layers, cobbles and boulders
258.9 3.1	Brown, loose to very dense, wet **SAND** fine grained some silt occ. sand seams and layers disturbed
255.4 6.6	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1	DO	10
2	DO	10
3	DO	40
4	DO	27
5	DO	33
6	DO	3
7	DO	55



Soil Engineers Ltd.

JOB NO.: 1706-S080

LOG OF BOREHOLE NO.: 10

FIGURE NO.: 10

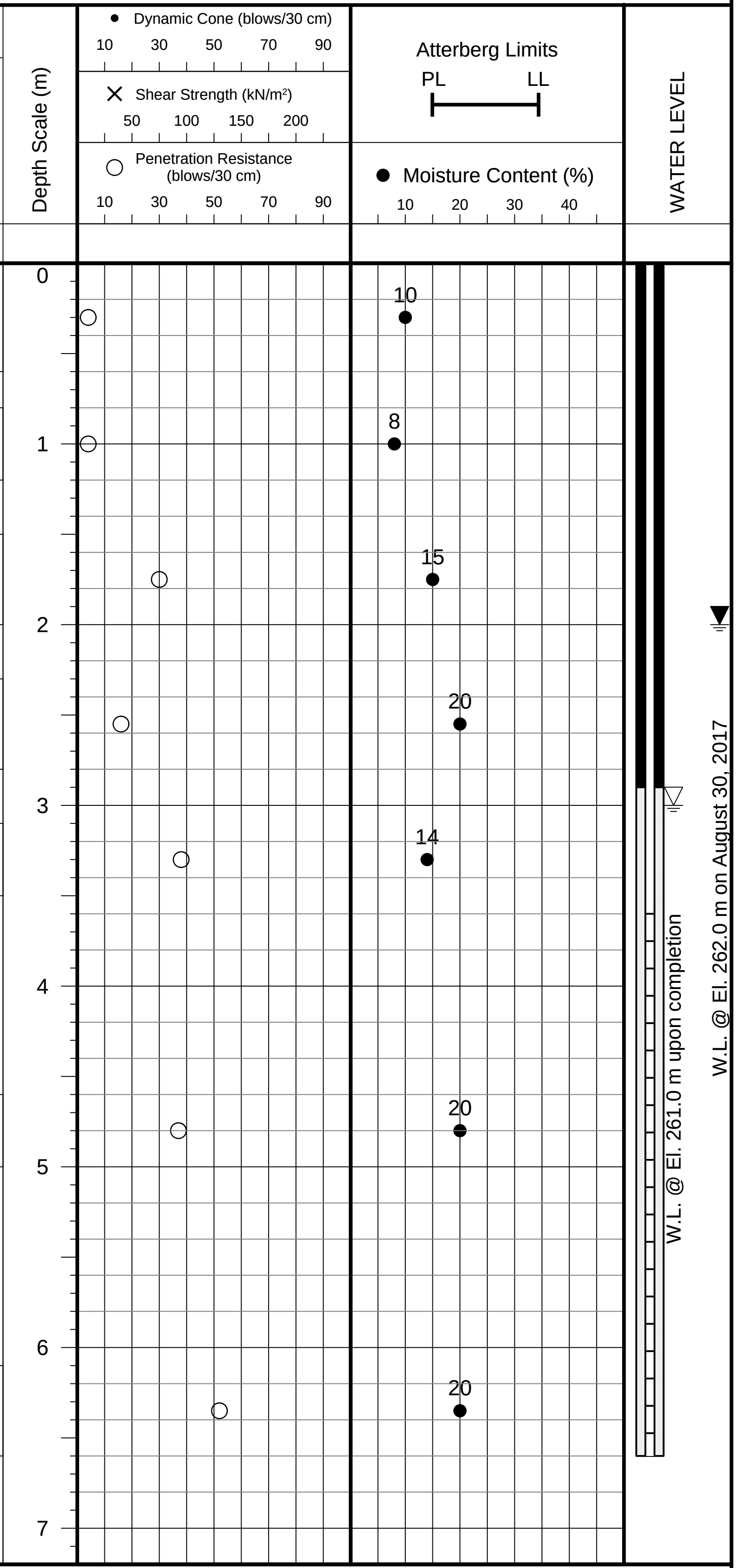
PROJECT DESCRIPTION: Due Diligence for Land Acquisition

METHOD OF BORING: Flight Auger (Hollow Stem)

PROJECT LOCATION: 750 Lockhart Road, City of Barrie

DRILLING DATE: July 26, 2017

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
264.0	Ground Surface			
0.0	**20 cm TOPSOIL**			
	PLOUGHED SOIL brown sand and silt mixed with topsoil	1	DO	4
		2	DO	4
1.0	Brown, loose to compact **SAND** weathered fine grained some silt occ. topsoil and rootlet inclusions	3	DO	30
261.7 2.3	Brown, compact, wet **SILT** a trace of clay	4	DO	16
260.9 3.1	Brown, dense to very dense, wet **SAND** fine to medium grained a trace to some silt occ. silt seams and layers	5	DO	38
		6	DO	37
		7	DO	52
257.4 6.6	**END OF BOREHOLE**			



W.L. @ El. 261.0 m upon completion

W.L. @ El. 262.0 m on August 30, 2017

Soil Engineers Ltd.

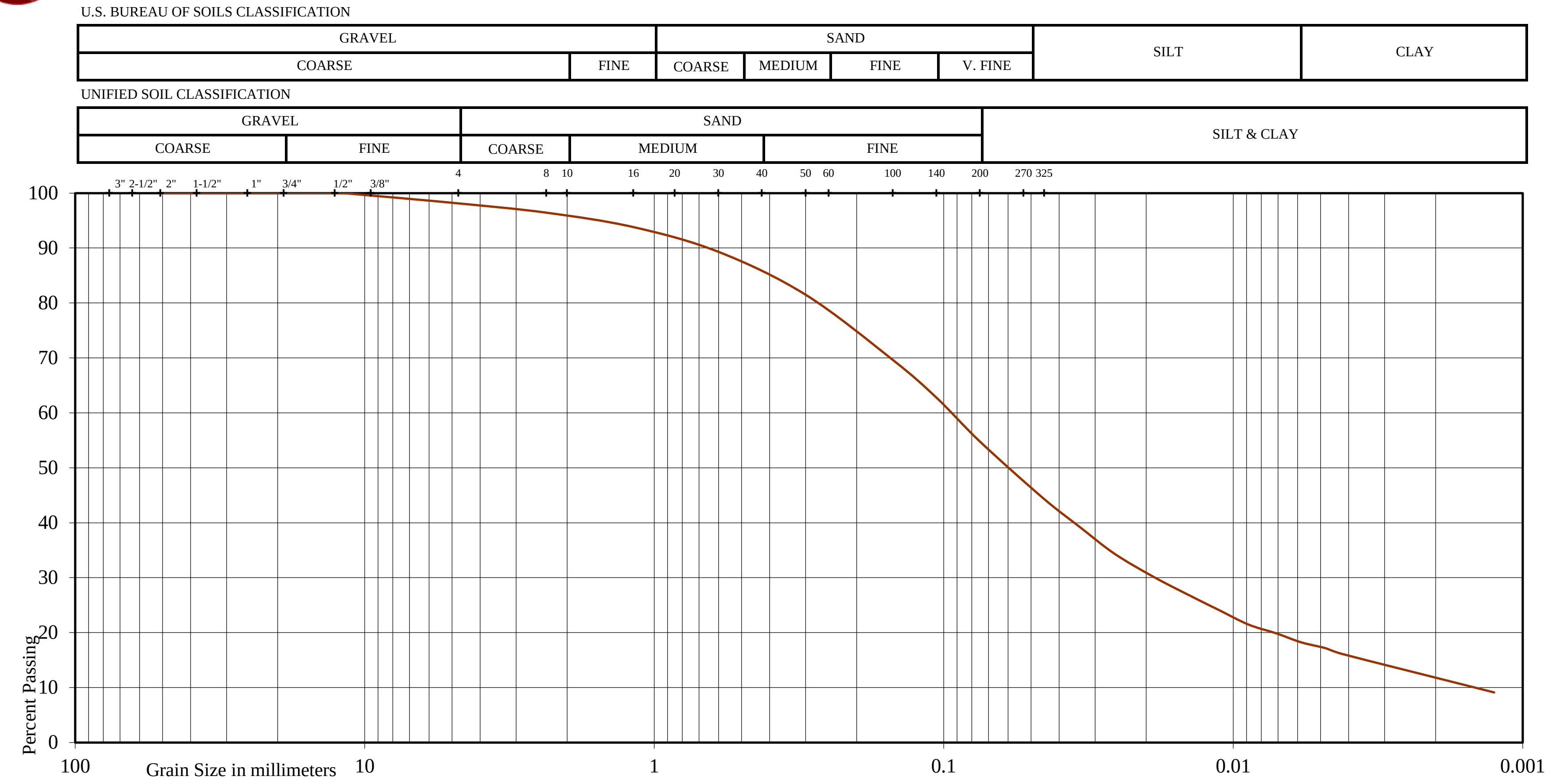
Appendix C

Hydraulic Conductivity Data

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1706-S080



Project: Due Diligence for Land Acquisition

Location: 750 Lockhart Road, City of Barrie

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 5

Plasticity Index (%) = -

Sample No: 8

Moisture Content (%) = 7

Depth (m): 6.3

Estimated Permeability

Elevation (m): 253.9

(cm./sec.) = 10^{-6}

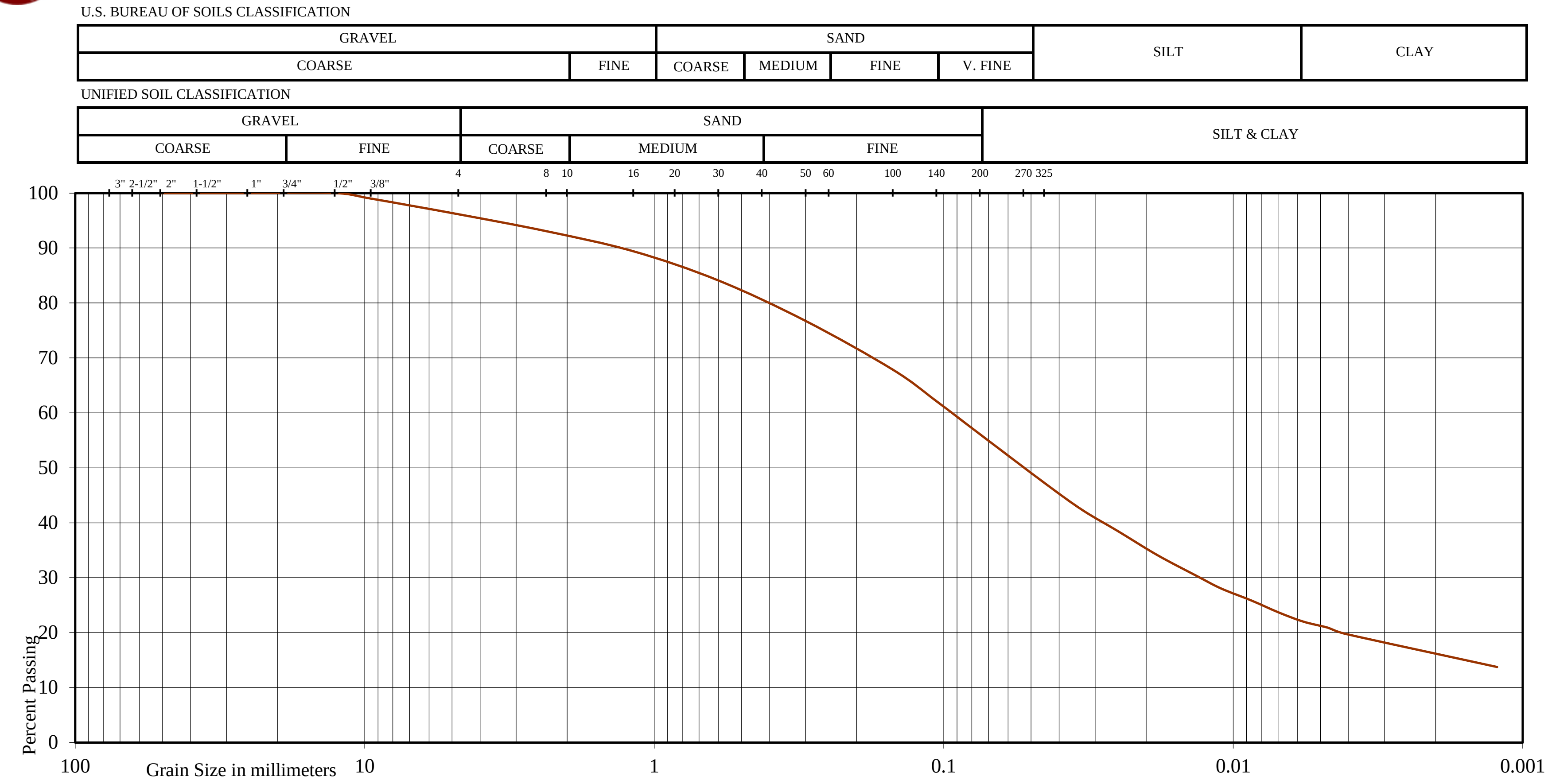
Classification of Sample [& Group Symbol]: SANDY SILT TILL, some clay, a trace of gravel

Figure: 11

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1706-S080



Project: Due Diligence for Land Acquisition

Location: 750 Lockhart Road, City of Barrie

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 8

Plasticity Index (%) = -

Sample No: 3

Moisture Content (%) = 12

Depth (m): 1.8

Estimated Permeability

Elevation (m): 253.9

(cm./sec.) = 10^{-7}

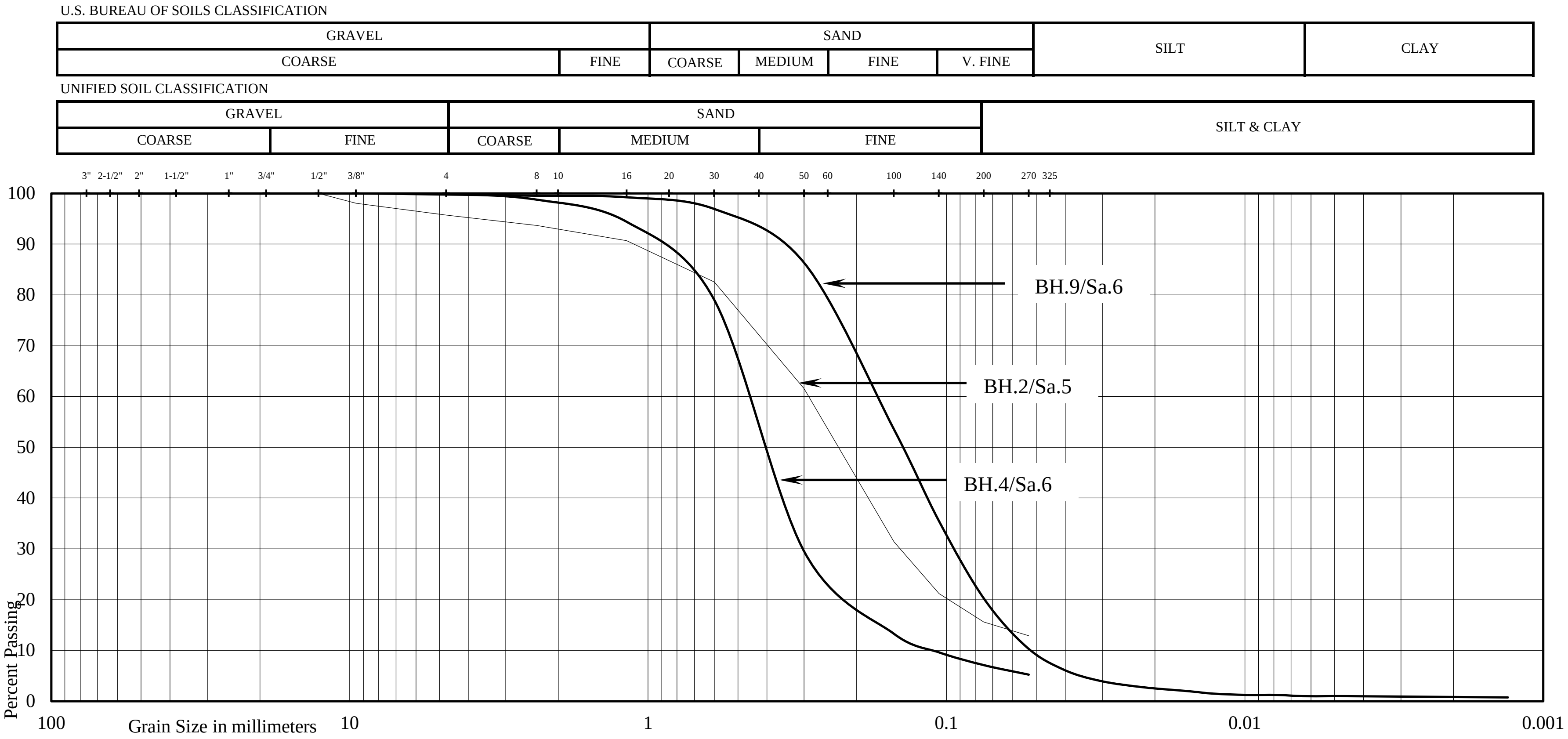
Classification of Sample [& Group Symbol]: SANDY SILT TILL, some clay, a trace of gravel

Figure: 12

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1706-S080



Project: Due Diligence for Land Acquisition

Location: 750 Lockhart Road, City of Barrie

Borehole No:	2	4	9
Sample No:	5	6	6
Depth (m):	3.3	4.0	4.8
Elevation (m):	263.5	263.4	257.2

BH./Sa.	2/5	4/6	9/6
Liquid Limit (%) =	-	-	-
Plastic Limit (%) =	-	-	-
Plasticity Index (%) =	-	-	-
Moisture Content (%) =	7	17	19
Estimated Permeability (cm./sec.) =	10^{-3}	10^{-2}	10^{-3}

Classification of Sample [& Group Symbol]: BH.2/Sa.5 and BH.4/Sa.6 - FINE TO MEDIUM SAND, a trace to some silt and gravel

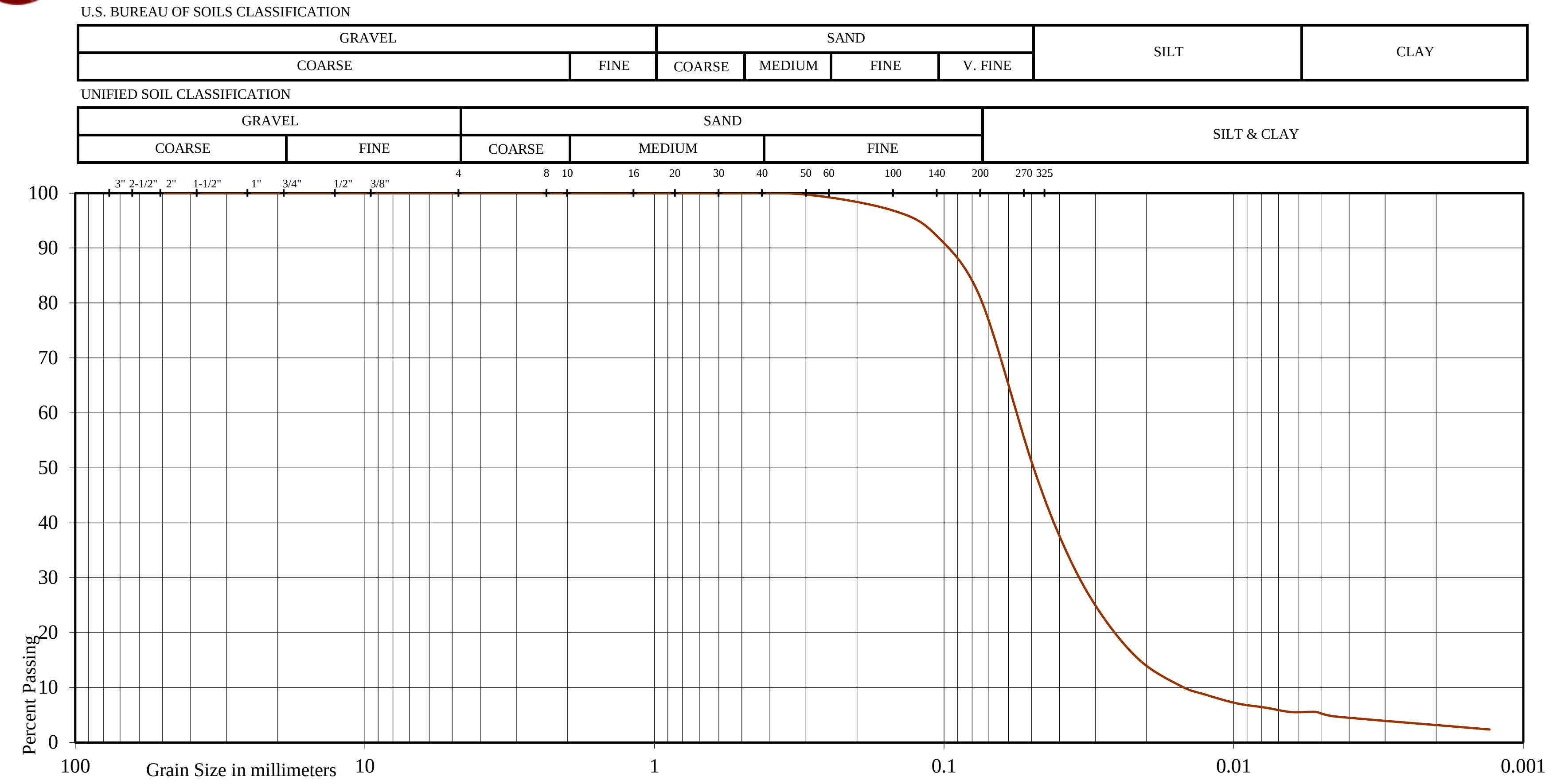
BH.9/Sa.6 - FINE SAND, some silt and a trace of clay

Figure: 13

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1706-S080



Project: Due Diligence for Land Acquisition

Location: 750 Lockhart Road, City of Barrie

Liquid Limit (%) =	-
Plastic Limit (%) =	-
Plasticity Index (%) =	-
Moisture Content (%) =	19
Estimated Permeability (cm./sec.) =	10^{-4}

Borehole No: 5

Sample No: 11

Depth (m): 11.0

Elevation (m): 249.2

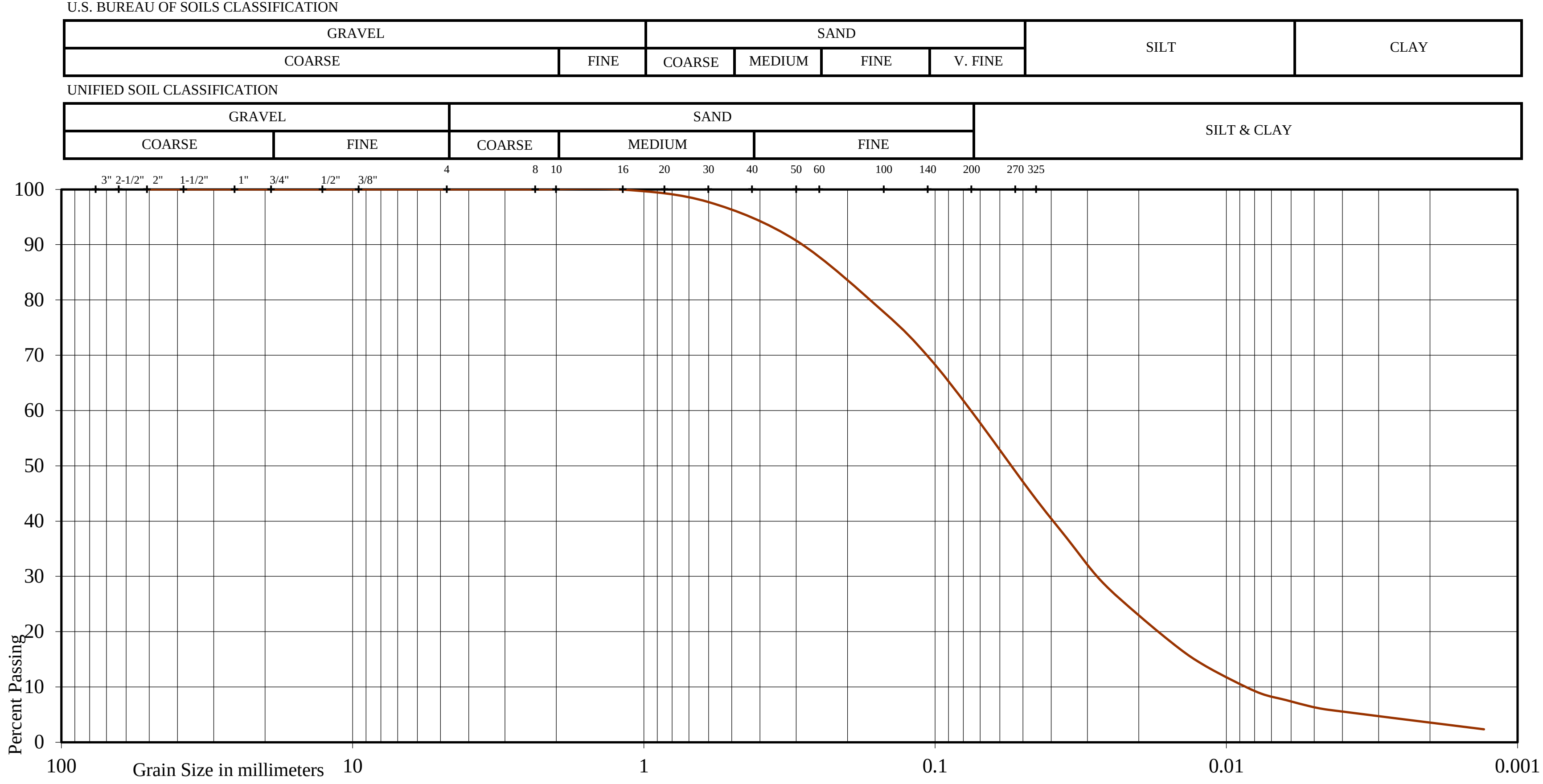
Classification of Sample [& Group Symbol]: SILT, some fine sand, a trace of clay

Figure: 14

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

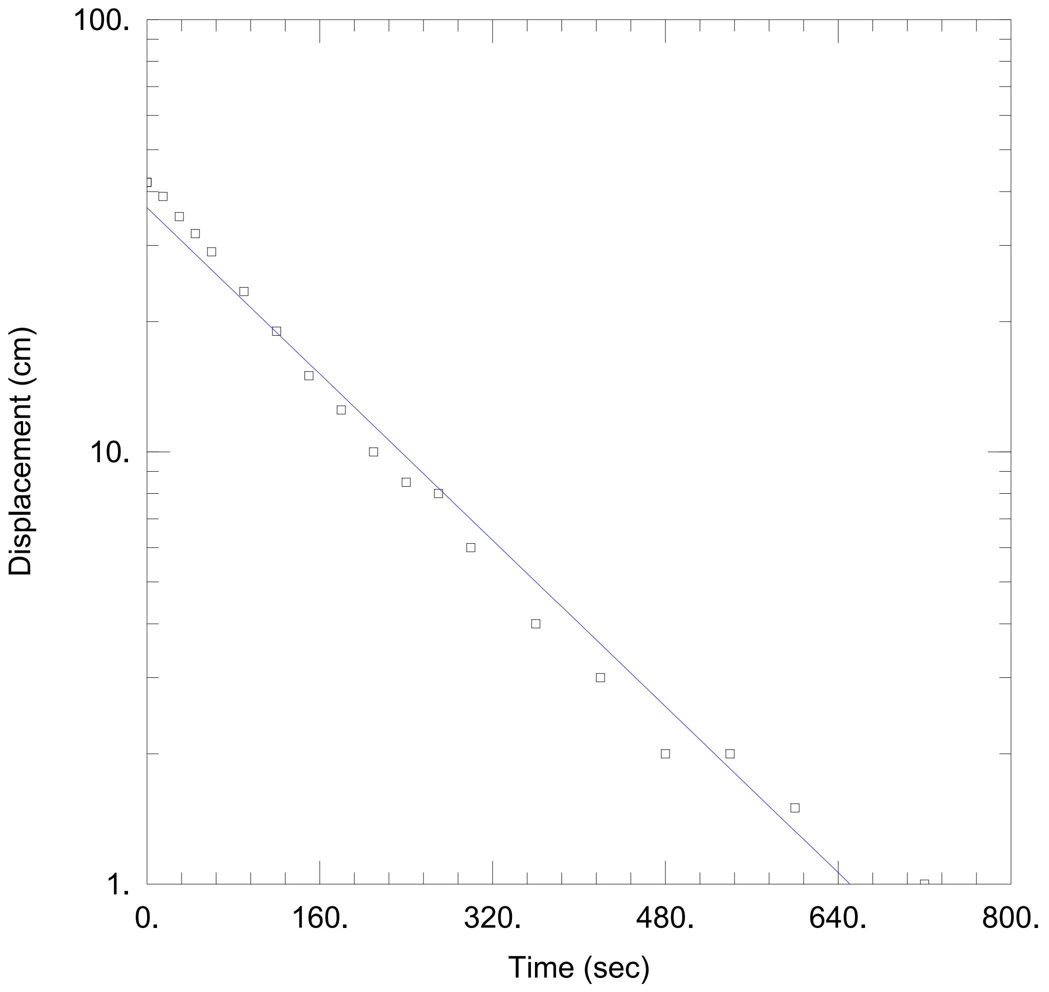
Reference No: 1706-S080



Project:	Due Diligence for Land Acquisition		
Location:	750 Lockhart Road, City of Barrie	Liquid Limit (%) =	-
		Plastic Limit (%) =	-
Borehole No:	8	Plasticity Index (%) =	-
Sample No:	9	Moisture Content (%) =	15
Depth (m):	9.3	Estimated Permeability	
Elevation (m):	246.4	(cm./sec.) =	10^{-4}

Classification of Sample [& Group Symbol]: SANDY SILT, a trace of clay

Figure: 15



HYDRAULIC CONDUCTVITY TEST AT BM-1

PROJECT INFORMATION

Company: R.J Burnside
Client: Ballymore
Project: 300041171
Location: Barrie
Test Well: BM-1
Test Date: April 24, 2018

AQUIFER DATA

Saturated Thickness: 199. cm
Anisotropy Ratio (Kz/Kr): 1.

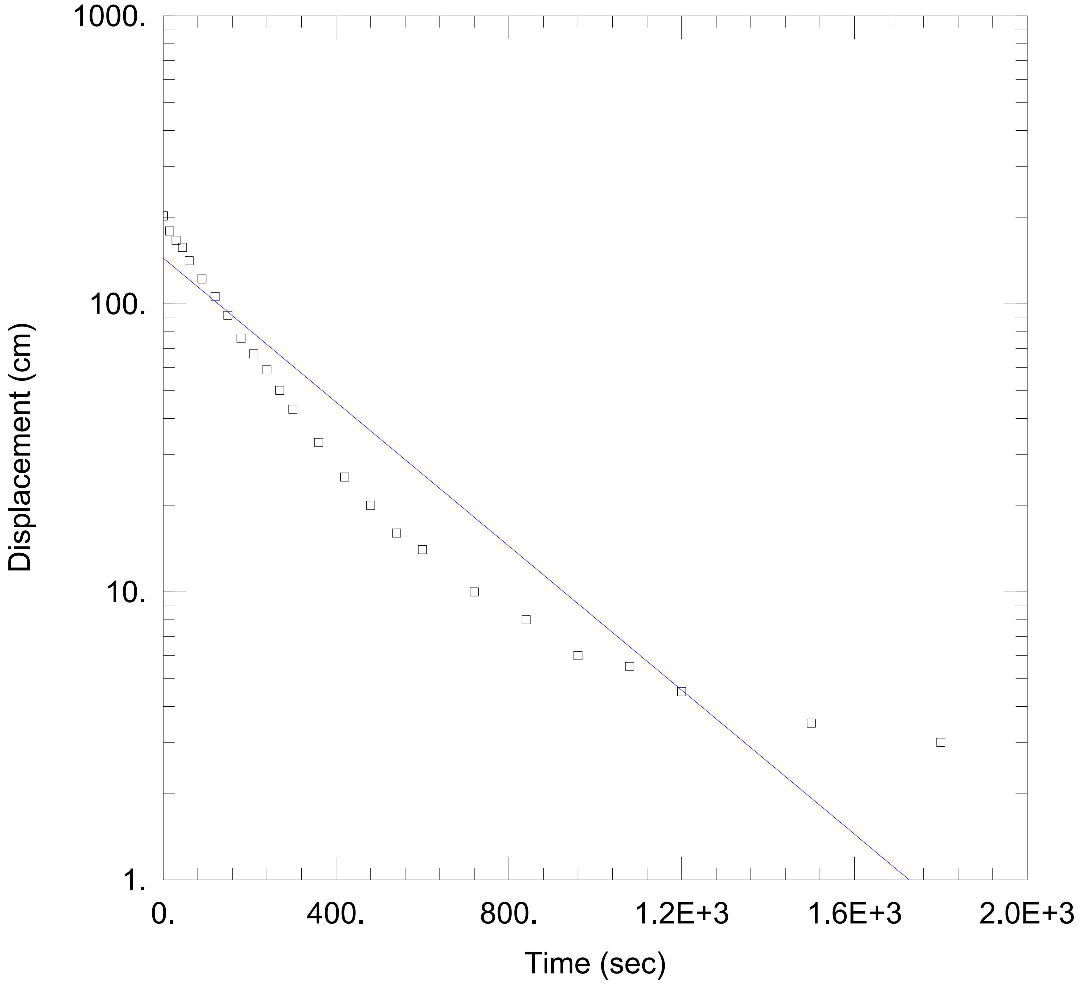
WELL DATA (BM-1)

Initial Displacement: 42. cm
Total Well Penetration Depth: 199. cm
Casing Radius: 2.54 cm
Static Water Column Height: 199. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.0004331 cm/sec
y0 = 36.7 cm



HYDRAULIC CONDUCTIVITY TEST AT BM-5D

PROJECT INFORMATION

Company: R.J Burnside
Client: Ballymore
Project: 300041171
Location: Barrie
Test Well: BM-5d
Test Date: April 24, 2018

AQUIFER DATA

Saturated Thickness: 895. cm
Anisotropy Ratio (Kz/Kr): 1.

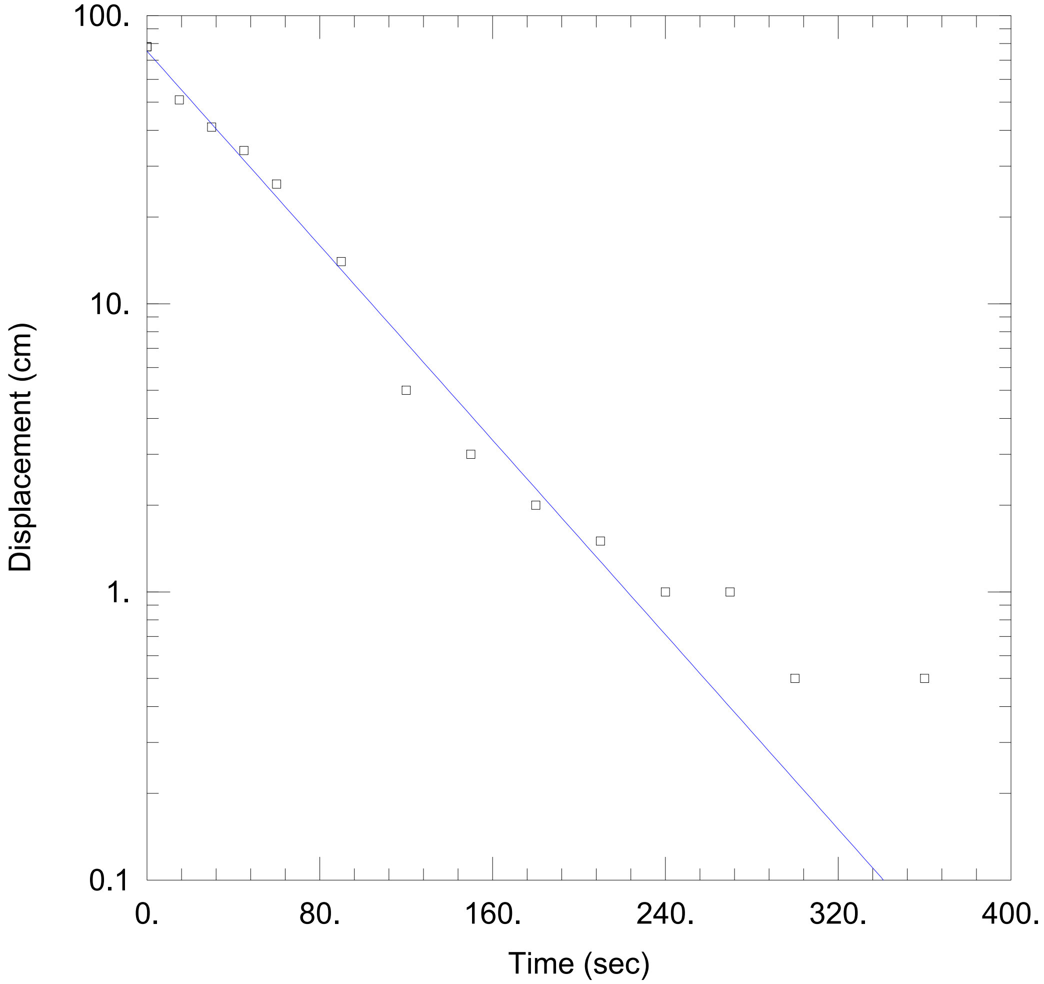
WELL DATA (BM-5d)

Initial Displacement: 202. cm
Total Well Penetration Depth: 895. cm
Casing Radius: 2.54 cm
Static Water Column Height: 895. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.0002252 cm/sec
y0 = 144.1 cm



HYDRAULIC CONDUCTIVITY TEST AT BM-7

PROJECT INFORMATION

Company: R.J Burnside
Client: Ballymore
Project: 300041171
Location: Barrie
Test Well: BM-7
Test Date: April 24, 2018

AQUIFER DATA

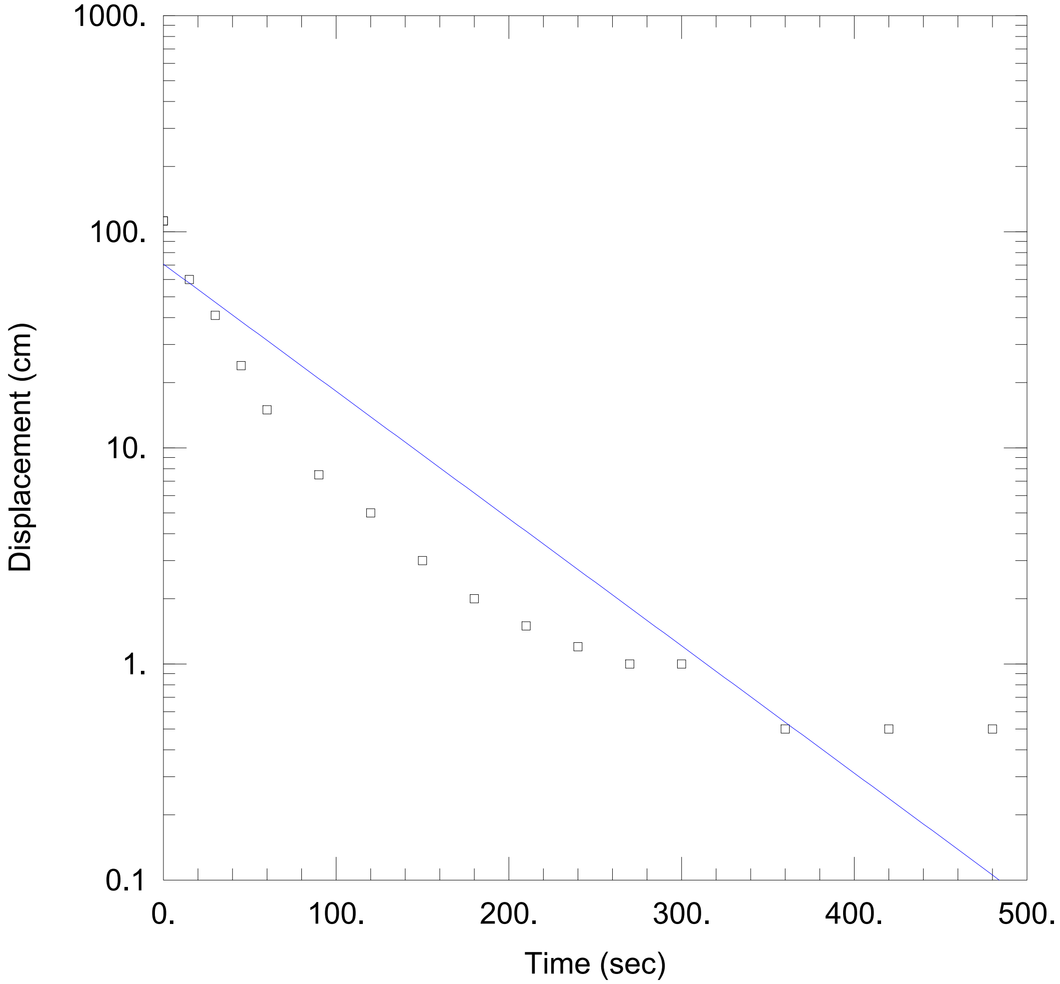
Saturated Thickness: 313. cm
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BM-7)

Initial Displacement: 78. cm
Total Well Penetration Depth: 313. cm
Casing Radius: 2.54 cm
Static Water Column Height: 313. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.00152 cm/sec
y0 = 75.27 cm



HYDRAULIC CONDUCTIVITY TEST AT BM-9

PROJECT INFORMATION

Company: R.J Burnside
Client: Ballymore
Project: 300041171
Location: Barrie
Test Well: BM-9
Test Date: April 24, 2018

AQUIFER DATA

Saturated Thickness: 490. cm
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BM-9)

Initial Displacement: 112. cm
Total Well Penetration Depth: 490. cm
Casing Radius: 2.54 cm
Static Water Column Height: 152. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.001061 cm/sec
y0 = 70.77 cm

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix D

Groundwater Level Data

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	30-Aug-2017		27-Sep-2017		2-Nov-2017		24-Nov-2017	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
BM-1	5.32	267.10	3.69	263.41	3.90	263.20	4.06	263.04	4.06	263.04
BM-5s	4.60	260.20	2.56	257.64	2.59	257.61	2.48	257.72	1.91	258.29
BM-5d	10.57	260.20	2.15	258.05	2.17	258.03	2.11	258.09	2.17	258.03
BM-7	3.64	264.30	1.00	263.30	1.14	263.16	1.16	263.14	1.07	263.23
BM-8s	4.50	255.70	1.38	254.32	1.37	254.33	0.60	255.10	0.73	254.97
BM-8d	11.28	255.70	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing
BM-9	5.93	262.00	1.87	260.14	1.92	260.08	1.78	260.22	1.63	260.37
BM-10	5.89	264.00	1.96	262.04	2.06	261.94	2.07	261.93	1.97	262.03
PZ1s-BM	1.30	**259.00**	-	-	-	-	1.18	257.82	0.01	258.99
PZ1d-BM	1.91	**259.00**	-	-	-	-	1.34	257.66	-0.11	259.11
PZ2s-BM	1.31	**258.00**	-	-	-	-	1.01	256.99	0.08	257.92
PZ2d-BM	1.90	**258.00**	-	-	-	-	1.22	256.78	0.50	257.50

Notes:

"-" denotes data unavailable

mbgs - meters below ground surface

masl - meters above sea level

Ground elevations from Soil Eng, 2016 borehole logs.

Bold ground elevations estimated from Google Earth.

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	18-Dec-2017		25-Jan-2018		22-Feb-2018		23-Mar-2018	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
BM-1	5.32	267.10	3.92	263.19	3.76	263.34	3.55	263.55	3.80	263.30
BM-5s	4.60	260.20	2.46	257.75	2.04	258.16	1.86	258.34	2.46	257.74
BM-5d	10.57	260.20	2.12	258.08	1.82	258.38	1.63	258.57	2.07	258.13
BM-7	3.64	264.30	1.23	263.07	0.85	263.45	0.72	263.58	1.12	263.18
BM-8s	4.50	255.70	0.96	254.74	0.59	255.11	0.45	255.25	0.96	254.75
BM-8d	11.28	255.70	Flowing	Flowing	Frozen	Frozen	Frozen	Frozen	Flowing	Flowing
BM-9	5.93	262.00	1.81	260.19	1.49	260.51	1.15	260.85	1.62	260.38
BM-10	5.89	264.00	2.06	261.94	1.75	262.25	1.46	262.54	1.83	262.17
PZ1s-BM	1.30	**259.00**	0.04	258.96	Frozen	Frozen	-0.03	259.03	Frozen	Frozen
PZ1d-BM	1.91	**259.00**	-0.05	259.05	Frozen	Frozen	-0.18	259.18	Frozen	Frozen
PZ2s-BM	1.31	**258.00**	0.09	257.91	Frozen	Frozen	0.07	257.93	Frozen	Frozen
PZ2d-BM	1.90	**258.00**	0.26	257.75	0.21	257.79	0.18	257.82	0.13	257.87

Notes:

"-" denotes data unavailable

mbgs - meters below ground surface

masl - meters above sea level

Ground elevations from Soil Eng, 2016 borehole logs.

Bold ground elevations estimated from Google Earth.

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	24-Apr-2018		17-May-2018		28-Jun-2018		14-Aug-2018	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
BM-1	5.32	267.10	3.33	263.77	3.28	263.82	3.66	263.44	4.07	263.03
BM-5s	4.60	260.20	1.69	258.51	2.23	257.97	2.50	257.70	2.20	258.00
BM-5d	10.57	260.20	1.51	258.69	1.87	258.33	2.19	258.01	2.68	257.52
BM-7	3.64	264.30	0.41	263.89	0.68	263.62	1.03	263.27	1.30	263.00
BM-8s	4.50	255.70	0.66	255.04	0.97	254.73	1.28	254.42	1.50	254.20
BM-8d	11.28	255.70	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing
BM-9	5.93	262.00	1.01	260.99	1.43	260.57	1.75	260.25	2.01	259.99
BM-10	5.89	264.00	1.37	262.63	1.54	262.46	1.88	262.12	2.16	261.84
PZ1s-BM	1.30	**259.00**	-0.06	259.06	0.00	259.00	0.06	258.94	0.18	258.82
PZ1d-BM	1.91	**259.00**	-0.22	259.22	-0.11	259.11	-0.05	259.05	0.04	258.96
PZ2s-BM	1.31	**258.00**	0.03	257.97	0.10	257.90	0.21	257.79	0.27	257.73
PZ2d-BM	1.90	**258.00**	0.10	257.90	-0.04	258.04	-0.02	258.02	-0.06	258.06

Notes:

"-" denotes data unavailable

mbgs - meters below ground surface

masl - meters above sea level

Ground elevations from Soil Eng, 2016 borehole logs.

Bold ground elevations estimated from Google Earth.

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	24-Oct-2018		17-Dec-2018	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
BM-1	5.32	267.10	4.33	262.77	3.98	263.12
BM-5s	4.60	260.20	2.21	257.99	2.27	257.93
BM-5d	10.57	260.20	2.73	257.47	2.00	258.20
BM-7	3.64	264.30	1.49	262.81	1.15	263.15
BM-8s	4.50	255.70	0.94	254.76	0.84	254.86
BM-8d	11.28	255.70	Flowing	Flowing	Flowing	Flowing
BM-9	5.93	262.00	1.95	260.05	1.66	260.34
BM-10	5.89	264.00	2.28	261.72	1.93	262.07
PZ1s-BM	1.30	**259.00**	0.07	258.93	0.02	258.98
PZ1d-BM	1.91	**259.00**	0.00	259.00	-0.05	259.05
PZ2s-BM	1.31	**258.00**	0.13	257.87	0.12	257.88
PZ2d-BM	1.90	**258.00**	-0.17	258.17	-0.07	258.07

Notes:

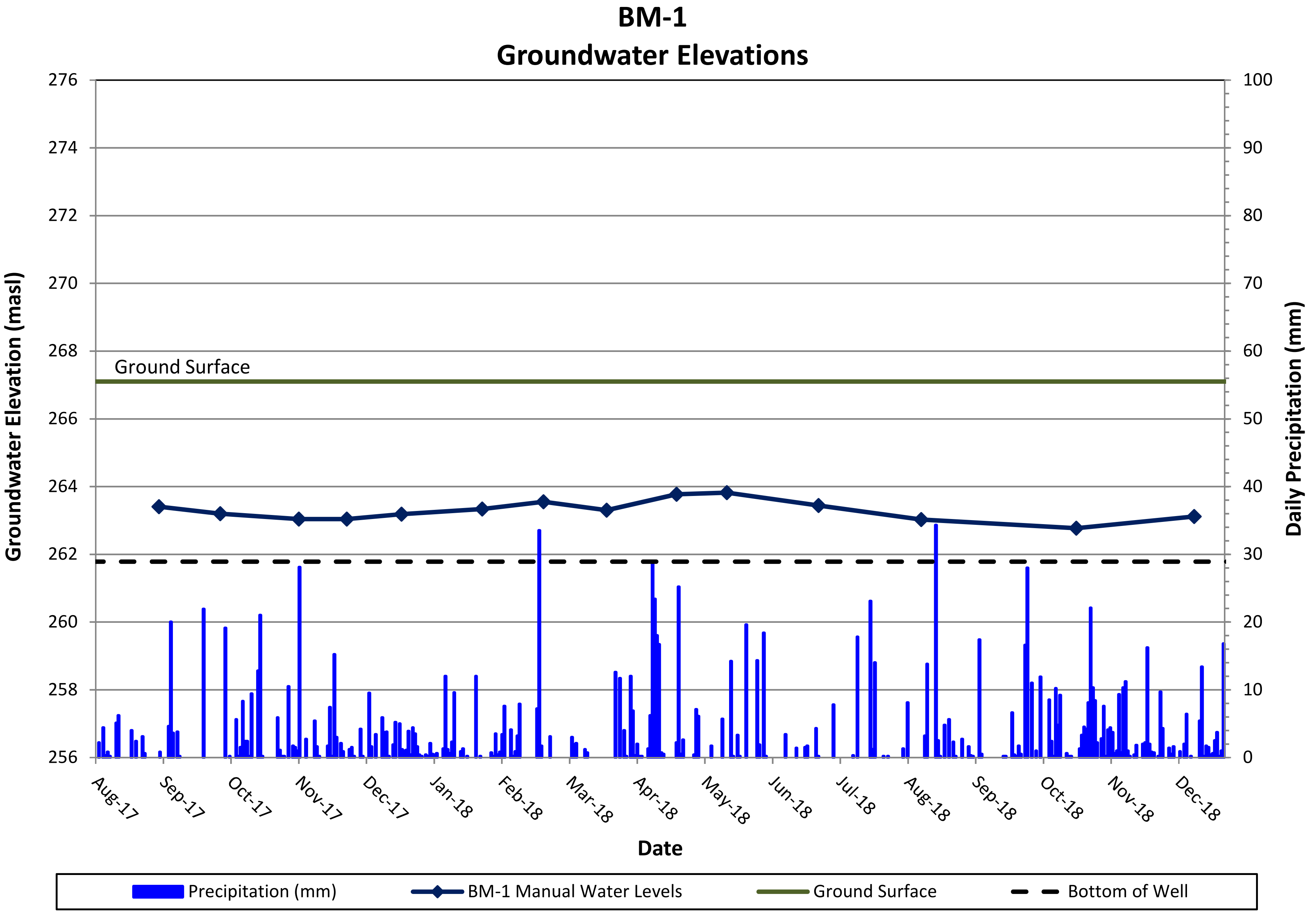
"-" denotes data unavailable

mbgs - meters below ground surface

masl - meters above sea level

Ground elevations from Soil Eng, 2016 borehole logs.

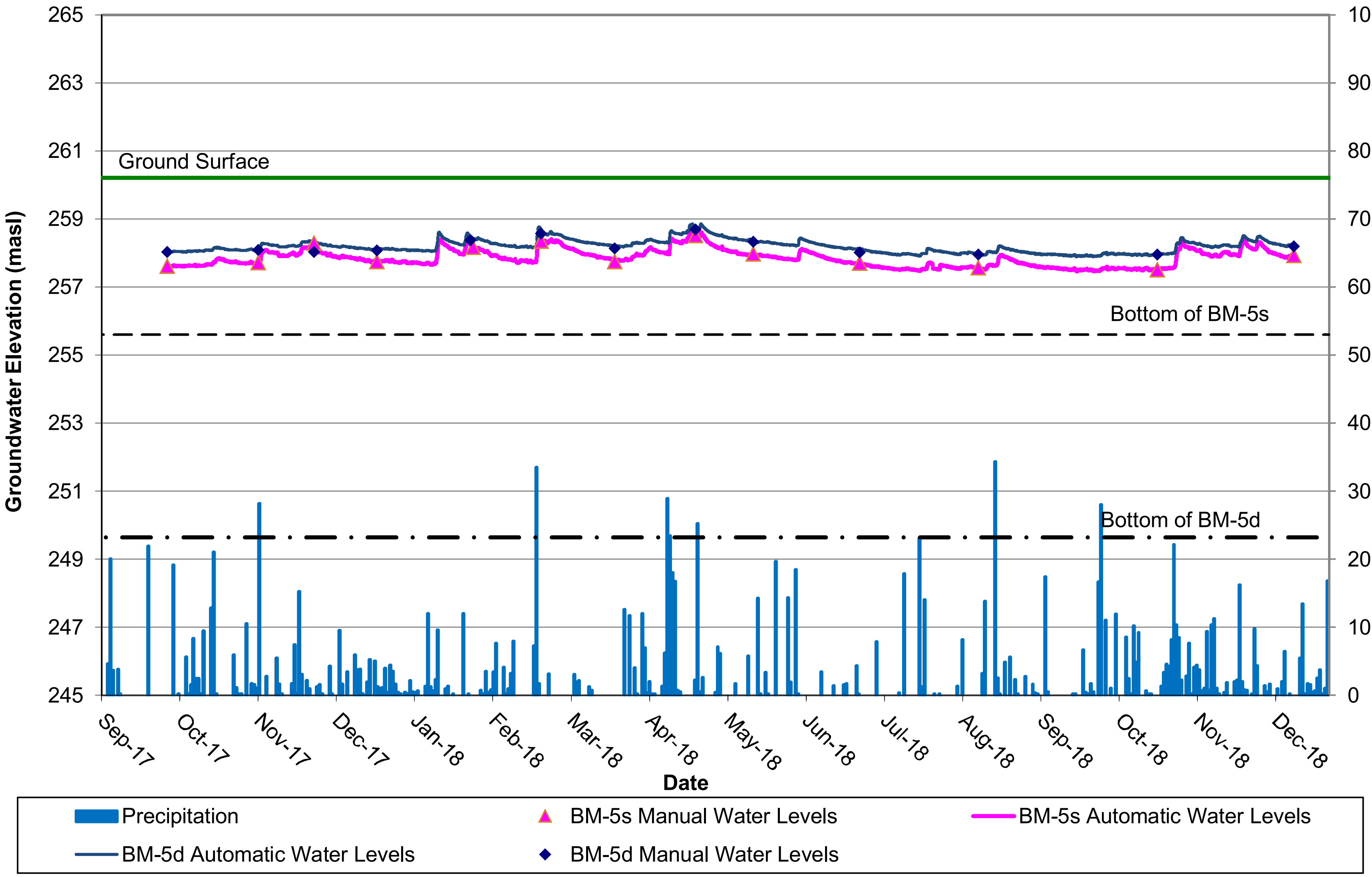
Bold ground elevations estimated from Google Earth.



R.J. Burnside & Associates Limited
300041171

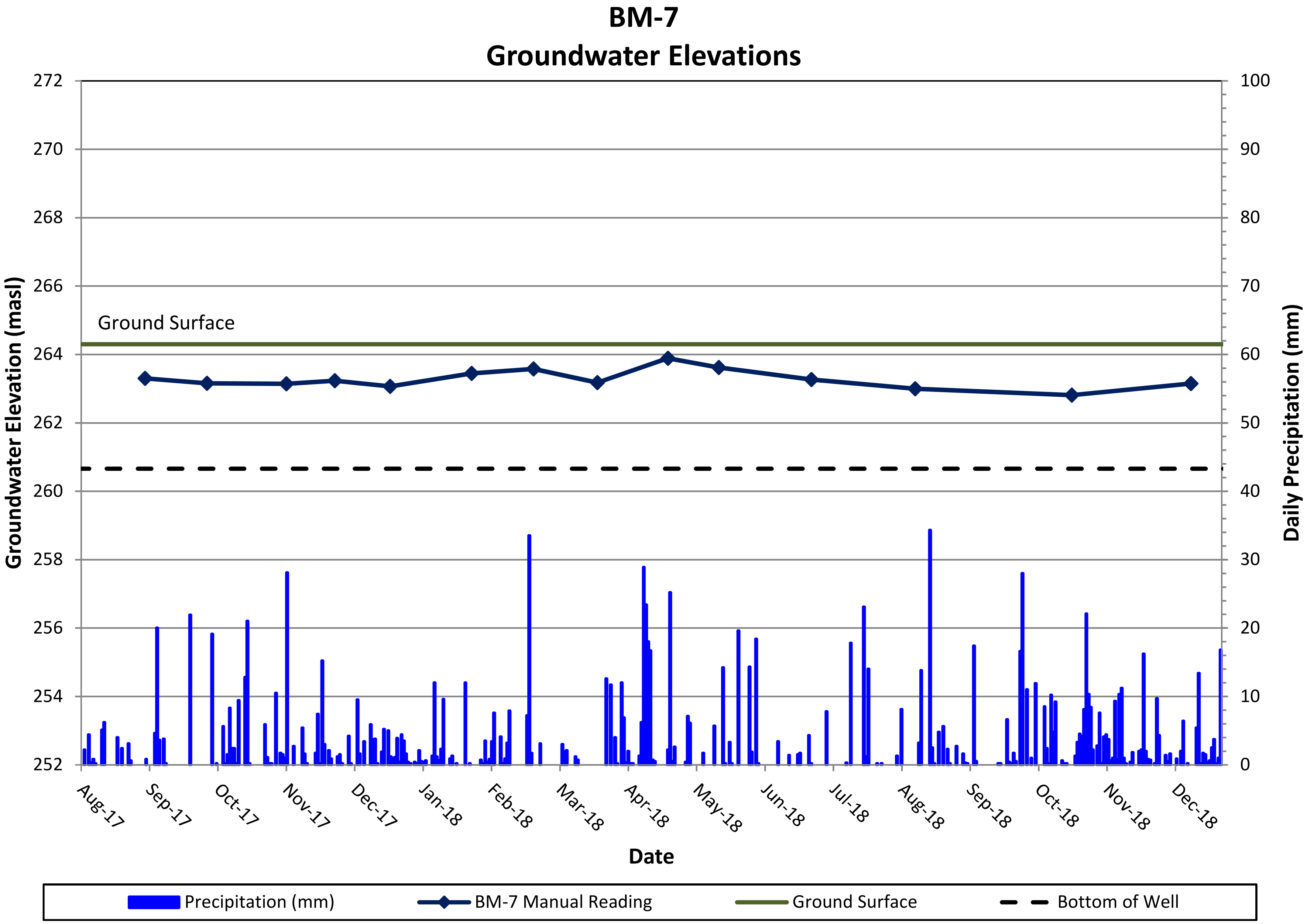
Figure D-1

BM-5s/d
Groundwater Elevations



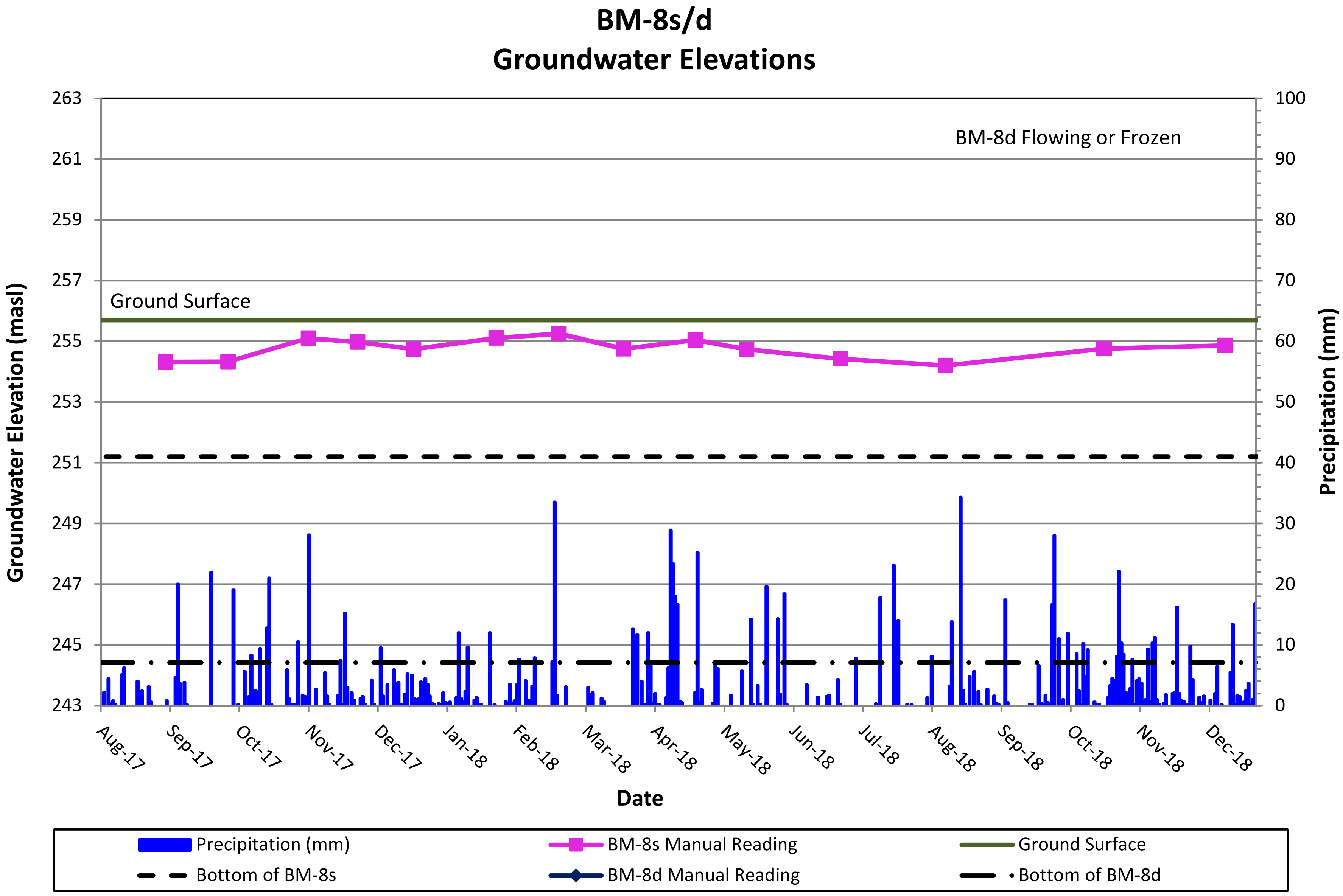
R.J. Burnside & Associates Limited
300041171

Figure D-2



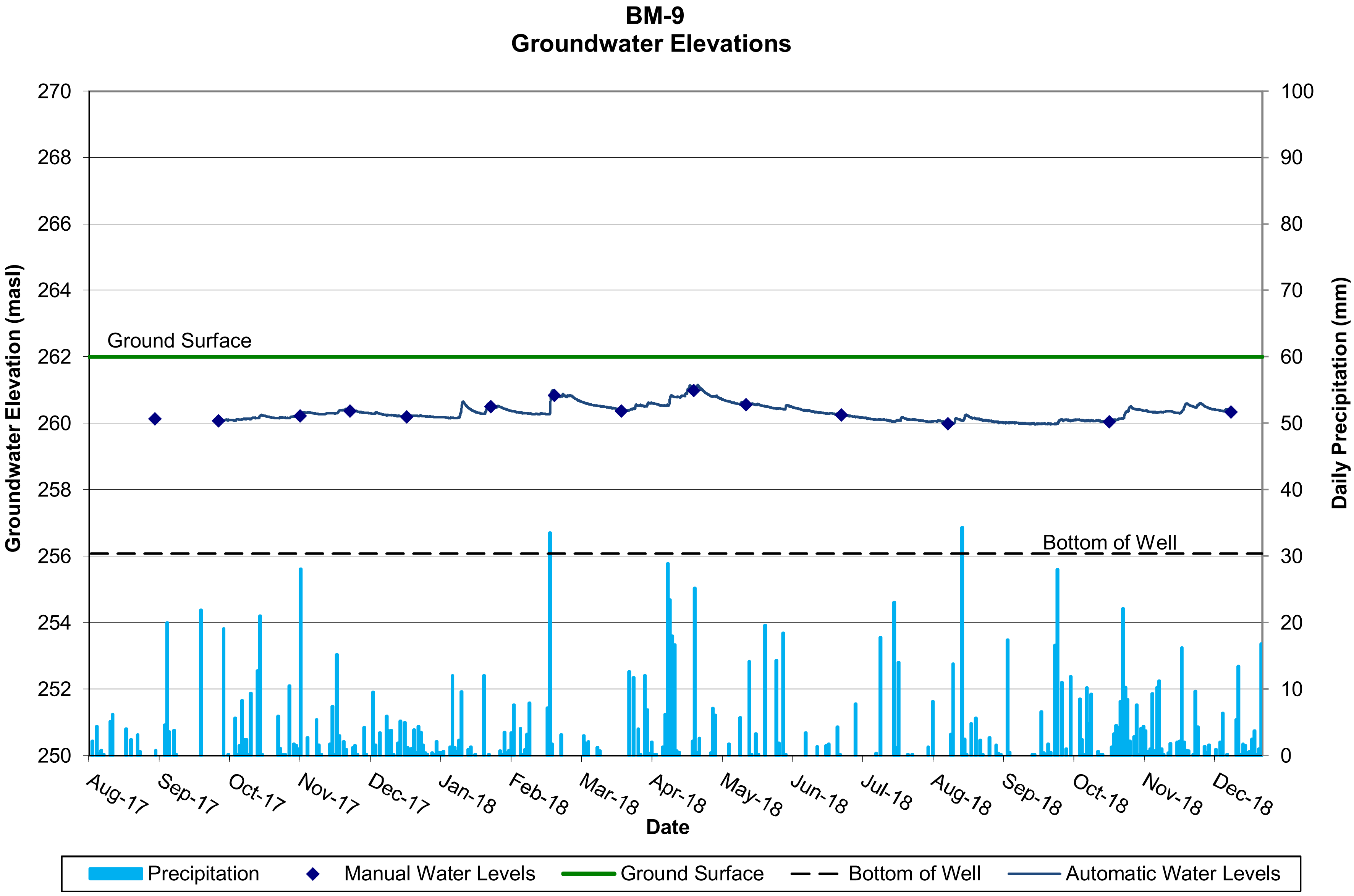
R.J. Burnside & Associates Limited
300041171

Figure D-3



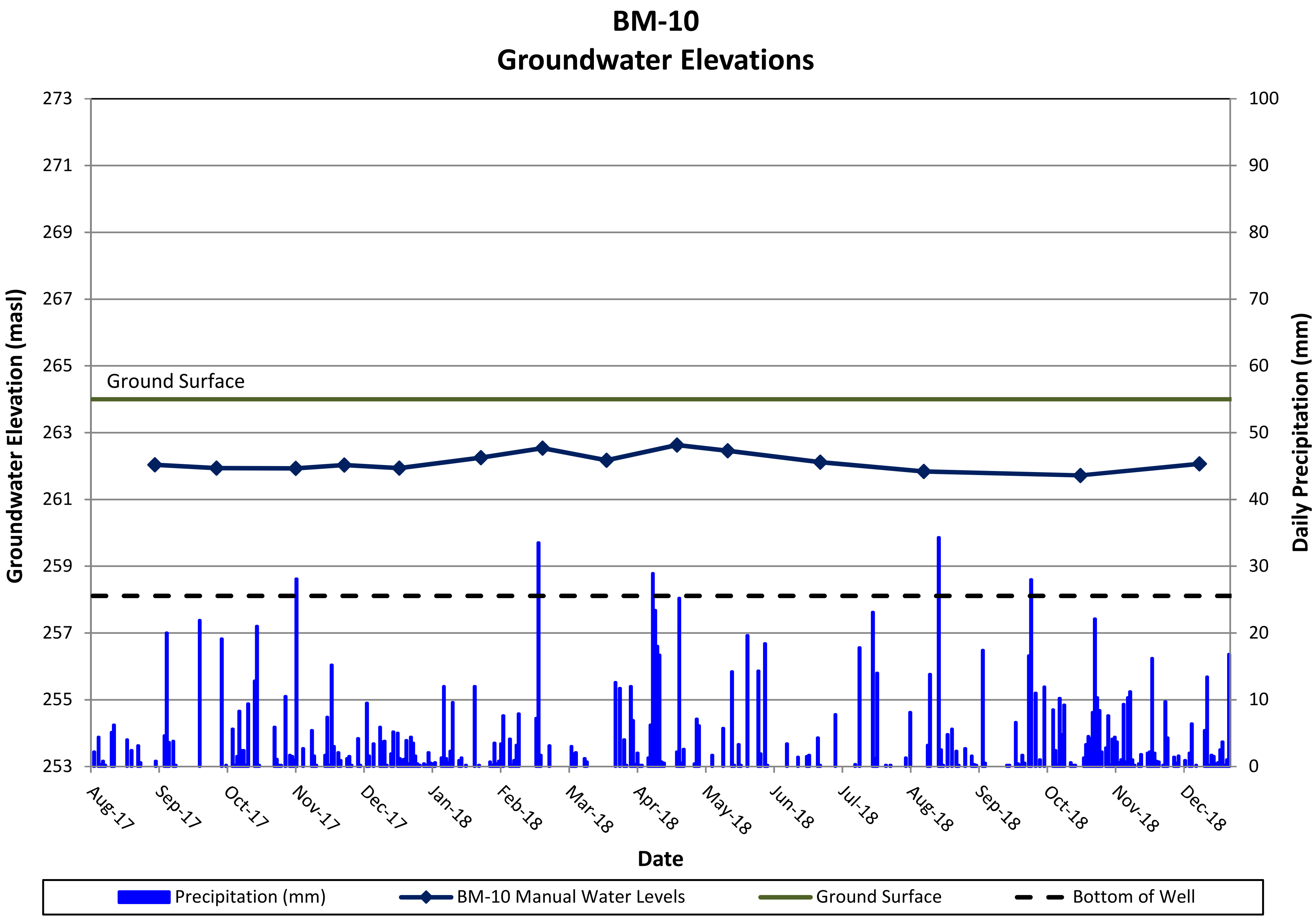
R.J. Burnside & Associates Limited
300041171

Figure D-4



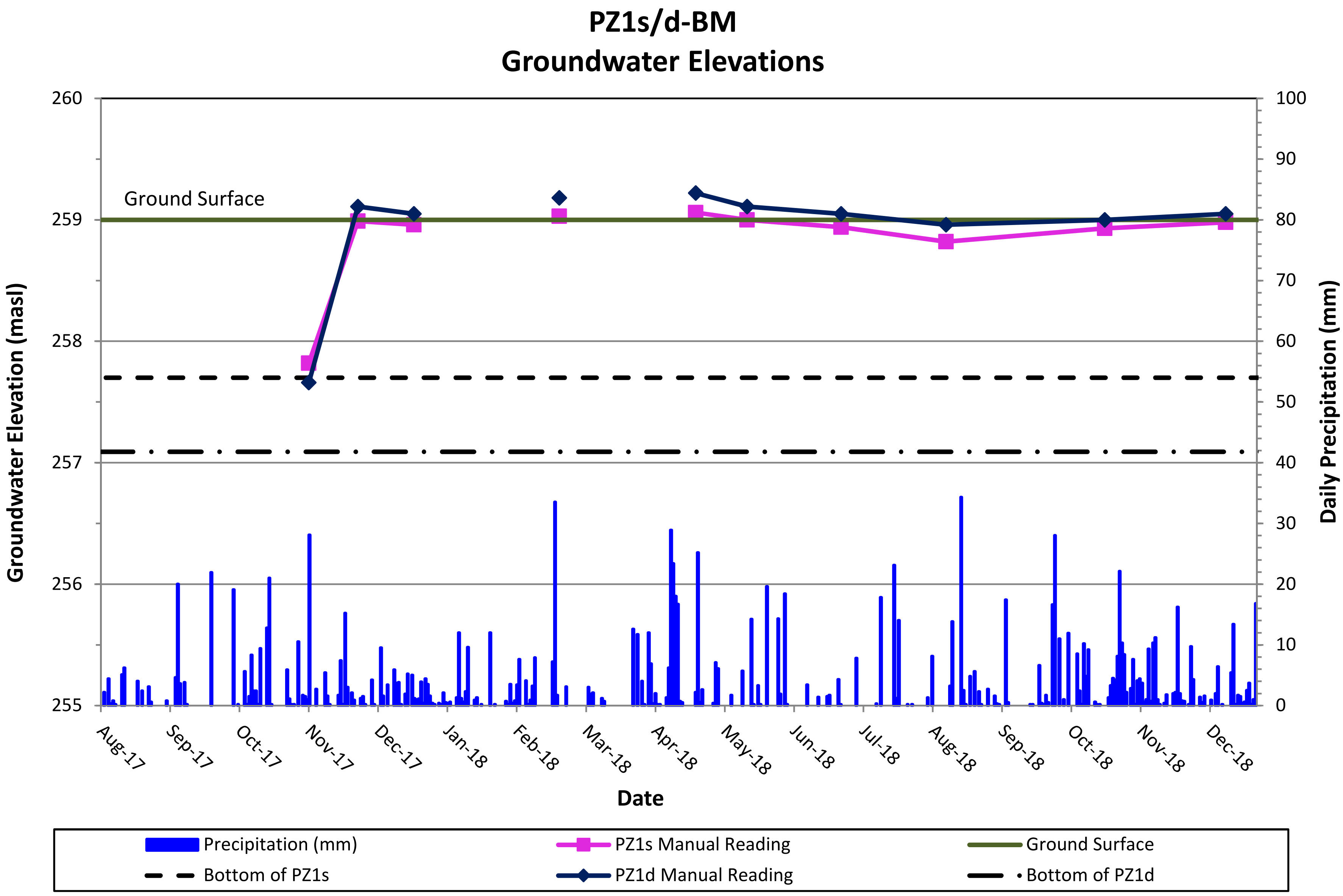
R.J. Burnside & Associates Limited
300041171

Figure D-5



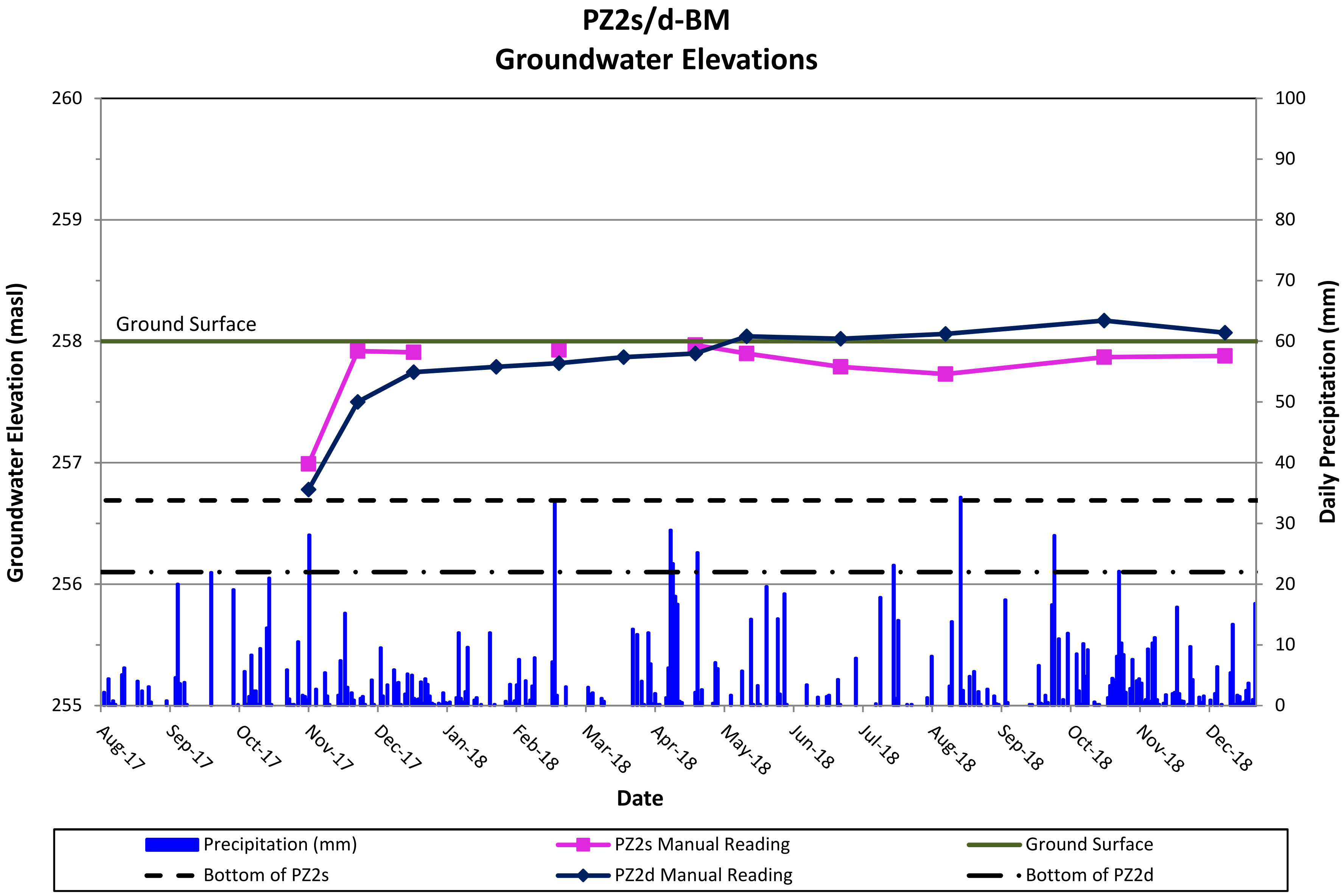
R.J. Burnside & Associates Limited
300041171

Figure D-6



R.J. Burnside & Associates Limited
300041171

Figure D-7



R.J. Burnside & Associates Limited
300041171

Figure D-8

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix E

Water Quality Data

Table E-1
Groundwater Quality

Monitoring Well				**BM-1**	**BM-5d**	**BM-9**
Date Sampled				**24-Apr-18**	**24-Apr-18**	**28-Apr-18**
Parameter	**Unit**	**RDL**	**ODWQS**			
Electrical Conductivity	µS/cm	2		749	1050	521
pH	pH Units	NA	(6.5-8.5)	7.99	7.9	7.84
Saturation pH				7.09	6.74	7.1
Langelier Index				0.9	1.16	0.74
Total Hardness (as CaCO3)	mg/L	0.5	(80-100)	**214**	**403**	**231**
Total Dissolved Solids	mg/L	20	500	490	654	314
Alkalinity (as CaCO3)	mg/L	5	(30-500)	275	347	246
Bicarbonate (as CaCO3)	mg/L	5		275	347	246
Carbonate (as CaCO3)	mg/L	5		<5	<5	<5
Hydroxide (as CaCO3)	mg/L	5		<5	<5	<5
Fluoride	mg/L	0.25	1.5	<0.25	<0.25	<0.25
Chloride	mg/L	0.50	250	77.7	134	17
Nitrate as N	mg/L	0.25	10.0	6.37	8.92	6.87
Nitrite as N	mg/L	0.25	1.0	<0.25	<0.25	<0.25
Bromide	mg/L	0.25		<0.25	<0.25	<0.25
Sulphate	mg/L	0.50	500	13.7	28.9	10.3
Ortho Phosphate as P	mg/L	0.50		<0.50	<0.50	<0.50
Reactive Silica	mg/L	0.05		9.13	13.9	10.8
Ammonia as N	mg/L	0.02		<0.02	0.02	<0.02
Total Phosphorus	mg/L	0.02		1.55	0.08	0.43
Total Organic Carbon	mg/L	0.5		2.1	4	1.4
Colour	TCU	5	5	**9**	**10**	**7**
Turbidity	NTU	0.5	5	**3520**	**10400**	**472**
Calcium	mg/L	0.05		76	139	80.3
Magnesium	mg/L	0.05		6	13.5	7.48
Sodium	mg/L	0.05	20 (200)	68.9	54	8.09
Potassium	mg/L	0.05		1.52	1.83	0.67
Aluminum (Dissolved)	mg/L	0.004	0.1	0.01	0.019	<0.004
Antimony	mg/L	0.003	0.006	<0.003	<0.003	<0.003
Arsenic	mg/L	0.003	0.025	<0.003	<0.003	<0.003
Barium	mg/L	0.002	1	0.028	0.141	0.018
Beryllium	mg/L	0.001		<0.001	<0.001	<0.001
Boron	mg/L	0.010	5	0.015	<0.010	<0.010
Cadmium	mg/L	0.001	0.005	<0.001	<0.001	<0.001
Chromium	mg/L	0.003	0.05	<0.003	<0.003	<0.003
Cobalt	mg/L	0.001		<0.001	<0.001	<0.001
Copper	mg/L	0.003	1	<0.003	<0.003	<0.003
Iron	mg/L	0.010	0.3	<0.010	<0.010	<0.010
Lead	mg/L	0.001	0.01	<0.001	<0.001	<0.001
Manganese	mg/L	0.002	0.05	<0.002	0.009	<0.002
Mercury (Dissolved)	mg/L	0.0001	0.001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	0.002		<0.002	<0.002	0.003
Nickel	mg/L	0.003		<0.003	<0.003	<0.003
Selenium	mg/L	0.004	0.01	<0.004	<0.004	<0.004
Silver	mg/L	0.002		<0.002	<0.002	<0.002
Strontium	mg/L	0.005		0.21	0.334	0.168
Thallium	mg/L	0.006		<0.006	<0.006	<0.006
Tin	mg/L	0.002		<0.002	<0.002	<0.002
Titanium	mg/L	0.002		<0.002	<0.002	<0.002
Tungsten	mg/L	0.010		<0.010	<0.010	<0.010
Uranium	mg/L	0.002	0.02	<0.002	<0.002	<0.002
Vanadium	mg/L	0.002	3	<0.002	<0.002	<0.002
Zinc	mg/L	0.005	5	<0.005	0.006	<0.005
Zirconium	mg/L	0.004		<0.004	<0.004	<0.004
% Difference/ Ion Balance	%	NA		7.02	6.72	9.98

ODWQS - Ontario Drinking Water Quality Standards

RDL - Reported Detection Limit

Bold indicates an exceedence of the ODWQS

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix F

Water Balance Calculations

WATER BALANCE CALCULATIONS

Ballymore Building (Barrie) Corp.
750 Lockhart Road
Barrie, ON
PROJECT No.300041171

BURNSIDE

TABLE F-1

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 150 mm (moderately-rooted vegetation in sandy loam soils)

Precipitation data from Barrie WPCC Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.7	-6.6	-2.1	5.6	12.3	17.9	20.8	19.7	15.3	8.7	2.7	-3.5	**6.9**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.19	3.91	6.90	8.66	7.97	5.44	2.31	0.39	0.00	**36.8**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	25.18	58.76	88.02	103.48	97.59	74.33	40.47	11.47	0.00	**499**
Adjusting Factor for U (Latitude 44° 20' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
WATER BALANCE COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	83	62	58	62	82	85	77	90	94	78	89	74	**933**
Potential Evapotranspiration (PET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
P - PET	83	62	58	34	8	-29	-57	-27	17	39	80	74	**340**
Change in Soil Moisture Storage	0	0	0	0	0	-29	-57	-27	17	39	58	0	**0**
Soil Moisture Storage max 150 mm	150	150	150	150	150	121	64	37	53	92	150	150	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
Soil Moisture Deficit max 150 mm	0	0	0	0	0	29	86	113	97	58	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	22	74	**340**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	58	43	41	24	5	0	0	0	0	0	16	52	**238**
Potential Direct Surface Water Runoff (independent of temperature)	25	19	17	10	2	0	0	0	0	0	7	22	**102**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	933	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	140	mm/year											
P-PE (surplus available for runoff from impervious areas)	793	mm/year											

Assume January storage is 100% of Soil Moisture Storage		
Soil Moisture Storage	150 mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003
*MOE SWM infiltration calculations		
topography - rolling to hilly land	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - sandy loam	0.4	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - predominantly cultivated land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.7**	
Latitude of site (or climate station)	44 ^{O} N.	

WATER BALANCE CALCULATIONS
Ballymore Building (Barrie) Corp.
750 Lockhart Road
Barrie, ON
PROJECT No.300041171

TABLE F-2

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 300 mm (wooded areas in sandy loam soils)

Precipitation data from Barrie WPCC Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.7	-6.6	-2.1	5.6	12.3	17.9	20.8	19.7	15.3	8.7	2.7	-3.5	**6.9**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.19	3.91	6.90	8.66	7.97	5.44	2.31	0.39	0.00	**36.8**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	25.18	58.76	88.02	103.48	97.59	74.33	40.47	11.47	0.00	**499**
Adjusting Factor for U (Latitude 44° 20' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
WATER BALANCE COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	83	62	58	62	82	85	77	90	94	78	89	74	**933**
Potential Evapotranspiration (PET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
P - PET	83	62	58	34	8	-29	-57	-27	17	39	80	74	**340**
Change in Soil Moisture Storage	0	0	0	0	0	-29	-57	-27	17	39	58	0	**0**
Soil Moisture Storage max 300 mm	300	300	300	300	300	271	214	187	203	242	300	300	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
Soil Moisture Deficit max 300 mm	0	0	0	0	0	29	86	113	97	58	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	22	74	**340**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	66	49	46	27	6	0	0	0	0	0	18	59	**272**
Potential Direct Surface Water Runoff (independent of temperature)	17	12	12	7	2	0	0	0	0	0	4	15	**68**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	933	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	140	mm/year											
P-PE (surplus available for runoff from impervious areas)	793	mm/year											

Assume January storage is 100% of Soil Moisture Storage
Soil Moisture Storage 300 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - rolling to hilly land	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - sandy loam	0.4	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - woodlands	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.8**	

Latitude of site (or climate station) 44 ° N.

WATER BALANCE CALCULATIONS
Ballymore Building (Barrie) Corp.
750 Lockhart Road
Barrie, ON
PROJECT No.300041171

TABLE F-3

Water Balance for Pre- and Post-Development Land Use Conditions (with no SWM/LID measures in place)
Wetland #3 Catchment

Land Use Description	Approx. Land Area* (m^2)	Estimated Impervious Fraction for Land Use*	Estimated Impervious Area (m^2)	Runoff from Impervious Area** (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area** (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area** (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Pre-Development Land Use												
Wetland	40,740	1.00	40,740	0.793	32,306	0	0.068	0	0.272	0	32,306	0
Open Space /Agricultural	22,651	0.00	0	0.793	0	22,651	0.102	2,308	0.238	5,386	2,308	5,386
Rural Residential	0	0.25	0	0.793	0	0	0.102	0	0.238	0	0	0
TOTAL PRE-DEVELOPMENT	**63,391**		**40,740**		**32,306**	**22,651**		**2,308**		**5,386**	**34,614**	**5,386**
Post-Development Land Use (with no LID measures in place)												
Townhomes	14,849	0.73	10,840	0.793	8,595	4,009	0.102	409	0.238	953	9,004	953
Future Development	0	0.75	0	0.793	0	0	0.102	0	0.238	0	0	0
Roadways	4,835	0.74	3,578	0.793	2,837	1,257	0.102	128	0.238	299	2,965	299
SWMF Block	0	0.50	0	0.793	0	0	0.102	0	0.238	0	0	0
Natural Heritage System	2,967	0.00	0	0.793	0	2,967	0.068	202	0.238	705	202	705
Wetland	40,740	1.00	40,740	0.793	32,306	0	0.068	0	0.238	0	32,306	0
TOTAL POST-DEVELOPMENT	**63,391**		**55,158**		**11,433**	**8,233**		**738**		**1,958**	**44,477**	**1,958**
										% Change from Pre to Post	128	64
										Effect of development (with no mitigation)	1.3 times increase in runoff	64% reduction of infiltration

* data provided by SCS Consulting Group Ltd.

** figures from Tables F-1 and F-2

To balance pre- to post-,
the infiltration target (m^3/a)= **3,429**

WATER BALANCE CALCULATIONS
Ballymore Building (Barrie) Corp.
750 Lockhart Road
Barrie, ON
PROJECT No.300041171

TABLE F-4

Water Balance for Pre- and Post-Development Land Use Conditions (with no SWM/LID measures in place)
Wetland #4 Catchment

Land Use Description	Approx. Land Area* (m^2)	Estimated Impervious Fraction for Land Use*	Estimated Impervious Area (m^2)	Runoff from Impervious Area** (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area** (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area** (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Exising Land Use												
Wetland	87,902	1.00	87,902	0.793	69,703	0	0.068	0	0.272	0	69,703	0
Open Space /Agricultural	90,621	0.00	0	0.793	0	90,621	0.102	9,236	0.238	21,550	9,236	21,550
Rural Residential	7,311	0.25	1,828	0.793	1,449	5,483	0.102	559	0.238	1,304	2,008	1,304
TOTAL PRE-DEVELOPMENT	**185,834**		**89,729**		**71,152**	**96,104**		**9,794**		**22,854**	**80,947**	**22,854**
Post-Development Land Use (with no LID measures in place)												
Townhomes	6,577	0.73	4,801	0.793	3,807	1,776	0.102	181	0.238	422	3,988	422
Future Development	29,197	0.75	21,897	0.793	17,364	7,299	0.102	744	0.238	1,736	18,108	1,736
Roadways	27,390	0.74	20,268	0.793	16,072	7,121	0.102	726	0.238	1,693	16,798	1,693
SWM Block	19,956	0.50	9,978	0.793	7,912	9,978	0.102	1,017	0.238	2,373	8,929	2,373
Natural Heritage System	14,814	0.00	0	0.793	0	14,814	0.068	1,006	0.238	3,523	1,006	3,523
Wetland	87,902	1.00	87,902	0.793	69,703	0	0.068	0	0.238	0	69,703	0
TOTAL POST-DEVELOPMENT	**185,834**		**144,847**		**45,155**	**40,988**		**3,674**		**9,747**	**118,532**	**9,747**
% Change from Pre to Post											146	57
Effect of development (with no mitigation)											1.5 times increase in runoff	57% reduction of infiltration

* data provided by SCS Consulting Group Ltd.

** figures from Tables F-1 and F-2

To balance pre- to post-,
the infiltration target (m^3/a)= **13,107**

WATER BALANCE CALCULATIONS
Ballymore Building (Barrie) Corp.
750 Lockhart Road
Barrie, ON
PROJECT No.300041171

TABLE F-5

Water Balance for Pre- and Post-Development Land Use Conditions (with no SWM/LID measures in place)
Wetland #6 Catchment

Land Use Description	Approx. Land Area* (m^2)	Estimated Impervious Fraction for Land Use*	Estimated Impervious Area (m^2)	Runoff from Impervious Area** (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area** (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area** (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Exising Land Use												
Wetland	2,834	1.00	2,834	0.793	2,247	0	0.068	0	0.272	0	2,247	0
Open Space /Agricultural	12,190	0.00	0	0.793	0	12,190	0.102	1,242	0.238	2,899	1,242	2,899
Rural Residential	1,280	0.25	320	0.793	254	960	0.102	98	0.238	228	352	228
TOTAL PRE-DEVELOPMENT	**16,304**		**3,154**		**2,501**	**13,150**		**1,340**		**3,127**	**3,841**	**3,127**
Post-Development Land Use (with no LID measures in place)												
Townhomes	0	0.73	0	0.793	0	0	0.102	0	0.238	0	0	0
Future Development	6,303	0.75	4,727	0.793	3,748	1,576	0.102	161	0.238	375	3,909	375
Roadways	6,627	0.74	4,904	0.793	3,889	1,723	0.102	176	0.238	410	4,064	410
SWM Block	0	0.50	0	0.793	0	0	0.102	0	0.238	0	0	0
Natural Heritage System	540	0.00	0	0.793	0	540	0.102	55	0.238	129	55	129
Wetland	2,834	1.00	2,834	0.793	2,247	0	0.068	0	0.238	0	2,247	0
TOTAL POST-DEVELOPMENT	**16,304**		**12,465**		**7,637**	**3,839**		**391**		**913**	**10,276**	**913**
										% Change from Pre to Post	268	71
										Effect of development (with no mitigation)	2.7 times increase in runoff	71% reduction of infiltration

* data provided by SCS Consulting Group Ltd.

** figures from Tables F-1 and F-2

To balance pre- to post-,
the infiltration target (m^3/a)= **2,214**