Hydrogeological Study in Support of Draft Plan

Barrie Lockhart Road LP
Barrie, Ontario

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1.0 Introduction

R.J. Burnside & Associates Limited (Burnside) has been retained by Barrie Lockhart Road LP (part of the Sorbara Group) to complete a hydrogeological assessment for lands located within the Hewitt's Secondary Plan Area in Barrie. The lands associated with the assessment, herein referred to as the subject lands are located north of Lockhart Road and east of Huronia Road 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 that included an assessment of regional hydrogeology (Burnside, 2016). The current assessment is aimed at updating information contained in the regional hydrogeological assessment and providing more detailed site-specific information for the subject lands in support of an application for draft plan approval.

1.1 Scope of Work

The scope of work completed for the hydrogeological study was developed to build upon the more regional work completed for the Hewitt's SPA (Burnside, 2016) and to address requirements for hydrogeological studies in support of draft plan approval. The scope of work for the hydrogeological assessment included the review of available regional information as well as the completion of the following site-specific tasks:

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.

3. Establish groundwater monitoring network: Groundwater monitoring locations were established to characterize seasonal variations in the water table in both the shallow and deep aquifers. Existing wells (MW11) and piezometers (PZ4) from previous studies were selected for inclusion in the monitoring program. Fifteen new monitoring wells (SB-1 to SB-15) were completed on the subject

lands as part of a geotechnical assessment and were incorporated into the current assessment. One piezometer nest (one shallow and one deep piezometer) was installed near a wetland feature (SB-PZ1s/d) to determine the nature of potential groundwater/surface water interactions in the vicinity of this feature. The locations of the monitoring wells and piezometers are shown on Figure 2. The 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 (MW11, SB-3, SB-4, and SB-6) 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 monthly since November 2017 in monitoring wells and piezometers. Automatic water level recorders (dataloggers) were installed in one monitoring well (MW11) and two piezometers (SB-PZ1d and PZ4) to document the range of groundwater fluctuations and the response of the groundwater table to precipitation events. 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 testing: Water quality data was collected from selected monitoring locations to typify the groundwater and surface water quality in the vicinity of the subject lands. Samples were collected in 2018 from two monitoring wells: SB-3 and SB-4 and one surface water sample SB-SW1. 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-development water balance calculations have been completed to assess the groundwater infiltration volumes for the subject lands. The local climate data and detailed water balance calculations are provided in Appendix F.

8. Data compilation, assessment of site conditions and reporting: The above data were all compiled reviewed and assessed to develop an understanding of the site specific hydrogeological conditions. The results of the assessment are presented in the current report.

2.0 Physical Setting

2.1 Topography and Drainage

The topography of the subject lands slopes in a northern direction towards Lover's Creek Swamp with elevations ranging from 269 masl, at the south portion of the subject lands, to 247 masl within Lover's Creek Swamp on the north portion of the subject lands (Figure 3).

The subject lands are located within the Lake Simcoe watershed and Lovers Creek subwatershed. Lover's Creek Swamp, a provincially significant wetland is located in the north portion of the subject lands. A tributary of Lover's Creek crosses the extreme northeast corner of the subject lands (Figure 3).

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 within the Peterborough Drumlin Field 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 being common in this area. 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 with bands of coarse-textured glaciolacustrine deposits located on the northern and central portion of the site (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 Balance (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 areas (aquitards) of varying thicknesses. The basic hydrostratigraphic sequence that was modelled in the regional studies (AquaResource, 2011) consists of four main aquifer areas (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 study area.
- 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 area. The upper aquifer A1 is reported to be present throughout the larger Barrie area, and has been interpreted to occur extensively in the study area.
- 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 area is used for the Innisfil Heights water supply.
- C2 – Intermediate aquitard.
- A3 – This area 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

Boreholes were drilled across the subject lands as part of a geotechnical investigation conducted by Peto MacCallum in 2017. The investigation included the completion of 15 boreholes that were constructed as monitoring wells. The locations of the boreholes/monitoring wells are shown on Figure 5 and the borehole logs are provided in Appendix B.

The geological information from the boreholes indicated that the overburden is generally composed of layers of glacial till and sand. The till deposits were generally composed of sandy silt to silty sand with varying amounts of clay and gravel. Some lenses of finer grained sediments were encountered in the boreholes and these lenses were interpreted to be discontinuous. Clayey silt was encountered below the surficial layer or topsoil at SB-1, SB-3 and MW11. The clayey silt extended to depths of about 2.0 m. The information provided by the borehole logs confirms the surficial geology mapping for the area.

To illustrate the shallow hydrostratigraphic sequence of the subject lands, schematic geologic cross-sections have been prepared (Figures 6 and 7) using the MECP well records (Appendix A) and the soils information collected during drilling of boreholes (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 layer of sandy silt till with a thickness ranging from 5 m to 24 m. The sandy silt till has occasional layers of sand and gravel. Underlying the sandy silt till layer is a layer of sand and gravel. The sand layer is interpreted to form the local aquifer where private supply wells are completed (Figures 6 and 7). Based on cross-sections produced in the Hewitt’s SIS (Burnside, 2015), the sand layer is interpreted to be underlain by a low permeability clay silt till at elevations between 210 masl and 230 masl.

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 on the subject lands as discussed below.

2.5.1 Grainsize Analysis

Grainsize analysis from the geotechnical investigations on the subject lands (Peto MacCallum, 2017) were reviewed (data provided in Appendix C).

Table 1: Summary of Grainsize Analyses and Hydraulic Conductivity

Sample ID	Depth of Sample (mbgs)	Soil Classification	Hydraulic Conductivity (cm/s)
SB-6 SS6	4.6	Till: Sand and Silt, trace clay, trace gravel	6.3×10^{-5}
SB-8 SS3	1.5	Till: Silty Sand, trace gravel	3.6×10^{-4}
SB-11 SS5	3.0	Till: Sand and Silt, trace clay, trace gravel	6.3×10^{-5}
SB-3 SS8	7.6	Silty Sand, trace gravel	2.3×10^{-3}

To estimate hydraulic conductivity based on grainsize analysis, an empirical formula method known as the Hazen estimation is used. This method is an approximation of hydraulic conductivity based on grainsize curves for sandy soils. The approximation does not strictly apply to finer grained materials, however, it is still considered useful to provide a general indication of the range of the hydraulic conductivity values. Hydraulic conductivity values were derived empirically using the Hazen method for eight of the samples. The grainsize distribution graphs are provided in Appendix C and the calculated hydraulic conductivity values are provided in Table 1.

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 four monitoring wells. 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)
SB-3	8.4	Silty Sand	1.3×10^{-5}
SB-4	3.9	Sand/Silt Till	1.3×10^{-4}
SB-6	3.3	Sand/Silt Till	2.2×10^{-4}
MW11	7.7	Sandy Silt	2.1×10^{-4}

*metres below ground surface

2.5.3 Hydraulic Conductivity Discussion

Grainsize analyses results indicate that the sediments within the overburden range in composition from silty sand with trace gravel (27% fines) to sand and silt (47% fines). 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 for the subject lands indicate that the overburden sediments in this area generally consist of varying amounts of sand and silt. The hydraulic conductivities based on grainsize analyses for the majority of the sediments is estimated in the range of 10^{-3} to 10^{-5} cm/sec.

The single well response test analyses resulted in similar hydraulic conductivities ranging from 10^{-4} to 10^{-5} cm/sec. The wells tested were all screened in the surficial sandy silt layer which forms the area to be impacted by development and is interpreted to be a low yielding aquifer (aquitard). Overall, the hydraulic conductivity of the overburden sediments on the subject lands consisting of sand and silt till is interpreted to range from 10^{-3} cm/sec (high) to 10^{-5} cm/sec (moderate).

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 city boundary which includes lands north of Mapleview Drive (Figure 1). It is also assumed that the subdivisions west of the subject lands and north of the subject lands (see Figure 2) are municipally serviced. Older homes (along Lockhart Road) outside of the previous municipal limits however are likely to have private water supply wells.

A review of the MECP water well records indicated that there are approximately 15 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 overburden with depths ranging from 4 m to 44 m. The locations of the MECP water well records are shown on Figure 5. Based on our interpretation of local stratigraphy and the interpreted geological cross-sections it is interpreted that water supply wells are most likely completed into the underlying sand and gravel layer that occurs at elevations approximately between 210 masl and 250 masl. These wells are assumed to be completed below the low hydraulic conductivity sandy silt layer that is at surface across most of the subject lands (Figure 6 and Figure 7).

The City of Barrie groundwater supply wells are located in deep aquifers (A3 and A4 in the regional hydrostratigraphy). These aquifers are interpreted to be found at elevations of 150 masl to 195 masl and 115 masl to 160 masl respectively and are therefore significantly below the surficial layer found on the subject lands and separated from any potential impact due to the proposed development (AquaResource et al., 2011). 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 more than 5 kilometres from the subject lands. 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 November 2017 and August 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 and 2018. In addition to the manual water level measurements recorded at each location, automatic water level recorders (dataloggers) collected hourly water level data at MW11, SB-PZ1d and PZ4. To prevent freezing and potential malfunctioning of dataloggers, they are not installed in piezometers during winter months. The loggers in SB-PZ1d and PZ4 were installed in April 2018 and these data are also included in the project record. The datalogger data collected are included on the hydrographs provided in Appendix D.

Hydrographs were not created for wells where water elevations were not available such as wells that were dry or flowing during the monitoring period.

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 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 pattern was observed in the on-site wells with seasonal variations ranging from 0.7 m to 4.2 m (Figures D-1 to D-10).

- Continuous water level data at MW11 is plotted against precipitation to determine if there is a correlation between changes in water level and the occurrence of precipitation events (Figures D-10). The logger data shows some correlation with variation in water levels and precipitation events. For example, in July 2018 a rain event of 37 m over two days resulted in an increase of 0.3 m.

- The groundwater table is interpreted to generally reflect the topography of the area. From November 2017 to August 2018, groundwater elevations in the monitoring wells ranged from 251.2 masl to 262.3 masl. Groundwater was measured at surface or above ground in monitoring wells in the lower topographic areas (MW11, SB-1, SB-3, SB-11) while groundwater was greater than 9 meters deep at SB-9 and SB-10 in the upper topographic areas.

- Several monitoring wells were seasonally dry only measuring water levels during the spring when the water table is the highest. These wells included SB-4, SB-8, SB-9, SB-10, SB-14 and SB-15.

- Water levels in piezometer nest SB-PZ1s/d were consistently within 0.05 m of ground surface. Water levels in the deep piezometer were higher than the shallow well during the summer months indicating discharge conditions (Figure D-11, Appendix D).

- Piezometer PZ4 showed typical seasonal variations in the shallow groundwater table with levels lowest during the summer and highest in the spring (Figure D-12).

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 (May 2018) obtained from the monitoring wells are shown on Figure 8, along with the interpreted groundwater elevation contours for the area. Arrows perpendicular to the groundwater elevation contours shown on Figure 8 illustrate the interpreted direction of the groundwater movement. Groundwater is interpreted to move in a north and west direction towards Lover’s Creek Swamp.

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 found at relatively higher topographic elevation. Areas where groundwater moves upward (i.e., areas of upward hydraulic gradients) are discharge areas and these generally occur in areas of relatively lower topographic elevation, such as along watercourses.

When evaluating groundwater recharge or discharge conditions, nested wells (two wells screened at different depths at the same location) can be used to determine vertical hydraulic gradients in the subsurface.

Piezometer nest SB-PZ1s/d is located at the edge of Lover’s Creek Swamp (Figure 2). The hydrograph of SB-PZ1s/d (Figure D-11) indicates discharge condition at this location with water levels in the deep piezometer higher than the shallow piezometer.

There were no other nested wells on the subject property however, artesian conditions at monitoring wells MW11, SB-1 and SB-3 suggest discharge conditions occur in the lower elevations of the subject lands. In the higher elevations of the subject lands there were several wells that were dry or seasonally dry wells (SB-4, SB-5, SB-8, SB-9, SB-10, SB-14 and SB-15) indicating that recharge conditions are present.

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, Lover’s Creek and Hewitt’s Creek subwatersheds by Earthfx (2012) using the groundwater 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 ESRGAs included headwater streams, cold water fisheries, wetlands, and brook trout and sculpin capture sites.

An ESGRA is mapped within the area of the Lover’s Creek Swamp in the subject lands (Figure 9). The groundwater flow map completed as part of this assessment (Figure 8) indicates that groundwater is moving towards the wetland and creek. Groundwater monitoring data however as discussed in Section 3.4 indicates discharge conditions within this area.

4.0 Water Quality

4.1 Groundwater Quality

Water quality data was collected from selected monitoring wells to typify the groundwater quality on the subject lands. Groundwater sampling was completed on May 22, 2018 at two groundwater monitoring wells (SB-3 and SB-4). 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).
- Both samples exceeded the ODWQS for total hardness (100 mg/L) with values ranging of 271 mg/L (SB-3) and 337 mg/L (SB-4). Hardness in groundwater is caused by dissolved calcium and magnesium and is typically related to the geologic material of the subsurface.
- Samples exceeded the ODWQS for turbidity (5 NTU) with values of 12 NTU (SB-3) and 15500 NTU (SB-4). This is likely a result of high silt content in the samples caused by a lack of well development. Groundwater is not intended for potable uses as part of the development and hence this exceedance is not regarded as an issue of concern.
- Nitrate was detected in both of the samples with values of 5.47 mg/L (SB-3) and 6.9 mg/L (SB-4). Nitrate in shallow groundwater is typically associated with areas where agricultural land use results in elevated nitrates in groundwater. Current land use on the subject lands is agricultural and is interpreted to be the cause of the elevated nitrates. The removal of agricultural land use as part of the development process is expected to alleviate this issue. It is however noted that both samples were below the ODWQS for nitrate, 10 mg/L.
- Total phosphorus was reported in the samples at 0.03 mg/L (SB-3) and 1.97 mg/L (SB-4). 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.

4.2 Surface Water Quality

To typify the surface water quality on the subject lands, a surface water sample (SW1) was collected on May 22, 2018 from the tributary of Lover’s Creek that crosses the northeast corner of the subject lands. The water sample was 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 surface water quality testing results from the analytical laboratory are provided in Table E-2, Appendix E and discussed below.

- The results show that the surface water sample met all of the Provincial Water Quality Standards (PWQS).
- The sample had similar levels of hardness, total dissolved solids and chloride to the groundwater sample from SB-3. This supports the interpretation that there is groundwater discharge in the wetland area and along Lover's Creek.
- Nitrate was not detected in the surface water sample. This may indicate that nitrate is being attenuated in the groundwater flow path and is not moving off site.
- Total phosphorus was reported in the samples at 0.03 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 surface water sample suggesting the reported concentration was due to particulate.

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). The detailed water balance calculations are provided in Appendix F.

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 area 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 5.2 km northwest 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. 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 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 agricultural lands with predominantly short to moderate-rooted vegetation (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 volumes for runoff and infiltration as presented on Table F-3 in Appendix F.

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. 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	238 mm/year	272 mm/year
Runoff	102 mm/year	68 mm/year

5.4 Pre-Development Water Balance (Existing Conditions)

The pre-development water balance calculations are presented in Table F-3 in Appendix F. As summarized on Table F-3, the total area of the subject lands is about 36.6 ha. The water balance component values from Table F-1 and Table F-2 were used to calculate the average annual volume of infiltration across the subject lands. Based on these component values, the pre-development infiltration volume for the subject lands is calculated to be about 64,100 m^3/year (Table F-3, Appendix F).

5.5 Potential Urban Development Impacts to Water Balance

Development of an area affects the natural water balance. The most significant difference 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. 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 across the subject lands). 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. There is an evaporation component from impervious surfaces and this is typically estimated to be between about 10% and 20% of the total precipitation. For the purposes of the calculations in this study, the evaporation has been estimated to be 15% of precipitation. 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 the subject lands on Table F-3 in Appendix F. 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 MOECC 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. In summary from these appendix tables, the average calculated post-development infiltration volume (without mitigation) is about 48,500 m^3/year.

Comparing the pre- and post-development infiltration volumes, shows that development has the potential to reduce the average infiltration on the subject lands from 64,500 m^3/year to 48,500 m^3/year, i.e., a reduction of about 16,000 m^3/year or 25%. These calculations assume no low impact development (LID) measures for stormwater management are in place.

5.7 Recommended Mitigation Strategies for Infiltration

The water balance calculations suggest that, without mitigation, the subject lands will receive about 75% of the current amount of average annual groundwater infiltration after development. 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.

Where feasible, measures to promote infiltration and minimize development impacts on the water balance should be incorporated into the development design. There, as outlined in the MOECC 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 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.

It is our understanding that subsurface exfiltration trenches, rain gardens and a below grade filtration gallery are being considered by the projects' engineers for LIDs on the subject lands (SCS, 2018). It is expected that these measures will provide adequate water to offset the infiltration deficit, however the impact of LID measures on infiltration should be confirmed at detailed design.

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 9 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 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 will 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 has been completed on behalf of the Hewitt's Land Owners Group to identify private water supply wells within 300 m of the Hewitt's SPA area. The survey confirmed the location of private wells along Lockhart Road. The private wells are assumed to be completed in the local sand and gravel layer that underlies the shallow sandy silt till zone which may be subject to impacts during construction. The low permeability of the shallow sandy silt till is expected to restrict the potential zone of influence due to construction activities. Dewatering of the subject lands will result in short-term removal of water from the subsurface however this impact is expected to be limited to the shallow sandy silt layer that is above and separated from the sand and gravel layer in which most of the private domestic wells are completed.

As noted in Section 6.1, the PTTW and EASR processes require a detailed hydrogeological study to be completed that evaluates the potential impacts of dewatering and looks at the area of potential impact from this activity. It is expected that the report will set out any domestic well monitoring requirements as well as a contingency and mitigation response plan. It is recommended that, prior to the completion of any dewatering activities, local residents be advised of the activity and that an impact response procedure be established. The impact response procedure will include a contact for any resident who notes an impact at their well. Impacts will also be reported to the MECP and replacement water supplied until the impact has dissipated.

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.

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Peto MacCallum, 2017. Geotechnical Investigation Proposed Lockhart Road Residential Subdivision, Barrie, Ontario. Peto MacCallum Ltd., May 2017.

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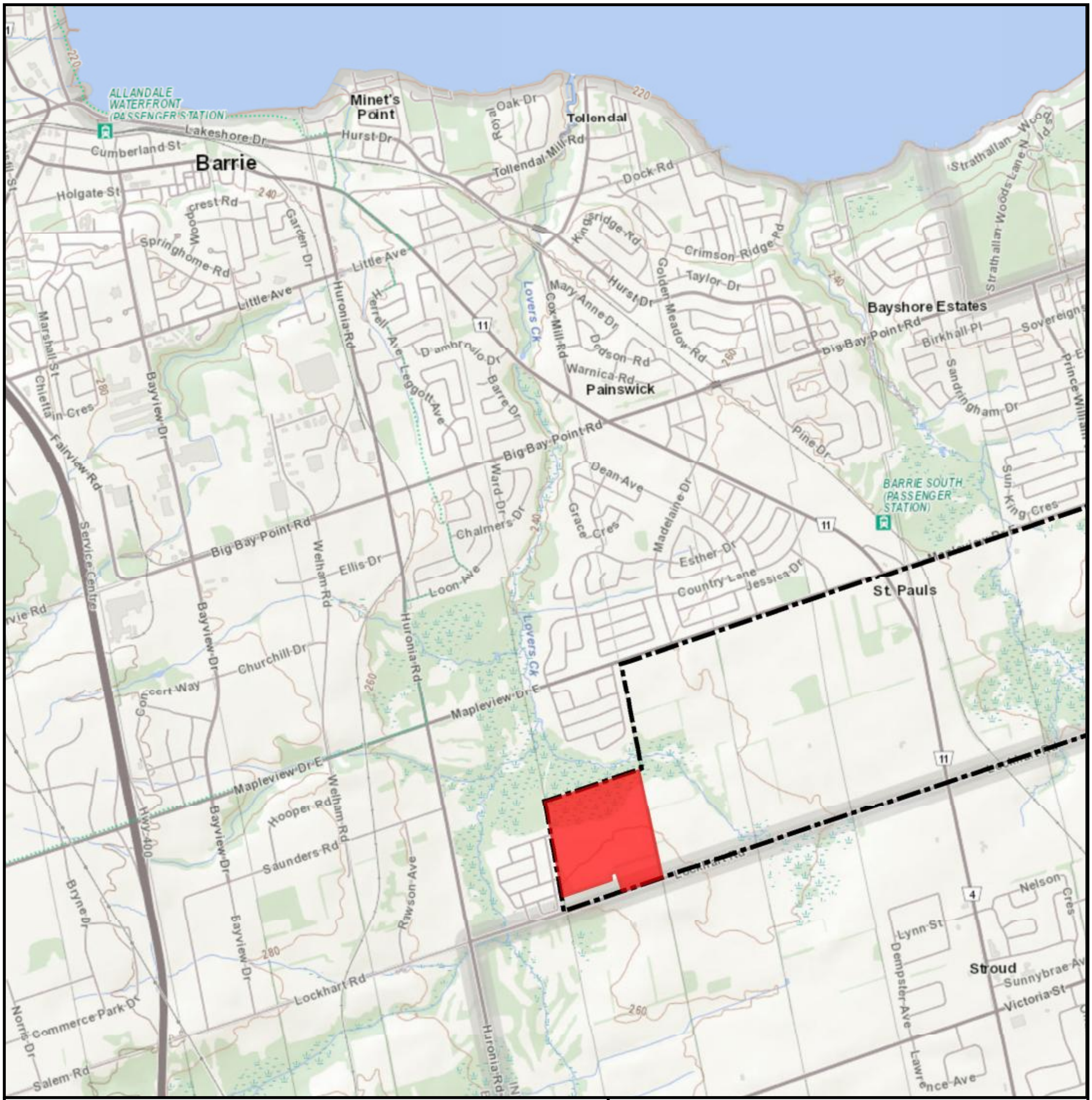
Figures



LEGEND

🟥 SUBJECT LANDS

▭ HEWITT'S SECONDARY PLAN AREA

0 500 1,000 2,000

Meters

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Client / Report

BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	SC	August 2018	1
Scale		Project No.	
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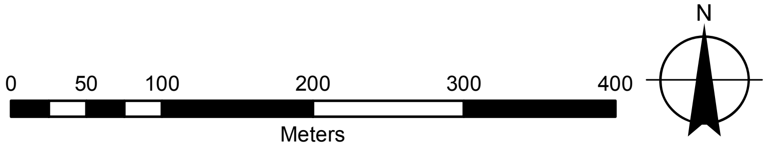
File Path: Nigel/Shared Work Areas/041514 Lockhart Road LPA:\041514 Lockhart Rd LP\041514 Site Location.mxd Print Date: 2018/08/22 Time: 11:04 AM

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

- ▭ SUBJECT LANDS
- ▭ HEWITT'S SECONDARY PLAN
- ⊕ MONITORING WELL (PETO, 2017)
- ⊕ MONITORING WELL (RJB, 2014)
- ● DRIVE POINT PIEZOMETER



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BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

SITE PLAN

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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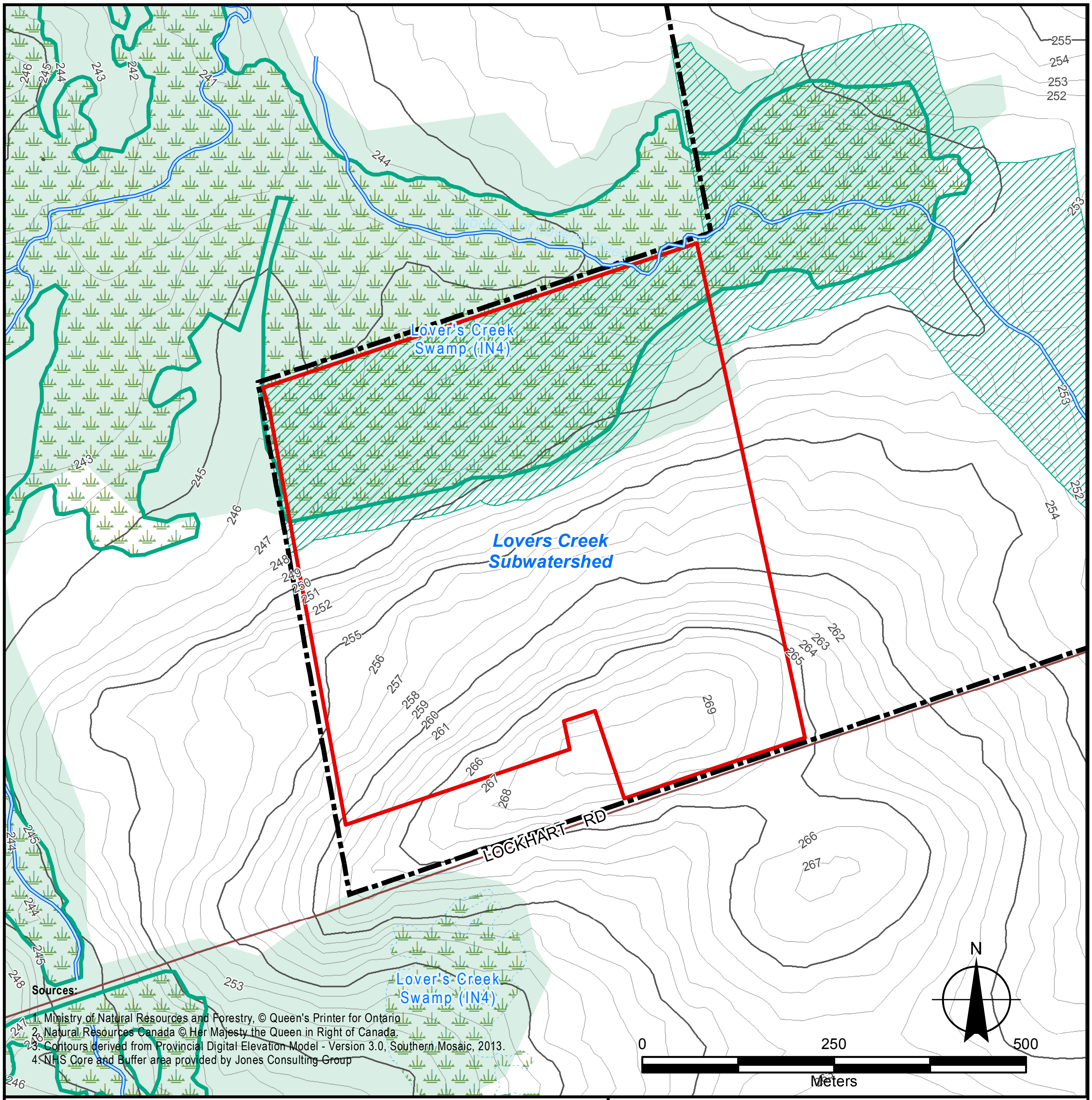

Sources:

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. Contours derived from Provincial Digital Elevation Model - Version 3.0, Southern Mosaic, 2013.
4. NHS Core and Buffer area provided by Jones Consulting Group

LEGEND

🟥	SUBJECT LANDS
▭	HEWITT'S SECONDARY AREA
—	WATERCOURSE
—	CONTOUR (5m intervals - masl)
—	CONTOUR (1m intervals - masl)
—	ROADWAY
▨	WETLAND
🟩	PROVINCIALLY SIGNIFICANT WETLAND
▨	NHS CORE AND BUFFER
🟩	WOODS / FOREST

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BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

TOPOGRAPHY AND DRAINAGE

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Scale		Project No.	
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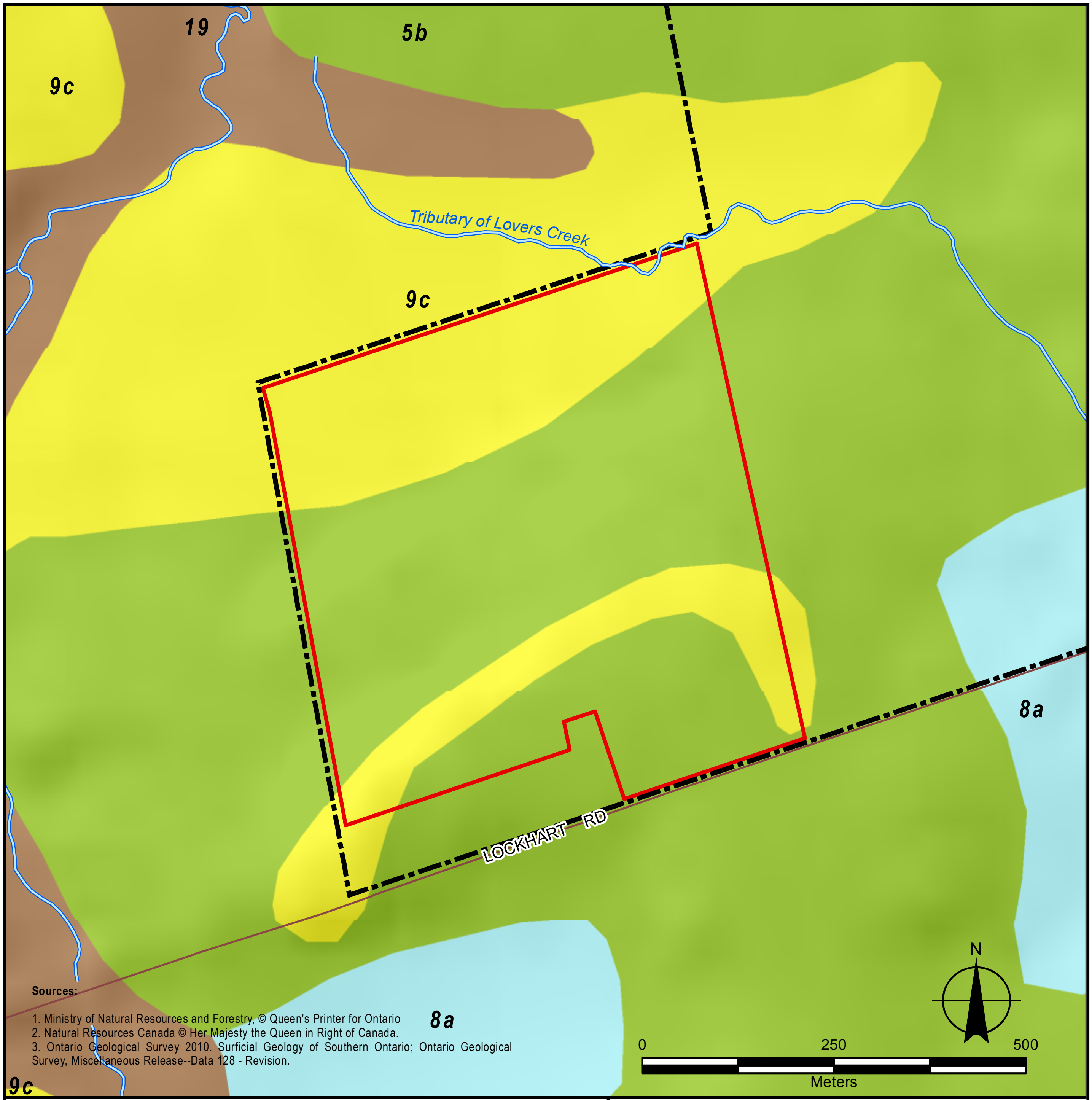

Sources:

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. Ontario Geological Survey 2010. Surficial Geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128 - Revision.

LEGEND

🟥	SUBJECT LANDS
▭	HEWITT'S SECONDARY AREA PLAN
—	WATERCOURSE
—	ROADWAY
🟩	5b: Stone-poor, carbonate-derived silty to sandy till
🟦	8a: Fine-textured glaciolacustrine deposits: Massive-well laminated
🟨	9b: Coarse-textured glaciolacustrine deposits: Littoral-foreshore deposits
🟨	9c: Coarse-textured glaciolacustrine deposits: Foreshore-basinal deposits
🟫	19: Modern alluvial deposits

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BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

SURFICIAL GEOLOGY

Drawn SK	Checked SC	Date August 2018	Figure No. 4
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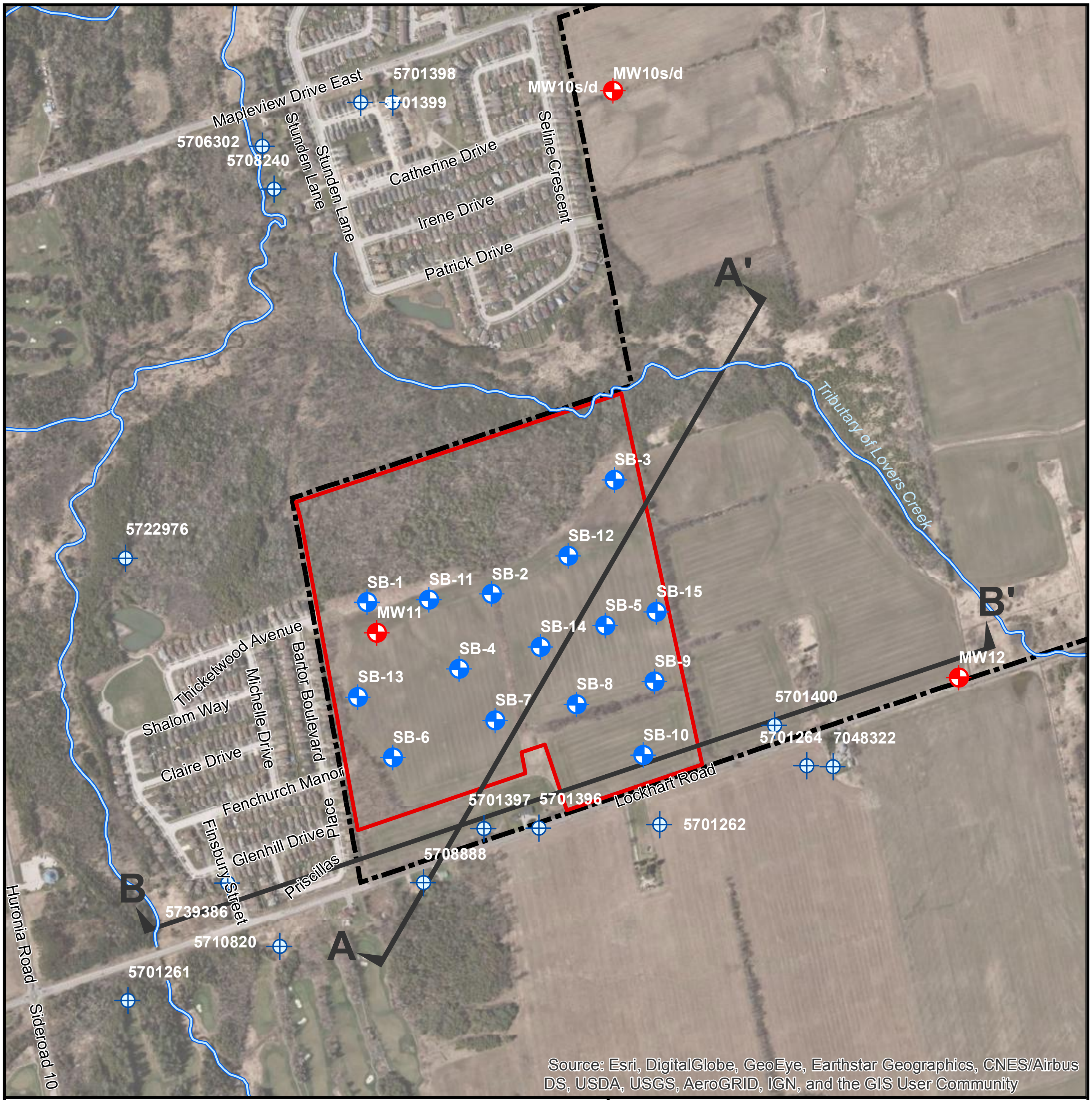
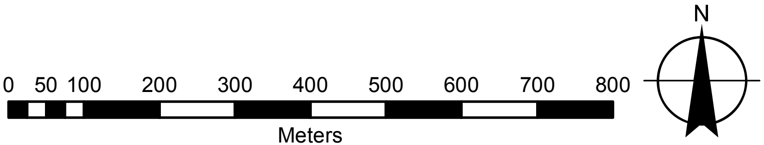


LEGEND

🟥	SUBJECT LANDS
▭	HEWITT'S SECONDARY PLAN AREA
⊕	MONITORING WELL (PETO, 2017)
⊕	MONITORING WELL (RJB, 2014)
⊕	MECP WELL RECORD LOCATION
⌴	CROSS SECTION LOCATION KEY



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BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

WELL PLAN

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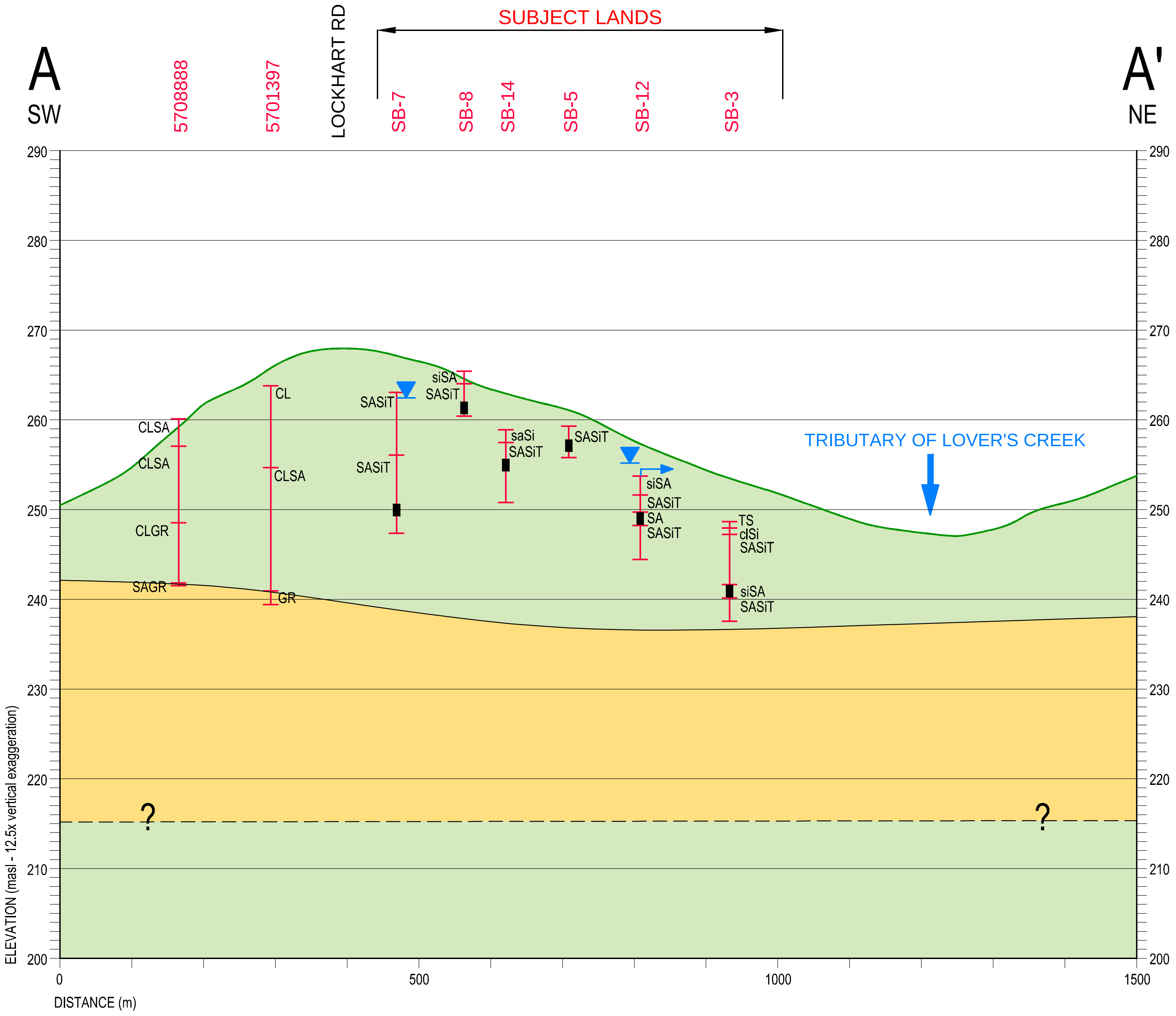

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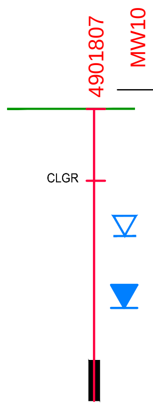

WELL / BOREHOLE ID
MOE WELL RECORD NUMBER
WELL
GEOLOGICAL STRATIGRAPHY
STATIC WATER LEVEL
(REPORTED ON MOE WELL RECORD)
MEASURED WATER LEVEL
(MAY, 2018)
WELL SCREEN

🟩 CLAY / SILT / TILL
🟨 SAND / GRAVEL
– – – INTERPRETED GEOLOGICAL CONTACT
↓ WATERCOURSE CROSSING
→ INDICATES FLOWING WELL

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

Client / Report

BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

*HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN*

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION A-A'

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Scale		Project No.	
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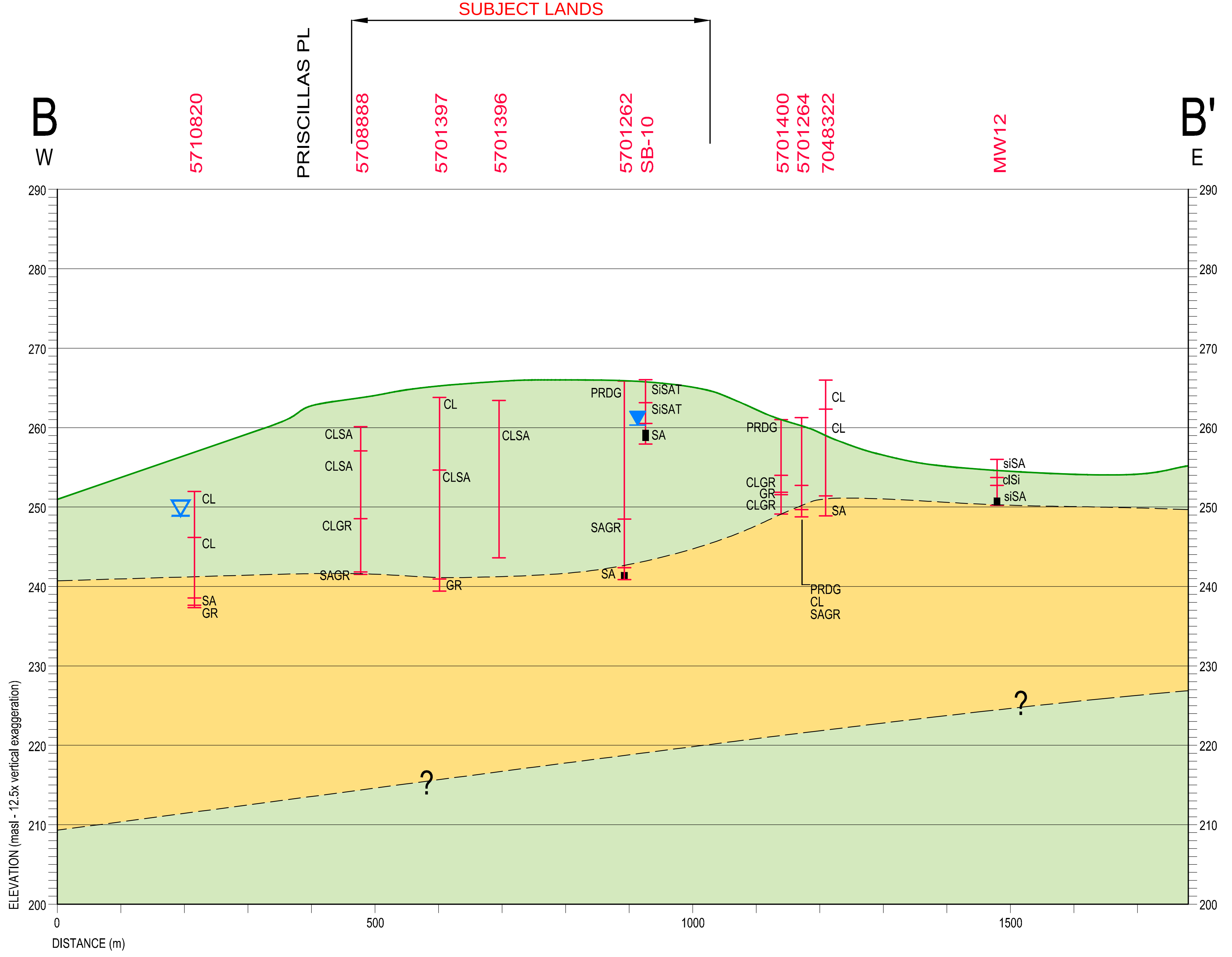

LEGEND

4901807 MW10

WELL / BOREHOLE ID

MOE WELL RECORD NUMBER

WELL

CLGR GEOLOGICAL STRATIGRAPHY

▽ STATIC WATER LEVEL (REPORTED ON MOE WELL RECORD)

▼ MEASURED WATER LEVEL (MAY, 2018)

▮ WELL SCREEN

🟩 CLAY / SILT / TILL

🟨 SAND / GRAVEL

– – – INTERPRETED GEOLOGICAL CONTACT

↓ WATERCOURSE CROSSING

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

Client / Report

BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION B-B'

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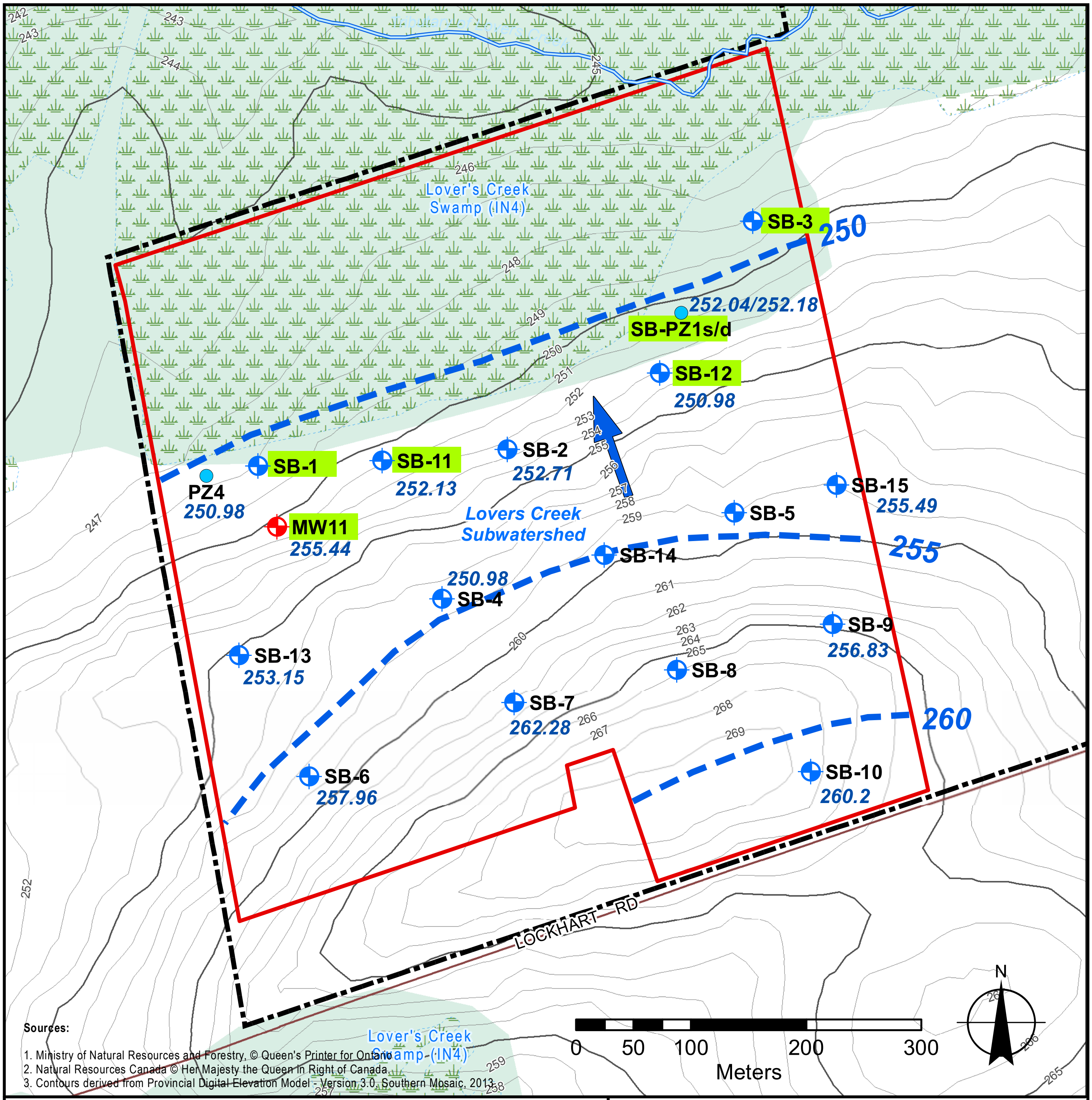

Sources:

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. Contours derived from Provincial Digital Elevation Model - Version 3.0, Southern Mosaic, 2013.

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🟥 SUBJECT LANDS

HEWITT'S SECONDARY AREA PLAN

MONITORING WELL (RJB, 2014)

MONITORING WELL (PETO, 2017)

● DRIVE POINT PIEZOMETER

WATERCOURSE

CONTOUR (5m intervals - masl)

CONTOUR (1m intervals - masl)

ROADWAY

WETLAND

WOODS / FOREST

🟩 INDICATES WATER LEVELS ABOVE GROUND SURFACE

INTERPRETED GROUNDWATER CONTOUR (masl)

255.49 MEASURED WATER LEVEL (masl - May 2018)

→ INTERPRETED GROUNDWATER FLOW DIRECTION

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Client / Report

BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

INTERPRETED GROUNDWATER FLOW

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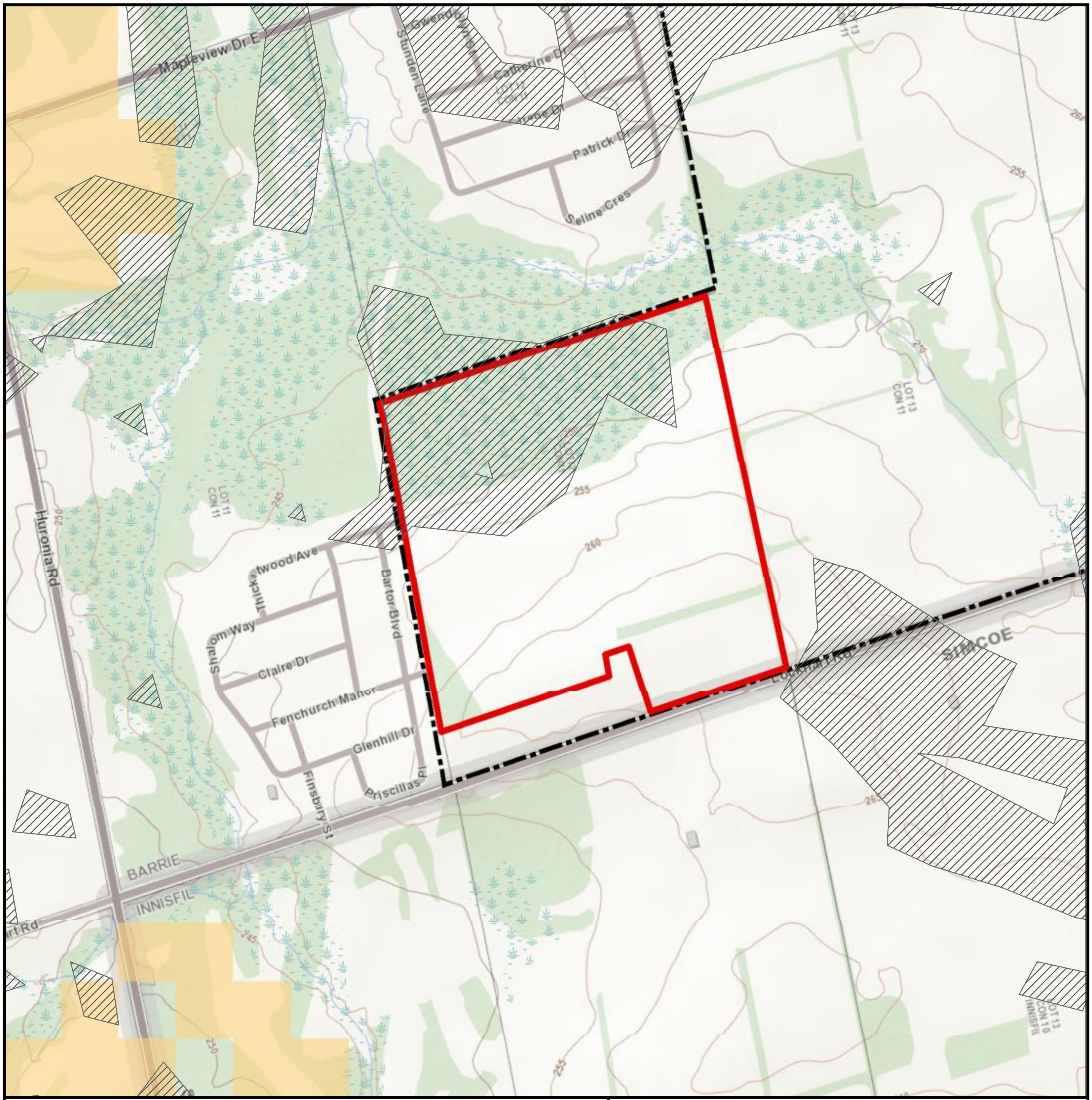


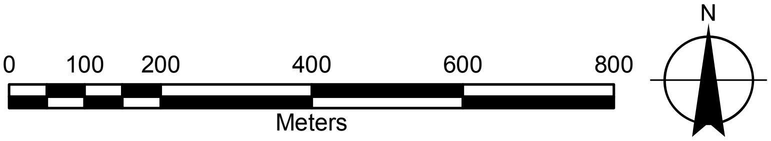
LEGEND

▭ SUBJECT LANDS

▭ HEWITT'S SECONDARY PLAN AREA

▨ ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (ESGRA, LSRCA)

🟧 SIGNIFICANT GROUNDWATER RECHARGE AREAS (SGRA, LSRCA)



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BARRIE LOCKHART ROAD LP
BARRIE, ONTARIO

HYDROGEOLOGICAL STUDY
IN SUPPORT OF DRAFT PLAN

Figure Title:

RECHARGE AREAS

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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File Path: Nigel/Shared Work Areas/041514 Lockhart Road LPA:\041514 Lockhart Rd LP\041514 Recharge Areas.mxd Print Date: 2018/08/23 Time: 12:28 PM

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Appendix A

MECP Water Well Records

Water Well Records

Thursday, March 01, 2018

10:51:45 AM

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 10 011	17 607060 4909238 W	1957/06 1637	4	FR 0111	34/38/6/2:0	DO	0139 6	5701261 ()	CLAY STNS 0047 STNS 0068 GRVL 0145
INNISFIL TOWNSHIP CON 10 012	17 607985 4909544 W	1961/09 2514	6	FR 0080	43/55/25/2:30	ST DO	0079 3	5701262 ()	PRDG 0057 MSND GRVL CLAY 0077 CSND 0082
INNISFIL TOWNSHIP CON 10 012	17 607574 4909443 W	1969/12 3203	5	FR 0060	24/45/2/2:0	DO		5708888 ()	BLCK LOAM 0002 BRWN CLAY MSND 0010 BRWN CLAY MSND STNS 0038 GREY CLAY GRVL 0060 GREY MSND GRVL 0061
INNISFIL TOWNSHIP CON 10 013	17 608286 4909644 W	2007/08 3413	6		15/42/10/2:	PS		7048322 (Z63967) A058559	BRWN CLAY 0012 GREY CLAY 0048 GREY SAND 0056
INNISFIL TOWNSHIP CON 10 013	17 608240 4909646 W	1960/11 2514	6	FR 0041	18/40/2/2:0	DO		5701264 ()	PRDG 0028 BRWN CLAY 0038 MSND GRVL 0041
INNISFIL TOWNSHIP CON 11 011	17 607234 4909442 W	2004/12 2513						5739386 (Z14909) A014862 A	
INNISFIL TOWNSHIP CON 11 011	17 607056 4910007 L	1987/11 2514	6	FR 0119	50/75/15/1:30	DO	0122 3	5722976 (NA)	BRWN CLAY 0034 GREY CLAY GVLY 0119 YLLW SAND 0125
INNISFIL TOWNSHIP CON 11 012	17 607294 4910723 W	1969/06 4608	30	FR 0008	8/13//1:0	DO		5706302 ()	BRWN CLAY STNS 0005 GREY GRVL 0010 GREY GRVL STNS 0015
INNISFIL TOWNSHIP CON 11 012	17 607775 4909538 W	1959/12 4102	30	FR 0065	20//1/:	ST DO		5701396 ()	BLUE CLAY MSND 0065
INNISFIL TOWNSHIP CON 11 012	17 607679 4909537 W	1964/09 3109	30	FR 0075	57//2/:	ST DO		5701397 ()	LOAM 0002 BLUE CLAY 0030 CLAY MSND STNS 0075 GRVL 0080
INNISFIL TOWNSHIP CON 11 012	17 607521 4910799 W	1966/09 3203	5	FR 0078	30/68/2/2:0	DO		5701398 ()	LOAM 0001 BRWN CLAY 0019 BRWN CLAY STNS 0030 GRVL CLAY MSND 0078 GRVL MSND 0079 GRVL MSND CLAY 0085
INNISFIL TOWNSHIP CON 11 012	17 607465 4910799 W	1966/12 3109	30	FR 0064	32//2/:	DO		5701399 ()	LOAM 0002 BRWN CLAY 0027 BLUE CLAY STNS 0062 GRVL 0070
INNISFIL TOWNSHIP CON 11 012	17 607314 4910648 W	1971/08 3203	6	FR 0048	6/45/4/2:30	DO	0048 4	5708240 ()	BRWN CLAY GRVL 0013 GREY CLAY STNS 0028 GREY CLAY SAND 0048 SAND 0052
INNISFIL TOWNSHIP CON 11 013	17 608514 4909816 W	2014/03 6809						7239311 (C25733) A152308 P	
INNISFIL TOWNSHIP CON 11 013	17 608220 4910394 L	1989/09 3030	36	UK 0006	6///:	DO		5725687 (61061)	BRWN LOAM 0001 BRWN SAND 0006 BRWN SAND 0023
INNISFIL TOWNSHIP CON 11 013	17 608184 4909716 W	1964/11 2514	6	FR 0030	18/30/4/2:0	ST DO		5701400 ()	PRDG 0023 BLUE CLAY GRVL BLDR 0030 GRVL 0031 BLUE CLAY GRVL BLDR 0039

TOWNSHIP CON LOT UTM DATE CNTR CASING DIA WATER PUMP TEST WELL USE SCREEN WELL FORMATION

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

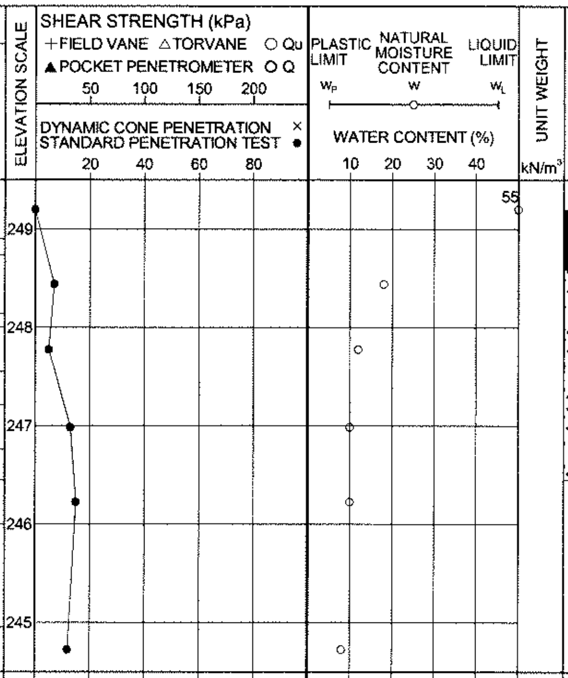
Peto MacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 1

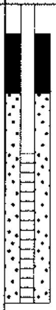
1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 14, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH / ELEV (metres)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES
	SURFACE ELEVATION 249.50			
0.14 249.36	TOPSOIL: Brown, silty sand, trace gravel, frozen	1	SS	0
	CLAYEY SILT: Very soft to firm, brown, clayey silt, trace sand, frozen	2	SS	7
1.4 248.1	SAND/SILT TILL: Loose to compact, brown, sandy silt/silty sand, trace gravel, cobbles and boulders, very moist to moist	3	SS	5
		4	SS	13
		5	SS	15
		6	SS	12
5.0 244.5	BOREHOLE TERMINATED AT 5.0 m			



GROUND WATER OBSERVATIONS AND REMARKS



Stick-up cover
Concrete
Bentonite seal
19 mm slotted pipe
Filter sand
First water strike at 2.7 m

Upon completion of augering
No water
No cave
Water Level Readings:

Date	Depth	Elev.
2017-03-28	+1.0	250.5

(Water above existing grade)

Depth scale (metres): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0

NOTES

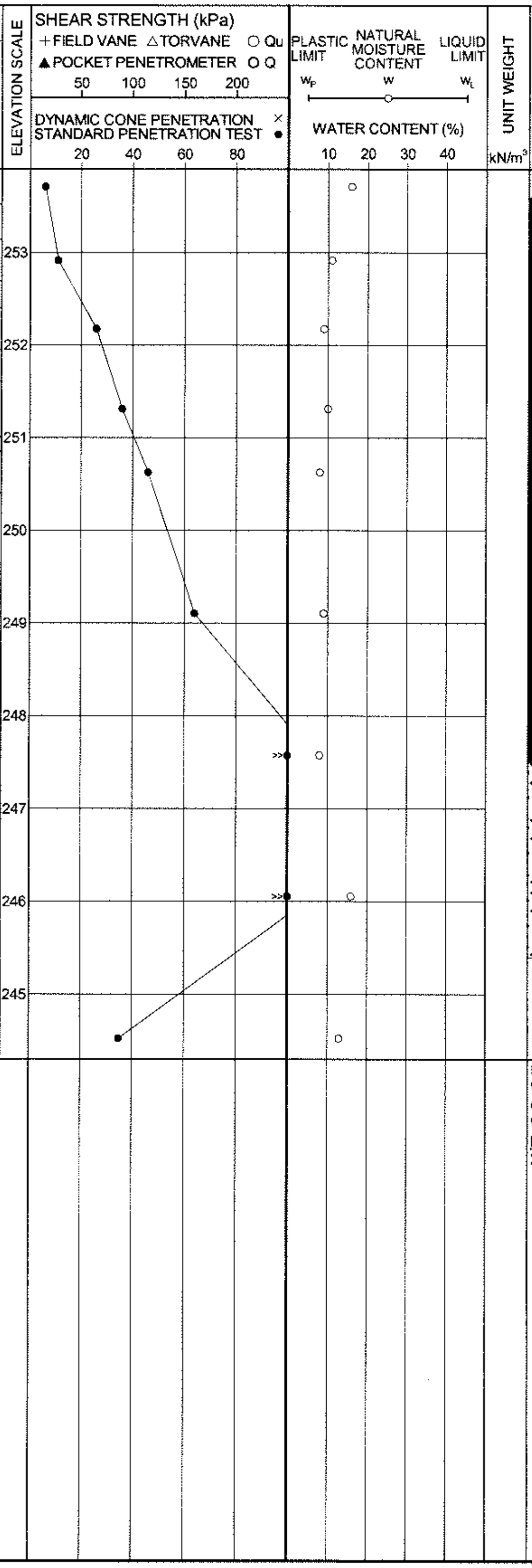
LOG OF BOREHOLE NO. 2

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 21, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH / ELEV (metres)	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES
	SURFACE ELEVATION 253.90			
0.0	TOPSOIL: Dark brown, silt, roots, moist	1	SS	6
0.70 253.20	SAND/SILT TILL: Compact to very dense, brown to grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist; with wet seams/layers	2	SS	11
		3	SS	26
		4	SS	36
		5	SS	46
		6	SS	64
		7	SS	91/280 mm
7.0 246.9	SAND: Very dense to dense, brown, sand, trace silt to silty sand, trace gravel, wet	8	SS	93/280 mm
		9	SS	35
9.6 244.3	BOREHOLE TERMINATED AT 9.6 m			

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0



GROUND WATER OBSERVATIONS AND REMARKS

GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Stick-up cover
Concrete

First water strike at 2.1 m

Bentonite seal

19 mm slotted pipe
Filter sand

Upon completion of augering
Water at 2.4 m
Cave at 8.5 m
Water Level Readings:

Date	Depth	Elev.
2017-03-28	0.8	253.1

NOTES

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 3

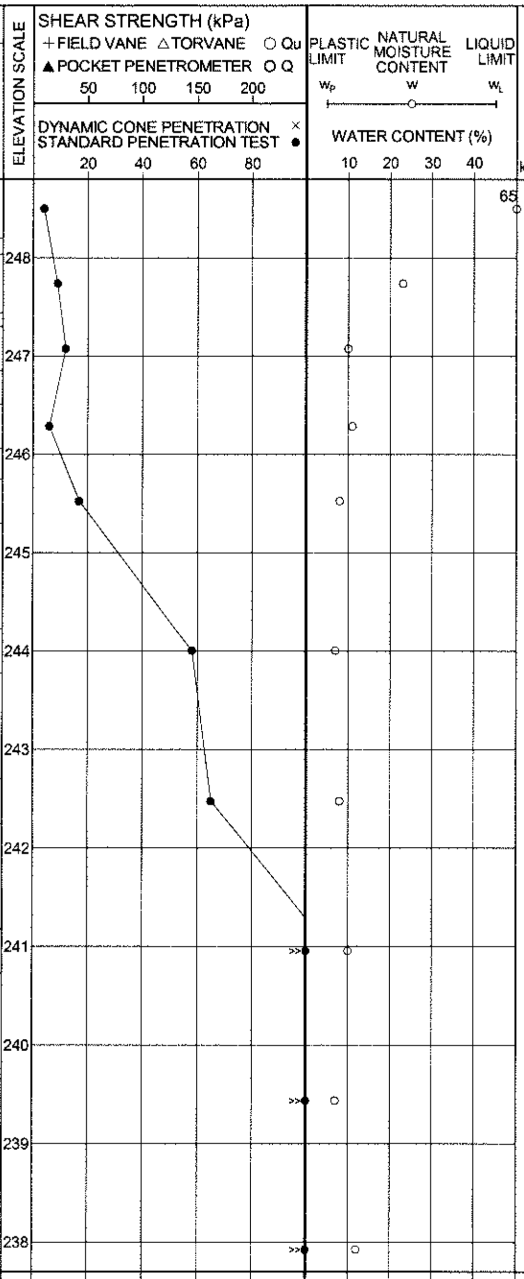
1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 16, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

SURFACE ELEVATION 248.80

DEPTH / ELEV (metres)	DESCRIPTION
0.0	TOPSOIL: Dark brown, silt some sand, roots, frozen
0.70 / 248.10	CLAYEY SILT: Stiff, brown, clayey silt, trace sand, frozen
1.4 / 247.4	SAND/SILT TILL: Loose to compact, grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist to very moist
7.0 / 241.8	SILTY SAND: Very dense, grey, silty sand, trace gravel, wet
8.5 / 240.3	SAND/SILT TILL: Very dense, grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist to very moist; with wet seams/layers
11.1 / 237.7	BOREHOLE TERMINATED AT 11.1 m

NUMBER	TYPE	"N" VALUES
1	SS	4
2	SS	9
3	SS	12
4	SS	6
5	SS	17
6	SS	58
7	SS	65
8	SS	83/280 mm
9	SS	83/280 mm
10	SS	50/150 mm



UNIT WEIGHT kN/m³

GROUND WATER OBSERVATIONS AND REMARKS

GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
8	67	25	

Stick-up cover
Concrete

First water strike at 3.1 m
Bentonite seal

50 mm slotted pipe
Filter sand

Upon completion of augering
Water at 1.4 m
Cave at 2.9 m
Water Level Readings:

Date	Depth	Elev.
2017-03-28	+1.0	249.8

(Water above existing grade)

NOTES

LOG OF BOREHOLE NO. 4

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 14, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

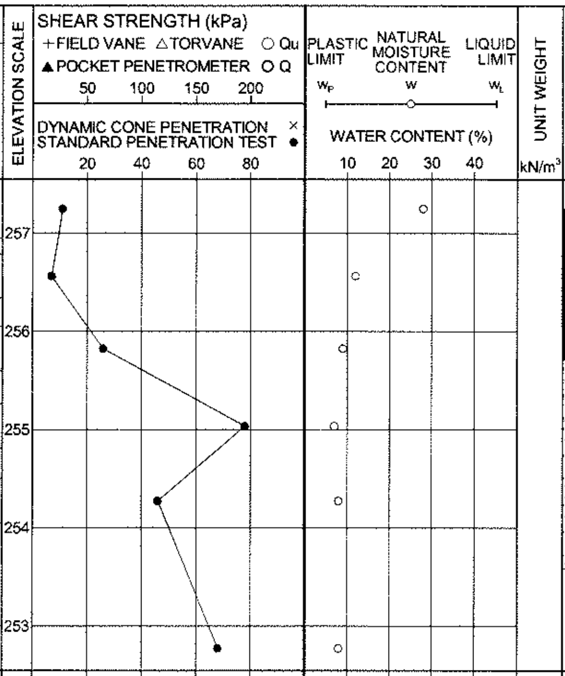
SOIL PROFILE

DEPTH ELEV (metres)	DESCRIPTION
	SURFACE ELEVATION 257.55
0.0	TOPSOIL: Dark brown, sandy silt, trace gravel, frozen
0.70 256.85	SAND/SILT TILL: Loose, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, frozen
1.4 256.2	SILTY SAND: Compact, brown, silty sand, trace gravel, very moist
2.1 255.5	SAND/SILT TILL: Dense to very dense, brown, silty sand to sandy silt, trace gravel, cobbles and boulders, moist; with wet seams/layers
5.0 252.6	BOREHOLE TERMINATED AT 5.0 m

STRAT PLOT

SAMPLES

NUMBER	TYPE	"N" VALUES
1	GS	11
2	SS	7
3	SS	26
4	SS	78
5	SS	46
6	SS	68



GROUND WATER OBSERVATIONS AND REMARKS

First water strike at 4.3 m

Upon completion of augering
No water
No cave
Water Level Readings:

Date	Depth	Elev.
2017-03-28	1.7	255.9

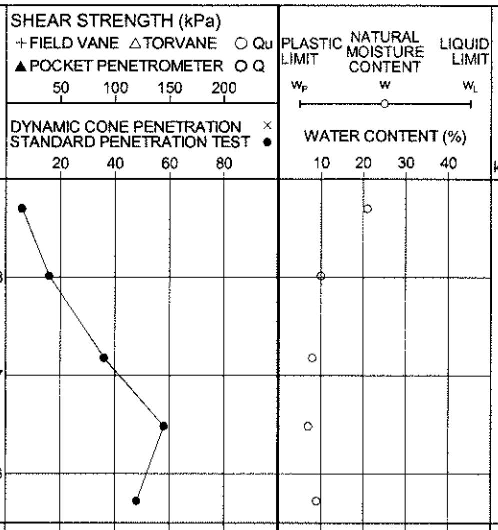
NOTES

LOG OF BOREHOLE NO. 5

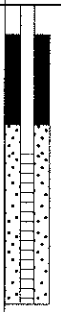
1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 16, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT kN/m³	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	SURFACE ELEVATION 259.00						
	TOPSOIL: Brown, silt, trace sand, roots, frozen	1	SS	6			
0.70 258.30	SAND/SILT TILL: Compact to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, moist; with wet seams/layers	2	SS	16	258		
		3	SS	36	257		
		4	SS	58			
		5	SS	48	256		
3.5 255.5	BOREHOLE TERMINATED AT 3.5 m						



GROUND WATER OBSERVATIONS AND REMARKS



Upon completion of augering
No water
No cave
Water Level Readings:

Date	Depth	Elev.
2017-03-28	2.9	256.1

NOTES

LOG OF BOREHOLE NO. 6

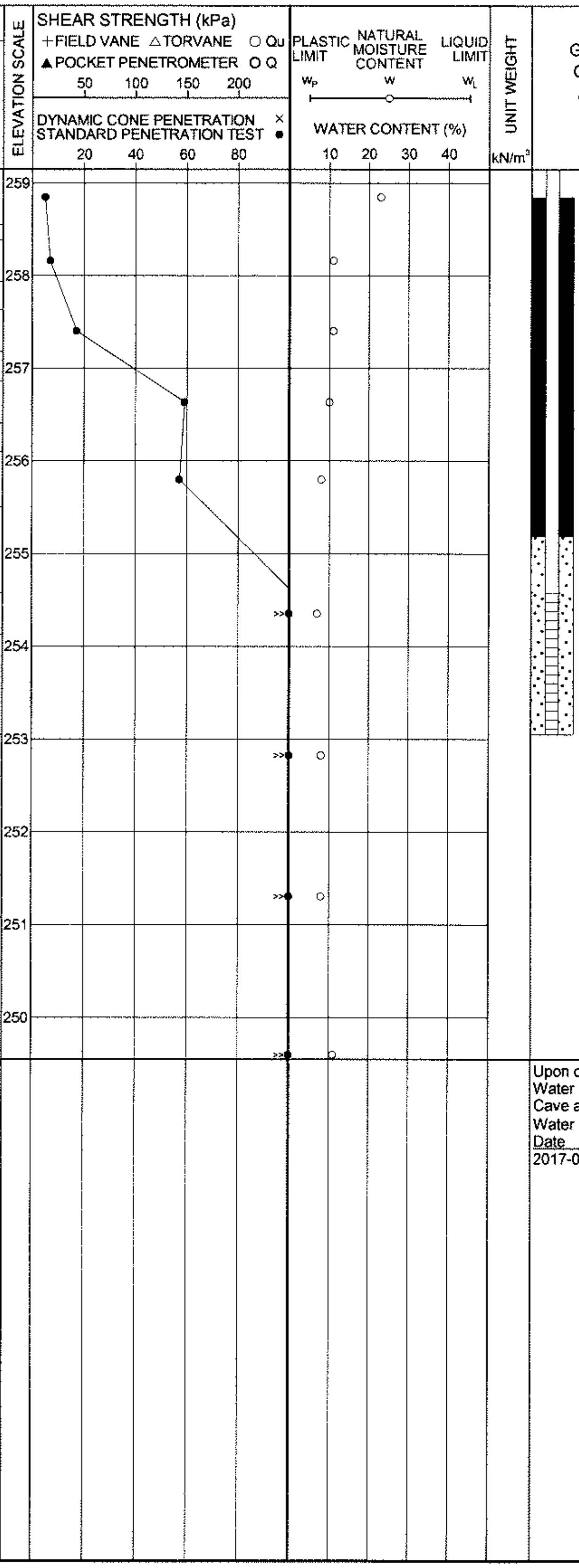
PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 14, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

SOIL PROFILE

DEPTH / ELEV (metres)	DESCRIPTION
	SURFACE ELEVATION 259.15
0.0	TOPSOIL: Brown, sandy silt, trace gravel, frozen
0.70 258.45	SAND/SILT TILL: Loose to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, very moist to moist; with wet seams/layers
9.6 249.6	BOREHOLE TERMINATED AT 9.6 m

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	5
2	SS	7
3	SS	17
4	SS	59
5	SS	57
6	SS	72/290 mm
7	SS	81/270 mm
8	SS	50/140 mm
9	SS	50/100 mm



GROUND WATER OBSERVATIONS AND REMARKS

GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Stick-up cover
Concrete

First water strike at 0.9 m

Bentonite seal

6 56 38

19 mm slotted pipe
Filter sand

Upon completion of augering
Water at 1.8 m
Cave at 2.1 m
Water Level Readings:

Date	Depth	Elev.
2017-03-28	2.8	256.4

NOTES

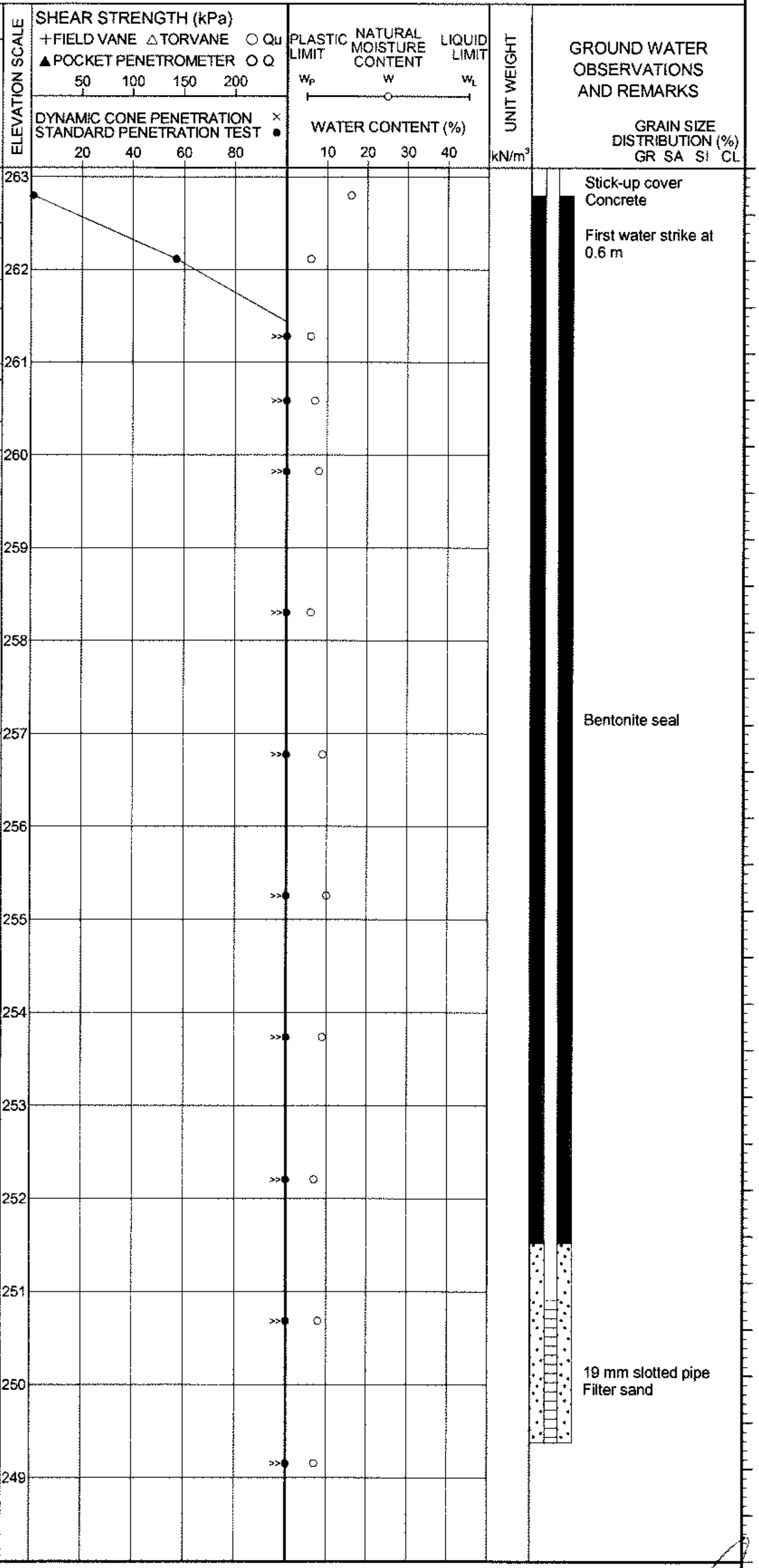
9

LOG OF BOREHOLE NO. 7

1 of 2

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING DATE March 20, 2017
BORING METHOD Continuous Flight Solid Stem Augers
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

SOIL PROFILE		SAMPLES		
DEPTH / ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES
	SURFACE ELEVATION 263.10			
0.0	TOPSOIL: Dark brown, silt, trace sand, roots, moist	1	SS	1
0.70 262.40	SAND/SILT TILL: Very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, moist to very moist	2	SS	57
		3	SS	85/280 mm
		4	SS	86/250 mm
		5	SS	76/250 mm
		6	SS	73/250 mm
		7	SS	50/100 mm
7.0 256.1	Becoming grey, with wet seams/layers			
		8	SS	50/80 mm
		9	SS	50/130 mm
		10	SS	50/130 mm
		11	SS	85/280 mm
		12	SS	72/250 mm
15.0	CONTINUED			



Stick-up cover
Concrete

First water strike at 0.6 m

Bentonite seal

19 mm slotted pipe
Filter sand

NOTES

LOG OF BOREHOLE NO. 7

2 of 2

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 20, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

SOIL PROFILE		SAMPLES				ELEVATION SCALE	SHEAR STRENGTH (kPa) +FIELD VANE △TORVANE ○ Qu ▲POCKET PENETROMETER ○ Q 50 100 150 200 / DYNAMIC CONE PENETRATION × STANDARD PENETRATION TEST ● 20 40 60 80	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30 40	UNIT WEIGHT	GROUND WATER OBSERVATIONS AND REMARKS / GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
DEPTH / ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				kN/m³	
15.0	CONTINUED FROM PREVIOUS PAGE									
	SAND/SILT TILL: Very dense, grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist to very moist; with wet seams/layers	▨	13	SS	50/130 mm	248	>>●	○		
15.7 247.4	BOREHOLE TERMINATED AT 15.7 m									Upon completion of augering Water at 3.0 No cave Water Level Readings: Date Depth Elev. 2017-03-28 4.8 258.3

15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0

NOTES

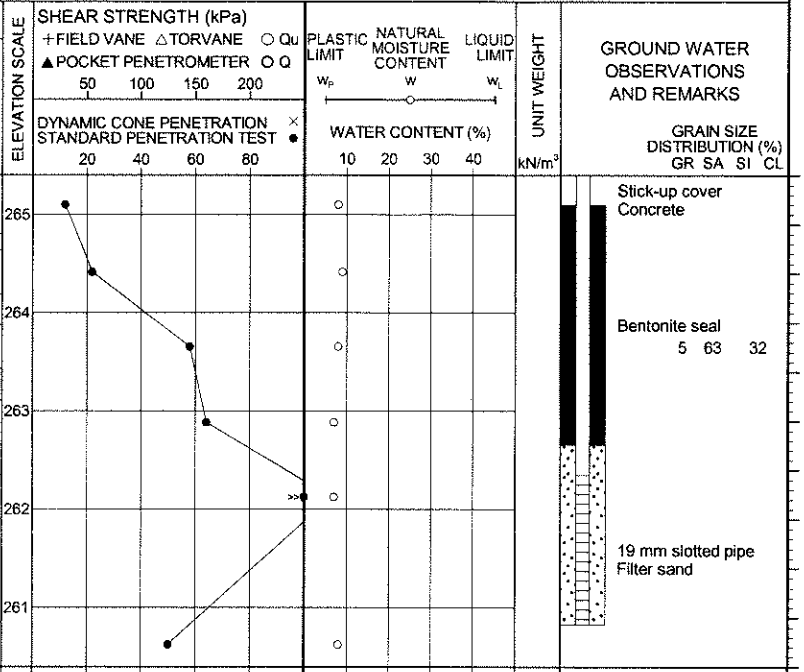
PML Peto MacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 8

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 16, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH / ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES
0.0	SURFACE ELEVATION 265.40				
	TOPSOIL: Dark brown, sand, trace silt, roots, frozen		1	SS	12
0.70 264.70	SILTY SAND: Compact, brown, silty sand, moist		2	SS	22
1.4 264.0	SAND/SILT TILL: Very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, moist		3	SS	58
			4	SS	64
			5	SS	87/280 mm
			6	SS	50
5.0 260.4	BOREHOLE TERMINATED AT 5.0 m				



GRAIN SIZE DISTRIBUTION (%) at sample 3: GR 5, SA 63, SI+CL 32

Upon completion of augering
No water
No cave
Water Level Readings:

Date	Depth	Elev.
2017-03-28	Dry	---

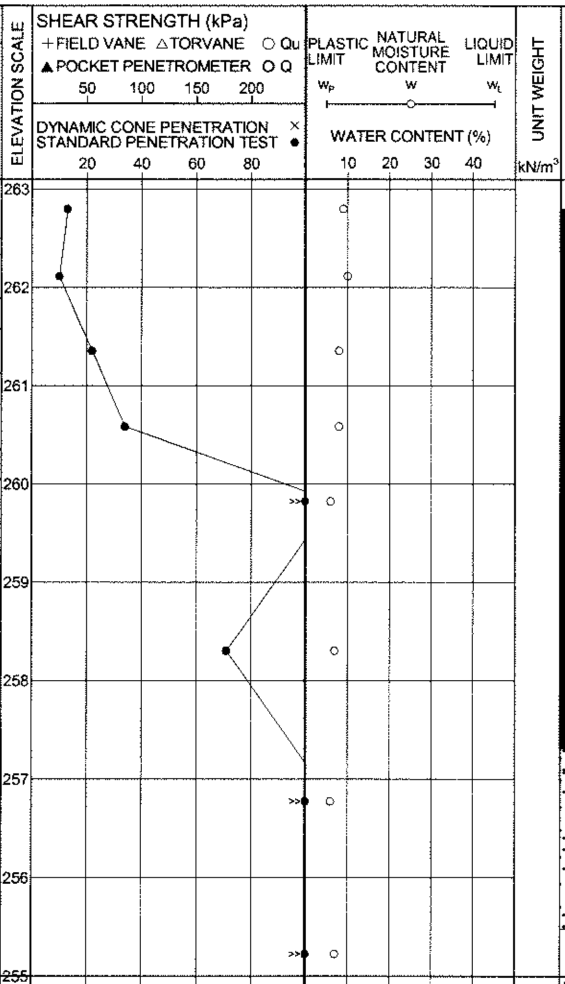
NOTES

LOG OF BOREHOLE NO. 9

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
PML REF. 17BF005
LOCATION Barrie, Ontario
BORING DATE March 17, 2017
ENGINEER GW
BORING METHOD Continuous Flight Solid Stem Augers
TECHNICIAN RM

SOIL PROFILE			SAMPLES		
DEPTH ELEV (metres)	DESCRIPTION SURFACE ELEVATION 263.10	STRAT PLOT	NUMBER	TYPE	"N" VALUES
	TOPSOIL: Brown, sand, trace to some silt, frozen		1	SS	13
0.70 262.40	SANDY SILT: Compact, brown to grey, sandy silt, moist		2	SS	10
1.4 261.7	SAND/SILT TILL: Compact to very dense, brown to grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist; with with seams/layers		3	SS	22
			4	SS	34
			5	SS	65/250 mm
			6	SS	71
			7	SS	77/250 mm
			8	SS	84/200 mm
8.1 255.0	BOREHOLE TERMINATED AT 8.1 m				



GROUND WATER OBSERVATIONS AND REMARKS

GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Upon completion of augering
No water
No cave
Water Level Readings:

Date	Depth	Elev.
2017-03-28	5.2	257.9

NOTES

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS

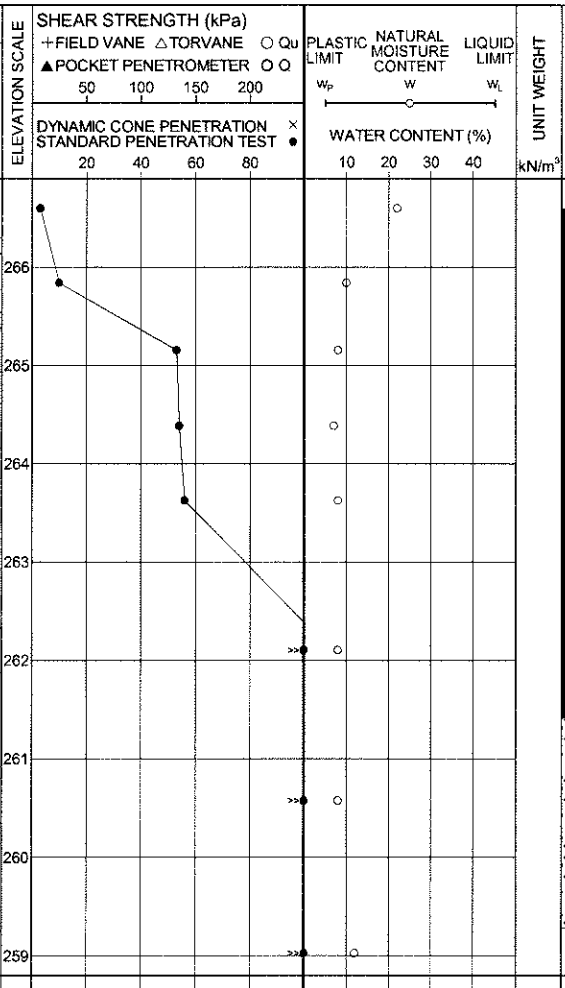
LOG OF BOREHOLE NO. 10

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 21, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH / ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER OBSERVATIONS AND REMARKS
0.0	SURFACE ELEVATION 266.90				
	TOPSOIL: Dark brown, silt, trace sand, moist	1	SS	3	Stick-up cover Concrete
0.70 266.20	SILT/SAND TILL: Compact to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, moist	2	SS	10	
		3	SS	53	
		4	SS	54	
2.9 264.0	Becoming grey	5	SS	56	Bentonite seal
		6	SS	70/280 mm	
5.5 261.4	SAND: Very dense, brown, sand, some silt, wet	7	SS	72/250 mm	First water strike at 6.1 m 50 mm slotted pipe Filter sand
		8	SS	50/130 mm	
8.1 258.8	BOREHOLE TERMINATED AT 8.1 m				Upon completion of augering Water at 6.7 m Cave at 7.0 m Water Level Readings:

Date	Depth	Elev.
2017-03-28	5.4	261.5



GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

NOTES

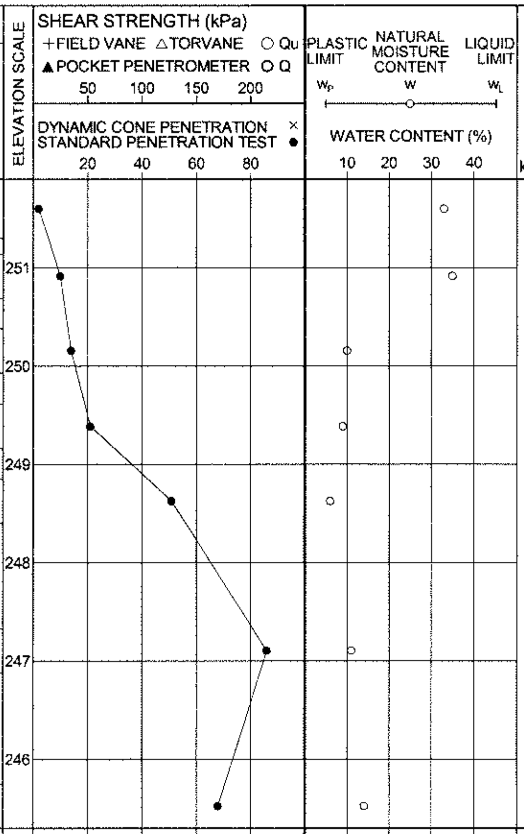
Peto MacCallum Ltd.
CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 11

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 17, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER OBSERVATIONS AND REMARKS	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SURFACE ELEVATION 251.90					
0.0	TOPSOIL: Dark brown, silt, trace sand, roots, frozen	1	SS	2	Stick-up cover Concrete	
0.70 251.20	SILTY SAND: Compact, brown, silty sand, trace organics, wet	2	SS	10		
1.4 250.5	SAND/SILT TILL: Compact to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, moist	3	SS	14	Bentonite seal First water strike at 1.5 m	
		4	SS	21		
		5	SS	51		2 52 46
4.0 247.9	Becoming wet				19 mm slotted pipe Filter sand	
		6	SS	86		
5.5 246.4	SAND: Very dense, grey, sand, some silt, trace gravel, wet	7	SS	68		
6.6 245.3	BOREHOLE TERMINATED AT 6.6 m				Upon completion of augering Water at 0.8 Cave at 0.9 m Water Level Readings: Date Depth Elev. 2017-03-28 0.4 251.5	



NOTES

LOG OF BOREHOLE NO. 12

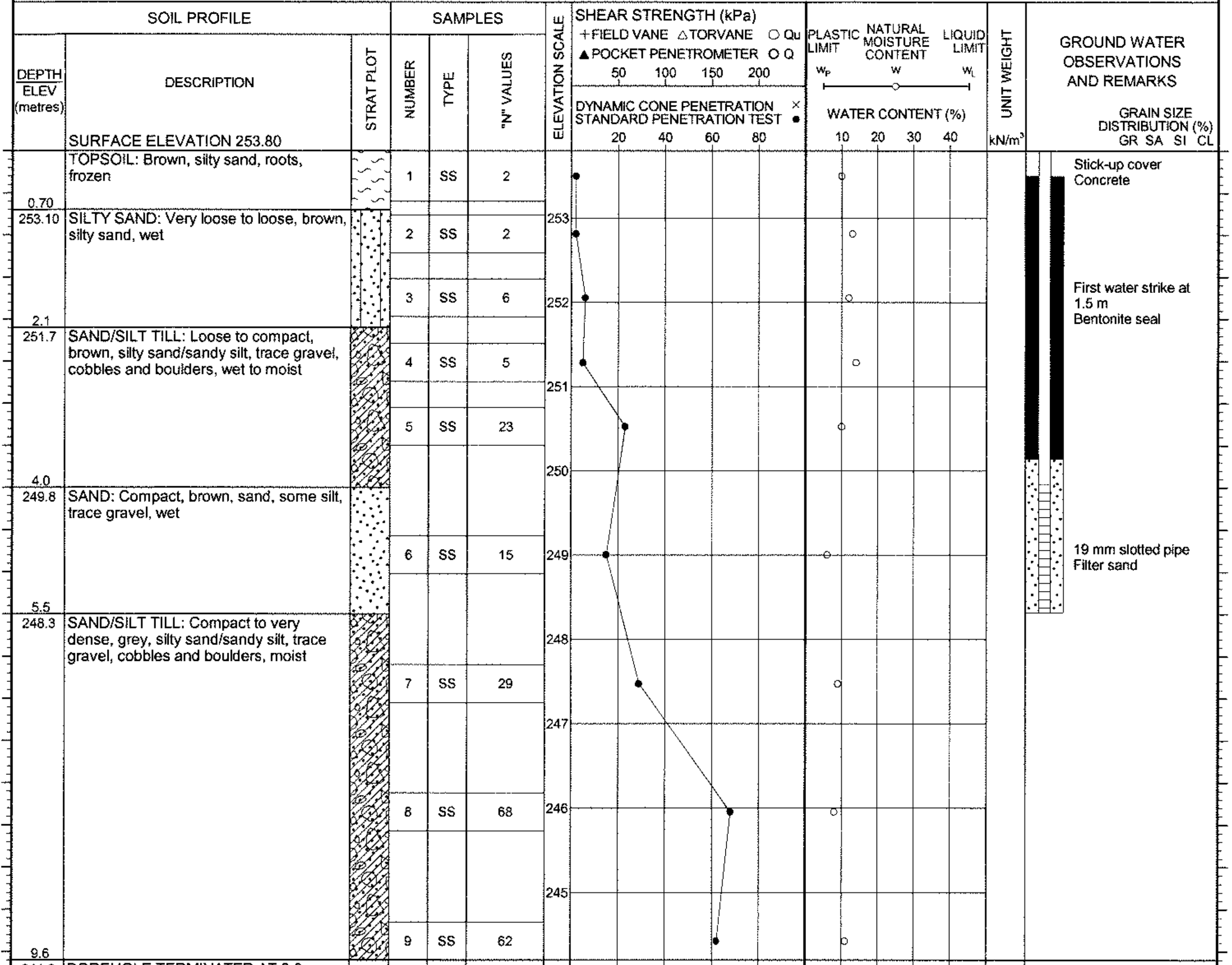
1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
PML REF. 17BF005
LOCATION Barrie, Ontario
BORING DATE March 17, 2017
ENGINEER GW
BORING METHOD Continuous Flight Solid Stem Augers
TECHNICIAN RM

SURFACE ELEVATION 253.80

DEPTH ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER OBSERVATIONS AND REMARKS
0.0	TOPSOIL: Brown, silty sand, roots, frozen	1	SS	2	Stick-up cover Concrete
0.70 253.10	SILTY SAND: Very loose to loose, brown, silty sand, wet	2	SS	2	
		3	SS	6	First water strike at 1.5 m Bentonite seal
2.1 251.7	SAND/SILT TILL: Loose to compact, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, wet to moist	4	SS	5	
		5	SS	23	
4.0 249.8	SAND: Compact, brown, sand, some silt, trace gravel, wet	6	SS	15	19 mm slotted pipe Filter sand
5.5 248.3	SAND/SILT TILL: Compact to very dense, grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist	7	SS	29	
		8	SS	68	
		9	SS	62	
9.6 244.2	BOREHOLE TERMINATED AT 9.6 m				Upon completion of augering Water at 1.5 m Cave at 6.1 m Water Level Readings:

Date	Depth	Elev.
2017-03-28	0.5	253.3



NOTES

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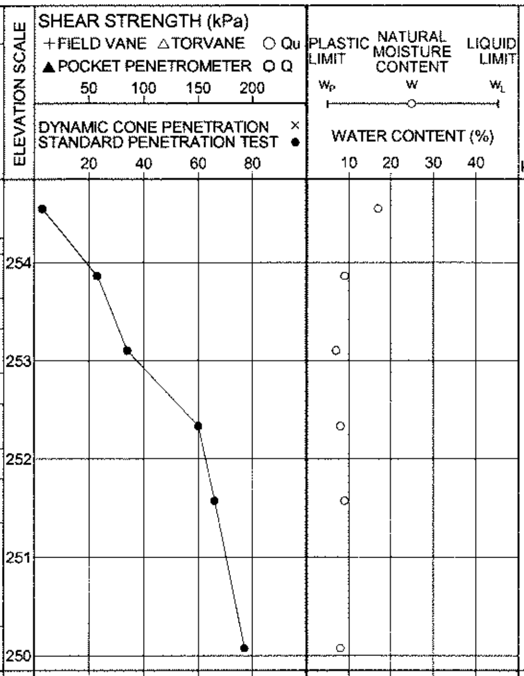
LOG OF BOREHOLE NO. 13

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING METHOD Continuous Flight Solid Stem Augers
BORING DATE March 21, 2017
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

DEPTH / ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER OBSERVATIONS AND REMARKS
	SURFACE ELEVATION 254.85					
0.0	TOPSOIL: Dark brown, silty sand, moist		1	SS	3	Stick-up cover Concrete
0.70 254.15	SAND/SILT TILL: Compact to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, very moist to moist		2	SS	23	Bentonite seal
			3	SS	34	First water strike at 1.5 m
			4	SS	60	
			5	SS	66	19 mm slotted pipe Filter sand
			6	SS	77	
5.0 249.9	BOREHOLE TERMINATED AT 5.0 m					Upon completion of augering Water at 0.9 m Cave at 1.4 m Water Level Readings:

Date	Depth	Elev.
2017-03-28	0.6	254.3



NOTES

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CONSULTING ENGINEERS

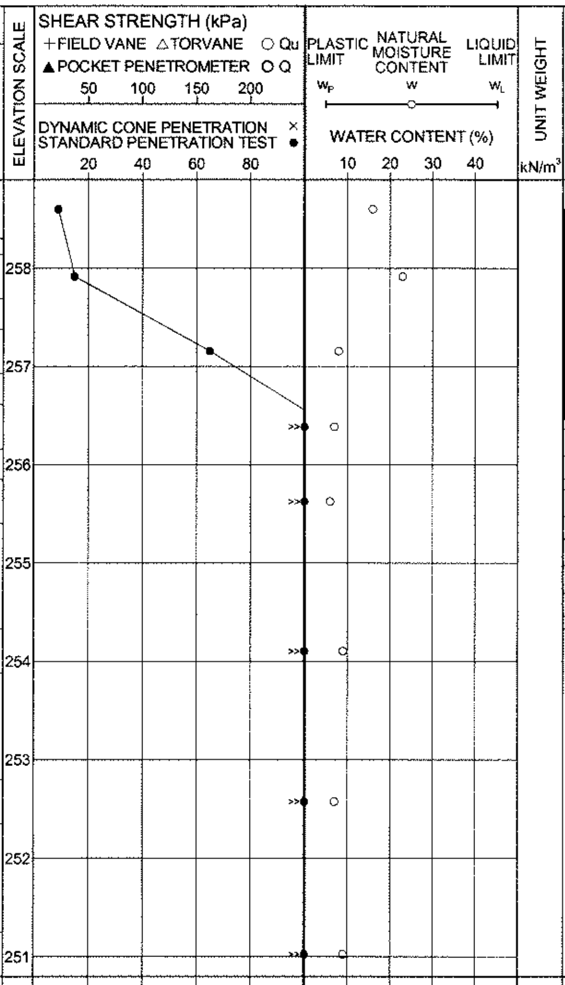
LOG OF BOREHOLE NO. 14

1 of 1

PROJECT Proposed Lockhart Road Residential Subdivision
PML REF. 17BF005
LOCATION Barrie, Ontario
BORING DATE March 21, 2017
ENGINEER GW
BORING METHOD Continuous Flight Solid Stem Augers
TECHNICIAN RM

DEPTH ELEV (metres)	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER OBSERVATIONS AND REMARKS
0.0	SURFACE ELEVATION 258.90				
	TOPSOIL: Dark brown, silt, trace clay, roots, moist	1	SS	9	Stick-up cover Concrete
0.70 258.20	SANDY SILT: Compact, brown, sandy silt, trace organics, wet	2	SS	15	
1.4 257.5	SAND/SILT TILL: Very dense, brown to grey, silty sand/sandy silt, trace gravel, cobbles and boulders, moist; with wet seams/layers	3	SS	65	Bentonite seal
		4	SS	73/250 mm	
		5	SS	90/250 mm	19 mm slotted pipe Filter sand
		6	SS	80/250 mm	
					First water strike at 5.5 m
		7	SS	83/250 mm	
		8	SS	80/250 mm	
8.1 250.8	BOREHOLE TERMINATED AT 8.1 m				Upon completion of augering Water at 5.5 m Cave at 6.1 m Water Level Readings:

Date	Depth	Elev.
2017-03-28	3.4	255.5



NOTES

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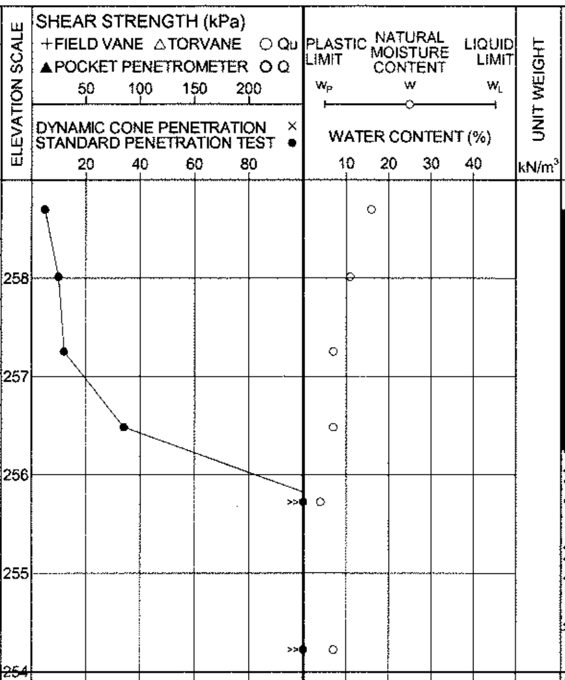
LOG OF BOREHOLE NO. 15

PROJECT Proposed Lockhart Road Residential Subdivision
LOCATION Barrie, Ontario
BORING DATE March 16, 2017
BORING METHOD Continuous Flight Solid Stem Augers
PML REF. 17BF005
ENGINEER GW
TECHNICIAN RM

SOIL PROFILE		SAMPLES			GROUND WATER OBSERVATIONS AND REMARKS
DEPTH ELEV (metres)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	
	SURFACE ELEVATION 259.00				
	TOPSOIL: Dark brown, sand, trace silt, roots and twigs, frozen	1	SS	5	Stick-up cover Concrete
0.70 258.30	SANDY SILT: Compact, brown, sandy silt, moist	2	SS	10	
1.4 257.6	SAND/SILT TILL: Compact to very dense, brown, silty sand/sandy silt, trace gravel, cobbles and boulders, very moist to moist	3	SS	12	Bentonite seal
		4	SS	34	
		5	SS	80/280 mm	19 mm slotted pipe Filter sand
		6	SS	84/280 mm	
5.0 254.0	BOREHOLE TERMINATED AT 5.0 m				Upon completion of augering No water No cave

Water Level Readings:

Date	Depth	Elev.
2017-03-28	Dry	---



GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

NOTES

PML - BH/TP LOG GEO/ENV WITH MWS 17BF005 2017-03-29 BH LOGS.GPJ ON_MOT.GDT 27/04/2017 3:28:56 PM

LOG OF DRILLING OPERATIONS

MW11

BURNSIDE

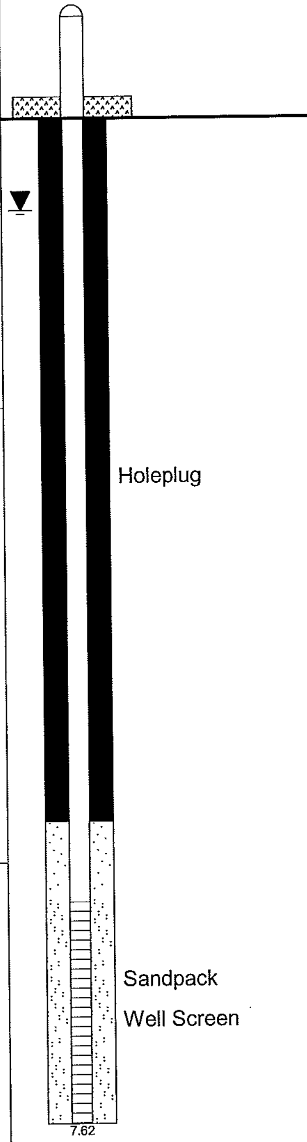
R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Guelph, Ontario N1H 1C4
telephone (519) 823-4995 fax (519) 836-5477

Page 1 of 1

Client: **Hewitt's Creek Landowners Group**	Project Name: **Hewitt's Secondary Plan Area**	Logged by: **C. Dinulescu**
Project No.: **300033110**	Location: **Barrie, ON**	Ground (m amsl): **254.20**
Drilling Co.: **Lantech Drilling**	Date Started: **3/26/2014**	Static Water Level Depth (m):
Drilling Method: **Hollow Stem Auger**	Date Completed: **3/26/2014**	Sand Pack Depth (m) : **5.33-7.62**

Surface Elevation (m): **254.20**

Stratigraphic Description	Depth (m)
TOPSOIL Black clayey silt.	0.20
Clayey SILT to Silty CLAY Light brown, very soft, saturated, some sand, trace gravel (rounded, < 2 cm diameter), iron staining, weakly plastic. More clay with depth. Turns grey at 2.10 m.	2.20
Silty SAND Brown-grey, fine to medium, compact, saturated, uniform, trace gravel (subrounded, <2 cm diameter), trace clay, occasional cobbles and iron staining. With depth, siltier, dense, wet	5.64
Sandy SILT Brown, stiff, wet, trace gravel, trace clay, weakly plastic. Between 5.8 - 6.1 m - hard/noisy drilling suggesting a layer of gravel and cobbles.	8.23



Num.	Type	Int.	N.Val.
	SS	☒	12
1	SS	☒	11
2	SS	☒	8
3	SS	☒	67
4	SS	☒	76/10"
5	SS	☒	84/10"
6	SS	☒	50/4"
7	SS	☒	50/4"
8	SS	☒	50/3"

Prepared By: **C. Dinulescu** Checked By: **D. Smikle** Date Prepared: **7/14/2014**

This borehole log was prepared for hydrogeological and/or environmental purposes and does not necessarily contain information suitable for a geotechnical assessment of the subsurface conditions. Borehole data requires interpretation by R. J. Burnside & Associates Limited personnel before use by others.

LEGEND
▼ Water found @ time of drilling
▽ Static Water Level -

MONITORING WELL DATA
Pipe: **51 mm dia. PVC**
Screen: **51 mm dia. PVC #10 slot**

SAMPLE TYPE
AC ■ Auger Cutting
CS Continuous
RC Rock Core
SS ☒ Split Spoon
AR ▨ Air Rotary
WC Wash Cuttings

BHLOG GUELPH P:\GINTPROJECTS\300 JOBS\300033110 BARRIE\300033110 BARRIE - CARMEN'S.GPJ TEMPLATE.GDT 11/10/15

BURNSIDE

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Appendix C

Hydraulic Conductivity Data

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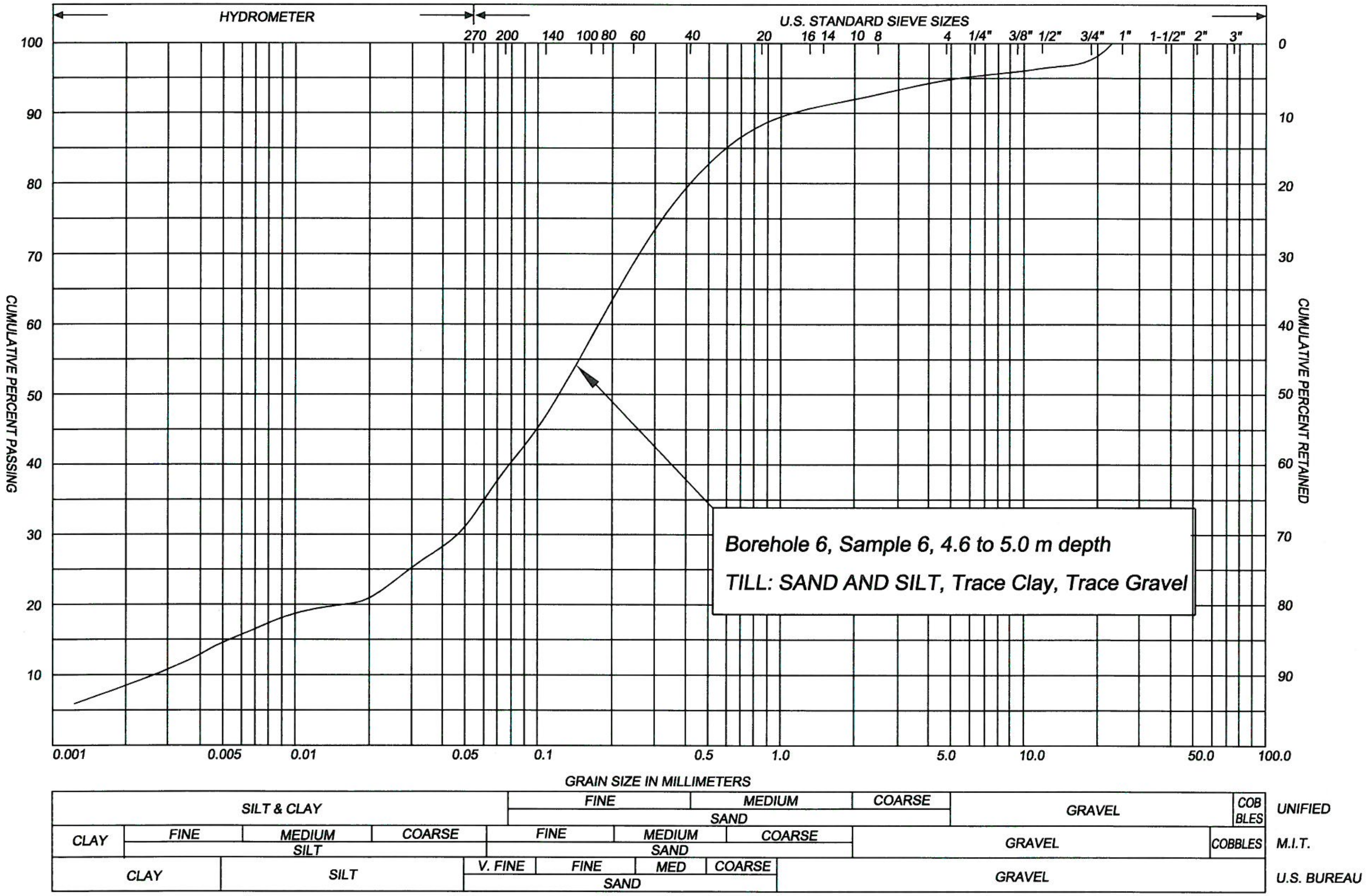
PARTICLE SIZE DISTRIBUTION CHART

PML Ref.: 17BF005
Figure No.: 1



Borehole 6, Sample 6, 4.6 to 5.0 m depth

TILL: SAND AND SILT, Trace Clay, Trace Gravel

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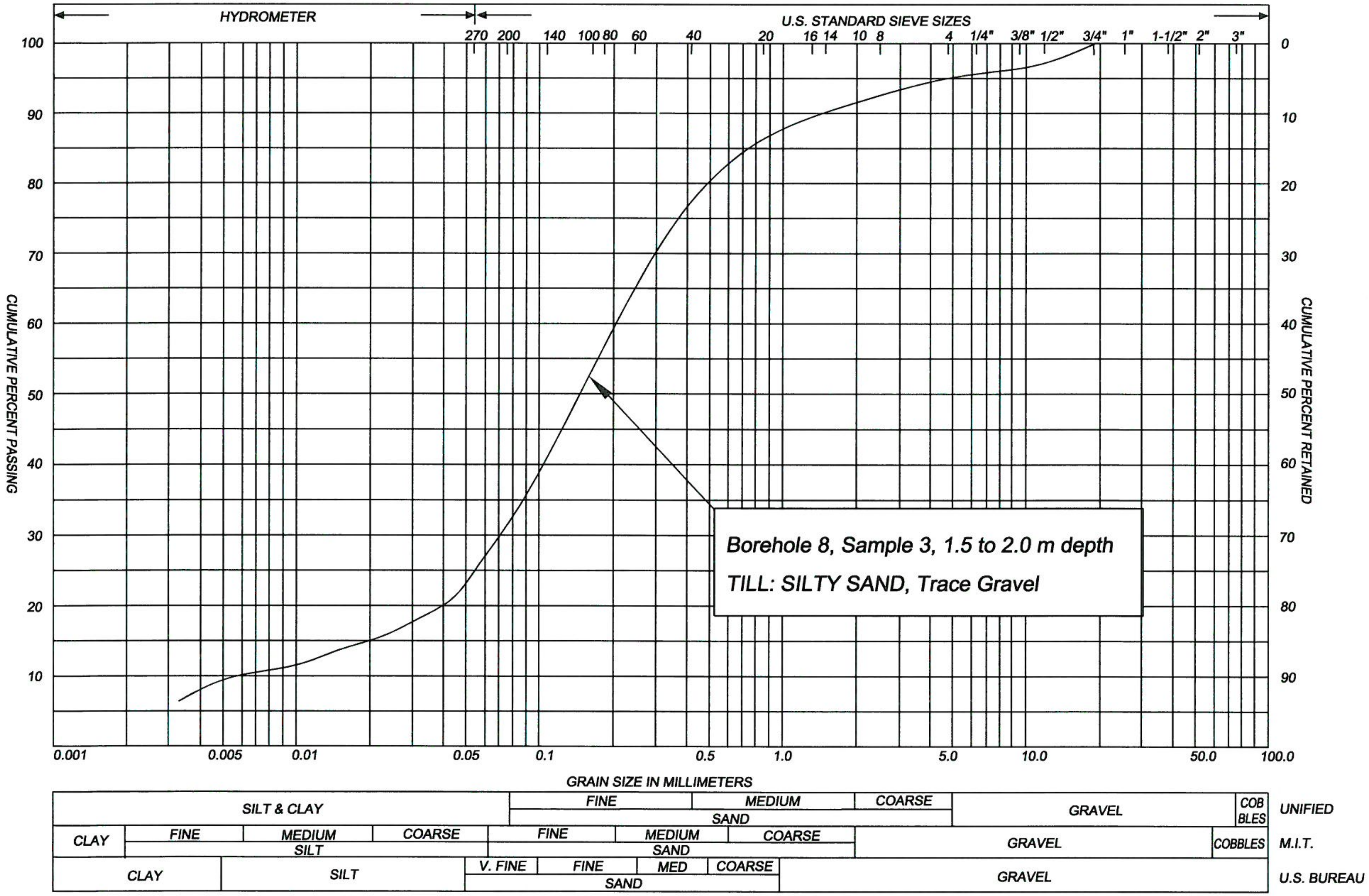
PARTICLE SIZE DISTRIBUTION CHART

PML Ref.: 17BF005
Figure No.: 2



Borehole 8, Sample 3, 1.5 to 2.0 m depth

TILL: SILTY SAND, Trace Gravel

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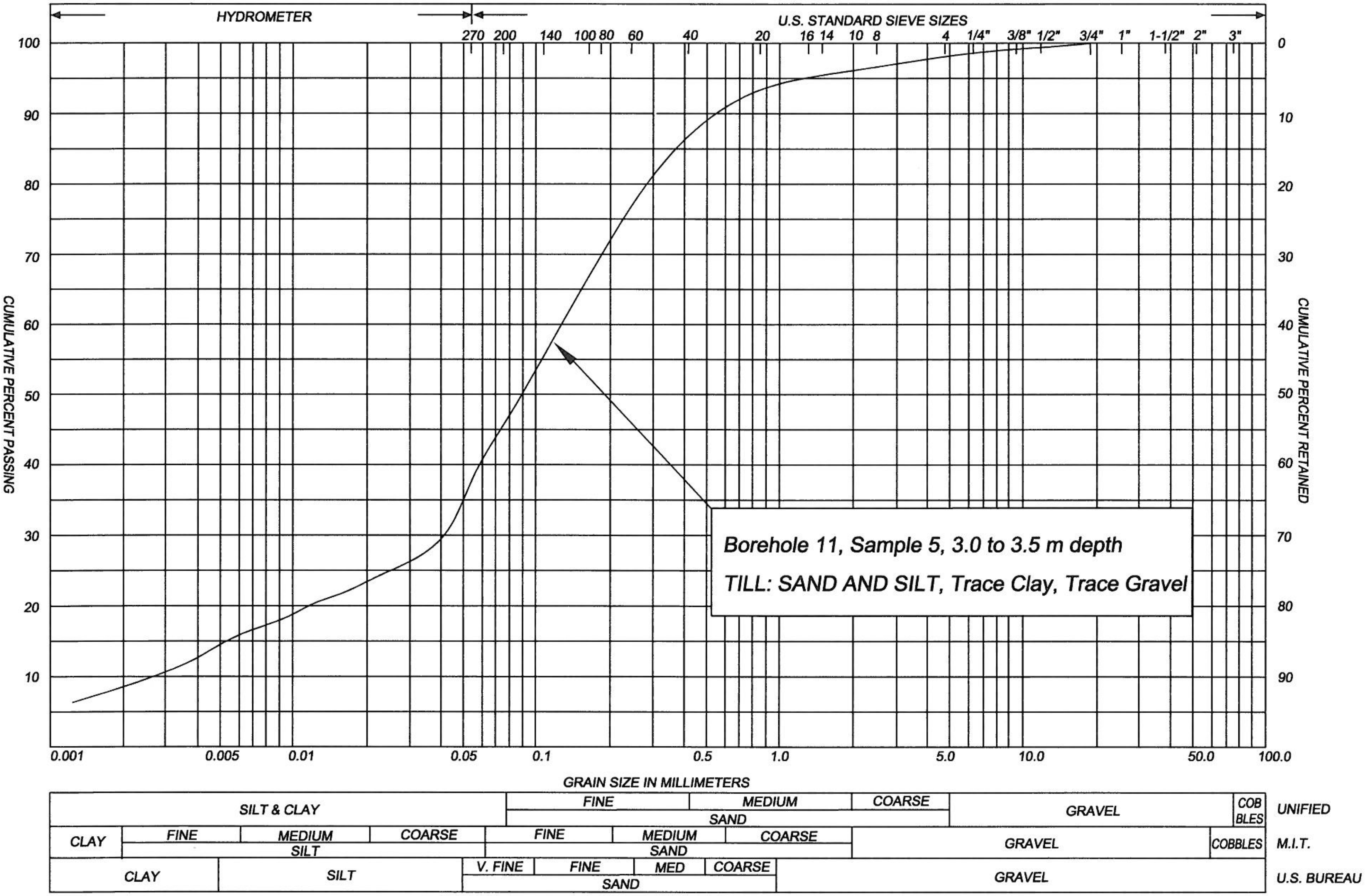
PARTICLE SIZE DISTRIBUTION CHART

PML Ref.: 17BF005
Figure No.: 3



Borehole 11, Sample 5, 3.0 to 3.5 m depth

TILL: SAND AND SILT, Trace Clay, Trace Gravel

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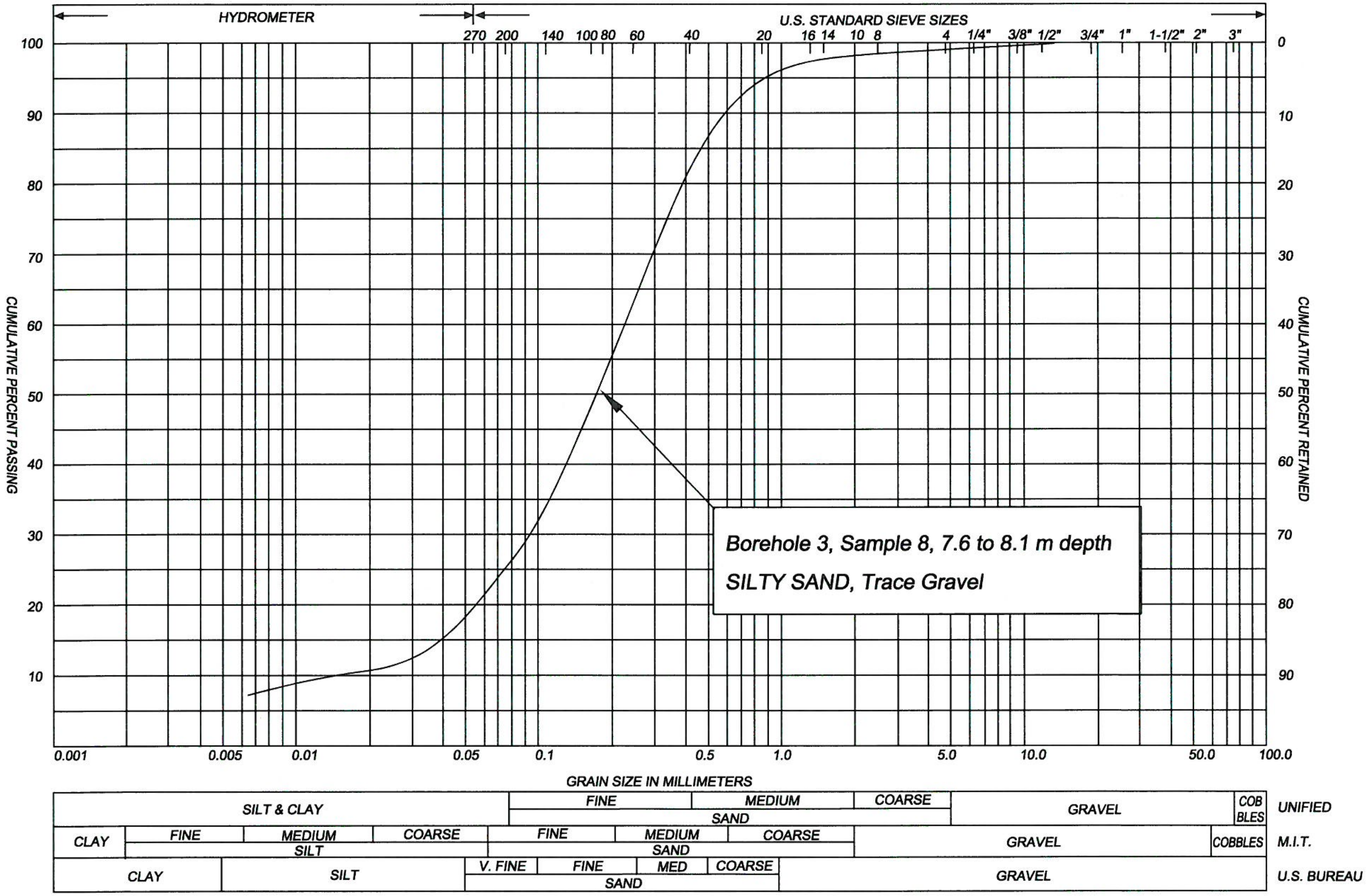
CONSULTING ENGINEERS

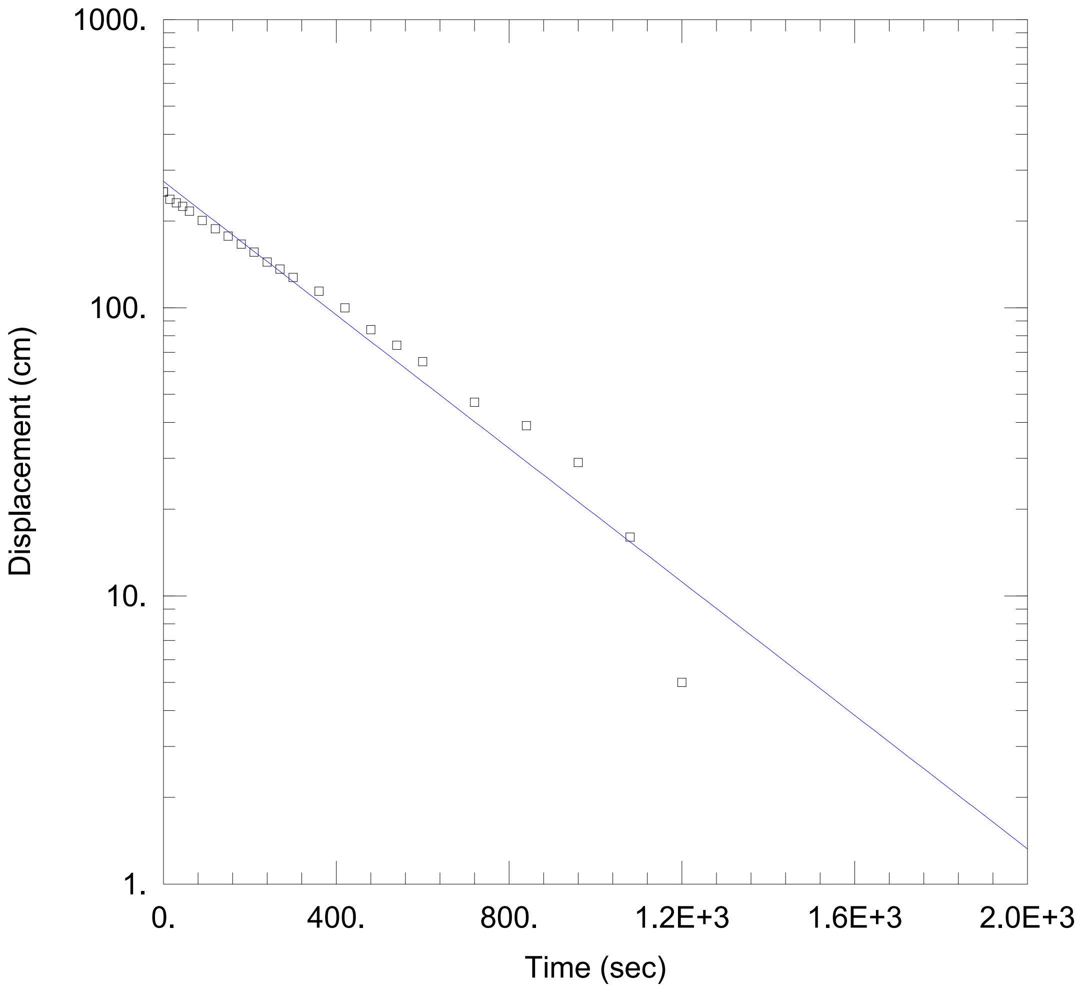
PARTICLE SIZE DISTRIBUTION CHART

PML Ref.:	17BF005
Figure No.:	4



Borehole 3, Sample 8, 7.6 to 8.1 m depth

SILTY SAND, Trace Gravel



HYDRAULIC CONDUCTIVITY TEST AT MW11

PROJECT INFORMATION

Company: R.J Burnside
Client: Sobara
Project: 300041514
Location: Barrie
Test Well: MW11
Test Date: May 22, 2018

AQUIFER DATA

Saturated Thickness: 837. cm

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW11)

Initial Displacement: 252. cm
Total Well Penetration Depth: 837. cm
Casing Radius: 2.54 cm

Static Water Column Height: 837. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

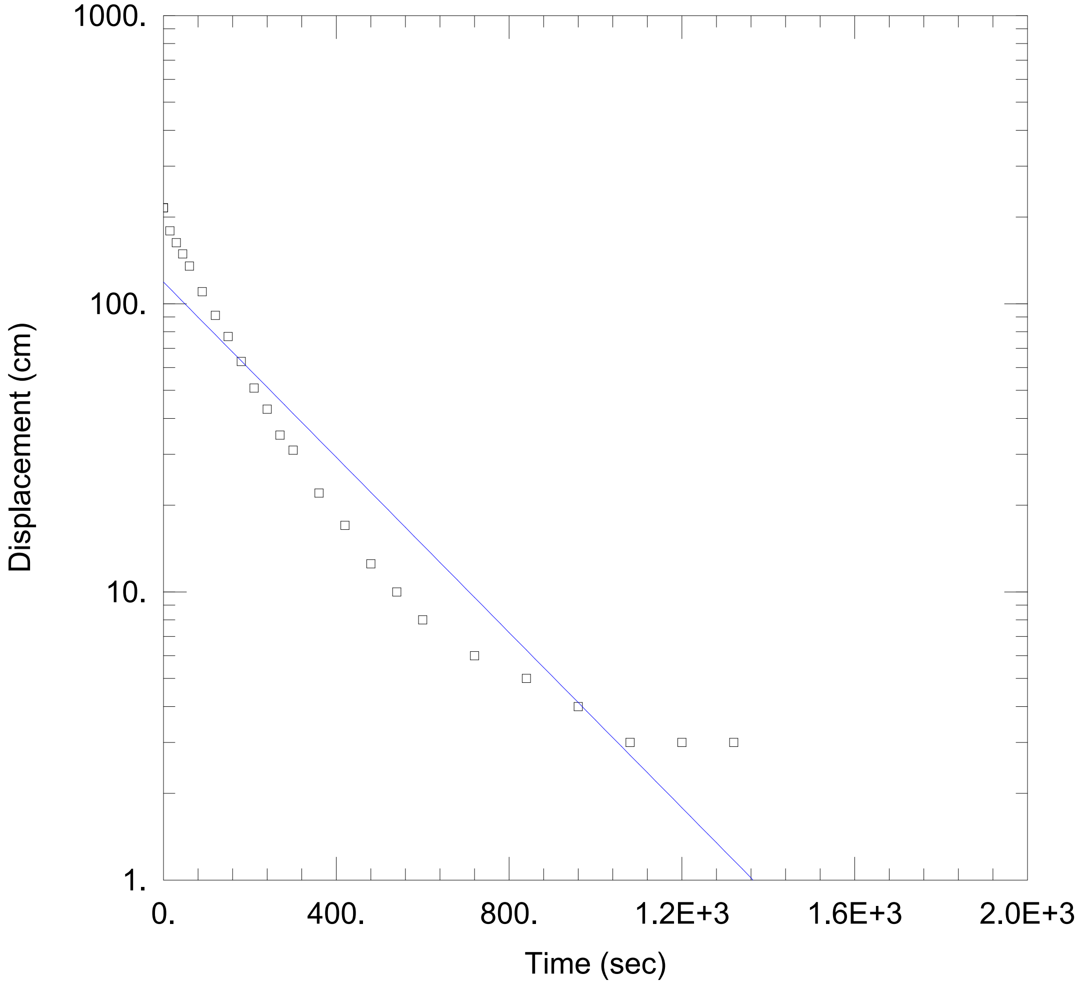
SOLUTION

Aquifer Model: Unconfined

Solution Method: Hvorslev

K = 0.0002086 cm/sec

y0 = 274.1 cm



HYDRAULIC CONDUCTIVITY TEST AT SB-6

PROJECT INFORMATION

Company: R.J Burnside
Client: Sobara
Project: 300041514
Location: Barrie
Test Well: SB-6
Test Date: May 22, 2018

AQUIFER DATA

Saturated Thickness: 212. cm
Anisotropy Ratio (Kz/Kr): 1.

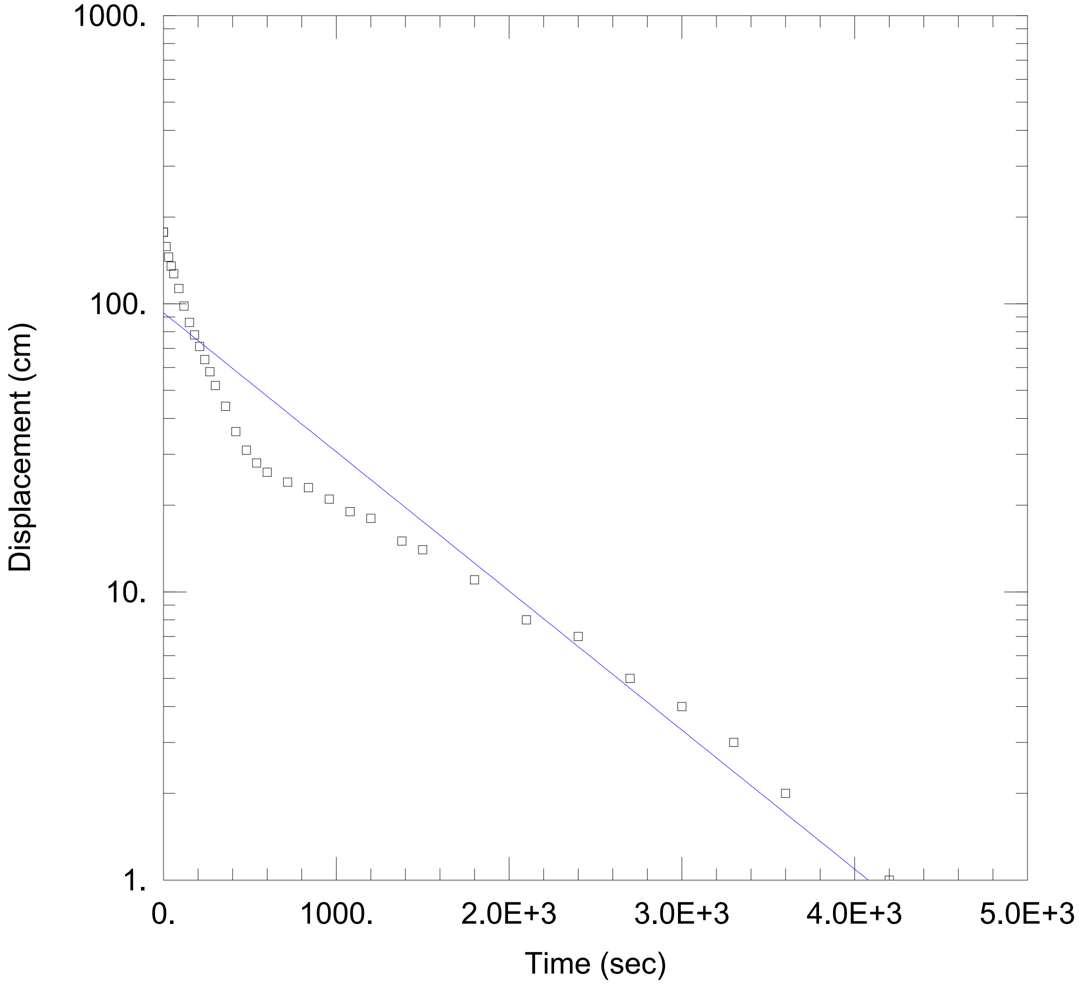
WELL DATA (SB-6)

Initial Displacement: 215. cm
Total Well Penetration Depth: 152. cm
Casing Radius: 2.54 cm
Static Water Column Height: 212. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.0002225 cm/sec
y0 = 118.8 cm



HYDRAULIC CONDUCTIVITY TEST AT SB-4

PROJECT INFORMATION

Company: R.J Burnside
Client: Sobara
Project: 300041514
Location: Barrie
Test Well: SB-4
Test Date: May 22, 2018

AQUIFER DATA

Saturated Thickness: 150. cm
Anisotropy Ratio (Kz/Kr): 1.

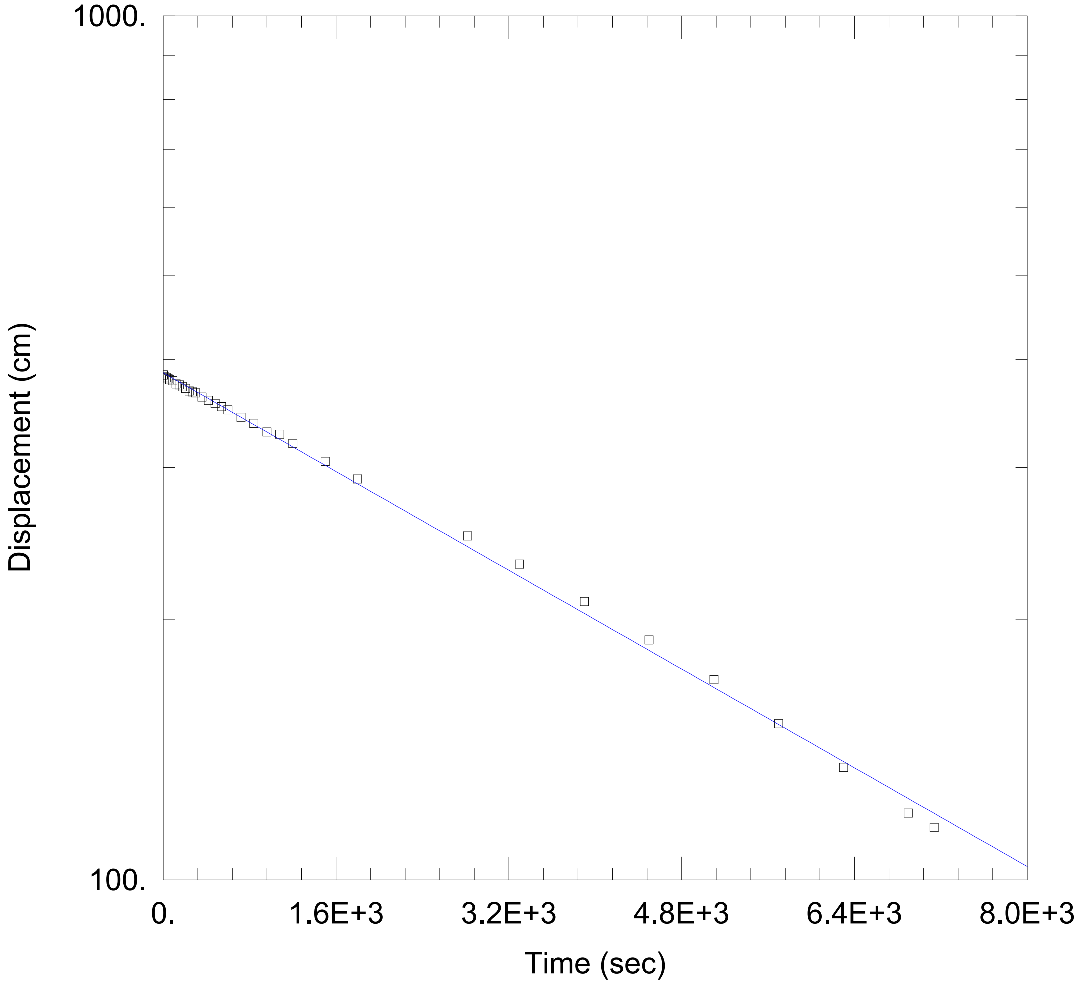
WELL DATA (SB-4)

Initial Displacement: 177. cm
Total Well Penetration Depth: 152. cm
Casing Radius: 2.54 cm
Static Water Column Height: 150. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.0001266 cm/sec
y0 = 92.96 cm



HYDRAULIC CONDUCTIVITY TEST AT SB-3

PROJECT INFORMATION

Company: R.J Burnside
Client: Sobara
Project: 300041514
Location: Barrie
Test Well: SB-3
Test Date: May 22, 2018

AQUIFER DATA

Saturated Thickness: 936. cm

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (SB-3)

Initial Displacement: 384. cm
Total Well Penetration Depth: 936. cm
Casing Radius: 2.54 cm

Static Water Column Height: 936. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined

Solution Method: Hvorslev

K = 1.287E-5 cm/sec

y0 = 386.1 cm

BURNSIDE

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Appendix D

Groundwater Level Data

Appendix D

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	24-Nov-2017		19-Dec-2017		25-Jan-2018		23-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)	Water Level (mbgs)	Water Elevation (masl)
SB-1	**4.31**	**249.50**	-0.19	249.69	Frozen	Frozen	-	-	Dry	Dry	Dry	Dry
SB-2	**4.38**	**253.90**	2.39	251.51	2.55	251.35	2.30	251.60	1.65	252.25	1.85	252.05
SB-3	**8.36**	**248.80**	Flowing	Flowing	Flowing	Flowing	-	-	Frozen	Frozen	Flowing	Flowing
SB-4	**3.88**	**257.55**	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
SB-5	**2.98**	**259.00**	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
SB-6	**6.10**	**259.15**	-	-	-	-	2.02	257.13	2.34	256.81	2.31	256.84
SB-7	**12.74**	**263.10**	-	-	-	-	Dry	Dry	Dry	Dry	2.83	260.27
SB-8	**4.33**	**265.40**	Dry	Dry	-	-	Dry	Dry	Dry	Dry	Dry	Dry
SB-9	**7.36**	**263.10**	Dry	Dry	-	-	Dry	Dry	Dry	Dry	Dry	Dry
SB-10	**9.24**	**266.90**	Dry	Dry	-	-	Dry	Dry	Dry	Dry	Dry	Dry
SB-11	**4.60**	**251.90**	0.68	251.23	0.79	251.11	0.39	251.51	0.58	251.32	0.39	251.51
SB-12	**5.50**	**253.80**	1.74	252.07	1.97	251.83	1.52	252.28	1.07	252.73	1.42	252.38
SB-13	**4.50**	**254.85**	1.91	252.94	2.50	252.36	2.09	252.76	2.00	252.85	1.95	252.90
SB-14	**3.71**	**258.90**	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
SB-15	**4.46**	**259.00**	Dry	Dry	4.31	254.69	Dry	Dry	Dry	Dry	Dry	Dry
MW11	**7.67**	**254.20**	-	-	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen
SB-PZ1s	**1.27**	**252.00**	-0.03	252.03	0.02	251.98	Frozen	Frozen	0.00	252.00	0.03	251.97
SB-PZ1d	**1.81**	**252.00**	0.30	251.70	0.05	251.95	Frozen	Frozen	0.04	251.96	Frozen	Frozen
PZ4	**1.87**	**251.00**	-	-	0.00	251.00	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen

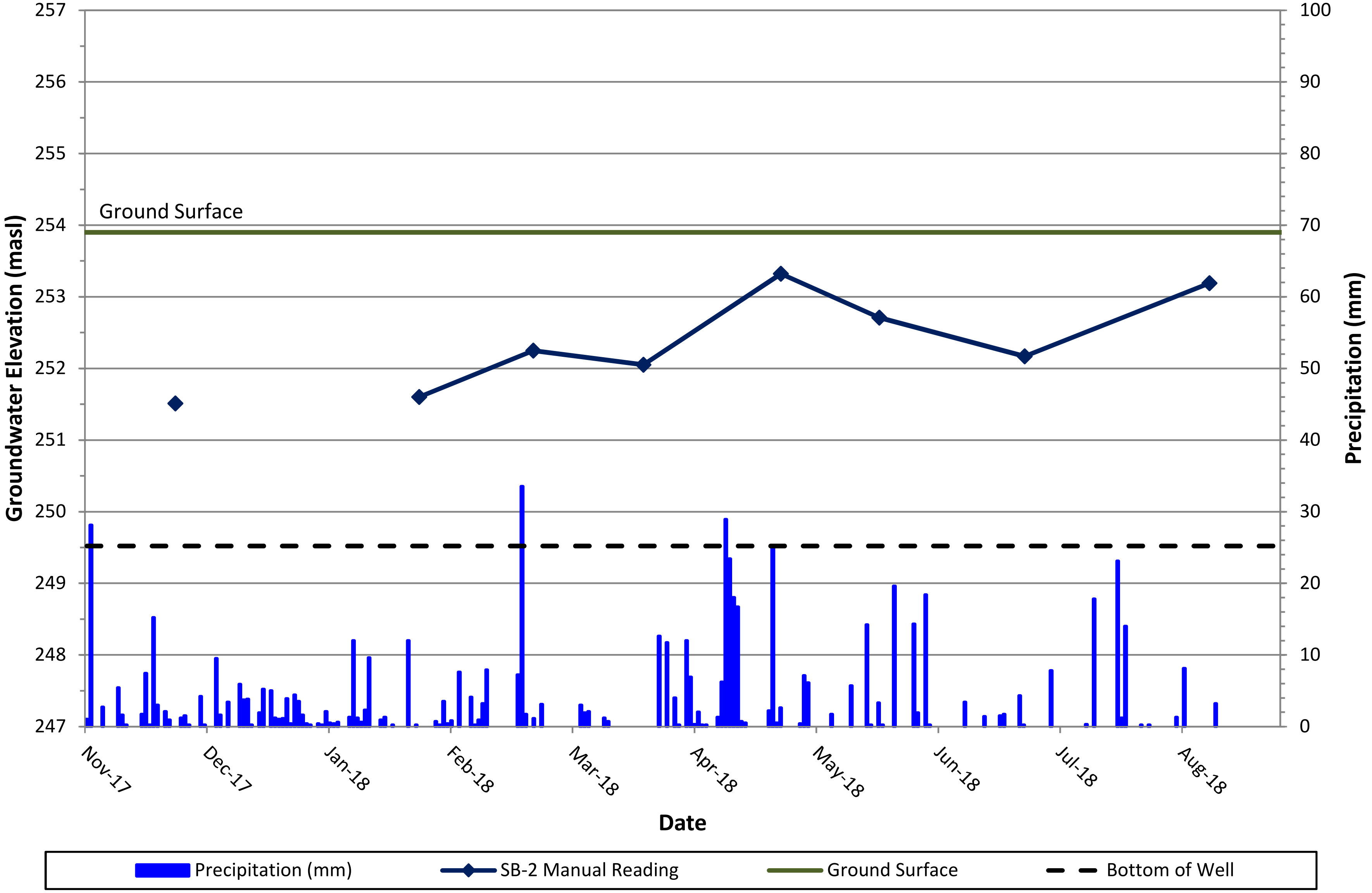
"-" denotes data unavailable

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	27-Apr-2018		22-May-2018		28-Jun-2018		27-Jul-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)	Water Level (mbgs)	Water Elevation (masl)
SB-1	**4.31**	**249.50**	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	-	-	-	-
SB-2	**4.38**	**253.90**	0.58	253.32	1.19	252.71	1.73	252.17	0.50	253.40	0.71	253.19
SB-3	**8.36**	**248.80**	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing
SB-4	**3.88**	**257.55**	0.47	257.08	2.36	255.19	0.44	257.11	Dry	Dry	Dry	Dry
SB-5	**2.98**	**259.00**	Dry	Dry	Dry	Dry	Dry	Dry	-	-	Dry	Dry
SB-6	**6.10**	**259.15**	0.34	258.81	1.19	257.96	2.08	257.07	-	-	4.54	254.61
SB-7	**12.74**	**263.10**	0.80	262.30	0.82	262.28	2.62	260.48	-	-	4.74	258.36
SB-8	**4.33**	**265.40**	3.84	261.56	Dry	Dry	Dry	Dry	-	-	Dry	Dry
SB-9	**7.36**	**263.10**	6.20	256.90	6.27	256.83	7.22	255.88	-	-	Dry	Dry
SB-10	**9.24**	**266.90**	7.39	259.51	6.70	260.20	-	-	-	-	Dry	Dry
SB-11	**4.60**	**251.90**	-0.65	252.55	-0.23	252.13	0.18	251.72	-	-	-	-
SB-12	**5.50**	**253.80**	0.39	253.41	-0.23	254.03	1.15	252.65	1.65	252.15	1.87	251.93
SB-13	**4.50**	**254.85**	0.52	254.33	1.70	253.15	2.45	252.40	3.35	251.50	3.68	251.17
SB-14	**3.71**	**258.90**	1.34	257.56	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
SB-15	**4.46**	**259.00**	3.23	255.77	3.51	255.49	4.20	254.80	4.30	254.70	4.30	254.70
MW11	**7.67**	**254.20**	Flowing	Flowing	-1.24	255.44	-1.02	255.22	-0.70	254.90	-0.56	254.76
SB-PZ1s	**1.27**	**252.00**	-0.06	252.06	-0.04	252.04	0.02	251.98	0.09	251.91	0.04	251.96
SB-PZ1d	**1.81**	**252.00**	-0.18	252.18	-0.14	252.14	-0.11	252.11	-0.01	252.01	0.01	251.99
PZ4	**1.87**	**251.00**	-0.07	251.07	0.02	250.98	0.15	250.85	0.23	250.77	0.19	250.81

"-" denotes data unavailable

SB-2 (Well Depth: 4.4 m, Screened in Sand/Silt Till, Sand)
Groundwater Elevations



R.J. Burnside & Associates Limited

Figure D-1

SB-4 (Well Depth: 3.9 m, Screened in Sands/Silt Till)
Groundwater Elevations

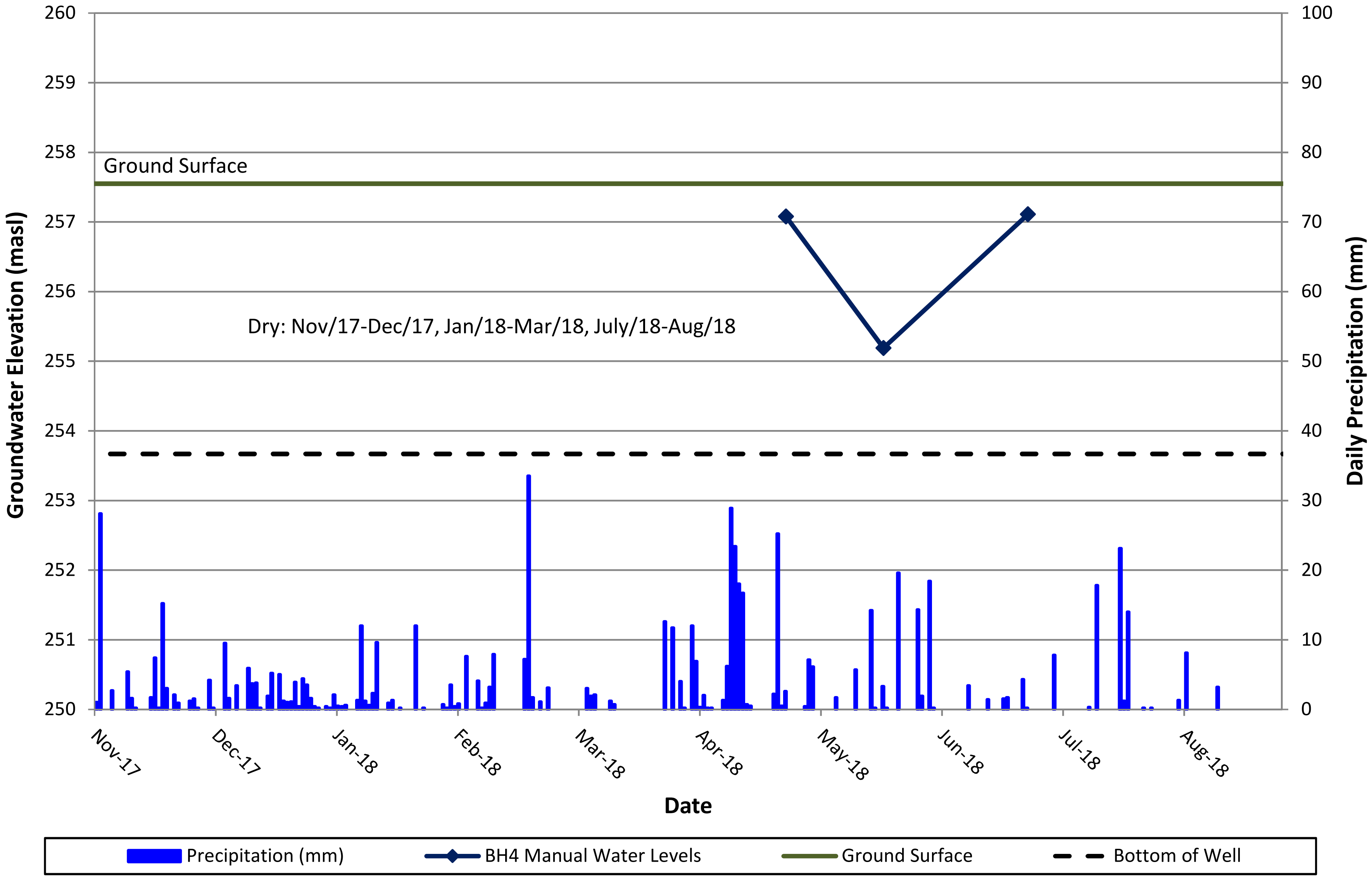
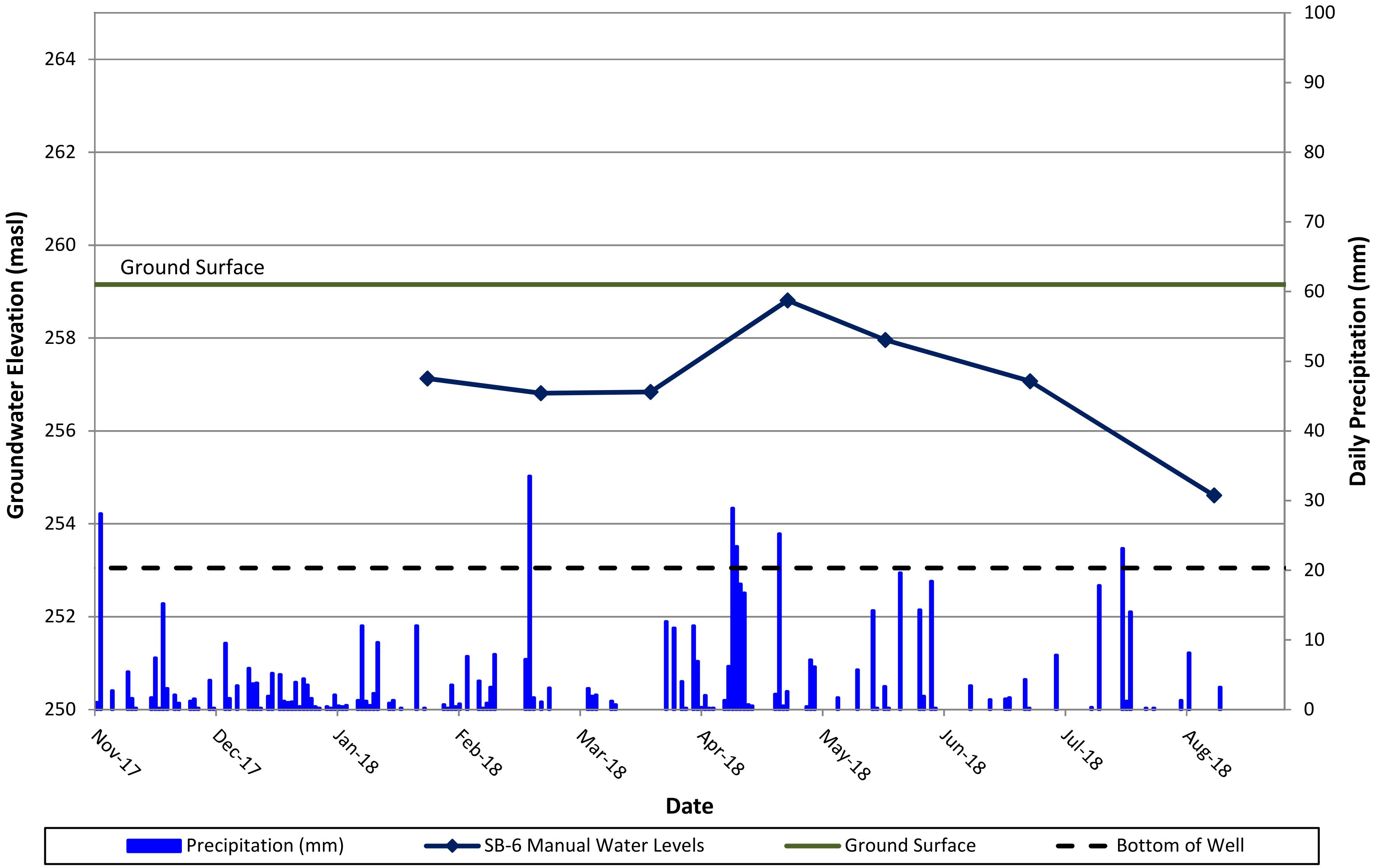
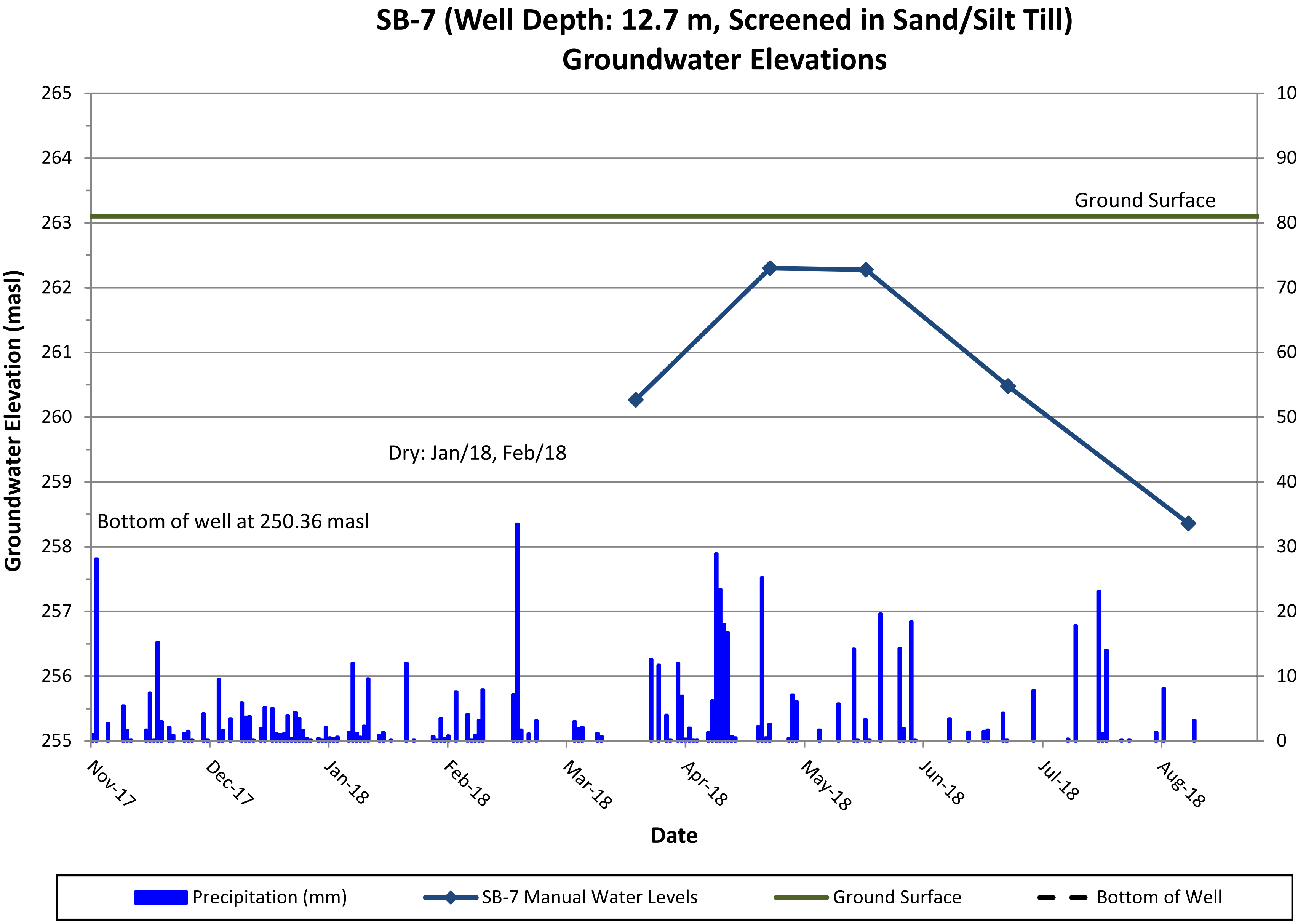


Figure D-2

SB-6 (Well Depth: 6.1 m, Screened in Sand, Silt Till.)
Groundwater Elevations




SB-7 (Well Depth: 12.7 m, Screened in Sand/Silt Till)
Groundwater Elevations
Groundwater Elevation (masl)
Daily Precipitation (mm)
265
264
263
262
261
260
259
258
257
256
255
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
Dry: Jan/18, Feb/18
Bottom of well at 250.36 masl
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Date
Precipitation (mm)
SB-7 Manual Water Levels
Ground Surface
Bottom of Well

SB-9 (Well Depth: 7.4 m, Screened in Sand/Silt Till)
Groundwater Elevations

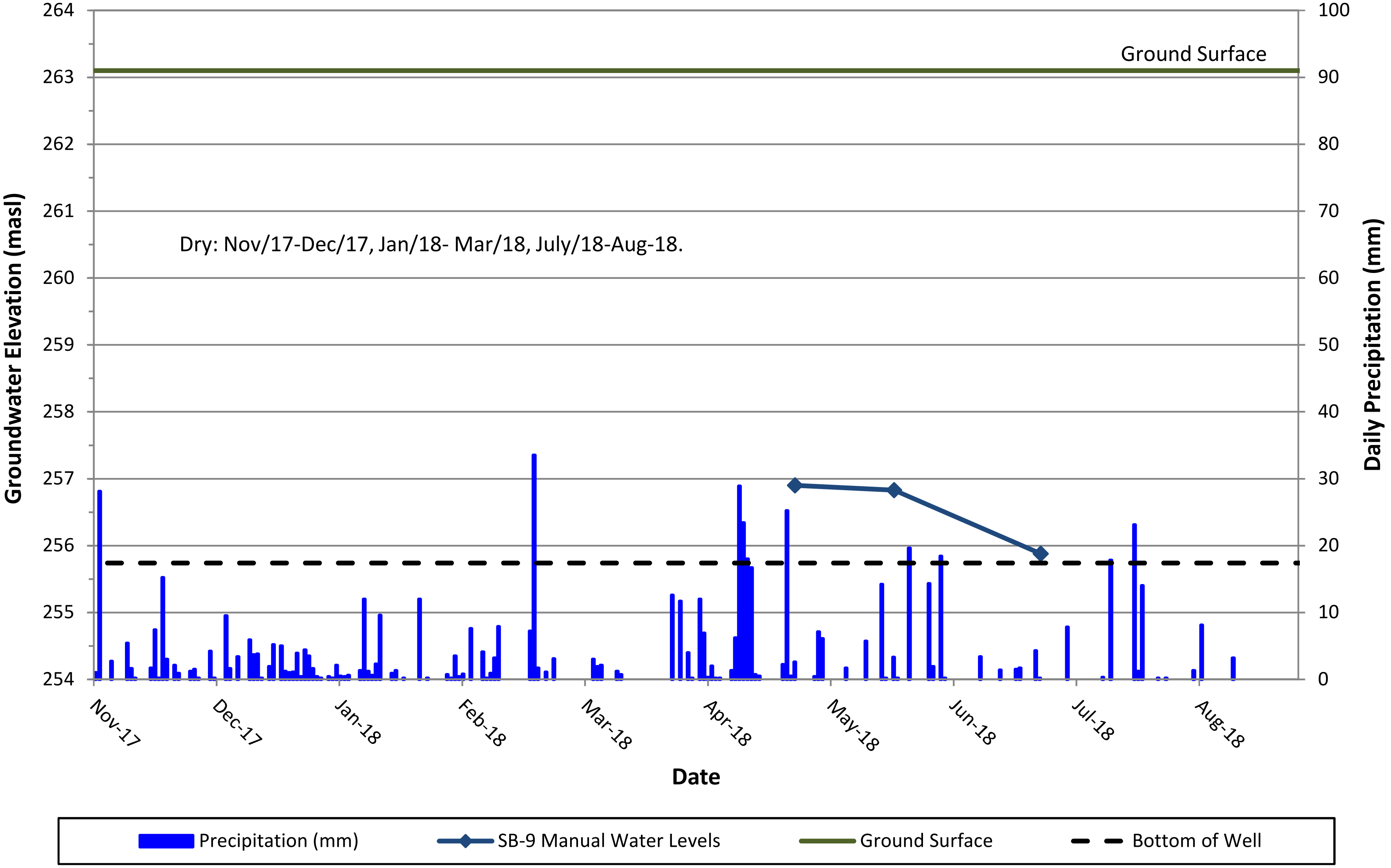


Figure D-5

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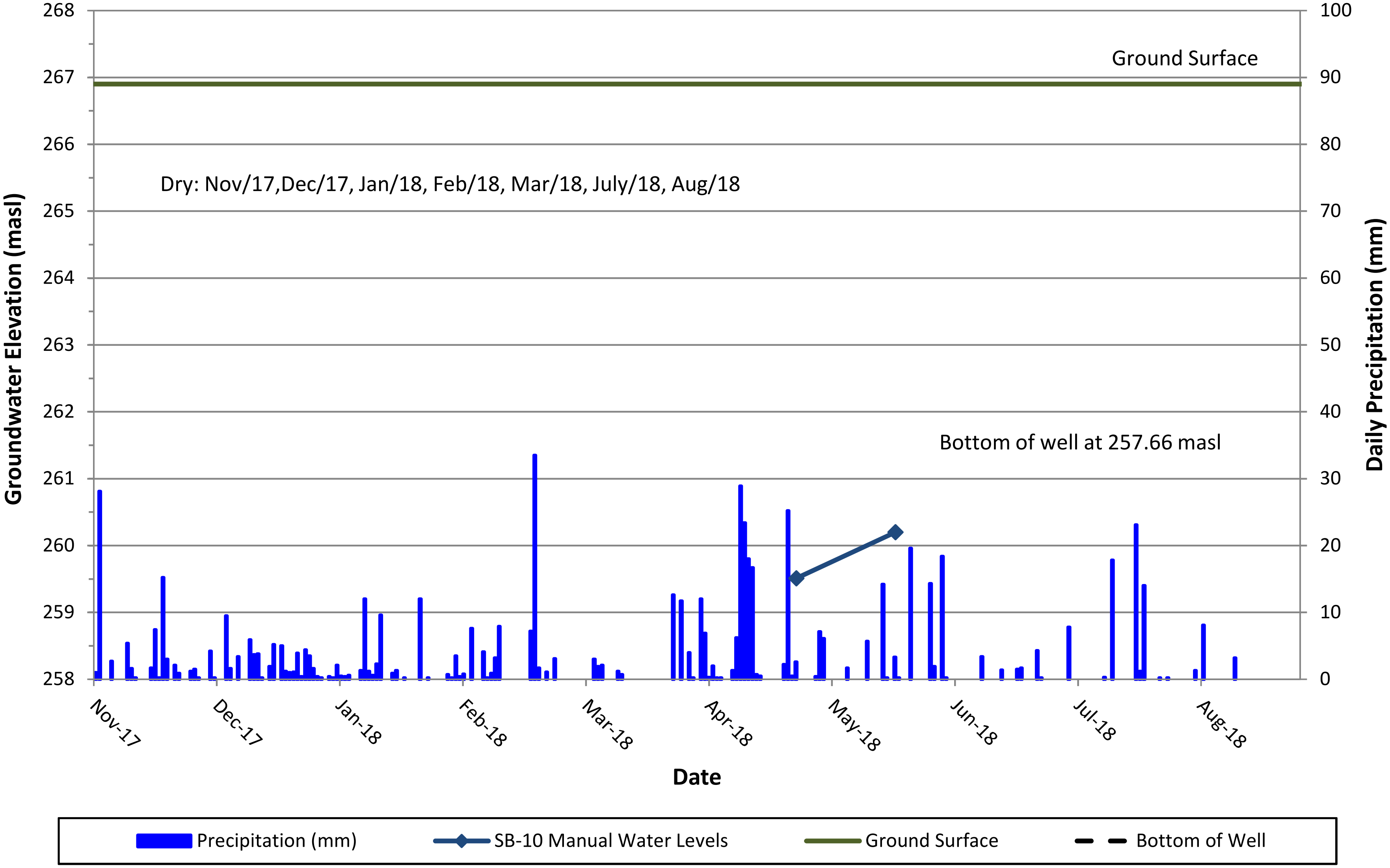
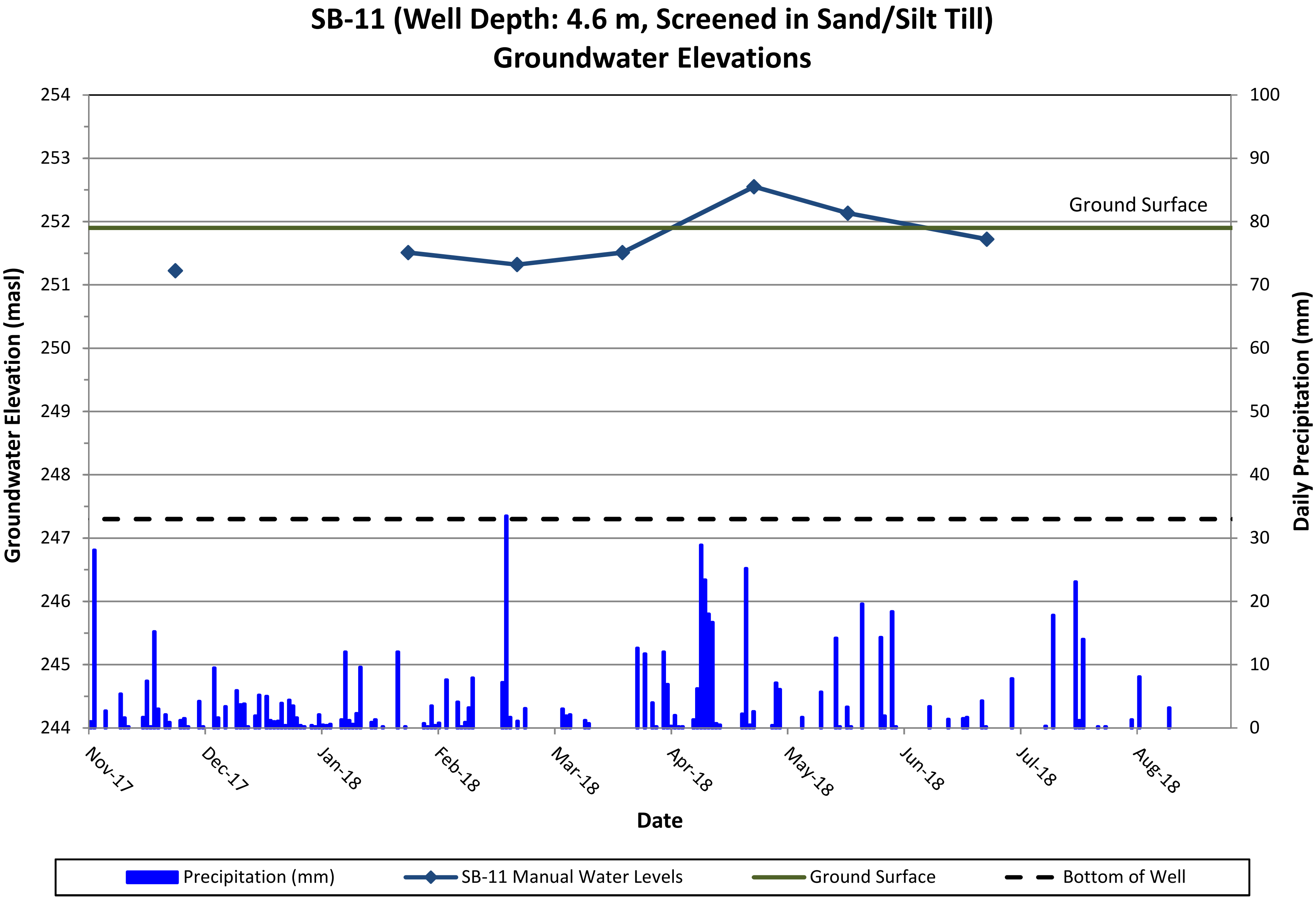
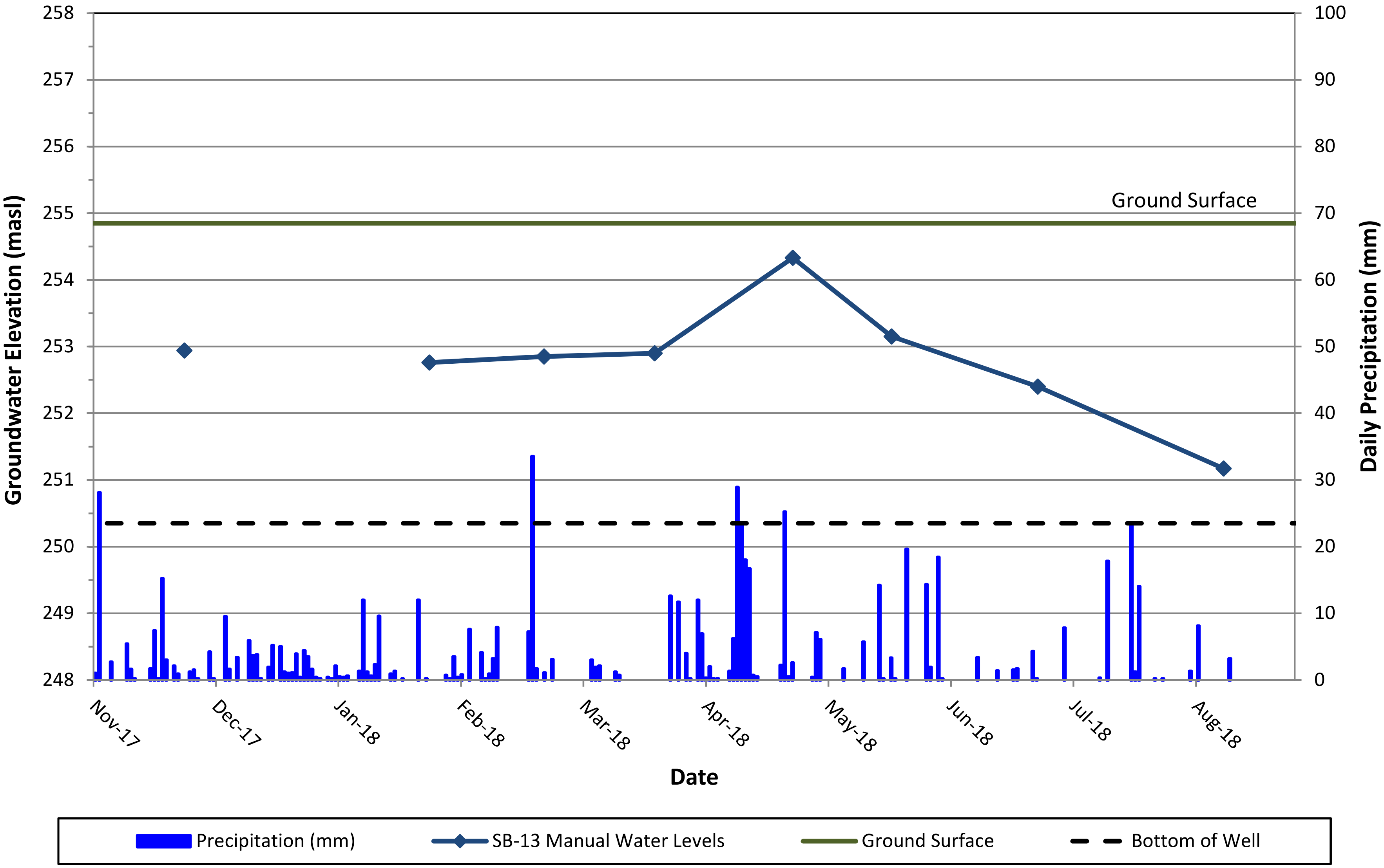
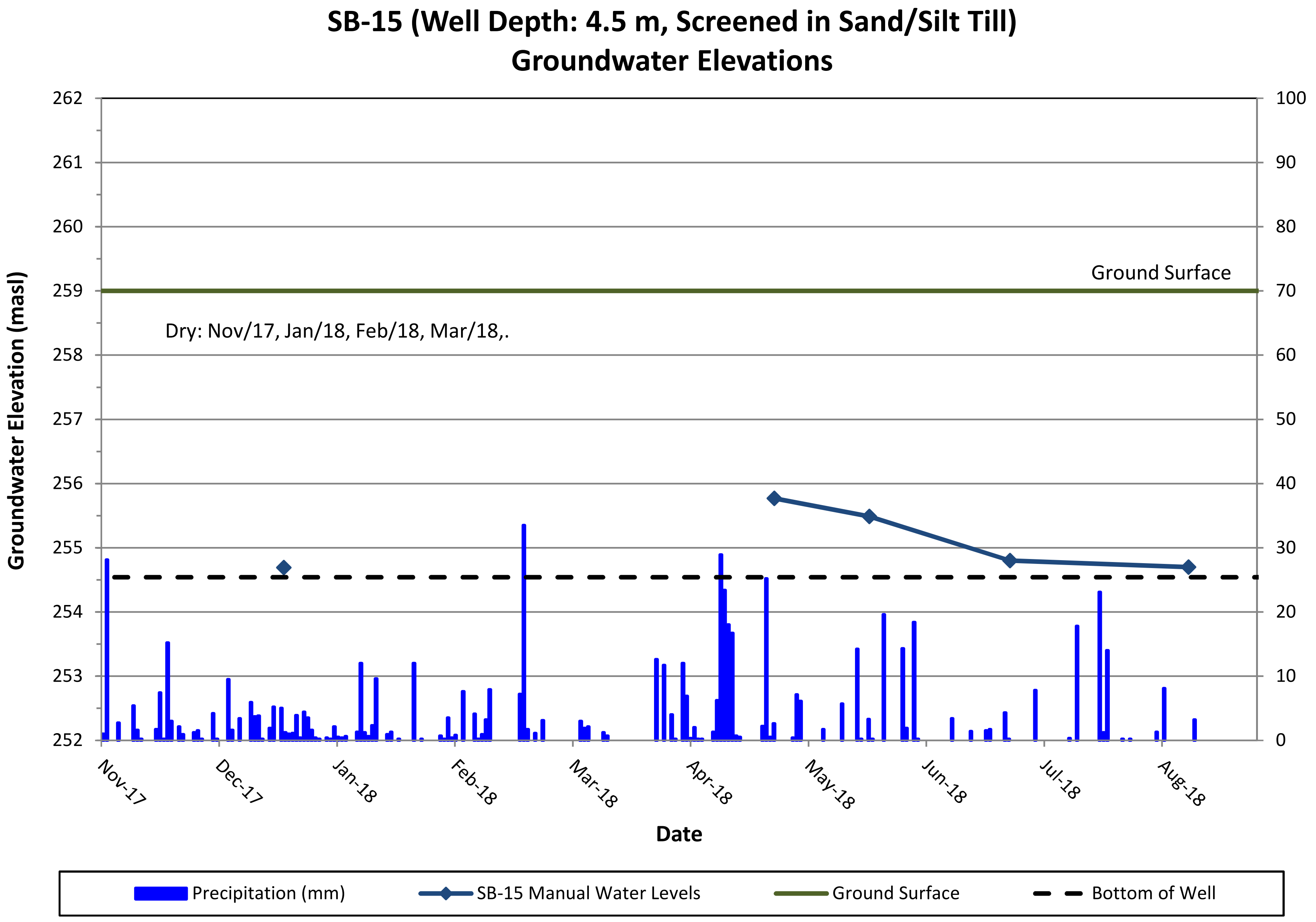
SB-10 (Well Depth: 9.2 m, Screened in Sand)
Groundwater Elevations



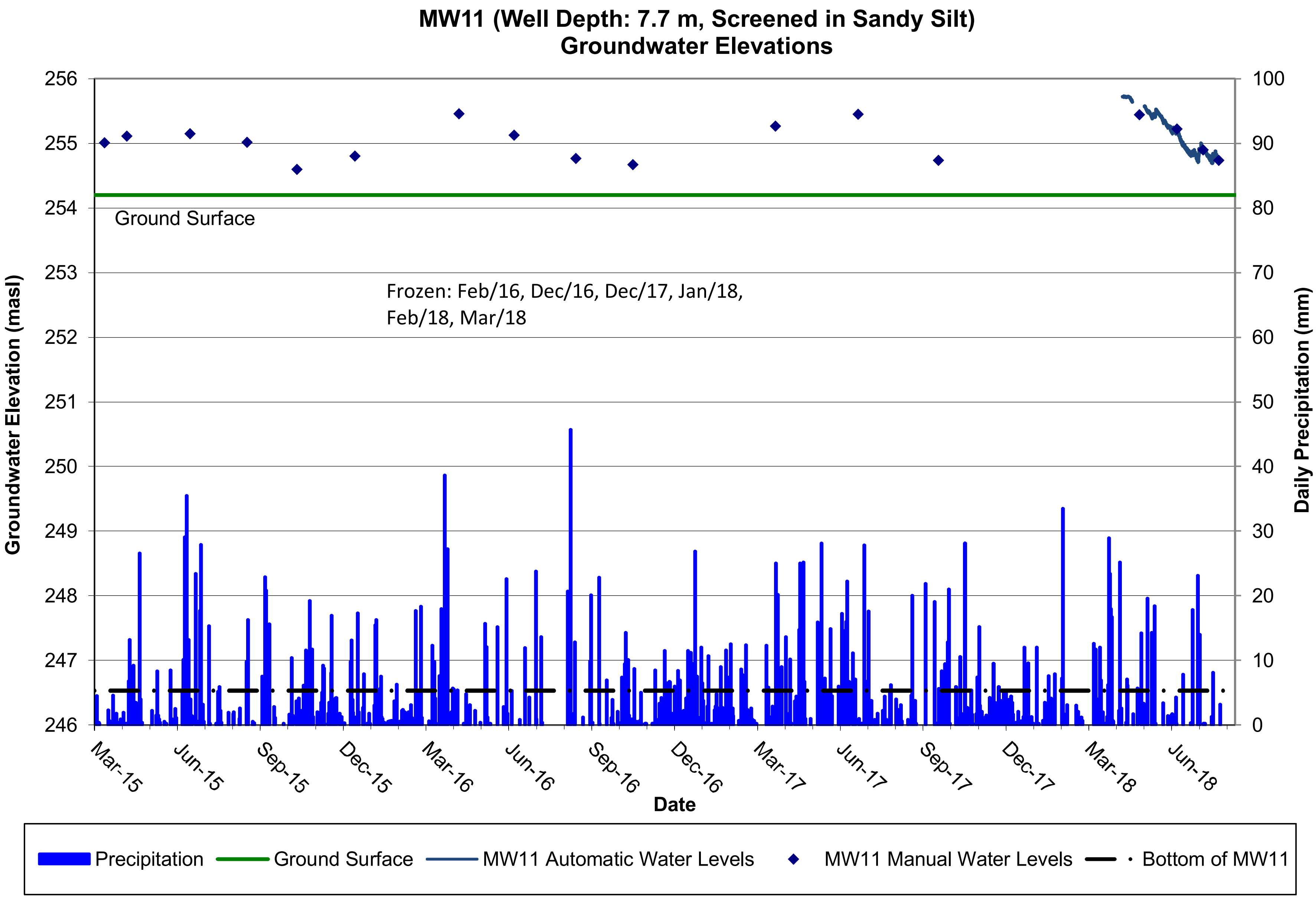

SB-11 (Well Depth: 4.6 m, Screened in Sand/Silt Till)
Groundwater Elevations
Groundwater Elevation (masl)
254
253
252
251
250
249
248
247
246
245
244
Daily Precipitation (mm)
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Date
Precipitation (mm)
SB-11 Manual Water Levels
Ground Surface
Bottom of Well

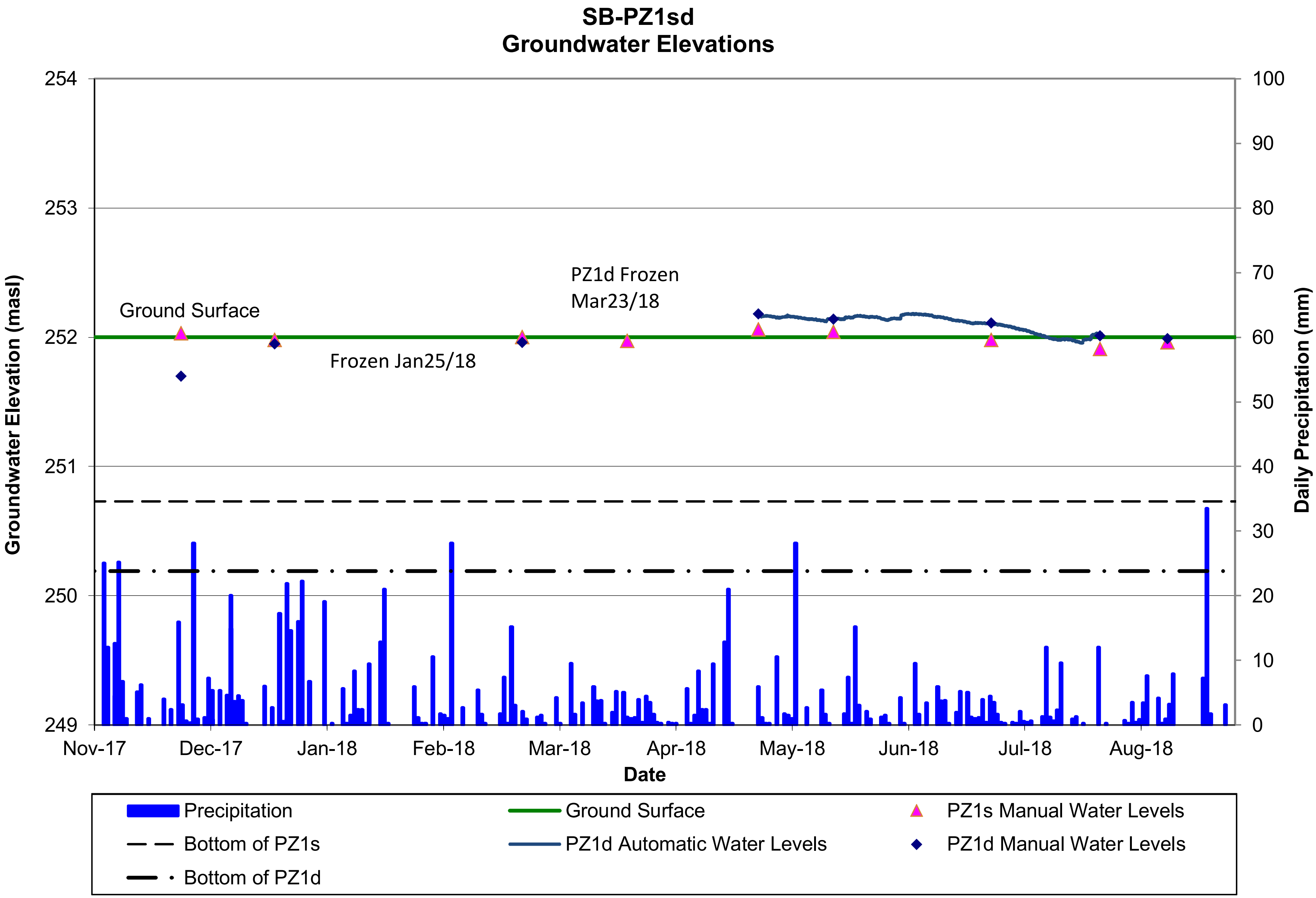
SB-13 (Well Depth: 4.5 m, Screened in Sand/Silt Till) Groundwater Elevations




SB-15 (Well Depth: 4.5 m, Screened in Sand/Silt Till)
Groundwater Elevations
Groundwater Elevation (masl)
262
261
260
259
258
257
256
255
254
253
252
Daily Precipitation (mm)
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
Dry: Nov/17, Jan/18, Feb/18, Mar/18,.
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Date
Precipitation (mm)
SB-15 Manual Water Levels
Ground Surface
Bottom of Well

MW11 (Well Depth: 7.7 m, Screened in Sandy Silt)
Groundwater Elevations




SB-PZ1sd
Groundwater Elevations
Groundwater Elevation (masl)
Daily Precipitation (mm)
254
253
252
251
250
249
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
Frozen Jan25/18
PZ1d Frozen
Mar23/18
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Date
Precipitation
Ground Surface
PZ1s Manual Water Levels
Bottom of PZ1s
PZ1d Automatic Water Levels
PZ1d Manual Water Levels
Bottom of PZ1d

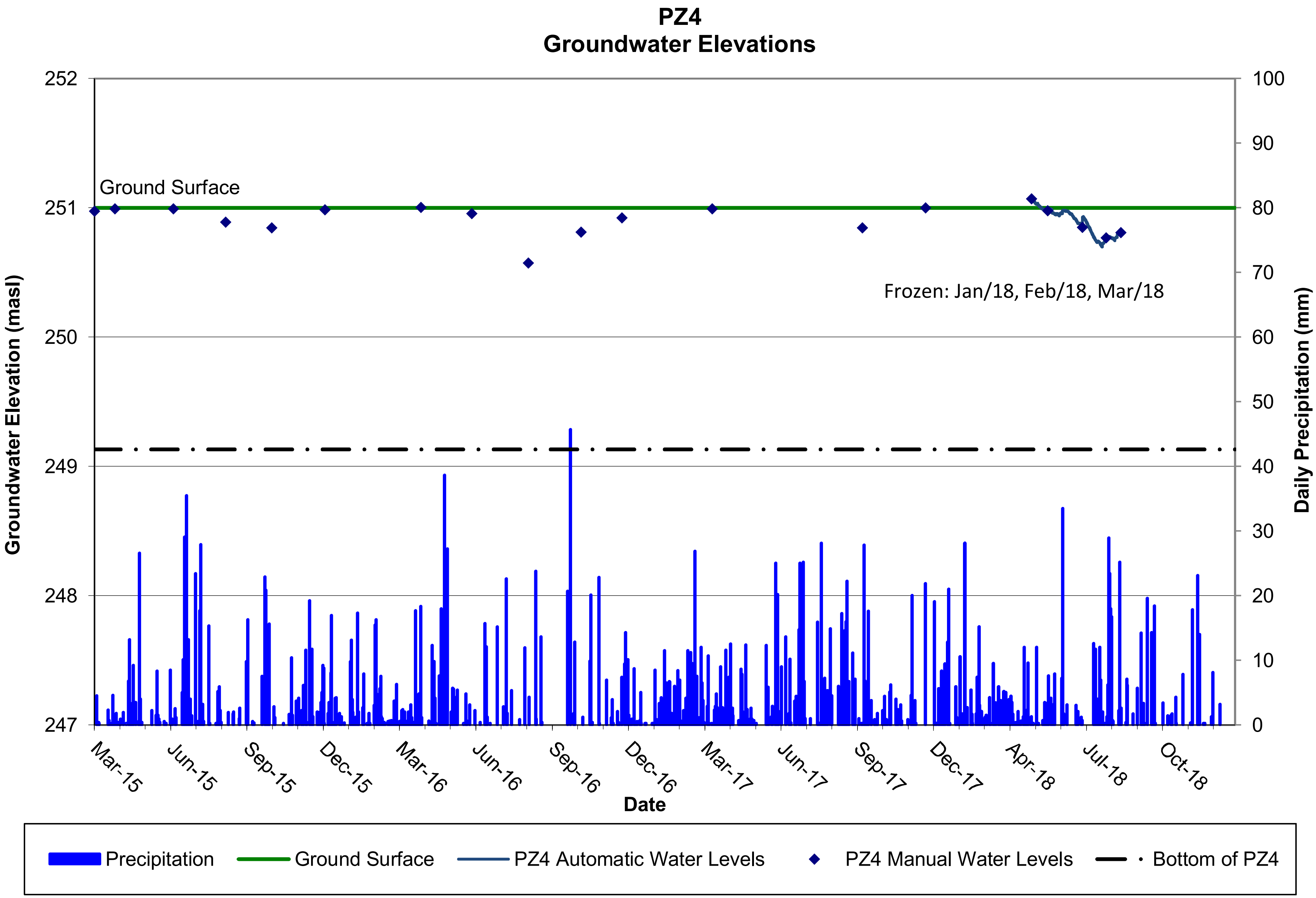


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Figure D-12

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Appendix E

Water Quality Data

Table E-1
Groundwater Quality

Monitoring Well				**SB-3**	**SB-4**
Date Sampled				**22-May-18**	**22-May-18**
Parameter	**Unit**	**RDL**	**ODWQS**		
Electrical Conductivity	µS/cm	2		533	639
pH	pH Units	NA	(6.5-8.5)	7.89	7.75
Saturation pH				7.01	6.8
Langelier Index				0.88	0.95
Total Hardness (as CaCO3)	mg/L	0.5	(80-100)	**271**	**337**
Total Dissolved Solids	mg/L	20	500	298	402
Alkalinity (as CaCO3)	mg/L	5	(30-500)	246	338
Bicarbonate (as CaCO3)	mg/L	5		246	338
Carbonate (as CaCO3)	mg/L	5		<5	<5
Hydroxide (as CaCO3)	mg/L	5		<5	<5
Fluoride	mg/L	0.10	1.5	<0.10	<0.10
Chloride	mg/L	0.20	250	11.7	21.2
Nitrate as N	mg/L	0.10	10.0	5.47	6.9
Nitrite as N	mg/L	0.10	1.0	<0.10	<0.10
Bromide	mg/L	0.10		<0.10	<0.10
Sulphate	mg/L	0.20	500	30.1	15
Ortho Phosphate as P	mg/L	0.20		<0.20	<0.20
Reactive Silica	mg/L	0.10		17.4	16
Ammonia as N	mg/L	0.02		<0.02	0.02
Total Phosphorus	mg/L	0.02		0.03	1.97
Total Organic Carbon	mg/L	1.0		0.7	5.2
Colour	TCU	5	5	<5	<5
Turbidity	NTU	15	5	**12.4**	**15500**
Calcium	mg/L	0.05		69.7	114
Magnesium	mg/L	0.05		23.5	12.6
Sodium	mg/L	0.05	20 (200)	5.48	4.92
Potassium	mg/L	0.05		1.81	0.97
Aluminum (Dissolved)	mg/L	0.004	0.1	<0.004	<0.004
Antimony	mg/L	0.003	0.006	<0.003	<0.003
Arsenic	mg/L	0.003	0.025	<0.003	<0.003
Barium	mg/L	0.002	1	0.054	0.033
Beryllium	mg/L	0.001		<0.001	<0.001
Boron	mg/L	0.010	5	<0.010	0.013
Cadmium	mg/L	0.001	0.005	<0.0001	<0.001
Chromium	mg/L	0.003	0.05	<0.003	<0.003
Cobalt	mg/L	0.001		<0.0005	<0.001
Copper	mg/L	0.003	1	0.001	<0.003
Iron	mg/L	0.010	0.3	<0.01	<0.010
Lead	mg/L	0.001	0.01	<0.001	<0.001
Manganese	mg/L	0.002	0.05	<0.002	<0.002
Mercury (Dissolved)	mg/L	0.0001	0.001	<0.0001	<0.0001
Molybdenum	mg/L	0.002		0.003	<0.002
Nickel	mg/L	0.003		<0.003	<0.003
Selenium	mg/L	0.004	0.01	<0.004	<0.004
Silver	mg/L	0.002		<0.0001	<0.002
Strontium	mg/L	0.005		0.267	0.212
Thallium	mg/L	0.006		<0.0003	<0.006
Tin	mg/L	0.002		<0.002	<0.002
Titanium	mg/L	0.002		<0.002	<0.002
Tungsten	mg/L	0.010		<0.010	<0.010
Uranium	mg/L	0.002	0.02	<0.002	<0.002
Vanadium	mg/L	0.002	3	<0.002	<0.002
Zinc	mg/L	0.005	5	0.005	<0.005
Zirconium	mg/L	0.004		<0.004	<0.004
% Difference/ Ion Balance	%	NA		4.78	7.86

ODWQS - Ontario Drinking Water Quality Standards

RDL - Reported Detection Limit

Bold indicates an exceedence of the ODWQS

Table E-2
Surface Water Quality

Sample Location				**SB-SW1**
Date Sampled				**22-May-18**
Parameter	**Unit**	**RDL**	**PWQO**	
Electrical Conductivity	µS/cm	2		497
pH	pH Units	NA	(6.5-8.5)	7.91
Saturation pH				6.95
Langelier Index				0.96
Total Hardness (as CaCO3)	mg/L	0.5		275
Total Dissolved Solids	mg/L	20		282
Alkalinity (as CaCO3)	mg/L	5		276
Bicarbonate (as CaCO3)	mg/L	5		276
Carbonate (as CaCO3)	mg/L	5		<5
Hydroxide (as CaCO3)	mg/L	5		<5
Fluoride	mg/L	0.05		<0.05
Chloride	mg/L	0.1		10.6
Nitrate as N	mg/L	0.05		<0.05
Nitrite as N	mg/L	0.05		<0.05
Bromide	mg/L	0.05		<0.05
Sulphate	mg/L	0.1		12.1
Ortho Phosphate as P	mg/L	0.1		<0.10
Reactive Silica	mg/L	0.05		10.5
Ammonia as N	mg/L	0.02		<0.02
Total Phosphorus	mg/L	0.02	0.03	0.03
Total Organic Carbon	mg/L	0.5		6.5
Colour	TCU	5		<5
Turbidity	NTU	0.5		0.9
Calcium	mg/L	0.05		86.9
Magnesium	mg/L	0.05		14
Sodium	mg/L	0.05		5.2
Potassium	mg/L	0.05		1.18
Aluminum (dissolved)	mg/L	0.004	0.075	<0.004
Antimony	mg/L	0.003		<0.003
Arsenic	mg/L	0.003	1	<0.003
Barium	mg/L	0.002		0.07
Beryllium	mg/L	0.001		<0.001
Boron	mg/L	0.01	2	0.011
Cadmium	mg/L	0.0001	0.0002	<0.0001
Chromium	mg/L	0.003	0.009	<0.003
Cobalt	mg/L	0.0005		<0.0005
Copper	mg/L	0.001	0.005	<0.001
Iron	mg/L	0.01	0.3	<0.01
Lead	mg/L	0.001	0.001	<0.001
Manganese	mg/L	0.002		0.009
Dissolved Mercury	mg/L	0.0001	0.0002	<0.0001
Molybdenum	mg/L	0.002	0.04	<0.002
Nickel	mg/L	0.003	0.025	<0.003
Selenium	mg/L	0.004	0.01	<0.004
Silver	mg/L	0.0001		<0.0001
Strontium	mg/L	0.005		0.225
Thallium	mg/L	0.0003	0.0003	<0.0003
Tin	mg/L	0.002		<0.002
Titanium	mg/L	0.002		<0.002
Tungsten	mg/L	0.01		<0.010
Uranium	mg/L	0.002	0.005	0.002
Vanadium	mg/L	0.002		<0.002
Zinc	mg/L	0.005	0.03	<0.005
Zirconium	mg/L	0.004		<0.004
Cation Sum	meq/L	NA		5.75
Anion Sum	meq/L			6.07
% Difference/ Ion Balance	%	NA		2.72

PWQS - Provincial Water Quality Standards

RDL - Reported Detection Limit

Bold indicates an exceedence of the PWQO

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Appendix F

Water Balance Calculations

WATER BALANCE CALCULATIONS
Barrie Lockhart Road LP
Barrie, ON

PROJECT No.300041514

TABLE F-1

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 150 mm (moderate rooted crops 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 ° N.

WATER BALANCE CALCULATIONS
Barrie Lockhart Road LP
Barrie, ON

PROJECT No.300041514

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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 43° 52' 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
Barrie Lockhart Road LP
Barrie, ON

PROJECT No.300041514

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TABLE F-3

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

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												
Rural Forest	56,200	0.00	0	0.793	0	56,200	0.068	3,818	0.272	15,274	3,818	15,274
Wetlands	104,000	1.00	104,000	0.793	82,468	0	0.102	0	0.238	0	82,468	0
Agricultural	207,200	0.00	0	0.793	0	207,200	0.102	21,117	0.238	49,272	21,117	49,272
TOTAL PRE-DEVELOPMENT	**367,400**		**104,000**		**82,468**	**263,400**		**24,935**		**64,546**	**107,404**	**64,546**
Post-Development Land Use (with no LID measures in place)												
Residential (Single Detached)	90,100	0.74	66,674	0.793	52,870	23,426	0.102	2,387	0.238	5,571	55,258	5,571
Residential (Townhouse)	26,000	0.72	18,720	0.793	14,844	7,280	0.068	495	0.238	1,731	15,339	1,731
Mixed Use	15,500	0.75	11,625	0.793	9,218	3,875	0.068	263	0.238	921	9,481	921
Stormwater Management Pond	6,700	0.50	3,350	0.793	2,656	3,350	0.068	228	0.238	797	2,884	797
Village Square	9,000	0.25	2,250	0.793	1,784	6,750	0.068	459	0.238	1,605	2,243	1,605
Institutional	24,100	0.75	18,075	0.793	14,333	6,025	0.068	409	0.238	1,433	14,742	1,433
Roads	60,400	0.67	40,468	0.793	32,090	19,932	0.068	1,354	0.238	4,740	33,444	4,740
Environmental Heitage System	132,500	0.00	0	0.793	0	132,500	0.068	9,002	0.238	31,509	9,002	31,509
Widening and Reserve	3,100	0.74	2,294	0.793	1,819	806	0.102	82	0.238	192	1,901	192
TOTAL POST-DEVELOPMENT	**367,400**		**163,456**		**129,615**	**203,944**		**14,680**		**48,498**	**144,295**	**48,498**
% Change from Pre to Post											134	25
Effect of development (with no mitigation)											1.3 times increase in runoff	25% reduction of infiltration

* data provided by SCS Consulting Group Inc.

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

To balance pre- to post-,
the infiltration target (m^3/a)= **16,048**